WEST VIRGINIA

SECRETARY OF STATE

KEN HECHLER

ADMINISTRATIVE LAW DIVISION

Form #3

Aug 12 11 14 AM '94

OFFICE OF WEST VIRGINIA SECRETARY OF STATE

NOTICE OF AGENCY APPROVAL OF A PROPOSED RULE AND FILING WITH THE LEGISLATIVE RULE-MAKING REVIEW COMMITTEE

AGENCY: West Virginia Division of Environmental Protection Office of Air Quality TITLE NUMBER: 45CSR6

CITE AUTHORITY WV Code 22-5-1 et seq.

AMENDMENT TO AN EXISTING RULE: YES X NO ___

IF YES, SERIES NUMBER OF RULE BEING AMENDED: 45CSR6

TITLE OF RULE BEING AMENDED: "To Prevent and Control Air Pollution From Combustion of Refuse"

IF NO, SERIES NUMBER OF NEW RULE BEING PROPOSED: ___

TITLE OF RULE BEING PROPOSED: ___

THE ABOVE PROPOSED LEGISLATIVE RULE HAVING GONE TO A PUBLIC HEARING OR A PUBLIC COMMENT PERIOD IS HEREBY APPROVED BY THE PROMULGATING AGENCY FOR FILING WITH THE SECRETARY OF STATE AND THE LEGISLATIVE RULE MAKING REVIEW COMMITTEE FOR THEIR REVIEW.

Roger T. Wall

Authorized Signature

81.00
6.80 w/o Comments

45CSR6

TO PREVENT AND CONTROL AIR POLLUTION FROM COMBUSTION OF REFUSE

STATEMENT OF CIRCUMSTANCE

Hercules Aerospace Corporation petitioned the West Virginia Division of Environmental Protection, Office of Air Quality, on June 2, 1994, to modify 45CSR6 and 45CSR25. The modification request resolves certain inconsistencies between the two rules and, in addition, sets forth a standard to allow the open burning of spent propellants.

APPENDIX B

FISCAL NOTE FOR PROPOSED RULES

Rule Title: 45CSR6 - To Prevent and Control Air Pollution from Combustion of Refuse

Type of Rule: X Legislative _____ Interpretive _____ Procedural

Agency: Office of Air Quality

Address: 1558 Washington Street, East

Charleston, WV 25311-2599

1. Effect of Proposed Rule	Annual		Fiscal Year		
	Increase	Decrease	Current	Next	There-after
Estimated Total Cost	$ -0-	$ -0-	$ -0-	$ -0-	$ -0-
Personal Services	-0-	-0-	-0-	-0-	-0-
Current Expense	-0-	-0-	-0-	-0-	-0-
Repairs and Alterations	-0-	-0-	-0-	-0-	-0-
Equipment	-0-	-0-	-0-	-0-	-0-
Other	-0-	-0-	-0-	-0-	-0-

2. Explanation of above estimates: The Office of Air Quality will not incur additional expenses as a result of the proposed regulations.

3. Objectives of these rules: To correct an inconsistency between 45CSR6 and 45CSR25 which will allow Hercules Aerospace Corporation to openly burn spent propellant according to 40 CFR §265.382.

4. Explanation of overall economic impact of proposed rule.

A. Economic impact on state government.

None

B. Economic impact on political subdivisions; specific industries; specific

groups of citizens.

None

C. Economic impact on citizens/public at large.

None

Date: July 6, 1994

Signature of agency head or authorized representative:

G. Dale Farley
Chief, Office of Air Quality

DATE: August 12, 1994

TO: LEGISLATIVE RULE-MAKING REVIEW COMMITTEE

FROM: G. DALE FARLEY
CHIEF, OFFICE OF AIR QUALITY
DIVISION OF ENVIRONMENTAL PROTECTION

LEGISLATIVE RULE TITLE: Series 6 - "To Prevent and Control Air Pollution from the Combustion of Refuse"

1. Authorizing statute(s) citation W. Va. Code §§22-5-1 et seq.

2. a. Date filed in State Register with Notice of Hearing:

July 6, 1994

b. What other notice, including advertising, did you give of the hearing?

Class I legal advertisement filed in a newspaper published in each of the Air Quality Control Regions of West Virginia.

Office of Air Quality mailing list.

c. Date of hearing(s): August 9, 1994

d. Attach list of persons who appeared at hearing, comments received, amendments, reasons for amendments.

Attached X No comments received

e. Date you filed in State Register the agency approved proposed Legislative Rule following public hearing: (be exact)

August 12, 1994

f. Name and phone number of agency person to contact for additional information:

G. Dale Farley, Chief

Office of Air Quality (Phone: 558-2275)

3. If the statute under which you promulgated the submitted rules requires certain findings and determinations to be made as a condition precedent to their promulgation:

a. Give the date upon which you filed in the State Register a notice of the time and place of a hearing for the taking of evidence and a general description of the issues to be decided.

N/A

b. Date of hearing: N/A

c. On what date did you file in the State Register the findings and determinations required together with the reasons therefor?

N/A

d. Attach findings and determinations and reasons:

Attached N/A

45CSR6

TO PREVENT AND CONTROL AIR POLLUTION FROM COMBUSTION OF REFUSE

SUMMARY

The purpose of 45CSR6 is to prevent and control air pollution from the combustion of refuse. The rule, with certain limited exceptions, prohibits open burning. The last effective amendment to the rule was on April 8, 1980.

The proposed rule modification is to allow Hercules Aerospace Corporation to openly burn spent propellent. Currently, such propellant can be burned under the provisions of 45CSR25, but inconsistencies exist between 45CSR25 and 45CSR6 which prohibit the open burning of the spent propellant. Resolving the inconsistencies requires the application of the most stringent provision, here, 45CSR6, which prohibits the open burning of the spent propellant. The proposed changes, in conjunction with changes to 45CSR25, will allow the burning of the spent propellant in accordance with the provisions of 40 CFR §265.382, a rule which applies, in part, to the open burning of military explosives.

In addition, definitions have been alphabetized, and the code sections updated in accordance with the provisions of the recently enacted Division of Environmental Protection legislation. Changes are indicated by strikeout and underlines.

TITLE 45
LEGISLATIVE RULES
~~AIR POLLUTION CONTROL COMMISSION~~
BUREAU OF ENVIRONMENT
DIVISION OF ENVIRONMENT
OFFICE OF AIR QUALITY

SERIES 6
TO PREVENT AND CONTROL AIR POLLUTION
FROM COMBUSTION OF REFUSE

§45-6-1. General.

1.1. Scope.

(a) The purpose of Series 6 is to prevent and control air pollution from combustion of refuse. Neither compliance with the provisions of this ~~regulation~~rule nor the absence of specific language to cover particular situations constitutes approval or implies consent or condonement of any emission which is released in any locality in such manner or amount as to cause or contribute to undesirable levels of air contaminants. Neither does it exempt nor excuse anyone from complying with other applicable laws, ordinances, regulations or orders of governmental entities having jurisdiction.

(b) All persons engaged in any form of combustion of refuse shall give careful consideration to the effects of the resultant emissions on the air quality of the area(s) affected by such burning. Important considerations include but are not limited to, the location and time of burning, the type of material being burned and the potential emissions and the prevailing meteorological conditions. Persons failing to give due consideration to these factors will be in violation of this ~~regulation~~rule.

(c) It is the intent of the ~~Commission~~Director that all incorporated areas and other local governmental entities prohibit open burning and develop alternative methods for disposal of waste material. If such action is not taken in any air basin, air quality control region or other such areas as the ~~Commission~~Director may designate, then such action may be taken by the ~~Commission~~Director to insure compliance with air quality standards.

1.2. Authority. -- W. Va. Code ~~§16-20-5~~§§22-5-1 et seq.

1.3. Filing Date. -- ~~March 30, 1979~~

1.4. Effective Date. -- ~~April 8, 1980~~

1.5. Incorporation by Reference - Federal Counterpart Regulation. - Not Applicable.

1.6 Determination of Stringency - Federal Counterpart Regulation - Not Applicable.

1.7 Constitutional Taking Determination. - The Director has determined that this rule will not result in the constitutional taking of real property.

§45-6-2. Definitions.

2.1. "Air Pollution", 'statutory air pollution' shall have the meaning ascribed to it in section two, article twenty, chapter sixteen of the Code of West Virginia, as amended.

~~2.2. "Commission" shall mean the West Virginia Air Pollution Control Commission.~~

~~2.3. "Person" shall mean any and all persons, natural or artificial, including any municipal, public or private corporation organized or existing under the law of this or any other state or country, and any firm, partnership or association of whatever nature.~~

~~2.4. "Particulate Matter" shall mean any material, except uncombined water, that exists in a finely divided form as a liquid or solid.~~

~~2.5. "Smoke" shall mean small gasborne and airborne particles emitted as the result of the combustion of refuse in sufficient numbers to be visible.~~

~~2.6. "Ringelmann Smoke Chart" shall mean the Ringelmann's Scale for Grading the Density of Smoke, published by the United States Bureau of Mines, or any chart, recorder, indicator, device or method which is a standardized method for the measurement of smoke density and is approved by the Commission as the equivalent of said Ringelmann Chart.~~

~~2.7. "Air Pollution Control Equipment" shall mean any equipment used for collecting or converting gasborne particulate or gaseous materials for the purpose of preventing or reducing emission of these materials into the open air.~~

~~2.8. "Incineration" shall mean the destruction of combustible refuse by burning in a furnace designed for that purpose. For the purposes of this regulation, the destruction of any combustible liquid or gaseous material by burning in a flare/flare stack shall be considered incineration.~~

~~2.9. "Incinerator" shall mean any device used to accomplish incineration.~~

~~2.10. "Flare", 'flare stack' shall mean and include a combustion source normally comprised of but not limited to a length of stack or pipe which has an attached burner mechanism designed to destroy liquid or gaseous material with an open or semi-enclosed flame.~~

~~2.11. "Open Burning" shall mean the combustion of refuse whereby the gaseous products of combustion are not conveyed through man-made means from one point to another and are discharged directly to the open air.~~

~~2.12. "Refuse" shall mean the useless and/or unwanted or discarded solid, liquid and/or gaseous waste materials resulting from community, commercial, industrial or citizen activities.~~

~~2.13. "Construction and Demolition Wastes" shall mean combustible waste building materials and rubble resulting from construction, remodeling, repair and demolition operations on houses, commercial buildings, pavements and other structures.~~

~~2.14. "Incinerator Capacity" shall be the manufacturer's or designer's guaranteed maximum charging rate or such other rate as may be determined by the Director in accordance with good engineering practices. In case of conflict the determination by the Director shall govern. For the purpose of this regulation the total of the capacities of all furnaces within one system shall be considered as the "Incinerator Capacity".~~

~~2.15. "Director" shall mean the director of the West Virginia Air Pollution Control Commission.~~

~~2.16. "Pathological Waste Incinerator" shall mean an incinerator used to dispose of animal and/or human tissue, bandages, medical wastes, and medical laboratory wastes.~~

~~2.17. "Industrial Waste Incinerator" shall mean an incinerator which is used to incinerate gaseous, liquid, semi liquid and/or solid by product waste from industrial sources.~~

~~2.18. "Opacity" shall mean the degree to which smoke and/or particulate matter emissions reduce the transmission of light and obscure the view of an object in the background.~~

~~2.19. "Sewage Sludge Incinerator" shall mean an incinerator which is used to incinerate the sludge produced by municipal or industrial sewage treatment plants.~~

2.2. "Air Pollution Control Equipment" shall mean any equipment used for collecting or converting gasborne particulate or gaseous materials for the purpose of preventing or reducing emission of these materials into the open air.

2.3. "Construction and Demolition Wastes" shall mean combustible waste building materials and rubble resulting from construction, remodeling, repair and demolition operations on houses, commercial buildings, pavements and other structures.

2.4. "Director" shall mean the director of the West Virginia Division of Environmental Protection.

2.5. "Flare", 'flare stack' shall mean and include a combustion source normally comprised of but not limited to a length of stack or pipe which has an attached burner mechanism designed to destroy liquid or gaseous material with an

open or semi-enclosed flame.

2.6. "Incineration" shall mean the destruction of combustible refuse by burning in a furnace designed for that purpose. For the purposes of this regulation, the destruction of any combustible liquid or gaseous material by burning in a flare/flare stack shall be considered incineration.

2.6. "Incinerator" shall mean any device used to accomplish incineration.

2.8. "Incinerator Capacity" shall be the manufacturer's or designer's guaranteed maximum charging rate or such other rate as may be determined by the Director in accordance with good engineering practices. In case of conflict the determination by the Director shall govern. For the purpose of this rule the total of the capacities of all furnaces within one system shall be considered as the "Incinerator Capacity".

2.9. "Industrial Waste Incinerator" shall mean an incinerator which is used to incinerate gaseous, liquid, semi-liquid and/or solid by-product waste from industrial sources.

2.10. "Opacity" shall mean the degree to which smoke and/or particulate matter emissions reduce the transmission of light and obscure the view of an object in the background.

2.11. "Open Burning" shall mean the combustion of refuse whereby the gaseous products of combustion are not conveyed through man-made means from one point to another and are discharged directly to the open air.

2.12. "Particulate Matter" shall mean any material, except uncombined water, that exists in a finely divided form as a liquid or solid.

2.13. "Pathological Waste Incinerator" shall mean an incinerator used to dispose of animal and/or human tissue, bandages, medical wastes, and medical laboratory wastes.

2.14. "Person" shall mean any and all persons, natural or artificial, including any municipal, public or private corporation organized or existing under the law of this or any other state or country, and any firm, partnership or association of whatever nature.

2.15. "Refuse" shall mean the useless and/or unwanted or discarded solid, liquid and/or gaseous waste materials resulting from community, commercial, industrial or citizen activities.

2.16. "Ringelmann Smoke Chart" shall mean the Ringelmann's Scale for Grading the Density of Smoke, published by the United States Bureau of Mines, or any chart, recorder, indicator, device or method which is a standardized method for the measurement of smoke density and is approved by the Director as the equivalent of said Ringelmann Chart.

2.17. "Sewage Sludge Incinerator" shall mean an incinerator which is used to incinerate the sludge produced by municipal or industrial sewage treatment plants.

2.18. "Smoke" shall mean small gasborne and airborne particles emitted as the result of the combustion of refuse in sufficient numbers to be visible.

Other words and phrases used in this ~~regulation~~rule, unless otherwise indicated, shall have the meaning ascribed to them in ~~section two, article twenty, chapter sixteen of the Code of West Virginia, 1931, as amended~~W. Va. code §22-5-2.

§45-6-3. Open Burning Prohibited.

3.1. General Provisions.

The open burning of refuse for the purpose of volume reduction, elimination or product recovery by any person, firm, corporation, association or public agency is prohibited except for the following exemptions:

(a) Vegetation grown on the premises of a home or farm, provided that there is compliance with the provisions of subsection 1.1.(b), and the health, safety, comfort and property of persons are protected from the effects of such burning.

(b) Fires set for the purpose of bona fide instruction and training of public and industrial employees and members of volunteer fire departments in the methods of fighting fires, provided that approval to conduct such burning is received from the Director or ~~his~~the Director's duly authorized representative.

(c) Open burning of construction and demolition wastes, provided that all the following conditions are met:

(1) There is no practical alternate method for the disposal of the material to be burned;

(2) The health, safety, comfort and property of persons are protected from the effects of such burning;

(3) Such burning shall not be conducted for salvage purposes; and,

(4) In non-rural areas approval to conduct such burning is received from the Director or ~~his~~the Director's duly authorized representative.

(d) Backyard open burning for the reduction of refuse produced on the premises as long as the amount does not exceed that weight normally produced by the everyday living habits of one (1) family, until such families are serviced by a municipal or private refuse collection service.

(e) Open burning of propellant and explosives wastes, provided that the open burning is conducted in accordance with 45 CSR 25.

3.2. The exemptions listed in subsection 3.1 are subject to the following stipulation:

Upon notification by the Director, no person shall cause, suffer, allow or permit any form of open burning during existing or predicted periods of atmospheric stagnation. Notification shall be made by such means as the Director may deem necessary and feasible.

§45-6-4. Emission Standards for Incinerators and Incineration.

4.1. No person shall cause, suffer, allow or permit particulate matter to be discharged from any incinerator into the open air in excess of the quantity determined by use of the following formula:

Emissions (lb/hr) = F x Incinerator Capacity (tons/hr)

Where,

the Factor, F, is as indicated in Table I below:

Table I: Factor, F, for Determining Maximum Allowable Particulate Emissions

	Incinerator Capacity	F Factor
A.	Less than 15,000 lbs/hr	5.43
B.	15,000 lbs/hr or greater	2.72

4.2. After the effective date of this regulation, in the Counties of Brooke, Hancock, Ohio, Marshall and Kanawha; and the Magisterial Districts of Valley (Fayette County), Scott and Pocatalico (Putnam County), Tygart (Wood County), the City of Fairmont and those portions of Union and Winfield Magisterial Districts west of I-79 (Marion County), no person shall cause, suffer, allow or permit the operation of any incinerator during the period starting one (1) hour before sunset and extending until two (2) hours after sunrise.

This subsection shall not apply to the operation of pathological, industrial, municipal or sewage sludge incinerators.

4.3. Emission of Visible Particulate Matter.

No person shall cause, suffer, allow or permit emission of smoke into the atmosphere from any incinerator which is as dark or darker in shade or appearance than that designated as No. 1 on the Ringelmann Smoke Chart or the equivalent opacity of this Ringelmann number.

4.4. The provisions of subsection 4.3. shall not apply to smoke, the shade or appearance of which is less than No. 2 on the Ringelmann Smoke Chart or the equivalent opacity of this Ringelmann number, for a period or periods aggregating no more than eight (8) minutes per start-up, or six (6) minutes in any sixty (60)-minute period for stoking operations.

4.5. No person shall cause, suffer, allow or permit the emission of particles of unburned or partially burned refuse or ash from any incinerator which are large enough to be individually distinguished in the open air.

4.6. Incinerators, including all associated equipment and grounds, shall be designed, operated and maintained so as to prevent the emission of objectionable odors.

4.7. Incineration of Residues and Hazardous Materials.

Persons responsible for the incineration of hazardous materials such as insecticides, empty insecticide containers, toxic materials, certain chemical residues, explosives, used bandages and other medical wastes, pathological wastes, human and animal remains and other like materials shall give the utmost care and consideration to the potential harmful effects of the emissions resulting from such activities. Evaluation of these facilities as to adequacy, efficiency and emission potential will be made on an individual basis by the ~~Commission~~Director , working in conjunction with other appropriate governmental agencies.

§45-6-5. Registration.

Within thirty (30) days after the effective date of this regulation, all persons owning and/or operating incinerators within the state shall have registered with the ~~Commission~~Director on forms made available by the Director, the name of the person, company or corporation operating the plant, the address, location, county, ownership (lessee, lessor), the principal officer of the company and any such other reasonable information as the Director may require including but not limited to make, model, capacity, operating temperature, fuel used, stack parameters and description of air pollution control equipment.

§45-6-6. Permits.

No person shall construct, modify or relocate any incinerator without first obtaining a permit in accordance with the provisions of ~~section eleven-b, article twenty, chapter sixteen of the Code of West Virginia, as amended, and Series thirteen of this agency~~W. Va. Code §22-5-1 et seq. and 45CSR13.

§45-6-7. Reports and Testing.

7.1. At such reasonable times as the Director may designate, the operator of any incinerator shall be required to conduct or have conducted stack tests to determine the particulate matter loading in exhaust gases when the Director has reason to believe, based on observed violations, that the stack emission limitation

is being violated or for compliance testing. Such tests shall be conducted in such manner as the Director may specify and be filed on forms and in a manner acceptable to the Director. The Director, or ~~his duly~~the Director's authorized representative, may at ~~his~~the Director's option witness or conduct such stack tests. Should the Director exercise his option to conduct such tests, the operator will provide all the necessary sampling connections and sampling ports to be located in such manner as the Director may require, power for test equipment and the required safety equipment such as scaffolding, railings and ladders to comply with generally accepted good safety practices.

7.2. The Director, or ~~his~~the Director's duly authorized representative, may conduct such other tests as ~~he~~the Director may deem necessary to evaluate air pollution emissions other than those noted above.

§45-6-8. Variances.

8.1. If it can be demonstrated to the ~~Commission~~Director that the disposal of certain materials by any method other than burning leads to ground water contamination, then the person responsible for the disposal of such materials shall submit to the ~~Commission~~Director within sixty (60) days a program leading to the construction of a suitable incinerator. If such program is accepted by the ~~Commission~~ Director, the person shall not be in violation as long as the program is observed.

8.2. Due to unavoidable malfunction of equipment, emissions exceeding those provided for in this ~~regulation~~rule may be permitted by the Director for periods not to exceed five (5) days upon specific application to the Director. Such application shall be made within twenty-four (24) hours of the malfunction. In cases of major equipment failure, additional time periods may be granted by the ~~Commission~~Director provided a corrective program has been submitted by the owner or operator and approved by the ~~Commission~~Director.

§45-6-9. Delayed Compliance Order.

9.1. The owner or operator of any incinerator in existence prior to the effective date of this ~~regulation~~rule which does not meet the emission limitations as specified in section 4.1 of this ~~regulation~~rule shall develop and submit to the ~~Commission~~Director, within such time as shall be allowed by the ~~Commission~~Director, an acceptable compliance program for the attaining and maintaining of the emission limitations of this ~~regulation~~rule as per section 4.1. The compliance program shall be embodied in a consent order as provided in ~~subsection seventeen, section five, article twenty, chapter sixteen of the Code of West Virginia, as amended~~W. Va. Code §22-1-6. Any owner or operator who is currently subject to a consent order that provides for compliance after the effective date of this ~~regulation~~rule shall be exempt from the requirements of this section.

9.2. In the event an owner or operator of an incinerator subject to this section fails to submit an acceptable control program within the time allowed, the ~~Commission~~Director shall, by final order, determine a reasonable control program for the attaining and maintaining of the emission limitations of this ~~regulation~~rule.

§45-6-10. Severability.

10.1. The provisions of this rule are severable and if any provisions or part thereof shall be held invalid, unconstitutional, or inapplicable to any person or circumstance; such invalidity, unconstitutionality, or inapplicability shall not affect or impair any of the remaining provisions, sections, or parts of this rule; or their application to any persons or circumstances.



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LEGISLATIVE

SECRETARY OF STATE
KEN HECHLER
ADMINISTRATIVE LAW DIVISION
Form #1

FILED
Jul 6 4 33 PM '94
OFFICE OF WEST VIRGINIA SECRETARY OF STATE

NOTICE OF PUBLIC HEARING ON A PROPOSED RULE

AGENCY: West Virginia Division of Environmental Protection, Office of Air Quality TITLE NUMBER: 45CSR6

RULE TYPE: Legislative ; CITE AUTHORITY W. Va. Code §§22-5-1 et seq.

AMENDMENT TO AN EXISTING RULE: YES X NO

IF YES, SERIES NUMBER OF RULE BEING AMENDED: 45CSR6

TITLE OF RULE BEING AMENDED: "To Prevent and Control Air Pollution From Combustion of Refuse"

IF NO, SERIES NUMBER OF NEW RULE BEING PROPOSED:

TITLE OF RULE BEING PROPOSED:

DATE OF PUBLIC HEARING: August 9, 1994 TIME: 9:00 a.m.

LOCATION OF PUBLIC HEARING: Office of Air Quality
1558 Washington Street, East
Charleston, WV 25311

COMMENTS LIMITED TO: ORAL ___, WRITTEN ___, BOTH X

COMMENTS MAY ALSO BE MAILED TO THE FOLLOWING ADDRESS: Same as Above.

The Department requests that persons wishing to make comments at the hearing make an effort to submit written comments in order to facilitate the review of these comments.

The issues to be heard shall be limited to the proposed rule.

ATTACH A BRIEF SUMMARY OF YOUR PROPOSAL.

SECRETARY OF STATE
KEN HECHLER
ADMINISTRATIVE LAW DIVISION
Form #1

FILED
Jul 6 4 34 PM '94
OFFICE OF WEST VIRGINIA SECRETARY OF STATE

NOTICE OF PUBLIC HEARING ON A PROPOSED RULE

AGENCY: West Virginia Division of Environmental Protection, Office of Air Quality TITLE NUMBER: 45CSR25

RULE TYPE: Legislative ; CITE AUTHORITY W. Va. Code §§22-5-1 et seq.

AMENDMENT TO AN EXISTING RULE: YES X NO

IF YES, SERIES NUMBER OF RULE BEING AMENDED: 45CSR25

TITLE OF RULE BEING AMENDED: "To Prevent and Control Air Pollution From Hazardous Waste Treatment, Storage, or Disposal Facilities"

IF NO, SERIES NUMBER OF NEW RULE BEING PROPOSED:

TITLE OF RULE BEING PROPOSED:

DATE OF PUBLIC HEARING: August 9, 1994 TIME: 9:00 a.m.

LOCATION OF PUBLIC HEARING: Office of Air Quality
1558 Washington Street, East
Charleston, WV 25311

COMMENTS LIMITED TO: ORAL ___, WRITTEN ___, BOTH X

COMMENTS MAY ALSO BE MAILED TO THE FOLLOWING ADDRESS: Same as Above.

The Department requests that persons wishing to make comments at the hearing make an effort to submit written comments in order to facilitate the review of these comments.

The issues to be heard shall be limited to the proposed rule.

ATTACH A BRIEF SUMMARY OF YOUR PROPOSAL

Proposed Rules Filed for Public Hearing

AGENCY	RULE/TYPE	AUTHORITY	HEARING/COMMENT PERIOD/LOCATION
Administration (148-6)	Parking Legislative	§5A-4-5	August 8, 1994, 4:30 p.m. Written Comments Only: Tara Justice Dept. of Administration 1900 Kanawha Blvd., E Building 1, Room E-119 Charleston, WV 25305-0120
Banking (106-17)	Notice & Treatment of Joint Accounts Legisltive	§31A-4-33	August 5, 1994, 5:00 p.m. Written Comments Only: WV Division of Banking State Capitol Complex Bldg. 3, Room 311 Charleston, WV 25305
Corrections (90-3)	Furlough Programs for Inmates Under the Custody & Control of the Comm. of the Dept. of Corrections Legislative	§25-1-13	July 30, 1994, 5:00 p.m. Written Comments Only: Rita A. Stuart Division of Corrections 112 California Avenue Bldg. 4, Room 300 Charleston, WV 25305
Corrections (90-5)	Recording of Inmate Telephone Calls Legislative	§25-1-17	July 30, 1994, 5:00 p.m. Written Comments Same as Above
DEP-Air Quality (45-5)	To Prevent & Control Air Pollution From the Operation of Coal Preparation Plants & Coal Handling Operations Legislative	§22-5-1	August 9, 1994, 9:00 a.m. Office of Air Quality 1558 Washington Street, E Charleston, WV 25311 Written Comments Same Address
DEP-Air Quality (45-6)	To Prevent & Control Air Pollution From Combustion of Refuse Legislative	§22-5-1	August 9, 1994, 9:00 a.m. Hearing & Written Comments Same as Above

OTHER

FILED

JUL 6 4 28 PM '94

OFFICE OF WEST VIRGINIA SECRETARY OF STATE

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5	-	To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)
45CSR6	-	To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)
45CSR25	-	To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)
45CSR36	-	Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)
45CSR37	-	Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Library of the Office of Air Quality located at the address below on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director

Eli McCoy
Deputy Director

July 1, 1994

The Wheeling News-Register and
Intelligencer
Legal Ad Department
1500 Main Street
Wheeling, WV 26003

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Mr. Tim Carroll
Office of Air Quality
Northern Panhandle Regional Office
1911 Warwood Avenue
Wheeling, West Virginia 26003

Dear Mr. Carroll:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5	-	To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)
45CSR6	-	To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)
45CSR25	-	To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)
45CSR36	-	Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)
45CSR37	-	Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Office of Air Quality, Northern Panhandle Regional Office, 1911 Warwood Avenue, Wheeling, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director

Eli McCoy
Deputy Director

July 1, 1994

The Parkersburg News
Legal Ad Department
519 Juliana Street
Parkersburg, WV 26102

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Ms. Dorothy Chittum
Librarian
Parkersburg/Wood County Public Library
3100 Emerson Avenue
Parkersburg, West Virginia 26104

Dear Ms. Chittum:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

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45CSR6	-	To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)
45CSR25	-	To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)
45CSR36	-	Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)
45CSR37	-	Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Parkersburg/Wood County Public Library, 3100 Emerson Avenue, Parkersburg, West Virginia on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Ms. Jeanne Chandler
Librarian
Office of Air Quality
1558 Washington Street, East
Charleston, WV 25311

Dear Ms. Chandler:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director
Eli McCoy
Deputy Director

July 1, 1994

Charleston Daily Mail
Legal Ad Department
1001 Virginia Street, East
Charleston, WV 25301

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

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OFFICE OF WEST VIRGINIA SECRETARY OF STATE

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5	-	To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)
45CSR6	-	To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)
45CSR25	-	To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)
45CSR36	-	Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)
45CSR37	-	Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Library of the Office of Air Quality located at the address below on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

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45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Library of the Office of Air Quality located at the address below on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director
Elf McCoy
Deputy Director

July 1, 1994

The Herald-Dispatch
Legal Ad Department
P. O. Box 2017
Huntington, WV 25720

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Mr. Matt Onion
Cabell County Public Library
455 9th Street Plaza
Huntington, West Virginia 25701

Dear Mr. Onion:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

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45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Cabell County Public Library, 455 9th Street Plaza, Huntington, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director
Elf McCoy
Deputy Director

July 1, 1994

Beckley Register/Herald
Legal Ad Department
P. O. Drawer P
Beckley, WV 25801

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Ms. Susan Vidovich
Librarian
Raleigh County Public Library
P. O. Box 1876
Beckley, West Virginia 25802

Dear Ms. Vidovich:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

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45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

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The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Raleigh County Public Library, P. O. Box 1876, Beckley, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director

Eli McCoy
Deputy Director

July 1, 1994

The Clarksburg Exponent
Legal Ad Department
P. O. Box 2000
Clarksburg, WV 26301

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Ms. Donna Riggs
Secretary
WV Air Pollution Control Commission
North Central Regional Office
109 Adams Street, Room M-2
Fairmont, West Virginia 26554-2800

Dear Ms. Riggs:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tim

Enclosures

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5	-	To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)
45CSR6	-	To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)
45CSR25	-	To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)
45CSR36	-	Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)
45CSR37	-	Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Office of Air Quality, North Central Regional Office, 517 1/2 East Park Avenue, Fairmont, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director

Eli McCoy
Deputy Director

July 1, 1994

Mineral Daily News Tribune
Legal Ad Department
P. O. Box 879
Keyser, West Virginia 26726

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Ms. Karen Hiser
Librarian
Keyser-Mineral County Public Library
105 North Main Street
Keyser, West Virginia 26726

Dear Ms. Hiser:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

NOTICE OF PUBLIC HEARING

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45CSR25	-	To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)
45CSR36	-	Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)
45CSR37	-	Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Keyser-Mineral County Public Library, 105 North Main Street, Keyser, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director

Eli McCoy
Deputy Director

July 1, 1994

The Record Delta
Legal Ad Department
P. O. Box 550
Buckhannon, WV 26201

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor
John M. Ranson
Cabinet Secretary

David C. Callaghan
Director
Ann A. Spaner
Deputy Director

July 7, 1994

Ms. Ruth B. Six
Librarian
Gassaway Public Library
100 Birch Street
Gassaway, West Virginia 26624

Dear Ms. Six:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

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45CSR36	-	Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)
45CSR37	-	Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Gassaway Public Library, 100 Birch Street, Gassaway, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director

Eli McCoy
Deputy Director

July 1, 1994

Elkins Inter-Mountain
Legal Ad Department
P.O. Box 1339
Elkins, WV 26241

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Elkins-Randolph County Public Library
c/o Librarian
416 Davis Avenue
Elkins, West Virginia 26241

Dear Librarian:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

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45CSR37	-	Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

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Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Elkins-Randolph County Public Library, 416 Davis Avenue, Elkins, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR QUALITY
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

David C. Callaghan
Director

Eli McCoy
Deputy Director

July 1, 1994

The Evening/Weekend Journal
Legal Ad Department
207 West King Street
Martinsburg, WV 25401

Dear Legal Ad Department:

Please publish the enclosed "Notice of Public Hearing" as soon as possible as a Class I legal advertisement. The publication must occur no later than Friday, July 8, 1994 and must not be published on Sunday as a matter of law. If you have any questions regarding this matter, please contact Tammy Mowrer at 558-2275.

You may submit your invoice and a tear sheet to the attention of Ms. Nadine Sitton, 1558 Washington Street, East, Charleston, West Virginia 25311.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosure

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor

John M. Ranson
Cabinet Secretary

David C. Callaghan
Director

Ann A. Spaner
Deputy Director

July 7, 1994

Ms. Peggy Y. Batten
Librarian
Martinsburg-Berkeley County Public Library
101 West King Street
Martinsburg, West Virginia 25401

Dear Ms. Batten:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

DEPARTMENT OF COMMERCE, LABOR & ENVIRONMENTAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
1558 Washington Street, East
Charleston, WV 25311-2599

Gaston Caperton
Governor
John M. Ranson
Cabinet Secretary

David C. Callaghan
Director
Ann A. Spaner
Deputy Director

July 7, 1994

Mr. Richard Poling
Office of Air Quality
Eastern Panhandle Regional Office
P. O. Box 99
Burlington, West Virginia 26710

Dear Mr. Poling:

On Tuesday, August 9, 1994 the West Virginia Air Pollution Control Commission will hold a public hearing on the following proposed legislative rules: 45CSR5, 45CSR6, 45CSR25, 45CSR36, 45CSR37, and 45CSR38. Please retain the enclosed documents for public review until after the August 9th hearing. Also, please have any interested party sign the enclosed register and return the register and any correspondence you may have regarding the proposed legislative rules.

Thank you very much for your cooperation and assistance in this matter. If you have any questions, please direct them to Tammy Mowrer at (304) 558-2275.

Sincerely yours,

Dale Farley
Chief, Office of Air Quality

DF/tlm

Enclosures

NOTICE OF PUBLIC HEARING

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45CSR38	-	Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

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The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following locations: Martinsburg-Berkeley County Public Library, 101 King Street, Martinsburg, WV and the Office of Air Quality's Burlington Office, P. O. Box 99, Burlington, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

I, as an officer of the News-Tribune, a daily newspaper published at Keyser, Mineral County, West Virginia, hereby certify that the Division of Environmental Protection in the case of Notice of Public Hearing: New Legislative Rules

vs.

a copy whereof is hereto annexed has been published for 1 consecutive day in said NEWS-TRIBUNE, the first publication being on the 7th day of, July 19 94.

Given under my hand at Keyser this 7th day of July, 19 94.

Publisher

Publisher's Fee

$31.50

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginnning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

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45CRS36 - Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule).

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45CRS38 - Provisions for Detemination of Compliance with Air Quality Management Rules (New Rule).

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Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Keyser-Mineral County Public Library, 105 North Main Street, Keyser, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office: G. Dale Farley, Office of Air Quality, Division of Environmental Protection, 1558 Washington Street, East, Charleston, WV 25311-2599.

7: 7

State of West Virginia, County of Randolph, ss.

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5—To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)

45CSR6—To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)

45CSR25—To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)

45CSR36—Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)

45CSR37—Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)

45CSR38—Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U.S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U.S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U.S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Elkins-Randolph County Public Library, 415 Davis Avenue, Elkins, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

7-7

I, James Hoffman, Publisher of THE INTER-MOUNTAIN, a newspaper published at Elkins, in said county, do hereby certify that the annexed advertisement was published on the following dates:

July 07

19 94 as required by law.

Given under my hand this 07 day of July 19 94

James Hoffman
Publisher

Printer's Fee: $ 41 69

Subscribed and sworn before me this 07 day of July, 19 94

Shirley A Kenear
Notary Public

My commission expires on the 15 day of April 19 2002

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5 - To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)

45CSR6 - To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)

45CSR25 - To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)

45CSR36 - Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under title 23 U.S.C. or the Federal Transit Act, to Applicable Air Quality Implementation Plans (New Rule)

45CSR37 - Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)

45CSR38 - Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U.S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the Federal Clean Air Act, as amended. 45CSR25 Will be submitted to U.S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U.S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Office of Air Quality, Northern Panhandle Regional Office, 1911 Warwood Avenue, Wheeling, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality

STATE OF WEST VIRGINIA,
COUNTY OF OHIO.

I, Bonnie Mattern *for the publisher of the*

WHEELING NEWS-REGISTER
~~WHEELING INTELLIGENCER~~ *newspapers published in the CITY OF*

WHEELING, STATE OF WEST VIRGINIA, hereby certify that the annexed publication was inserted in said newspaper on the following dates:

July 8, 1994

commencing on the 8 *day of* July, *19* 94

Given under my hand this 13 *day of* July, *19* 94

Bonnie Mattern

Sworn to and subscribed before me this 15th *day of* July *19* 94 *at WHEELING, OHIO COUNTY, WEST VIRGINIA*

Marjorie A. Strauss
Notary Public

of, in and for OHIO COUNTY, WEST VIRGINIA.

My Commission expires Sept 26, 2000

OFFICIAL SEAL
NOTARY PUBLIC
STATE OF WEST VIRGINIA
MARJORIE A. STRAUSS
1500 Main Street
Wheeling, West Virginia 26003
My Commission Expires Sept. 26, 2000

NOTICE

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5
To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)

45CSR6
To Prevent and Control Air Pollution from the *Combustion of Refuse* (Amendments)

45CSR25
To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)

45CSR36
Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. *or the Federal* Transit Act. To Applicable Air Quality Implementation Plans (New Rule)

45CSR37
Provisions to Control *Sulfur Dioxide Emissions* and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)

45CSR38
Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U.S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 (Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street, East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Cabell County Public Library, 455 9th Street Plaza, Huntington, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of
Environmental Protection
1558 Washington
Street, East
Charleston, WV 25311-2599
LH-931 7-7,94

AFFIDAVIT OF PUBLICATION

T VIRGINIA,
COUNTY OF CABELL, TO-WIT:

I, Connie Rappold being first duly sworn, depose and say that I am Legal Clerk for The Herald-Dispatch, a corporation, who publishes at Huntington, Cabell County, West Virginia, the newspaper: The Herald-Dispatch, a independent newspaper, in the morning seven days each week, Monday through Sunday including New Year's Day, Memorial Day, the Fourth of July, Labor Day, Thanksgiving and Christmas; that I have been duly authorized by the Board of Directors of such corporation to execute this affidavit of publication for an on behalf of such corporation and the newspaper mentioned herein; that the legal advertisement attached in the left margin of this affidavit and made a part hereof and bearing number LH-931 was duly published in

The Herald-Dispatch

one time, ~~once a week for xxxxxxx successive weeks~~, commencing with its issue of the 7th day of July, 19 94, and ending with the issue of the 7th day of July, 19 94, and was posted at the East door of the Cabell County Courthouse on the 7th day of July, 19 94: that said legal advertisement was published on the following dates: July 7, 1994

_____ ; that the cost of publishing said annexed advertisement as aforesaid was _____ ; that such newspaper in which such legal advertisement was published has been and is now published regularly, at least as frequently as once a week for at least fifty weeks during the calendar year as prescribed by its mailing permit, and has been so published in the municipality of Huntington, Cabell County, West Virginia, for at least one year immediately preceding the date on which the legal advertisement set forth herein was delivered to such newspaper for publication; that such newspaper is a newspaper of "general circulation" as defined in Article 3, Chapter 59, of the West Virginia Code, within the publication area or areas of the municipality of Huntington, Cabell and Wayne Counties, West Virginia, and _____ that such newspaper is circulated to the general public at a definite price or consideration; that such newspaper on each date published consists of not less than four pages without a cover; and that it is a newspaper to which the general public resorts for passing events of a political, religious, commercial and social nature, and for current happenings, announcements, miscellaneous reading matters, advertisements and other notices.

Connie Rappold

Taken, subscribed and sworn to before me in my said county this 7th day of June, 19 94

My commission expires October 24, 2000.

Notary Public
Cabell County,
West Virginia

IOM Form A-133 (867H)

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5 - To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)

45CSR6 - To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)

45CSR25 - To Prevent Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)

45CSR36 - Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)

45CSR37 - Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)

45CSR38 - Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U.S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U.S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Parkersburg/Wood County Public Library, 3100 Emerson Avenue, Parkersburg, West Virginia on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

Jul 8

HEATHER BYERS being first duly sworn, says that the

NOTICE OF PUBLIC HEARING

hereto attached was printed in the Parkersburg News a DAILY newspaper published in the City of Parkersburg, Wood County, West Virginia, and posted at the front door of the Court House for ONE successive weeks, the first publication and posting thereon being on the 8th day of July 19 94, and subsequent publication on the ..... day of ..... 19 ....., the ..... day of ..... 19 ....., the ..... day of ..... 19 ....., and the ..... day of ..... 19 .....

Printer's Fee $ 40.24

6 2/8 " x 103= 643.75 words @ .0625

Heather J. Byers

Subscribed and sworn to before me this 8th day of July 19 94.

Melanie Zyla
Notary Public for Wood County, West Virginia

My commission expires 3-23-04

Parkersburg Printing Co. - 5/71

CHARLESTON NEWSPAPERS
P.O. Box 2993
Charleston, West Virginia 25330
Billing 348-4898
Classified 348-4848
1-800-WVA-NEWS
FEIN 55-0676079

INVOICE DATE	
ACCOUNT NBR	037143002
SALES REP ID	0016
INVOICE NBR	371430020711005

Legal pricing is based upon 67 words per column inch at a rate of $.0725 per word
Each successive insertion is discounted by 25% of the first insertion rate ($.054375 per word

ISSUE DATE	AD TYPE	PUB	DESCRIPTION / REFERENCE NBR PURCHASE ORDER #	AD NUMBER	AD SIZE / TOTAL RUN	RATE	GROSS AMOUNT	NET AMOUNT
07/08	LEGF	DM	PUBLIC HEARING 125107001	L213110	3X0550 16.50	4.85	80.03	80.03
			TOTAL INVOICE AMOUNT					80.03

State of West Virginia, **AFFIDAVIT OF PUBLICATION**

I, Sandra Biggs of

THE DAILY MAIL, A DAILY REPUBLICAN NEWSPAPER,
published in the city of Charleston, Kanawha County, West Virginia, do solemnly swear that the annexed notice of:
PUBLIC HEARING
was duly published in said paper(s) during the dates listed below, and was posted at the front door of the court house of said Kanawha County
West Virginia, on the 9TH day of JULY 1994. Published during the following dates: 07/08/94-07/08/94
Subscribed and sworn to before me this 12 day of July
Printers fee $ 80.03

Sarah J. Withrow
Notary Public of Kanawha County, West Virginia

OFFICIAL SEAL
NOTARY PUBLIC
STATE OF WEST VIRGINIA
SARAH J. WITHROW
1801-T LINCOLN DRIVE
SO. CHARLESTON, WV 25309
My Commission Expires April 28, 2003

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5 - To prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)

45CSR6 - To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)

45CSR25 - To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)

45CSR36 - Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S. C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)

45CSR37 - Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)

45CSR38 - Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U.S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U.S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U.S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Library of the Office of Air Quality located at the address below on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

(213110)

The items listed hereon conform to specification, were received and are approved for payment.
Date: 07-21-94 Signed: N. Sutton

Appn. Yr.	Acct #:	Line Item:
95	7827.17	035
Off. Code: 5	Fed. Code: 524	P.C.: 529
Purchase Auth. SA No. 4	Vendor FEIN # 550-676-079 SS # ____-__-____	Off Ap Date

FIMS FUND	FIMS FY	FIMS ORG	FIMS ACT	FIMS OBJ CODE	DO
8708	1995	0313	096	___	

AFFIDAVIT OF PUBLICATION

BECKLEY NEWSPAPERS INC.

BECKLEY, WEST VIRGINIA 25801

July 8, , 1994

STATE OF WEST VIRGINIA
COUNTY OF RALEIGH, to wit:

I, Robert E. Zutaut being first duly sworn upon my oath, do depose and say that I am Advertising Manager of Beckley Newspapers Inc., a corporation, publisher of the newspaper entitled The Register-Herald, an Independent newspaper; that I have been duly authorized by the board of directors of such corporation to execute this affidavit of publication; that such newspaper has been published for more than one year prior to publication of the annexed notice described below; that such newspaper is regularly published daily, for at least fifty weeks during the calendar year, in the municipality of Beckley, Raleigh County, West Virginia; that such newspaper is a newspaper of "general circulation," as that term is defined in article three, chapter fifty-nine of the Code of West Virginia, 1931, as amended, within the publication area or areas of the aforesaid municipality and county; that such newspaper averages in length four or more pages, exclusive of any cover, per issue; that such newspaper is circulated to the general public at a definite price of consideration; that such newspaper is a newspaper to which the general public resorts for passing events of a political, religious, commercial and social nature, and for current happenings, announcements, miscellaneous reading matters, advertisements and other notices; that the annexed notice

of Public Hearing
(Description of notice)

was duly published in said newspaper once a week for one successive week (Class I), commencing with the issue of the 8th day of July, 1994, and ending with the issue of the 8th day of July, 1994, (and was posted at the

on the day of); that said annexed notice was published on the following dates:

July 8, 1994 and that the cost of publishing said annexed notice as aforesaid was $ 44.30.

Signed R. E. Zutaut
Robert E. Zutaut, Advertising Manager
Beckley Newspapers

Taken, subscribed and sworn to before me in my said county this

8th day of July, 1994

My commission expires March 27, 2001

Notary Public of Raleigh County, West Virginia

OFFICIAL SEAL
NOTARY PUBLIC
STATE OF WEST VIRGINIA
DIANA L. SLONE
BECKLEY NEWSPAPER
P. O. DRAWER P OR R
BECKLEY, WV 25801
My Commission Expires March 27, 2001

COPY OF PUBLICATION

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5 - To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)

45CSR6 - To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)

45CSR25 - To Prevent And Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)

45CSR36 - Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)

45CSR37 - Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)

45CSR33 - Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon Authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U.S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U.S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U.S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be in the Office of Air Qu Conference Room at Washington Street Charleston, West Virginia. hearing is open to the p Written comments by interested parties will accepted from the date of notice until the close of hearing and made part of th ord. Oral comments wil accepted at the public he and will be limited to five nutes per person per rule. period for public comment and at the close of the hearin

Copies of the prop legislative rules may be obt from the Office of Secreta State or may be reviewed d normal business hours at following location: Ra County Public Library, P.O. 1876, Beckley, WV on and July 8, 1994.

Please provide any w comments or questions to following contact and office: G. Dale Farley, Office of Quality, Division Environmental Protection, Washington Street, Charleston, WV 25311-2599. 7-8-Fri-1-RH

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5 - To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)

45CSR6 - To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)

45CSR25 - To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)

45CSR36 - Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U. S. C. or the Federal Transit Act. To Applicable Air Quality Implementation Plans (New Rule)

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45CSR38 - Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

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Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Office of Air Quality, North Central Regional Office, 517 1/2 East Park Avenue, Fairmont, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

PUBLISHER'S CERTIFICATE

OFFICE OF AIR QUALITY

'94 AUG 11 P 12:15

STATE OF WEST VIRGINIA,

COUNTY OF HARRISON

I, Deborah S. Veltri

Classified Office Manager of THE CLARKSBURG EXPONENT, a newspaper of general circulation published in the City of Clarksburg, County and State aforesaid, do hereby certify that the annexed

Notice of Public Hearing

was published in said THE CLARKSBURG EXPONENT one time, on the

7 day of July 19 94

The publisher's fee for said publication is $ 25.25

Deborah S Veltri
Classified Office Mgr. of The Clarksburg Exponent

SEAL

Subscribed and sworn to before me this 7 day of July 94

Debra Kay Swiger
Notary Public in and for Harrison County, WV.

My commission expires on the 25th day of August 2003

Form CA-14 E

OFFICIAL SEAL
NOTARY PUBLIC
STATE OF WEST VIRGINIA
Debra Kay Swiger
Route 1, Box 208A
Wallace, WV 26448
My Commission Expires August 25, 2003

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia division of Environmental Protection will hold public hearings on the following proposed new legislative rules and rule amendments:

45CSR5 - To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handling Operations (Amendments)
45CSR6 - To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)
45CSR25 - To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)
45CSR36 - Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)
45CSR37 - Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)
45CSR38 - Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the Federal Clean Air Act, as amended. 45CSR25 will be submitted to U. S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resource Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U. S. EPA for the Charleston, Parkersburg, and Huntington/ Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

This public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following location: Gassaway Public Library, 100 Birch Street, Gassaway, WV on or after July 8, 1994.

Please provide any written comments or questions to the following contact and office:
G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599
7-8

State of West Virginia, County of Upshur, ss:

.....Mark Davis.....Advertising Manager
Record Delta, a newspaper published at Buckhannon in the said county, do hereby certify that the annexed .....NOTICE OF PUBLIC HEARING.....
.....
.....
was published once a week for ....ONE (1).....successive weeks in said Record Delta newspaper published as aforesaid, commencing on the .8th day....
.....of July..... days of 19..94.....

Given under my hand this .8th day of July.... day of 19 94.....
...Advertising Manager

Printers fee $ .34.50.....

WEST VIRGINIA, UPSHUR COUNTY, TO-WIT:

Subscribed and sworn to before me this 8th day of July day of 19 94...
.....Phyllis J. Neuhiarth.....Notary Public.

My Commission expires May 26, 2003.....

OFFICIAL SEAL
NOTARY PUBLIC
STATE OF WEST VIRGINIA
PHYLLIS J. NEUHIARTH
RT. 2, BOX 93
FRENCH CREEK, WV 26218
My Commission Expires May 26, 2003

NOTICE OF PUBLIC HEARING

On Tuesday, August 9, 1994, beginning at 9:00 a.m., the West Virginia Division of Environmental Protection will hold public hearings on the following proposed new legislative rules or rule amendments:

45CSR5- To Prevent and Control Air Pollution from the Operation of Coal Preparation Plants and Coal Handeling Operations (Amendments)

45CSR6- To Prevent and Control Air Pollution from the Combustion of Refuse (Amendments)

45CSR25- To Prevent and Control Air Pollution from Hazardous Waste Treatment, Storage, or Disposal Facilities (Amendments)

45CSR36- Requirements for Determining Conformity of Transportation Plans, Programs, and Projects Developed, Funded or Approved Under Title 23 U.S.C. or the Federal Transit Act, To Applicable Air Quality Implementation Plans (New Rule)

45CSR37- Provisions to Control Sulfur Dioxide Emissions and Ambient Air Quality Levels of Sulfur Dioxide in Hancock County (New Rule)

45CSR380- Provisions for Determination of Compliance with Air Quality Management Rules (New Rule)

Upon authorization and promulgation, the above rules, with the exception of 45CSR25, will be submitted to the U.S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the federal Clean Air Act, as amended. 45CSR25 will be submitted to U.S. EPA as a component part of the State's rules for program authorization relative to the hazardous waste management provisions under the federal Resources Conservation and Recovery Act.

After conclusion of the hearing on the proposed rules above, the Division of Environmental Protection will hold a hearing on proposed minor revisions to the maintenance plans associated with West Virginia's three redesignation requests currently pending before U.S. EPA for the Charleston, Parkersburg, and Huntington/Ashland ozone nonattainment areas. These revisions contain language which clarifies West Virginia's commitments for contingency measures that had been incorporated in the original November 13, 1992 Redesignation Request, the Update to the November 13, 1992 Redesignation Request, dated February 28, 1994 for the Charleston/Parkersburg areas and the Amendment to the November 12, 1992 Redesignation Request, dated November 12, 1993 for the Huntington/Ashland area.

The public hearing will be held in the Office of Air Quality's Conference Room at 1558 Washington Street East, Charleston, West Virginia. The hearing is open to the public. Written comments by all interested parties will be accepted from the date of this notice until the close of the hearing and made part of the record. Oral comments will be accepted at the public hearing and will be limited to five minutes per person per rule. The period for public comment will end at the close of the hearing.

Copies of the proposed legislative rules may be obtained from the Office of Secretary of State or may be reviewed during normal business hours at the following locations: Martinsburg-Berkeley County Public Library, 101 King Street, Martinsburg, WV and the Office of Air Quality's Burlington Office, P.O. Box 99, Burlington, WV on and after July 8, 1994.

Please provide any written comments or questions to the following contact and office:

G. Dale Farley
Office of Air Quality
Division of Environmental Protection
1558 Washington Street, East
Charleston, WV 25311-2599

7:8(11)

Certificate of Publication

This is to certify the annexed advertisement

WV DEPT.COMM.,LABOR, ENV. RES. DIV. ENV. PROTECTION OFFICE OF AIR QUALITY

NOTICE OF PUBLIC HEARING

appeared for 1 consecutive days weeks in The Journal Publishing Company a newspaper published in the City of Martinsburg, W. Va., in its issue beginning

7/8

and ending

OFFICIAL SEAL
NOTARY PUBLIC
STATE OF WEST VIRGINIA
CHERYL D. GEORGE
Box 505½ Jefferson Street
Martinsburg, W.Va. 25401
My Commission Expires September 14, 1998

The Journal

Fee $ 43.61

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Washington, D.C. 20037

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Upper Kanawha Valley Committee
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AUGUST 9, 1994

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W VA OFFICE OF AIR QUALITY

AUGUST 9, 1994

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[illegible]	WVDEP OAQ	Charleston
Kara Watson	"	"
Jeanne Chandler	WVDEP - PIO	Charleston

PUBLIC HEARING

WEST VIRGINIA DIVISION OF ENVIRONMENTAL PROTECTION

OFFICE OF AIR QUALITY

* *

The following is a transcript of a public hearing held at the West Virginia Division of Environmental Protection, Office of Air Quality, 1558 Washington Street, Charleston, Kanawha County, West Virginia, on August 9, 1994, at 9:00 a.m., and taken by Christy L. Morris, Certified Court Reporter and Notary Public, pursuant to notice.

* *

S U P E R I O R C O U R T R E P O R T I N G
Christy L. Morris, CCR
3719 Virginia Avenue, S.E.
Charleston, West Virginia 25304
(304) 925-2244 Mobile 542-4606

ORIGINAL

PROCEEDINGS

45CSR6

TO PREVENT AND CONTROL AIR POLLUTION
FROM COMBUSTION OF REFUSE

MS. CHANDLER: The purpose of this public hearing is to hear discussions on proposed Rule 45CSR6.

To Prevent And Control Air Pollution From Combustion of Refuse.

The purpose of 45CSR6 is to prevent and control air pollution from the combustion of refuse. The rule, with limited -- with certain limited exceptions, prohibits open burning. The last effective amendment to the rule was on April 8, 1980.

The proposed rule modification is to allow Hercules Aerospace Corporation to openly burn spent propellent. Currently, such propellant can be burned under the provisions of 45CSR25, but inconsistencies exist between 45CSR25 and 45CSR6, which prohibit the open burning of the spent propellant. Resolving the inconsistencies requires the application

of the most stringent provision, here, 45CSR6, which prohibits the open burning of the spent propellant.

The proposed changes, in conjunction with changes to 45CSR25, will allow the burning of the spent propellant in accordance with the provisions of 40 CFR 265.382, a rule which applies, in part, to the open burning of military explosives.

In addition, definitions have been alphabetized, and the code sections updated in accordance with the provisions of the recently enacted Division of Environmental Protection legislation.

Upon authorization and promulgation, 45CSR6 will be submitted to the U. S. Environmental Protection Agency for EPA approval and incorporation into the West Virginia State Implementation Plan under the Federal Clean Act, as amended.

The floor is now open for public comment. Oral comments will be limited to five minutes.

MR. HULBURT: Yes, my name is David Hulburt and I represent Hercules Aerospace Company, Allegheny Ballistics Laboratory or ABL as I will refer to it. By

way of brief background, ABL is two contiguous plants, which are operated as a single entity by Hercules. Plant 1 is owned by the Navy; leased by Hercules and consists of approximately 1,577 acres. Whereas, plant 2 is owned and operated by Hercules and consists of about 57 acres.

The main products produced at the plant are solid precautions systems for U. S. defense industries such as Solid Propellant Rocket Motors for Tactical Missiles, Launch Gas Generators for Ballistic Fleet Submarine Missiles and Explosive Warheads for Missiles. So, you know, producing these products we have to handle and process a number of propellant and explosive ingredients and formulation.

We petition for change to rule 6 specifically to add paragraph 3.1(e) to the list of those activities which were exempted from the prohibition for open burning, namely to read open burning of propellant and explosives containing wastes, provided that the open burning is conducted in accordance with 45CSR25.

Subsequent to that petition and

discussion with the Office of Air Quality, Hercules has no exception to deleting the word "containing" as it is now contained within the proposed change at this point.

The need for this change we feel is rather obvious. First of all, due to the nature of our operations there are explosive and propellant waste which are unavoidably generated. Secondly, at present there are no alternate treatment/disposal methods currently proven other than open burning to handle this, and this has been recognized by the EPA and subsequently by West Virginia in including it specifically under 40 CFR, parts 264 and 265.

We believe this indeed, then, has some rationale in the one, the activity is currently permitted under the provision of 45CSR25 in its reference to the Federal regulations. This proposed change admittedly has the effect of eliminating the inconsistency that currently exists between 45CSR6 and 45CSR25.

Further, the change has no effect on any air pollution issue in that air pollution issues are well regulated already under 45CSR25, which as it

stands the requirements with regard to conducting the open burning in a matter that does not threaten human health or the environment.

We will be submitting written documentation as well as this presentation and supporting documentation on the studies which has been done which support the conclusion that open burning of propellant explosives can be done in an environmentally acceptable matter. This concludes my oral comment.

MS. CHANDLER: Thank you, Mr. Hulburt.

MR. FARLEY: My name is Dale Farley and I am Chief of the Office of Air Quality. One of the comments that I wanted to make on the rule has already been made by the Hercules official here and that is that it relates to the removal of the word "containing" in section 3.1(e). We have discussed that with Hercules, the people from Hercules, the rationale behind that and the have accepted it. I think that is pretty well understood.

The other thing that I wanted to mention is for a matter of record is that since this change has been requested by a specific company it is important to

point out that notwithstanding that this could affect other companies. I think we are aware of one other facility in the eastern panhandle that may be affected by this. For one of a better term; allowance of burning of the explosive wastes.

The one thing I do want to emphasize is that this is has been kind of an awkward point of discussion in this matter is that to make this change, obviously the Office of Air Quality wants to be assured that allowing the opening burning explosive wastes and explosive contaminated waste would not be detrimental to human health and the environment consistent with the phrasing in Reg. 25.

The company has -- Hercules has submitted a number of documents which I thought were preliminary to support that position that this is not a detrimental activity with respect to any criteria established to this point.

It is also important to point out that Hercules has also procured some, I believe, three-hundred thousand dollars or something to that effect to do a much more extensive study of the affects of the

open burning in areas, particularly this area and bordering areas of Maryland where we had the complaints of this activity. And those studies will not be completed until about the end of this year.

So, the only thing I want to point out is that we fully expect the company to revoke the submissions today and the additional information will be provided even after -- perhaps after the filing of this rule to fully support this particular change to the rule. And that in the event that some very detrimental finding would come out of the additional studies, we would have to revisit the -- or rather consider the removal of this regulation from the rule-making process at that time.

MS. CHANDLER: Thank you, Mr. Farley. Are there any other comments to 45CSR6? There being nothing further, the public hearing for 45CSR6 is concluded.

REPORTER'S CERTIFICATE

STATE OF WEST VIRGINIA,

COUNTY OF KANAWHA, to wit:

I, Christy L. Morris, Certified Court Reporter and Notary Public duly certify and commissioned, do hereby certify that the foregoing is a true and accurate transcript of the proceedings had in the public hearing on the 9th day of August, 1994.

Given under my hand and notarial seal this 11th day of August, 1994.

C. L. Morris CCR
Certified Court Reporter
Notary Public

MY COMMISSION EXPIRES: 12/11/95

WVDEP/OAQ RESPONSE TO PUBLIC COMMENT ON PROPOSED 45CSR6 TO PREVENT AND CONTROL AIR POLLUTION FROM THE COMBUSTION OF REFUSE

Two oral submissions were presented. The first was by a representative of Hercules Aerospace Company (ABL) which operates the Allegheny Ballistics Laboratory in West Virginia near Cumberland, Maryland. The commenter noted that Hercules had petitioned OAQ to amend Rules 6 and 25 in order to correct a technical conflict in the two rules to allow the open burning of spent explosive material at ABL in accordance with a military standard. Hercules contends that open burning is the only currently available method of disposal. The commenter noted that he had no objection to removing the word "containing" in Section 3.1(e). OAQ will revise the rule accordingly. He also noted that Hercules was submitting written comments and backup materials to support the revision to rules 6 and 25 as directed by OAQ.

Dale Farley, Chief of the OAQ, was the second commenter. He commented that Hercules had submitted a number of documents that were still deemed by OAQ to be preliminary to support the position that ABL's open burning of explosive wastes is not a detrimental activity (with respect to human health and environmental impacts). In addition, he noted that Hercules is in the process of entering into an approximately three hundred thousand dollar contract with an outside contractor to conduct additional detailed studies for any public health and environmental effects resulting from the open burning of spent explosive material. He further noted that OAQ is proposing amending the rule based upon preliminary data but pending the results of the study. Tentatively, the initial results from the detailed study are expected to be completed by the end of December, 1994.

Two written submissions were received. One comment stated that incorporating the section containing the determination of stringency in relation to federal counterpart regulations in the rule [Section 1.6] is inappropriate. The comment notes that W.Va. Code §22-1-3 requires the Director of the Division of Environmental Protection to provide a written statement in circumstances in which the Director determines that the rule should not be the same in substance as the counterpart federal regulation. DEP responds that even though this rule does not intend to incorporate a counterpart federal regulation by reference, no reason exists to exclude the determination from the rule and the "incorporation by reference" section and that as a matter of Division of Environmental Protection policy, that the specific "Determination of Stringency" section be included in each rule proposed by the individual Offices within the Division. DEP responds that the section and "incorporation by reference" section as stated is satisfactory. However, OAQ will revise this rule to add a section pertaining to "severability" in the event that this section or other sections of the rule are invalidated.

Another comment in the written submission was that incorporating the "Constitutional Takings Determination" section in the rule [Section 1.7] is inappropriate. The comment notes that an explanation of the takings determination simply be included as part of the rule filing. DEP does not disagree with the comment, but notes that no specific reason exists to exclude the determination, and that as a matter of Division of Environmental Protection policy, that the specific "Constitutional Takings Determination" section be included in each rule proposed by the individual Offices within the Division. OAQ responds that the section as stated is satisfactory.

One written comment noted that the word "director" was inadvertently omitted in Section 2.16 following the phrase "smoke density and is approved by". OAQ agrees and will amend Section 2.16 accordingly.

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MICHAEL P. MCTHOMAS
DIRECT DIAL NO. (304) 347-8339

August 9, 1994

VIA HAND DELIVERY

G. Dale Farley, Chief
Office of Air Quality
1558 Washington Street, East
Charleston, West Virginia 25311

Dear Mr. Farley:

Enclosed for filing are the written comments of the West Virginia Manufacturers Association for the Division of Environmental Protection, Office of Air Quality proposed legislative rule, 45 CSR 6, "To Prevent Uncontrollable Air Pollution from Combustion of Refuse."

If you have any questions regarding the comments, please feel free to call me.

Very truly yours,

Michael P. McThomas

MPM:cdl
Enclosure

COMMENTS OF THE
WEST VIRGINIA MANUFACTURERS ASSOCIATION
ON PROPOSED REGULATION 6
TO PREVENT AND CONTROL AIR POLLUTION
FROM COMBUSTION OF REFUSE
45 CSR 6

August 9, 1994

COMMENTS OF THE
WEST VIRGINIA MANUFACTURERS ASSOCIATION
ON PROPOSED REGULATION 6
TO PREVENT AND CONTROL AIR POLLUTION
FROM COMBUSTION OF REFUSE

August 9, 1994

I. INTRODUCTION

On July 6, 1994, the West Virginia Division of Environmental Protection, Office of Air Quality ("DEP" or "OAQ") filed with the Secretary of State proposed amendments to Regulation 6, "To Prevent and Control Air Pollution From The Combustion of Refuse," of Title 45 of the West Virginia Code of State Rules. Accompanying the proposed rule was a notice inviting written comment for a public hearing to be held August 9, 1994. Pursuant to this notice, the West Virginia Manufacturers Association ("WVMA") files these comments.

The WVMA represents a broad cross-section of large and small industrial concerns throughout West Virginia. Because WVMA members are subject to, and significantly affected by, changes in the state air program, the WVMA has actively participated in the development of the state program since its inception.

II. GENERAL COMMENTS

A. Incorporation by Reference.

The WVMA recommends that proposed section 1.5 be deleted from the rule, and instead, a statement finding that no federal counterpart exists be presented

with the usual materials requested by statute, including fiscal note and narrative description of proposed changes. The determination required of the Director of DEP pursuant to W. Va. Code § 22-1-3 should be filed with the proposed rule and not made part of the proposed rule. West Virginia Code § 22-1-3(c) provides, in pertinent part, as follows:

> The director shall file, contemporaneously with the proposed rule, a statement setting forth whether the rule is the same in substance as a counterpart federal regulation. If the director determines that the rule should not be the same in substance as a counterpart federal regulation, then the director shall file contemporaneously with the proposed rule, a statement setting forth the differences between the proposed rule and the counterpart federal regulation.

W. Va. Code § 22-1-3(b)(1994). There is no directive to include the reasons or statement in the rule itself. Rather, the statute contemplates a separate statement to accompany the rule when filed with the Secretary of State.

B. Determination of Stringency.

The WVMA also asserts that it is inappropriate to incorporate this section into the proposed rule. Pursuant to W. Va. Code § 22-1-3a, where rules promulgated by the Director will be more stringent or less stringent than their federal counterpart, the Director is required to provide a written statement, setting out specific reasons which demonstrate that each particular, substantive provision that varies from the federal counterpart regulation is (in the case of a more stringent rule) or is not (in the case of a less stringent rule) "reasonably necessary to protect, preserve or enhance the quality of West Virginia's environment or human health or safety." The statement required

of the Director must take into consideration the scientific evidence, specific environmental characteristics of West Virginia or an area thereof, or stated legislative findings, policies or purposes relied upon by the Director in making the preceding determination. Accordingly, to comply with the legislative mandate, the Director's statement would need to be detailed and address specific provisions.

The WVMA submits that the statement required from the Director should not be included as a section in the rule, but, instead, should be attached with the documents normally filed with a proposed rule. Clearly, the legislature did not contemplate that the Director's statement regarding stringency of specific provisions in a proposed rule would be incorporated into the rule and adopted as law. This proposed section should, therefore, be deleted from the final rule, and, after examining the proposed rule, the Director should publish an appropriate statement by filing it with the Secretary of State with the documents accompanying the rule.

C. Constitutional Takings Determination.

The WVMA also believes that it is inappropriate to incorporate this section into the proposed rule. Accordingly, the WVMA recommends that this proposed section be deleted from the final rule and that the Director's "takings" analysis be placed in the documents to accompany the rule when filed with the Secretary of State.

III. SPECIFIC COMMENTS

Section 2.16

In Section 2.16, the word "director" was inadvertently left out of the sentence during the transition of changing "commission" to "director." Therefore, following the words "smoke density and is approved by" the WVMA suggests the addition of the word "director."

IV. CONCLUSION

The WVMA appreciates the opportunity to comment on this proposed rule.

Karen S. Price, President
West Virginia Manufacturers Association
2001 Quarrier Street
Charleston, West Virginia 25311
(304) 342-2123

Prepared by:
Robinson & McElwee
P.O. Box 1791
Charleston, West Virginia 25326
Contact: Michael P. McThomas, Esquire
(304) 347-8339

DIVISION OF ENVIRONMENTAL PROTECTION

GASTON CAPERTON
GOVERNOR

10 McJunkin Road
Nitro, WV 25143-2506

DAVID C. CALLAGHAN
DIRECTOR

August 9, 1994

Ms. Judy Cooper
Director, Administrative Law Division
Secretary of State's Office
Building 1, Suite 157K
Charleston, West Virginia 25305

RE: CSR-45-6 - To Prevent and Control Air Pollution From Combustion of Refuse

Dear Ms. Cooper:

This is to advise you that I am giving approval for the filing of the above-captioned rule with your Office and with Legislative Rule-Making Review Committee as an agency-approved rule.

Your cooperation in this regard is very much appreciated. If you have any questions or require additional information, please feel free to contact Roger T. Hall at 759-0515.

Sincerely yours,

David C. Callaghan
Commissioner
Bureau of Environment

DCC;RTH:cc

Attachment

Hercules Aerospace Company
Allegany Ballistics Laboratory
P. O. Box 210
Rocket Center, WV 26726-0210
(304) 726-5000

August 4, 1994

Bureau of Environment
Division of Environmental Protection
Office of Air Quality
1558 Washington Street East
Charleston, WV 25311

Attention: Mr. Dale Farley, Chief

Comments on Proposed Changes to 45 CSR 6

Hercules Aerospace Company, Allegany Ballistics Laboratory (Hercules ABL), petitioned for and supports the proposed change to 45 CSR 6 [3.1(e)], which would allow an exemption from the prohibition of open burning of refuse for propellant and explosives wastes, provided the open burning is conducted in accordance with 45 CSR 25. Hercules ABL does not object to deletion of the word *"containing"* from paragraph 3.1(e) of the proposed rule. The following comments and rationale are submitted for the record in conjunction with the August 9, 1994 hearing on the subject matter.

Need for the Proposed Rule Change

Allegany Ballistics Laboratory is comprised of approximately 1577 acres of Navy-owned facility and approximately 57 acres of Hercules owned facility, which is operated by Hercules Aerospace Company. Current employment is over 500 people. Employment is expected to increase by 200-300 over the next several years with the consolidation of another Hercules location to ABL. The principal products manufactured at ABL are solid propellant propulsion systems and explosive warheads for government defense agencies. Propellant and explosive wastes are generated during manufacturing and processing. There is currently no proven technology for treatment/disposal of these wastes other than open burning. Regulatory change to Rule 6 to exempt open burning of propellant and explosive wastes is needed to allow the facility to remain in operation until such time as feasible alternate technologies may become available and implemented.

Rationale for the Proposed Rule Change

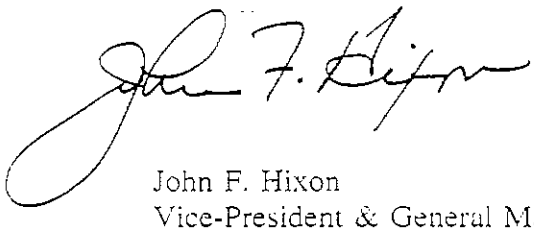
The principal rationale for the proposed rule change is that it has no regulatory effect other than eliminating the inconsistency with Rule 25. The EPA, in recognition that alternate technologies for treatment/disposal of explosives wastes did not exist, specifically exempted these wastes from its open burning prohibition for hazardous wastes in 40 CFR 265.382. The State of West Virginia, in 45 CSR 25, has adopted this EPA regulation by reference.

The proposed change to Rule 6 would have no effect on safety, health, or the environment. These issues are properly and adequately addressed under the EPA regulations adopted by reference in 45 CSR 25. The Department of Defense Explosives Safety Board (DDESB) has concurred in distance provisions for siting of ABL's burning grounds based on overpressure considerations only. Modeling of combustion products and dispersion of emissions supports the absence of a health or environmental threat. A risk assessment to demonstrate compliance with the environmental and health standards of 40 CFR 265.382 will be conducted.

Relevant Studies

A number of studies have been conducted by others as well as by Hercules on matters which have some bearing on the potential safety, health, and environmental issues associated with the open burning of explosives wastes. A discussion of these studies is being provided under separate cover. In addition, current issues surrounding open burning as practiced at ABL are discussed. Copies of pertinent documents are being provided with the separate discussion.

Sincerely,



John F. Hixon
Vice-President & General Manager

dah

HERCULES

Hercules Aerospace Company
Allegany Ballistics Laboratory
P. O. Box 210
Rocket Center, WV 26726-0210
(304) 726-5000

August 4, 1994

Bureau of Environment
Division of Environmental Protection
Office of Air Quality
1558 Washington Street East
Charleston, WV 25311

Attention: Mr. Dale Farley, Chief

Comments on Proposed Changes to 45 CSR 25

Hercules Aerospace Company, Allegany Ballistics Laboratory (Hercules ABL), petitioned for and supports the proposed change to 45 CSR 25 [3.2d], which would allow for shorter distance provisions than those contained in 40 CFR 265.382 to be applied to the open burning of explosives wastes. The following comments and rationale are submitted for the record in conjunction with the August 9, 1994 hearing on the subject matter.

Need for the Proposed Rule Change

The need for the proposed rule change is contingent upon West Virginia's interpretation of the inclusiveness of its adoption by reference of the Code of Federal Regulations in 45 CSR 25. The EPA has provided for shorter distance provisions than those specified in 40 CFR 265.382 by publishing a Final Rule correction in 54FR26198-26199. There is apparently some difference of opinion among Office of Air Quality personnel as to whether this correction is included under the adoption by reference. The proposed rule change was petitioned to remove possible ambiguous interpretation of this matter.

The ABL Burning Ground has been at its present location for over thirty years. This site does not meet the distance provisions of 40 CFR 265.382. It does meet the shorter distance provisions of DoD 4145.26-M, which is the governing siting document under which Hercules operates with the Government. The location also conforms to the American Table of Distances for Commercial Explosives with regard to off-site receptors. Hercules could find no suitable cost-effective alternate burning ground location on the facility which would meet the distance provisions of 40 CFR 265.382.

Rationale for the Proposed Rule Change

The basis of the development of the distance provisions in 40 CFR 265.382 was the disposal of cased military explosives, which present fragment missile hazard as well as potential overpressure hazard. The EPA recognized that these distance provisions did not necessarily apply to the open burning or open detonation of commercial explosives, and published the Final Rule correction, in which they stated "A permit may be issued with shorter distance provisions (e.g., based on the American Table of Distances for Commercial Explosives) as long as the Part 264 Subpart X environmental performance standards for protection of human health and the environment are met."

As the lessee of government facilities and a government contractor, Hercules Aerospace Company, Allegany Ballistics Laboratory is bound by the explosive safety criteria of DoD 4145.26-M, Contractors' Safety Manual. The ABL burning ground is sited, and open burning is conducted, in conformance with the distance provisions of this document. Given the offset of off-site receptors from the ABL property line, conformance with DoD 4145.26-M ensures conformance with the American Table of Distances as well for off-site receptors.

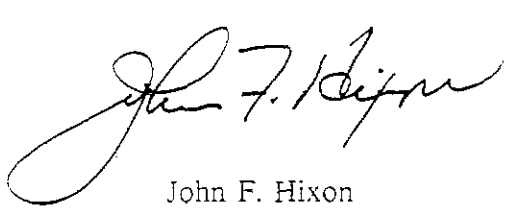
Proposed Rule Language

Office of Air Quality personnel have indicated a preference for distance to the property line provisions as well as to specific receptors. The American Table of Distances does not have distance to property line provisions. The provisions of DoD 4145.26-M include criteria for property line distance. Hercules would not object to replacing the second sentence of the proposed rule paragraph 3.2.d with the following: *"The distance to property line provisions of DOD Contractors' Safety Manual for Ammunition and Explosives, DoD 4145.26-M and the distance to off-site inhabited buildings, public highways and passenger railways provisions of the American Table of Distances, IME Safety Library Publication No. 2 apply otherwise."*

Relevant Studies

A number of studies have been conducted by others as well as by Hercules on matters which have some bearing on the potential safety, health, and environmental issues associated with the open burning of explosives wastes. A discussion of these studies is being provided under separate cover. In addition, current issues surrounding open burning as practiced at ABL are discussed. Copies of pertinent documents are being provided with the separate discussion.

Sincerely,



John F. Hixon
Vice-President & General Manager

HERCULES

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August 4, 1994

Bureau of Environment
Division of Environmental Protection
Office of Air Quality
1558 Washington Street East
Charleston, WV 25311

Attention: Mr. Dale Farley, Chief

Supporting Materials for Comments on Proposed Changes to 45 CSR 6 and 45 CSR 25

Under separate cover, Hercules Aerospace Company, Allegany Ballistics Laboratory, has provided its comments on the proposed changes to 45 CSR 6 and 45 CSR 25, which are the suject of hearings scheduled on August 9, 1994. This letter transmits and submits copies of pertinent documents and discusses the studies and issues relevant to open burning of propellant/explosive wastes, the operations which occasioned the petition for regulatory change.

Sincerely,

John F. Hixon
Vice-President & General Manager

Enclosure w/Exhibits

dah

STUDIES AND ISSUES RELEVANT TO

OPEN BURNING OF PROPELLANT/EXPLOSIVE WASTES

OPEN BURNING PRODUCTS OF COMBUSTION - POLU13 CODE

Under the sponsorship of the Navy Ordnance Environmental Support Office, a computer program (POLU13) was developed to predict the combustion products when explosives or like materials are open burned or open detonated. The computer program was validated by comparing the computer predictions to actual emissions data measured during open burning of Navy waste propellants at Dugway, Utah. General conclusions from the open burning trials and computer predictions for the Navy propellants are:

It is expected that sufficient oxygen is available in open burning to completely oxidize explosive wastes.

Expected fate of the elements in propellant is:

HYDROGEN	Formation of H2O, H2, and HCl
CARBON	Formation of CO and CO2
NITROGEN	Predominantly N2. Some traces of NO2 may be formed.
OXYGEN	Combines with all of the elements except zinc, if present.
ALUMINUM	All aluminum goes to Al2O3 solid. First element oxidized.
CHLORINE	Predominantly HCl, with some metal chlorides.
LEAD, ZINC	May form chlorides or oxides or remain as elemental metal.

A copy of the report documenting the development and validation of the POLU13 code is provided as Exhibit 1.

OPEN BURNING PRODUCTS OF COMBUSTION - Hercules ABL Study

Parametric modeling studies using POLU13 were run for five propellants and one explosive, representing the "families" of formulations produced and processed at ABL. The parameter was the amount of air intake, which was varied from 50% to 80% to bracket the 60-70% value ascertained as likely in the POLU13 validation studies. The results of these modeling studies are summarized in the attached study report, Exhibit 2.

Principal findings of the modeling are as follows:

Principal species in the combustion emissions regardless of formulation are nitrogen, carbon dioxide, and water vapor.

At the low end of the assumed air intake range, some carbon may appear as carbon monoxide rather than carbon dioxide, but based on POLU13 validation studies, full oxidation of carbon to the dioxide is expected.

As expected, as excess air intake occurs, oxygen begins appearing in the combustion "products."

In formulations containing ammonium perchlorate, the chlorine comes off principally as hydrogen chloride. At the high range of assumed air intake, the model predicts some conversion of HCl to Cl2.

Aluminum and zirconium, when present, come off as their oxides, the amount being independent of air intake.

Iron, when present, comes off as a chlorides and oxides.

Lead, when present, comes off as the element or one or more oxides.

Minor amounts of hydrogen, hydrogen sulfide, or methane are predicted in some specific propellant/air intake combinations.

In no case, were significant amounts of nitrogen oxides predicted in the combustion products.

Based on the products of combustion, their levels, hazard properties, and regulatory limits, it was determined that the species of primary interest from a potential environmental/health perspective were hydrogen chloride, chlorine, and lead compounds. Hydrogen chloride/chlorine is of interest because it is a significant combustion product for the formulations containing ammonium perchlorate. Although lead is a relatively minor constituent, lead has an extremely low NAAQS limit, and it is therefore of potential concern. The only other compound of possible interest is the aluminum oxide, which is present in significant amounts in aluminized propellant. At most, however, it is present in combustion products (as aluminum) at a comparable level to HCl. The TWA for aluminum oxide is greater than the Ceiling Limit for HCl. Furthermore, not all the aluminum oxide becomes airborne; some remains in the ash residue. Establishing that HCl/Cl2 does not pose a health threat should therefore ensure that aluminum oxide exposure does not either.

EMISSION PRODUCTS FROM OB/OD - "BangBox" and "Field Test" Studies

In recognition that open burning/open detonation are currently the primary means of demilitarization employed by the Department of Defense, and the increasing need for data on OB/OD combustion products to support environmental documentation requirements, the Single Manager for Conventional Ammunition within the DoD undertook studies to provide the scientific data to answer the question of environmental acceptability of OB/OD thermal treatment methods.

These studies included a number of small-scale propellant/explosive detonation and burning trials within a controlled ambient air environment (BangBox Test Series), and a number of large scale field trials (Field Test Series). The EPA (Office of Solid Waste/Atmospheric Research and Exposure Assessment Laboratory) has validated and accepted these methods for the characterization of emissions from OB/OD thermal treatment operations. Volumes 1, Test Summary, of both the BangBox Test Series and the Field Test Series are provided as Exhibits 3 and 4.

Conclusions from the OB of propellant in the BangBox Series are summarized as:

> Based on propellant carbon conversion to CO_2, open burning of double-base and composite propellant is an extremely efficient thermal treatment method.
>
> Further work is needed to determine the fate of chlorine in the combustion products.
>
> None of the most toxic polychlorinated dibenzodioxins were detected. A marginal detection of less toxic polychlorinated dibenzofurans occurred in one sample, but it is believed the source was not derived from the composite propellant.

The executive summary in the Field Test Series includes the following pertinent conclusions and recommendations:

> The study suggests that the bulk explosives and propellants examined during field testing may be treated in an environmentally safe manner by surface OB/OD methods.
>
> Site-specific testing is needed to provide data to support risk assessments.
>
> Over 99 percent of the total carbon contained in tested propellants was accounted for in the form of carbon dioxide following the burn event.
>
> Propellants used in the program did not add measurable levels of contamination to the soil beyond 12 meters from the propellant burns.

STATUS OF RCRA PERMITTING OF OB/OD OF EXPLOSIVE WASTES

Members of the Ohio Hazardous Waste Facility Board conducted a survey of the status of OB/OD Subpart X permit applications, OB/OD emissions issues, estimated health risks from OB/OD, and alternatives to OB/OD. The study was presented at the Air and Waste Management Association Conference in June 1993. A copy of their paper is provided as Exhibit 5.

Findings and conclusions presented in this paper include:

> OB/OD will likely remain the primary treatment method for waste explosives.
>
> Alternatives such as explosive waste incinerators are cost prohibitive for many users and manufacturers.
>
> There is a nationwide lack of commercial incineration capacity for the offsite generator [for energetic materials].
>
> The Dugway results suggest that OB/OD is an environmentally safe practice for the wastes which were studied.
>
> Two potential alternate technologies (fuel additives or co-firing fuels) have not progressed past bench scale studies. Overall safety and risk considerations will make it difficult to field these technologies.
>
> The Ohio Hazardous Waste Facility Board prefers actual emissions data (e.g. Bang Box) to emissions estimates based upon computer simulations of OB/OD treatment.

AIR DISPERSION MODELING OF OB EMISSIONS - Hercules ABL Study

Air dispersion modeling studies of OB emissions at ABL were performed using the SCREEN2 dispersion model (the SCREEN2 model was specifically requested by the WVDEP/OAQ). Output of the POLU13 combustion products study was used to provide input to the model. Weather data from the ABL weather station was used to provide wind speed and direction statistics. Potential receptors were selected based on locations of residences adjacent to the facility. Worst case stability data was used for each wind speed, receptor distance combination. Potential emissions of lead compounds, hydrogen chloride, and chlorine were studied. These studies indicate that OB as practiced at ABL does not present a threat to human health or the environment. A copy of the study is provided as Exhibit 6.

SAFETY SITE PLAN FOR ABL BURNING GROUND

A Facilities Project for upgrading the present burning grounds at ABL was submitted and approved by the Navy in 1993. This project included provision for burn pans, minor relocation of burn pads to optimize distance from the property line and on-site buildings, refurbishing the control bunker, and some diking. As part of this project, a safety site plan was submitted to the Department of Defense Explosive Safety Board (DDESB), seeking concurrence in siting and establishment of explosive limits solely on the distance provisions of DoD 4145.26-M based on potential overpressure hazard only. Verbal notification has been received that the DDESB has approved the proposed site plan as submitted. The project is currently on "HOLD" pending overall resolution of open burning issues. Open burning practices are being conducted in conformance with the overpressure distance provisions. A copy of the Safety Site Plan submittal is provided as Exhibit 7.

CITIZEN CONCERNS WITH OB AT ABL

In mid-1993 ABL became aware of citizen concerns, principally relating to black smoke and particulate which were associated with open burning at ABL. An "open meeting" was arranged by the Maryland Department of the Environment and attended by eight citizens residing in Maryland, generally north of the ABL burning ground. Although ABL received no formal notice of this meeting, we became aware of it and sent a representative to hear the concerns voiced. Our assessment of the concerns is that they related to smoke and particulate which primarily is associated with burning of propellant/explosives contaminated wastes as opposed to near pure propellant/explosives waste.

As part of ongoing waste minimization efforts, and in response to the concerns voiced, ABL has taken a number of measures and studies to further minimize P/E contaminated wastes and to mitigate any smoke or particulate generated in open burning. These measures are described in detail below. These measures have largely eliminated black smoke and particulate.

ATSDR HEALTH CONSULTATION ON OB AT ABL

Staff from the Agency for Toxic Substances and Disease Registery (ATSDR) visited ABL from May 10-12, 1994 to conduct a site scoping visit and to meet with the public. Some citizens expressed concern that the smoke from burning wastes at ABL could be hazardous, and requested ATSDR address that issue. In response, ATSDR issued a health consultation, a copy of which is provided as Exhibit 9. ATSDR could not rule out adverse health effects based on the information they had at hand, and recommended that air monitoring and soil sampling and analysis be done.

HERCULES ABL COMMENTS & RESPONSE TO ATSDR CONSULTATION

Hercules ABL is not in agreement with several of the statements and conclusions made in the consultation. Our comments aand rationale for disagreement are included in Exhibit 10, which is being provided to ATSDR through NAVSEA, to whom the consultation was addressed. ABL is responding to the recommendations for air monitoring and soil sampling as discussed under "Risk Assessment" below. The specific response to ATSDR is also in the Exhibit 10.

P/E CONTAMINATED WASTE MINIMIZATION

A number of measures have been implemented in the past year to minimize the amounts of wastes which must be burned. They have also significantly reduced the smoke and particulate generated. Skids and crates used in shipment of P/E materials were formerly presumed to have been contaminated and were burned as a matter of course. This practice has been discontinued. These items are now inspected, and are not burned unless there is visual evidence of actual contamination. Nitramine explosives used as ingredients are packaged in muslin bags, which in turn are placed in plastic bags inside of fibre drums. Formerly, the fibre drums were presumed to have been contaminated and were burned as a matter of course. This practice has also been discontinued, and these items are also inspected, and are burned only if there is visual evidence of contamination. Elimination of these items has had a significant effect on smoke minimization. The wax coating on the drums was an apparent major contributor to smoke generation. A study of reuse of plastic surface formers on the TOW program has been completed. It was determined that these parts could be reused nine times before surface condition and dimensional stability of the parts render them no longer usable. At the completion of useful life, these parts are now cleaned and decontaminated and disposed of by landfilling. Other items of disposable plastic tooling are being evaluated on a case-by-case basis. Hard tooling will be used in future programs wherever feasible to eliminate or minimize contaminated items that must be burned.

Waste minimization measures accounted for a 20% reduction in P/E contaminated wastes burned during the second half of 1993 compared to the first half of the year on a per pound of propellant mixed basis.

OB SMOKE & PARTICULATE MITIGATION

To address the issue of smoke & particulate short term, a number of measures have been taken. These include combustion improvement measures, and mitigation measures.

Combustion improvement measures are those measures designed to achieve the optimum combustion of the P/E contaminated wastes that are open burned. Several measures to optimize the configuration and placement of wastes for burning have been implemented in the recent past. Waste consisting of sawdust soaked with contaminated acetone is now burned as a thin layer alone, or supplemented with P/E waste to optimize fuel/oxidizer and facilitate combustion.

Similarly, contaminated plastic waste is being burned in conjunction with bulk P/E to optimize the fuel/oxidizer ratio. Use of a grating to elevate the wastes off the pad surface to allow more ready access for combustion air has been implemented. Injection of air or oxygen into the combustion zone to further facilitate optimum fuel/oxidizer ratio was studied, but found not to be effective with the current overall configuration. Additional burn pans were fabricated to permit smaller, simultaneous burns of the waste.

Smoke/Particulate mitigation measures are those measures which may help to control the transport of smoke/particulate from the burning ground. Open burning of P/E contaminated waste has been changed from mid-afternoon to the morning hours to take advantage of generally more favorable wind direction and wind speed. A "roof" was installed over the P/E contaminated waste pad to "trap" particulate which may be potentially generated.

To eliminate smoke & particulate from contaminated waste long term, it is planned to construct an incinerator to treat this class of P/E waste. As an interim mitigation measure, ABL is studying the feasibility of SWISH technology as a means of optimizing the combustion process. The SWISH unit is classified as an enclosed open burning technology. Principals from Sandia National Laboratories will be at ABL in early August, and it is anticipated that they will be awarded a contract to construct a SWISH passive afterburner at ABL following their visit.

OB RISK ASSESSMENT

In order to obtain hard data to demonstrate compliance with environmental performance standards, ABL will have a muti-media risk assessment of its open burning operations conducted. Discussions have been opened with the Atmospheric Research Group of Sandia Laboratories to conduct this study. Representatives from Sandia are scheduled to be at ABL on August 8, 1994 to inspect the site and scope the work. ABL intends to enter into a contract with Sandia subsequent to this visit, with all work being completed and a report issued by the end of 1994. Sampling and analysis plans for air, soil, and groundwater will be reviewed with ATSDR, the Navy Environmental Health Center (NEHC) and the WVDEP/OAQ.

ALTERNATE TECHNOLOGIES RESEARCH

ABL continues to research possible alternate technologies to open burning other than incineration. ABL has entered into discussions with Sandia regarding their SWISH technology for "enclosed open burning" of wastes. This technology permits optimization of open burning combustion and minimizes smoke and particulate emissions. Representatives from Sandia will be at ABL on August 8 to discuss this technology as well. ABL intends to contract with Sandia to conduct trials on their unit in Albuerquerque, and construct a SWISH at ABL if the technology appears promising. Sandia must obtain New Mexico approval for the trials under NEPA, but expects the trials can be conducted in the fall of 1994.

ABL has identified Talon Industries as a firm that may have applicable technology for recovery/reuse of propellants and explosives. This technology has been demonstrated and is in use on double base propellants without binders. Most ABL propellants and explosives have cross-linked binders to achieve desired mechanical and dimensional stability. Funding sources are being solicited and ABL is in negotiations with Talon for a bench scale study to determine the feasibility of applying these technologies to ABL propellant/explosive wastes. If bench scale studies are promising it is ABL's intent to construct a pilot scale facility at ABL to prove-out the technology. The pilot scale project is anticipated to begin in late 1994, pending the results of the bench scale studies.

ABL has identified Molten Metal Technologies as a firm that has technology that may be applicable to propellant/explosive waste treatment. An initial line of communication has been opened with Molten Metal. This technology is centered on elemental recovery and compound destruction. ABL will pursue this lead to determine its possible feasibility and make whatever arrangements are necessary to explore it further if it appears promising.

RESOLUTION OF OPEN BURNING ISSUES

Hercules ABL has been actively pursuing resolution of P/E opening burning issues with West Virginia regulatory and legislative bodies and personnel over the past year. A chronology of meetings and milestone documents is provided in Exhibit 11.

LIST OF EXHIBITS

Exhibit 1	"Computer Predictions of Pollution Products from Open Burn and Open Detonation of Navy Explosives and Propellants," January 1987
Exhibit 2	"Open Burning Products of Combustion Study," submitted to WV/OAQ 2/16/94
Exhibit 3	"Development of Methodology and Technology for Identifying and Quantifying Emission Products from Open Burning and Open Detonation Thermal Treatment Methods." Bangbox Test Series, Volume 1, Test Summary, January 1992
Exhibit 4	"Development of Methodology and Technology for Identifying and Quantifying Emission Products from Open Burning and Open Detonation Thermal Treatment Methods," Field Test Series A, B, and C, Volume 1, Test Summary, January 1992
Exhibit 5	"Status of RCRA Permitting of Open Burning and Open Detonation of Explosive Wastes," 93-TP-36B.01, June 1993
Exhibit 6	"Open Burning Emissions Study, SCREEN2 Air Dispersion Modeling," June 29, 1994
Exhibit 7	"Request for Modification to Burning Ground Site Plan," July 12, 1993
Exhibit 8	"Contractors' Safety Manual," DoD 4145.26-M, pages 6-3a, 6-4
Exhibit 9	"Health Consultation for Allegany Ballistics Laboratory (#30BF)," June 24, 1994
Exhibit 10	"ATSDR Health Consultation for ABL, Comments and Responses," July 25, 1994
Exhibit 11	Chronology of Open Burning Issues Resolution Matters

OPEN BURNING PRODUCTS OF COMBUSTION STUDY

Revision 1

A. SUMMARY

The products of combustion (POC) from open burning of six representative propellants/explosives (P/E) were predicted using the POLLU13 computer model. This model was developed under the sponsorship of the Ordnance Environmental Support Office at the Naval Ordnance Station, Indian Head, Maryland (NOSIH) specifically to predict the pollution products caused by open burning (OB) or open detonation (OD) of explosives and like materials. The model was previously validated by comparing actual data to predicted data. POLLU13 was written specifically to provide input data for air dispersion models such as INPUFF, and has been recognized by the EPA for such use.

A prime parameter in the model is the air to P/E ratio. Previous studies done by the Navy indicate that complete oxidation of hydrogen and carbon atoms to water and carbon dioxide is expected in open burning, and that this occurs for most formulations at 50 - 80% air uptake. Formulations based on ammonium perchlorate (AP) oxidizer also have hydrogen chloride as a principal combustion product. At very high air uptake, some of the HCl converts to chlorine. Metal atoms such as aluminum, zirconium, and iron, when present, typically are oxidized to the respective oxides. Lead atoms, when present, remain as the base metal until the higher air uptake level, when they are oxidized to one or more of the oxides.

It would appear that hydrogen chloride/chlorine are the primary combustion products of interest from a potential environmental/health perspective. AP, when present in a formulation, is typically present as a major constituent. Estimated annual emission of HCl/Cl2 is about 10,000 pounds. Aluminum is at most about 20% of the P/E formulation, and is absent from many formulations. Estimated emission of Al2O3 is 4250 pounds per year. Other metal compounds are typically present at very low levels in the formulation (1-2%). Total lead emissions are estimated at about 300 pounds per year.

The next steps in the overall study are to obtain regulatory (WV/EPA) agreement on the use of INPUFF for dispersion modeling, install and startup INPUFF, and input the results of the POC model into the INPUFF model to obtain predictions of airborne concentrations as a function of distance and direction from the open burning site.

B. P/E MATERIALS IN THE POC STUDY

Six formulations were selected for study as being representative of the families of propellants and explosives currently being and projected for future manufacturing. These six include three composite rocket propellants, one double base rocket propellant, one double base gas generator propellant, and one warhead explosive. The pertinent aspects of formulation composition are discussed below.

1. Composite Rocket Propellants

The primary constituent of composite rocket propellant is AP oxidizer, which is embedded in a rubber binder, which acts as the fuel. In some formulations, aluminum (Al) is added as additional fuel, replacing some of the AP. AP plus Al is typically 85-88% of the formulation. Minor constituents may include plasticizers, wetting agents, cross-linking agents, combustion rate modifiers, stabilizers, etc. Typical rubber binders are hydroxy terminated polybutadiene (HTPB) or carboxy terminated polybutadiene (CTPB), which are cross-linked by isocyanates to form urethane linkages.

The three compositions chosen represent a moderately aluminized CTPB propellant, an HTPB propellant, and a highly aluminized HTPB propellant. Major constituents, and minor constituents of interest from a health/environmental perspective are summarized below.

CONSTITUENT	CTPB	HTPB	HTPB-Al
Ammonium Perchlorate	80.0	85.0	68.0
Aluminum	6.0	0.0	20.0
Binder	9.1	8.7	6.5
Zirconium Oxide	0.0	1.0	1.0
Miscellaneous Balance	4.9	5.3	4.5
TOTAL	**100.0**	**100.0**	**100.0**

2. Double Base Rocket Propellant

Typical compositions in this category currently and planned for manufacture are based on nitrate esters and nitramines cross-linked with isocyanates. Minor constituents include plasticizers, combustion rate and stabilizer agents. The composition data for the propellant of this class included in the study is given below.

CONSTITUENT	XLDB
Nitramine (RDX)	62.0
Nitrate Esters (NG/BTTN)	25.8
Lead Salt	1.3
Zirconium Oxide	1.0
Miscellaneous Balance	9.9
TOTAL	**100.0**

3. Gas Generator Propellant

Typically gas generator propellants are manufactured by adding a casting solvent to a casting powder. The powder swells in the solvent, producing a unitary mass. Principal constituents are nitrate ester, nitrocellulose, and plasticizer. Composition data for the propellant included in the POC study is given below.

CONSTITUENT	GASGEN
Nitrocellulose (NC)	41.4
Nitrate Ester (NG)	40.8
Plasticizer (Triacetin)	13.8
Lead Oxide	1.5
Miscellaneous Balance	2.5
TOTAL	**100.0**

4. Warhead Explosive

The principal ingredient of warhead explosives mixed and cast at ABL are nitramines (RDX) in a binder/filler, which is typically cross-linked with isocyanates. The composition of the explosive included in the study is given below.

CONSTITUENT	WARHD
Nitramine (RDX)	82.0
Binder (PPG/IDP)	16.1
Miscellaneous Balance	1.9
TOTAL	**100.0**

C. PRODUCTS OF COMBUSTION

1. Principal Products of Combustion

The products of combustion of the six propellant/explosive formulations studied are summarized in Table I. Principal products have been printed in bold type. Carbon dioxide and water vapor are primary products for all of the formulations. Formulations containing ammonium perchlorate (AP) also have hydrogen chloride as a major combustion product. The less well oxygen-balanced formulations have some carbon monoxide product at the lower air uptake (oxygen balance is indicated by disappearance of CO as a product, and appearance of O2 as a product). Nitrogen is primarily from the combustion air. All of the formulations contain some nitrogen (propellant N2), which comes off as N2. The amount of propellant N2 for the six formulations is as follows:

FORMULATION	N2, LB/100LB
CTPB	9.6
HTPB	10.3
HTPB - Al	8.1
XLDB	28.7
GASGEN	12.7
WARHD	31.2

The formulations which contain aluminum also have aluminum oxide as a combustion product. At the higher air uptake ratios, the chlorine from the AP begins to come off as chlorine rather than hydrogen chloride.

2. Minor Combustion Products

The CTPB and HTPB propellants contain iron oxide at 1% or less. The iron oxide is unchanged in the combustion process, coming off as Fe2O3 at the same percentage it exists in the propellant. The XLDB and HTPB propellants contain 1% zirconium carbide. This combusts to about 1.2% zirconium oxide (ZrO2). The XLDB propellant, which contains 1.3% lead salt, has about 0.75% lead as a combustion product. The GASGEN propellant, which contains 1.47% lead compound, has about 1.36% lead as a combustion product. Lead is one of the final species to be oxidized as the air uptake is increased. Hydrogen gas (2% or less) and hydrogen sulfide (0.2% or less) may be present at the lower end of the air uptake range. Other chemical species are present in trace quantities only, and there were none with particular health/environmental concerns.

D. ANNUAL EMISSIONS LOADING

Propellant/explosives wastes open burned in 1993 were used to calculate the estimated annual emissions of the various combustion species. In addition to the six types of propellant/explosive formulations discussed above, waste ingredients (AP, RDX, HMX), waste casting solvent (NG/TA mixture), and spent acetone solvent (about one-third XLDB propellant) were included in the estimation. Total P/E wastes burned were about 141,000 pounds.

The estimated annual emissions loading is summarized in Table II as a function of the air uptake ratio. Oxygen, hydrogen, and unoxidized carbon species (C, CH_4, and CO) are overstated because the fact that fuel-rich and fuel-lean formulations are typically burned together was not taken into account. Carbon, methane, and hydrogen species come principally from the combustion of acetone (at 80% air uptake the XLDB/Acetone mixture is still fuel-rich). The carbon monoxide species comes from combustion of acetone, NG/TA and the WARHEAD formulation which are fuel-rich at the assumed air uptake. Actual loadings of these species are expected to be lower by virtue of the fact that wastes are burned in combination, and the actual air uptake may be higher than the upper limit used in the study. For these reasons, the data should be taken as first order estimates only. Additional computer modeling is planned to explore the sensitivity of these species to air uptake and/or combination burning.

GLOSSARY

AP	Ammonium Perchlorate. Ingredient which functions as an oxidizer.
BTTN	Butanetriol Trinitrate. A nitrate ester explosive ingredient.
CTPB	Propellant family based on carboxy terminated polybutadiene binder.
GASGEN	Propellant family used for gas generators
HTPB	Propellant family based on hydroxy terminated polybutadiene binder.
HTPB-Al	HTPB propellant also containing aluminum.
IDP	Isodecyl Pelargonate. A propellant ingredient that functions as a plasticizer.
INPUFF	Air Dispersion Model
NC	Nitrocellulose. A propellant ingredient.
NG	Nitrogycerin. A nitrate ester explosive.
POC	Product(s) of Combustion
POLLU13	Combustion model computer code for predicting open burning POCs.
PPG	Polypropylene Glycol. A propellant ingredient that functions as a plasticizer.
RDX	Cyclotrimethylene trinitrosamine. A nitramine explosive.
TA	Triacetin. A propellant ingredient which functions as a plasticizer.
WARHD	Explosive family representative of warhead explosives.
XLDB	Cross-linked Double Base propellant family.

TABLE I

PRODUCTS OF COMBUSTION
OPEN BURNING OF REPRESENTATIVE PROPELLANTS & EXPLOSIVES
Values are Pounds per 100 Pounds Burned

	CTPB				HTPB				HTPB-Al			
%AIR	50.0	60.0	70.0	80.0	50.0	60.0	70.0	80.0	50.0	60.0	70.0	80.0
N2	88.39	127.83	193.55	324.96	89.10	128.53	194.24	325.65	87.04	126.39	192.12	323.58
CO2	39.32	39.32	39.31	39.31	41.98	41.98	41.98	41.97	19.71	35.58	35.88	35.88
H20	31.12	31.09	31.69	34.79	32.71	33.09	34.86	38.12	23.54	27.81	27.84	28.38
HCl	24.18	24.31	21.85	9.26	25.88	24.33	17.14	3.97	20.96	20.51	20.77	18.60
CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.30	0.19	0.00	0.00
O2	4.03	14.54	31.64	64.14	8.13	18.37	34.42	66.78	0.00	0.88	18.47	53.30
Al2O3	11.33	11.33	11.33	11.33					37.79	37.79	37.78	37.78
Fe2O3	0.60	0.98	0.99	0.99	0.48	0.49	0.49	0.49				
ZrO2					1.19	1.19	1.18	1.18				
FeCl2	0.59	0.01	0.00	0.00	0.01	0.00	0.00	0.00				
Cl2	0.08	0.44	2.87	15.11	0.42	1.97	8.96	21.77	0.00	0.00	0.00	0.00
H2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.01	0.00	0.00
Pb												
PbO												
Pb3O4												
H2S												
C												
CH4												
%	99.82	99.94	99.97	99.98	99.95	99.98	99.98	99.99	99.91	99.66	99.86	99.50

	XLDB				GASGEN				WARHD			
%AIR	50.0	60.0	70.0	80.0	50.0	60.0	70.0	80.0	50.0	60.0	70.0	80.0
N2	107.57	146.99	212.69	344.11	91.58	131.00	196.71	328.13	110.05	149.47	215.18	346.60
CO2	54.38	73.70	75.03	75.03	67.16	85.59	93.95	93.93	41.39	53.24	75.61	92.69
H20	22.45	26.44	26.66	26.66	21.22	25.52	27.25	27.20	13.18	20.19	30.88	36.93
HCl												
CO	13.15	0.85	0.00	0.00	17.16	5.47	0.00	0.00	32.59	25.11	10.87	0.00
O2	0.00	0.00	16.89	52.13	0.00	0.00	12.80	48.00	0.00	0.00	0.00	23.57
Al2O3												
Fe2O3												
ZrO2	1.19	1.19	1.19	1.18								
FeCl2												
Cl2												
H2	0.47	0.03	0.00	0.00	0.66	0.18	0.00	0.00	2.64	1.87	0.67	0.00
Pb	0.76	0.66	0.00	0.00	1.36	1.35	0.00	0.00				
PbO	0.01	0.12	0.82	0.01	0.00	0.02	1.46	0.01				
Pb3O4	0.00	0.00	0.00	0.83	0.00	0.00	0.00	1.49				
H2S					0.18	0.12	0.00	0.00	0.10	0.10	0.10	0.00
C									0.00	0.00	0.00	0.00
CH4									0.04	0.00	0.00	0.00
%	99.99	99.99	99.98	99.99	99.66	99.70	99.65	99.75	99.99	99.99	99.99	99.96

TABLE II

ESTIMATED ANNUAL EMISSIONS
Pounds

	% AIR UPTAKE			
	50	60	70	80
N2	132,852	186,836	276,809	456,746
CO2	59,809	72,572	89,077	114,689
H20	32,707	35,470	39,086	43,336
HCl	8,483	8,520	7,676	3,363
CO	16,576	14,477	13,923	14,625
O2	3,245	7,152	16,370	41,803
Al2O3	4,238	4,238	4,238	4,238
Fe2O3	205	333	337	335
ZrO2	349	349	349	343
FeCl2	200	4	0	0
Cl2	1,364	1,488	2,325	6,496
H2	2,622	2,521	2,344	2,136
Pb	277	264	127	122
PbO	1	20	168	6
Pb3O4	0	0	0	166
H2S	33	31	25	0
C	14,255	12,287	8,620	1,768
CH4	3,946	3,127	2,318	1,732
TOTAL	281,161	349,687	463,792	691,905

Exhibit 7

HERCULES

Hercules Aerospace Company
Allegany Ballistics Laboratory
P. O. Box 210
Rocket Center, WV 26726-0210
(304) 726-5000

July 12, 1993

Defense Logistics Agency
Defense Contract Management Command
Defense Contract Management District Mid-Atlantic
Defense Contract Management Area Operation Pittsburgh
1612 William S. Moorehead Federal Building
1000 Liberty Avenue
Pittsburgh, PA 15222-4190

Attention: Ms. Colleen Berns

Dear Ms. Berns:

REQUEST FOR MODIFICATION TO BURNING GROUND SITE PLAN

This site plan modification is proposed to site the burning ground pads at ABL as individual sites rather than as an entity. This, together with measures being taken to prevent fragment hazard, will enable ABL to be in full compliance with the Q/D requirements of DOD 4145.26-M with respect to maintaining inhabited building distance (IBD) to the plant boundary. This request is submitted for your consideration in accordance with the requirements of DOD 4145.26-M, Chapter 1, Subpart "Site and Construction Plans".

4.a SCALED DRAWINGS

The enclosed site plan (Drawing No. 4243100) of the existing area showing the proposed location of the burning ground modifications reflects the distance and structure relationships within the area surrounding the project. The site plan is a scaled drawing of 1" = 200'.

4.b Q/D RELATIONSHIP OF FACILITY TO OTHER PLANT FACILITIES

The distances between the modified burning ground facility to be constructed and other installation facilities, boundaries, public railway, and other geographic features are indicated on the site plan or can be scaled from the site plan.

The IBD distance is based on the absence of fragments. Fragments are prevented by (1) burning the propellant or explosives (P/E) in an unconfined state, (2) limiting the bed depth to less than 3 inches to assure burning rather than an explosive reaction, (3) wetting dry nitramines prior to burning, and (4) barricading and shielding the one site where cased rocket motor sections would be burned.

The IBD distance is based on the explosive limits of the individual pads. Pads 1-4 and 6-8 are spaced a minimum of 150 feet from each other which meets the separation requirements of DOD 4145.26-M, Paragraph 15.E.4 for open burning operations. Pad 5 is designed for cased propellant and is for special use applications only. Pad 5 is spaced midway between Pads 4 and

6 and is less than 150 feet from either. If Pad 5 is in use, Pads 4 and 6 will not be used; and if Pad 4 or 6 is in use, Pad 5 will not be used simultaneously in order to maintain the 150 foot separation.

It should be noted that adjacent property is sparsely populated farmland which (if a fragment hazard existed) would be covered by a 900 ft IBD for that special category of habitation. For informational purposes, the 900 ft distance is shown on the site plan and it is seen that inhabited buildings lie outside the 900 ft distance. The railroad on the north side of the North Branch Potomac River is a non-passenger, freight railroad.

4.c OTHER ABL FACILITIES WITHIN IBD OF BURNING GROUND

A portion of the fenced-in area for storage of closed out inert material is partially within the burning ground IBD. This fenced in area is locked and there is only intermittent traffic to the area. Access control is maintained by posted warnings to keep out during the burning ground operating period.

4.d A & E ITEMS & HAZARDOUS MATERIALS WITHIN IBD[1]

There are no buildings or A&E items within the IBD of the facility.

4.e A & E ITEMS AT BURNING GROUND

The facility consists of eight, open air burning pads. The pads will be used for burning propellant and explosives, and scrap contaminated with propellant or explosives. The pads and their planned explosive quantities are listed in Table I (page 3).

4.f BUILDINGS WITH EXPLOSIVES WITHIN IBD OF FACILITY

There are no buildings containing explosives within the IBD of the facility.

[1] For this site modification submission request, A & E are defined as being propellants, explosives, and propellant or explosive ingredients. No ammunition items are included.

TABLE I. A & E ITEMS AT BURNING GROUND[2]

PAD #	MATERIAL HANDLED	EXPLOSIVE LIMIT
1	P/E contaminated combustible waste, maximum 10% P/E contamination.	200 LB
2	Same as Pad #1.	200 LB
3	Uncased rocket propellant, contaminated/defective propellant or explosive ingredients, waste heavily contaminated with P/E, liquid explosive.	400 LB
4[3]	Same as #3.	300 LB
5[3]	Cased Propellant	100 LB
6[3]	Same as #3.	200 LB
7	Same as #3.	100 LB
8	Same as #3.	200 LB

[2] A & E items can be Class 1.1 or Class 1.3.

[3] If Pad 4 or 6 contains explosives, Pad 5 may not simultaneously contain explosives. If Pad 5 contains explosives, neither Pads 4 or 6 may contain explosives.

4.g FACILITIES WHOSE IBD INCLUDE THE BURNING GROUND

The net explosive weight (NEW) in facilities whose IBD include the burning ground are listed in Table II. The buildings listed are those that contain over 100 lb. of explosive whose 1250 IBD include the Burning Ground and those containing less than 100 lb. of explosives whose 670 ft. IBD include the Burning Ground.

TABLE II. FACILITIES WHOSE IBD INCLUDE BURNING GROUND

BUILDING NO.	EXPLOSIVES CLASS	NEW
27	1.1	1,000
47	1.1	1,725
57	1.1	300
156	1.1	700
207	1.1/1.3	300/11,000
245	1.1	100
246	1.1	100
260	1.1	100
361	1.1	20,000
100[4]	1.1	300
189[4]	1.1	1,000
287[4]	1.1	1,600
336[4]	1.1	500
248[5]	1.1	400
375[6]	1.1	6,500

[4] Buildings 100, 189, 287, and 336 will be demolished as a part of the ABL Facility Restoration Plan.

[5] Building 248 will be converted to a non-explosive building in the Facility Restoration Plan - FY 1991. It will become the control room for the new Mix Building 375.

[6] New Building in Facility Restoration Plan - FY 1991. Building 375 will be located at the present site of Building 336.

5.a PERSONNEL LIMITS FOR THE FACILITY

The personnel limits for the facility will be 6 operators and 4 transients within the total fenced-in area of the burning ground. Personnel limits are considered flexible and may be increased by local facility management. Personnel limits are established using the principle of DOD 4145.26-M, that the limits shall be the minimum required to perform the work safely and efficiently.

5.b GENERAL DETAILS

Burning at Pads 1 through 8 will be accomplished in earth filled steel pans that are elevated to permit detection of any break-through or leakage that might contaminate the soil. Pad 5 is barricaded and earth covered to prevent potential fragment flight from cased rocket motor sections.

5.c DESCRIPTIONS OF OPERATIONS AND EQUIPMENT

The types of materials to be burned include uncased class 1.1 and 1.3 propellant (single and double base, and composite) and propellant ingredients, liquid explosives, nitramines (RDX, HMX), propellant/explosives contaminated process waste, explosive waste from labs, and cased rocket motors.

A total of eight (8) burning pads are included in the site plan. Pads 3, 4, 6, 7 and 8 include two parallel use pans, only one of which would be used at a time.

The solid propellant and/or explosives will be spread out on the pads to a depth limited to that required to prevent an explosion due to confinement or exceeding critical height. Liquid explosives will be mixed with sawdust and spread out in a thin layer to be burned in the same manner. Dry nitramines would be wet with kerosene prior to burning. Depth of bed will not exceed 3 inches in any case.

Cased sections of motors, or contaminated equipment that have some potential for fragment throw will be burned at Pad #5. This pad is earth covered and barricaded to restrain and/or intercept and totally prevent fragment ejection.

The parallel pans will be loaded alternately so that both pans at a pad are not loaded at the same time. Twenty four hours will elapse between burnings on a pad, unless the pad has been saturated with water and has passed a safety inspection. No burning will take place when wind velocity exceeds 15 miles per hour.

5.d TERRAIN FEATURES

There are no terrain features that constitute natural barricading.

5.e DEVIATIONS FROM SAFETY STANDARDS

There are no deviations from pertinent safety standards. Adequate measures exist to prevent fragmentation hazards and adequate separation of pads exists to permit siting based on overpressure criteria for individual pad explosive limits. Thirty-five years of operating history in open burning of waste propellants, explosives, and explosive contaminated waste at this same site supports this position.

Sincerely,

M. W. Stewart
Contract Administrator

WRWorkman

Enclosure - Drawing 4243100

cc: w/enclosures (1 copy)
S. Hoffman, NSSC/Washington, DC (Code 654C1)
S. L. Brown, DCMDM/Philadelphia, PA
R. W. Homison, DCMAO/Pittsburgh, PA

w/o enclosure
J. F. Hixon
P. K. Amtower
L. H. Mull
D. A. Hulburt
M. W. Miller
R. E. Hadra

7. When determining inhabited building and public traffic route distances, use table 6-1 for class 1, division 1; table 6-2 for specified class 1, division 1; tables 6-6 through 6-9 for class 1, division 2; table 6-10 for class 1, division 3; and table 6-11 for class 1, division 4.

8. When determining intraline and intermagazine distances, use tables 6-3 through 6-5 for class 1, division 1; tables 6-6 through 6-9 for class 1, division 2; table 6-10 for class 1, division 3; and table 6-11 for class 1, division 4.

9. In the application of inhabited building and public traffic route distances, table 6-1, the property boundary will be treated as the governing * target. In interpreting application to navigable waterways as public traffic * routes, occasional small fishing and pleasure boats may be ignored.

C. CLASS 1, DIVISION 1 (MASS DETONATING)

Entire quantities of items in this division can detonate almost instantaneously. Some examples: bulk explosives, some propellants, mines, bombs, * demolition charges, torpedo and missile warheads, rockets, palletized projectiles loaded with TNT or Composition B, 8-inch and larger high-capacity projectiles loaded with Explosive D, mass-detonating CBUs, and mass-detonating ammunition components. *

NEW Over	Not Over	Distance in Feet to Inhabited Building From			Distance in Feet to Public Traffic Route From		
		Standard Earth-Covered Magazine		Other PES	Standard Earth-Covered Magazine		Other PES
		Front or Side	Rear		Front or Side	Rear	
1	2	3	4	5	6	7	8
0	1	35	25	40	21	15	24
1	2	44	32	50	26	19	30
2	5	60	43	69	36	26	40
5	10	75	54	87	45	32	52
10	20	95	68	110	57	41	65
20	30	110	78	125	65	47	75
30	40	120	86	140	72	51	83
40	50	130	92	150	77	55	89
50	100	160	115	190	97	70	115
100	200	205	145	235	125	88	140
200	300	235	165	270	140	100	160
300	400	260	185	295	155	110	175
400	500	280	200	320	165	120	190
500	600	295	210	340	175	125	205
600	700	310	220	355	185	135	215
700	800	325	230	375	195	140	225
800	900	340	240	390	205	145	235
900	1,000	350	250	400	210	150	240
1,000	1,500	400	285	460	240	170	275
1,500	2,000	440	315	505	265	190	305
2,000	3,000	505	360	580	305	215	350
3,000	4,000	555	395	635	335	240	380
4,000	5,000	600	430	685	360	255	410
5,000	6,000	635	455	730	380	275	440

Table 6-1. Class 1, Division 1: Inhabited Building and Public Traffic Route Distances.

Health Consultation for Allegany Ballistics Laboratory (#30BF),
Rocket City, West Virginia
Federal Programs Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

STATEMENT OF ISSUES:

Staff from ATSDR visited Allegany Ballistics Laboratory, Rocket City, West Virginia (ABL) from May 10-12, 1994, to conduct a site scoping visit and to meet with the public. Agency for Toxic Substances and Disease Registry (ATSDR) staff toured the facility and the surrounding area and met with the Allegany County Maryland Health Department.

Several community health concerns were identified when ATSDR held a public availability session at the county health department. The community's greatest concern is that people are breathing smoke from wastes that are burned at ABL. The wastes burned include excess explosives, explosive contaminated materials, and waste propellants. The burn site is within 1,000 feet of their homes. People were concerned that the smoke produced could be hazardous to their health. One citizen specifically asked ATSDR to address this issue.

As a result of those meetings with the public and discussions with ABL staff, ATSDR has concluded that the open-burning of these wastes at ABL poses a potential public health hazard. ATSDR recommends that the Navy Sea Systems Command conduct air monitoring to determine if further action is needed to protect the health of the public.

ABL Site:

ABL consists of two plants; only plant number one is on the National Priorities List. The plants are on the West Virginia side of the North Branch Potomac River (Figure 1). ABL operations began in the mid 1940s. Plant number one is a government owned contractor-operated facility (GOCO) and primarily produces solid propellant rocket motors and explosives for warheads.

OPEN-BURNING:

Excess explosives, propellants, and materials that have come in contact with explosives (such as gloves, packing material, vermiculite, and absorbent pads) are burned at the Open-Burn area. Several homes on the Maryland side of the river on McKenzie Tower Road are directly downwind and within 1,000 feet of the Open-Burn area. These residents are exposed to smoke generated from the open-burning.

ABL is in a valley; therefore, wind speed and direction varies greatly. Generally, the wind blows from the southwest. ABL staff reported that the plant's open-burning practices have changed. Since the plant has undergone cutbacks, production is down, and less material needs to be burned. Also, because of the increase in community concerns related to the open-burning, the plant has taken steps to recycle contaminated items and to decrease the amount of material that needs to be burned. In addition, the plant now burns the explosives, propellants, and explosive contaminated materials in the morning, when the wind speed is decreased. Burning operations take place once or twice a day. Previously, burning occurred in the afternoons and several times a day.

ABL has not conducted any air sampling. ATSDR staff is concerned that the waste explosives may not be completely combusted, the breakdown products of the wastes (i.e., packing material and gloves) may be harmful, and the particulates may also pose a health risk. ATSDR literature search produced no information on the chemical compounds produced during the open-burning of explosives.

CONTAMINANTS:

Rocket motors consist of four major classes of components: 1) hardware such as cases and nozzles; 2) insulation materials for the cases and nozzles; 3) solid propellant grains; and 4) igniters. The bulk of propellants produced at ABL use the slurry cast process which is a combination of the

double-cast and the composite propellant technologies. Materials used in these technologies include nitrocellulose, nitroglycerin, cyclotetramethylenetetranitramine (HMX), lead and other metals, cyclotrimethylenetrinitramine (RDX), ammonium perchlorate, stabilizers, modifiers, plasticizers, and nitrate esters.

The compounds with the greatest known toxicity are RDX, HMX, and nitroglycerin. However, little is known about the burn products from any of those three compounds.

RDX: No data are available regarding levels of RDX in outdoor air. RDX can enter the ambient air through the release of contaminated particulate matter formed during the incineration of RDX-containing mixtures. Information about the health effects of inhaled RDX in humans is primarily limited to plant workers who inhaled unknown (high) concentrations of finely powdered RDX dust. Effects have included insomnia, restlessness, irritability, disorientation, convulsions, and unconsciousness. All exposed workers generally recovered within one day. No abnormalities were observed in workers' blood or urine. When exposure was stopped, no further adverse effects were seen (1). No information is available on the burn products of RDX.

HMX: Little information is available about human exposure to HMX. Health effects of HMX were studied in explosive plant workers, but results were inconclusive because HMX was a contaminant of other products such as TNT and RDX. Some dermal toxicity following exposure to HMX was noted (2). ATSDR could find no information on the burn products of HMX.

Nitroglycerin: Outdoor air data for nitroglycerin are unavailable. Occupational exposures have been documented (3,4). Exposures to nitroglycerin in industrial situations are frequently associated with exposures to nitroglycol (e.g., such as during the production of explosives), therefore, establishment of effects due directly to exposure to

nitroglycerin is difficult (3). Withdrawal of nitrated compounds such as nitroglycerin and nitroglycol caused sudden death in industrial workers who were exposed all week on the job. They were adapted and dependent on the continuous presence of nitroglycerin and nitroglycol to maintain a minimum level of coronary flow (4). ATSDR could find no information on the burn products of nitroglycerin.

Particulates: Breathing in particulate matter has been found to be hazardous to human health especially for respiratory impaired individuals. Acute effects of particulates in air on the respiratory system are well established and include exacerbations of chronic respiratory disease, restrictions in activity, and increases in emergency room visits and hospitalizations due to respiratory illness (5). The National Ambient Air Quality Standard for particulate matter <10 μm in diameter (PM_{10}) is 150 $\mu g/m^3$, averaged over 24 hours (see enclosure).

HEALTH EFFECTS:

The local residents report that they are regularly exposed to smoke from the open-burning practices at ABL. Maryland residents voiced their concerns to ATSDR and the Allegany County Maryland Health Department. Their symptoms include headaches, nausea, vomiting, and respiratory complaints. Symptoms were voiced more frequently by the young and the old, who may be more susceptible. Many families live along McKenzie Tower Road, and their ages vary widely, from infants to the elderly. Further complaints include discomfort from noxious odors and visible particles, which coat clothes and food left outside. In addition, residents are concerned that contaminants in the smoke may have contaminated the surface soil. The area is rural and many of the McKenzie Tower Road residents have vegetable gardens and orchards. The land is also used for grazing dairy and beef cattle.

CONCLUSIONS:

1. Excess particulate matter generated during open-burning is migrating into the McKenzie Tower Road area.

2. It is unlikely that complete combustion is achieved during the open-burning of the waste products at ABL. Ash generated at the Open-Burn area is put into 55-gallon drums and sent to a hazardous waste disposal site. Because the ash is hazardous, it is likely that the potentially uncombusted products in the smoke are hazardous to people downwind of the Open-Burn area.

3. Air monitoring data are needed before ATSDR can determine whether adverse health effects will be likely. Therefore, ATSDR can not rule out adverse health effects from the Open-Burn area.

4. Contaminants in air may be deposited in surface soil and on vegetation (i.e., grass used for grazing).

5. The very young and the elderly persons who live downwind of the Open-Burning area may be more sensitive to the potential contaminants and particulates being released into the air.

RECOMMENDATIONS:

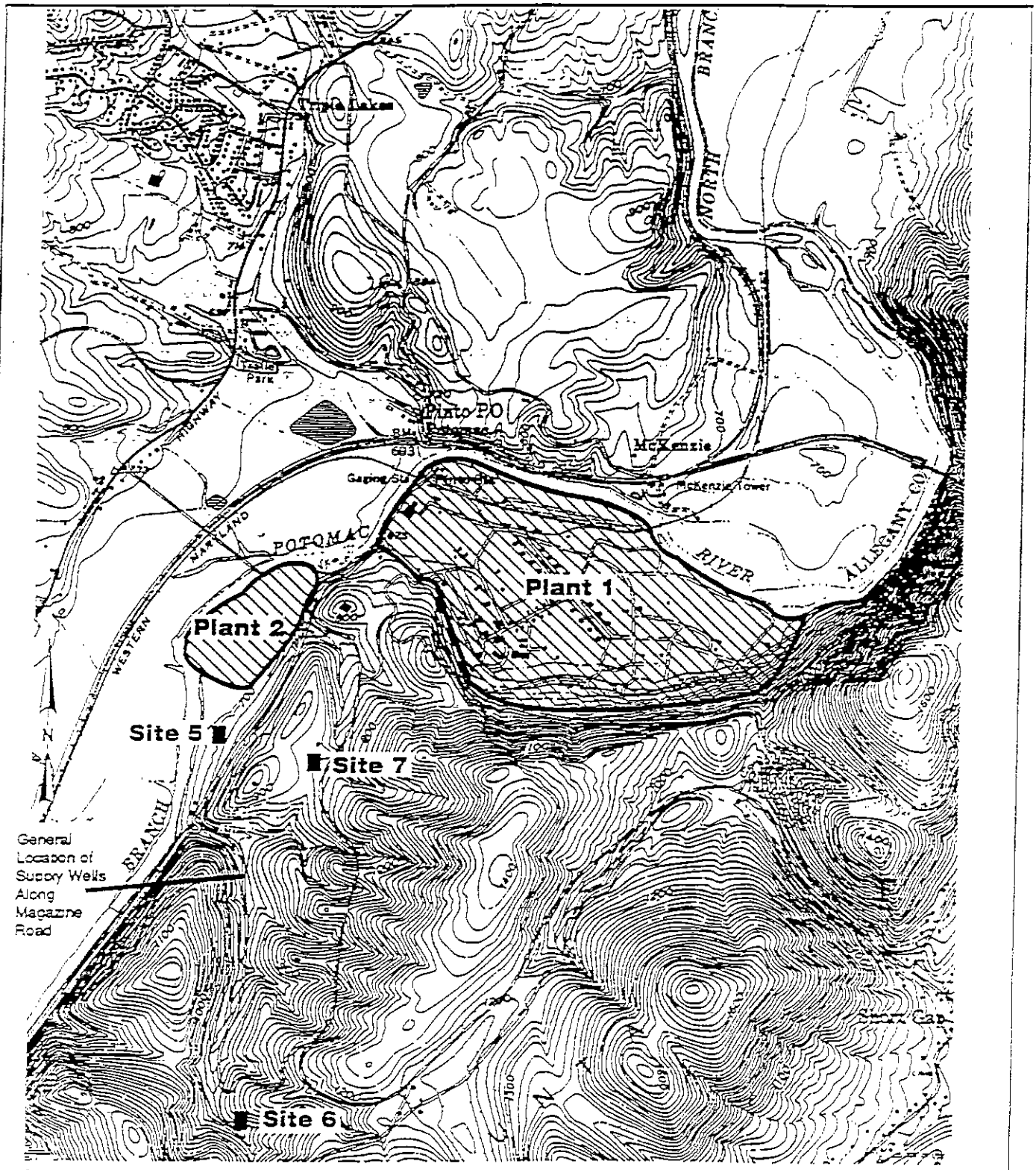
1. Consider either relocating the burn area, or using an appropriate remediation technology to stop exposure to particulates and potentially uncombusted products until air monitoring data indicate that the open-burning is not hazardous to people.

2. To evaluate the past and present public health hazard posed by the open-burning practice, ATSDR recommends ambient air sampling be conducted during and after open-burning to determine whether hazardous materials are being released and to identify concentrations of airborne contaminants and particulates. The

source (Open-Burn area) and the exposure points (i.e., on the McKenzie Tower Road residents' property) should both be sampled. ATSDR will review the air sampling workplan when it becomes available.

3. Conduct surface soil sampling and analysis at suspected exposure points in the McKenzie Tower Road area to determine if air-borne contaminants have been deposited on surface soil (1 to 3 inches below the ground surface). ATSDR will review the surface soil sampling workplan when it becomes available.

If further clarification is necessary or if additional data become available, please contact Ms. Joan Davis at 404-639-6070.



Source: USGS 7.5 minute Cresaptown, WV-MD quadrangle map.

Figure 1

Allegany Ballistics Laboratory

Clean Air Month — May 1994

Since 1972, the American Lung Association (ALA) has sponsored Clean Air Week each May to educate the public about the relation between clean air and respiratory health. This year Clean Air Week has been expanded to Clean Air Month; its theme, "Clean Air Is Up To You!" emphasizes the role of each person in promoting clean air.

Through local Clean Air Month activities, ALA will emphasize approaches—such as driving less, conserving energy, keeping indoor air clean, and supporting clean air regulations—to reduce air pollution. Local ALA chapters will sponsor environmental health fairs, school presentations, and other community events. Approximately 50 communities in the United States also will participate in the Clean Air Challenge, a pledge-based event to raise funds for local clean air programs and other efforts aimed at preventing lung disease. In addition, many local ALA offices will implement Clean Commute Day(s) to encourage motorists to try alternative forms of transportation (e.g., carpools, mass transit, or bicycles). This issue of *MMWR* includes a report that provides estimates of the number of persons potentially exposed to particulate air pollution.

Additional information about Clean Air Month and related activities is available from local ALA offices (telephone [800] 586-4872) or from the national office (1740 Broadway, New York, NY 10019-4374; telephone [212] 315-8700).

Health Objectives for the Nation

Populations at Risk from Particulate Air Pollution — United States, 1992

Despite improvements in air quality since the 1970s, air pollution remains an important environmental risk to human health. A national health objective for the year 2000 is to reduce exposure to air pollutants so that at least 85% of persons live in counties that meet U.S. Environmental Protection Agency (EPA) standards (objective 11.5) (*1*). This report provides estimates from the American Lung Association (ALA) of populations potentially at risk from exposure to particulate air pollution in the United States during 1992.

The National Ambient Air Quality Standard for particulate matter <10 µm in diameter (PM_{10}) is 150 µg/m^3, averaged over 24 hours (*2*). The federal standard is met if this value is not exceeded more than once per calendar year, and the annual arithmetic mean is ≤50 µg/m^3. Information in this report is based on the second highest maximum 24-hour PM_{10} concentrations recorded by at least one monitor in 1992 (EPA, unpublished data, 1993). Both the federal "exceedance" definition (≥155 µg/m^3) and a similar approach applied to the California standard* (≥55 µg/m^3) were used as cutoff values. Estimates of the numbers of persons potentially exposed to levels of PM_{10}

*California's particulate matter air quality standard of 50 µg/m^3 averaged over 24 hours (*3*) is the most stringent standard in the United States.

Particulate Air Pollution — Continued

above these cutoff values were derived from 1991 census figures for each county (U.S. Bureau of the Census, unpublished data, 1992).

For this report, a population at risk was defined as persons who have a "significantly higher probability of developing a condition, illness, or other abnormal status," as described by EPA (*4*). Five at-risk populations were included: preadolescent children (aged ≤13 years), the elderly (aged ≥65 years), persons aged <18 years with asthma, adults (aged ≥18 years) with asthma, and persons with chronic obstructive pulmonary disease (COPD) (e.g., chronic bronchitis and emphysema). Age-specific county populations for 1991 were estimated by applying the population age distribution of each state (U.S. Bureau of the Census, unpublished data, 1992) to the counties within that state. The number of persons with asthma or COPD in each county was estimated by applying age-specific prevalences from CDC's National Health Interview Survey (*5*) to age-specific population estimates for each county. Although PM_{10} levels are presented on a county basis, they do not indicate that all areas of the county were subject to that level or that all persons in the county were exposed to the recorded concentration.

During 1992, PM_{10} levels were ≥155 μg/m^3 in 16 counties; an estimated 23 million persons (9.1% of the total U.S. population) resided in these counties (Table 1). Approximately 92 million additional persons (36% of the U.S. population) resided in counties in which PM_{10} levels were 55 μg/m^3–154 μg/m^3. Overall, an estimated 115 million persons (45% of the U.S. population) resided in counties with PM_{10} levels ≥55 μg/m^3 (Table 1). In the United States during 1992, 46% of persons with asthma lived in communities with levels of particulate air pollution higher than the California standard.

TABLE 1. Estimated number and percentage of the total population and at-risk* subgroups residing in counties with particulate air pollution with a diameter of <10 μm (PM_{10}) at levels ≥155 μg/m^3 and ≥55 μg/m^3† — United States, 1992§

Population at risk	PM_{10} levels ≥155 μg/m^3		PM_{10} levels ≥55 μg/m^3	
	No.	(%)¶	No.	(%)¶
Total population	22,894,856	(9.1)	114,671,632	(45.5)
Preadolescent children (aged ≤13 yrs)	4,931,408	(9.5)	23,794,139	(46.0)
Elderly (aged ≥65 yrs)	2,649,477	(8.3)	14,010,297	(44.1)
Persons (aged <18 yrs) with asthma	387,220	(9.5)	1,878,848	(45.9)
Persons (aged ≥18 yrs) with asthma	697,444	(9.1)	3,523,475	(46.2)
Persons with chronic obstructive pulmonary disease**	1,243,407	(9.1)	6,263,409	(46.0)

*Population-at-risk estimates should not be added to form totals. These categories are not mutually exclusive.

†PM_{10} ≥155 μg/m^3 is the federal "exceedance" definition; PM_{10} ≥55 μg/m^3 is the California "exceedance" standard.

§The PM_{10} level of the county does not imply responsibility for the disease status of its population.

¶Of the total population in the category, the proportion of each population subgroup potentially exposed.

**Includes chronic bronchitis and emphysema.

Particulate Air Pollution — Continued

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Editorial Note: Particulate matter (e.g., dust, dirt, and smoke) is a complex and varying mixture of substances. Sources include motor-vehicle emissions, factory and utility smokestacks, residential wood burning, construction activity, mining, agricultural tilling, open burning, wind-blown dust, and fire. Some particles are formed in the atmosphere through the condensation or transformation of other chemical substances. Particles with diameters <10 µm pose a greater health risk than larger particles because particles of this size are easily inhaled deep into the lungs.

Increased risks for illness and death have been associated with particulate air pollution at levels comparable to those presented in this report (*6–8*). Acute effects on the respiratory system are well established and include exacerbations of chronic respiratory disease, restrictions in activity, and increases in emergency department visits and hospitalizations for respiratory illness (*8*). Persons with asthma are particularly sensitive to the effects of particulate air pollution (*8*). A national health objective for the year 2000 is to reduce asthma morbidity, measured by a reduction in asthma hospitalizations, from 188 per 100,000 in 1987 to no more than 160 per 100,000 (objective 11.1) (*1*).

The estimates presented in this report underscore the potential public health importance of particulate air pollution. Although levels of airborne particulate pollution declined substantially from 1988 to 1992 (emissions of PM_{10} decreased 8% and air concentrations of PM_{10} decreased 17%) (*9*), continued efforts are required to reduce health risks associated with particulate air pollution. EPA is reviewing technical and scientific information to determine whether the federal ambient air quality standard for particulate matter, established in 1987, should be revised.

ALA recently issued *The Perils of Particulates* (*10*), which includes national and county estimates of populations at potential risk for exposure to particulate air pollution. Copies are available from local offices of the ALA, telephone (800) 586-4872.

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Exhibit 10

ATSDR HEALTH CONSULTATION FOR ABL

COMMENTS AND RESPONSES

JULY 25, 1994

Hercules Aerospace Company

Allegany Ballistics Laboratory

Rocket Center, WV 26726

Comments on ATSDR Health Consultation

ATSDR has researched the literature on the toxicological properties of several major propellant/explosive (P/E) ingredients. However, we believe these do not have a bearing on products of combustion from open burning (OB) of P/E wastes. P/Es are formulated and designed to be reactive and burn in the absence of any air, and in the case of OB with additional air available, are essentially fully combusted. There should be no unreacted ingredients in the combustion products.

ATSDR appears to have overlooked the available information on products of combustion from open burning of propellants/explosives. ATSDR visitors were advised of the availability of such data during the site scoping visit, namely:

1) POLU13 products of combustion code, and validation POC measurements (Ref 1)
2) "Bang Box" open burning trials and data (Ref 2)
3) POLU13 products of combustion predictions for ABL P/E families (Ref 3)

Since the ASTDR site scoping visit, Hercules has completed air dispersion modeling studies which indicate that products of combustion from OB of P/E should not threaten human health (Ref 4).

Hercules does not agree with ATSDR's statement that several homes "are directly downwind" ... of the Open-Burn area. On-site weather data indicates that the prevailing winds during periods of open burning are from the west to northwest. The homes are only "downwind" the infrequent portion of the time the wind direction makes them so. Burning is not initiated if the wind direction is not favorable, but on occasion a wind shift may occur after burning is initiated and before it is completed. For the same reasons, Hercules does not agree with the local residents report that they are "regularly exposed" to smoke from ABL's open burning practices.

Response to Health Consultation Recommendations

ATSDR made three recommendations in their health consultation. Each of these recommendations is stated below followed by Hercules' response and planned actions.

1. **Consider either relocating the burn area, or using an appropriate remediation technology to stop exposure to particulates and potentially uncombusted products until air monitoring data indicate that the open-burning is not hazardous to people.**

To resolve the immediate issue, Hercules has undertaken a number of smoke and particulate mitigation measures. Smoke and particulate are more likely associated with burning of P/E contaminated wastes (cellulosics and plastics) that P/E itself. Hercules has discontinued the burning of items such as skids and fiber drums, which were formerly presumed to be contaminated. These items are now inspected, and burned only if they are visually contaminated with P/E. Plastic mold tooling is now reused (up to 10 times) and then decontaminated and sent

to landfill rather than burning. Contaminated waste is now placed on grates to provide better air access for cleaner burning, and the time of day during which burning is done has been adjusted to take advantage of more optimum wind conditions. These measures have largely mitigated smoke and particulate emissions.

Addressing the long term issue, Hercules has entered into discussions with Sandia National Laboratory to explore the feasibility of using the Sandia SWISH (Small Wind Shielded) technology to further mitigate smoke and particulate emissions. This technology is based on enclosed open burning, which controls time, temperature, and turbulence to optimize the combustion process. Representatives from Sandia will be at ABL on August 8, 1994. We anticipate subsequently contracting with Sandia to conduct trials at Sandia and to construct a SWISH at ABL if the trials prove favorable.

In a previous survey, Hercules could find no suitable cost-effective alternate burning ground site (using 1250 foot offset from property line). Hercules is conducting a new search for possible alternate sites in light of getting DDESB and State agreement that siting can be based on overpressure considerations only.

2. **To evaluate the past and present public health hazard posed by the open-burning practice, ATSDR recommends ambient air sampling be conducted during and after open-burning to determine whether hazardous materials are being released and to identify concentrations of airborne contaminants and particutlates. The source (Open-Burn area) and the exposure points (i.e., on the McKenzie Tower Road resident's property) should both be sampled. ATSDR will review the air sampling workplan when it becomes available.**

Hercules has entered discussions with the Atmospheric Research group at Sandia to provide a risk assessment of the open burning practice, to include air monitoring and plume tracking. The Sandia contact will be at ABL on August 8, 1994 to inspect the topography of the site and scope the work. We anticipate subsequently contracting for this effort, with a period of performance of September through December 1994. The air sampling workplan will be provided to ATSDR for review upon completion. Timely review and comment will be required to expedite problem resolution.

Pending the actual air sampling effort, ABL has conducted air dispersion modeling studies for the open burning of P/E. Lead compounds, hydrogen chloride, and chlorine emissions were studied using the SCREEN2 code. These studies indicate potential exposures do not present a health threat. In addition, Hercules is working with the AMCCOM group at Dugway Proving Ground to have our propellants characterized for open burning emissions in conjunction with development of an improved "Bang Box," which is being constructed to provide better closure on chlorine balance. These tests will validate the POLU13 products of combustion predictions.

Exhibit 11

CHRONOLOGY OF OPEN BURNING ISSUES RESOLUTION MATTERS

30 Jun 93	Meeting between Hercules ABL (HI/ABL) and Office of Air Quality (OAQ) personnel in Charleston to discuss open burning (OB) regulatory issues.
30 Jul 93	Letter from HI/ABL to OAQ summarizing 30 Jun 93 meeting and submitting proposed approaches to resolving OB regulatory issues.
25 Aug 93	Meeting between OAQ and HI/ABL at ABL to discuss OB issues further.
23 Sep 93	Submission of Open Burning Regulatory Issues Resolution Plan.
28 Oct 93	Letter advising OAQ of EPA's Final Rule Correction (54FR26198-26199) allowing shorter distance provisions than 40CFR265.382.
16 Feb 94	Submission of HI/ABL OB Products of Combustion Study
18 Feb 94	Letter updating status of OB Regulatory Issues resolution activities.
22-24 Feb	Meetings in Charleston with OAQ, Judiciary Committee, Governor's Staff, and Legislative personnel.
2 Jun 94	Petition to OAQ for change to 45CSR6 and 45CSR25.
29 Jun 94	Submission of OB Air Emission Modeling Studies results.
22 Jul 94	Comments on working draft of proposed Consent Order.

Status of RCRA Permitting of Open Burning and Open Detonation of Explosive Wastes

Robert G. Teer
Robert E. Brown
Harry E. Sarvis
Ohio Hazardous Waste Facility Board
Columbus, Ohio

AIR & WASTE MANAGEMENT
ASSOCIATION

SINCE 1907

For Presentation at the
86th Annual Meeting & Exhibition
Denver, Colorado
June 13 - 18, 1993

The Ohio Hazardous Waste Facility Board (Board), and the Ohio Environmental Protection Agency, comprise the Ohio hazardous waste permitting process. For a new or modified permit to be issued, the Board must determine whether the proposed operation of a treatment, storage, and disposal facility represents the minimum adverse environmental impact, considering the state of available technology, the nature and economics of various alternatives, and other pertinent considerations. The Board is currently reviewing its first application for open burning and open detonation (OB/OD) of explosive wastes. It is anticipated that two other Ohio facilities will also come before the Board seeking similar permits. In preparation for these permit applications, the Board staff has conducted this survey of OB/OD permitting activities in the United States, as well as a review of attempts to measure the emissions from the OB/OD of explosive wastes.

At the United States Environmental Protection Agency (USEPA) regulatory level, facilities treating explosive wastes by OB/OD were required to apply for Part B permits and comply with 40 CFR 264 Subpart X by Nov 8, 1992. As a result the USEPA has received numerous Part B applications for OB/OD of explosive wastes. A telephone survey was conducted of USEPA officials regarding their progress on issuing Part B Permits for OB/OD treatment facilities. Though USEPA guidelines for issuing such permits are still in a draft stage, three permits have been issued to date.

A telephone survey of members of the Institute of Manufacturers of Explosives (IME), based in Washington, D. C., was also completed. Questions regarding their permitting status, efforts in obtaining permits, and plans for using OB/OD for explosive wastes or the possible development of alternative treatment facilities were discussed.

A number of respondents in both surveys stated that because little is known about what air pollutants are released during OB/OD it is difficult to demonstrate the environmental safety of this practice in the manner required for issuance of a RCRA permit.

The only research we were able to find where an attempt was made to quantitatively determine the hazardous emissions from OB/OD of explosive wastes was the U.S. Army's BangBox studies. A careful review of this work is presented including the main points of our numerous telephone conversations with the workers in the BangBox studies. From a permit reviewer's point of view, the strengths and weaknesses of this work are discussed. Our conclusion is that this effort is very promising, however, more measurements are required to verify the reproducibility of the data and to obtain a data base for the many wastes which might be candidates for treatment by OB/OD.

A SURVEY OF THE STATUS OF USEPA OB/OD PERMIT APPLICATIONS

USEPA officials (Table I) in each of the ten USEPA regions were contacted in our telephone survey. They reported that more

than 100 permit applications are pending across the country and that most of these have been pending since November 1988. One permit in Region IV and two permits in Region VI have been issued to date. Seven draft permits are likely to be released for comment within the next year: one in Region II, four in Region VI, one in Region IX, and one in Region X. The remaining applications are in much earlier stages of the review process.

Three reasons were given for the slow OB/OD permitting. Some officials stated they believe OB/OD facilities present less of an environmental hazard than most other hazardous wastes treatment facilities. Therefore a low priority is given to the processing of OB/OD permits for explosive wastes.

Many officials stated that the lack of National Subpart X permitting guidelines has delayed the permitting of OB/OD units. A draft USEPA Subpart X Model Permit document was distributed for comments in April 1992. Carol Witt-Smith of the USEPA in Region V expects the guidelines to be completed within this year. The selection of an appropriate air model is still to be decided in the guidelines.

Finally, many applications have not adequately addressed the issue of air pollution and its impact on the surroundings. Applicants have been unable to determine what pollutants are generated by OB/OD and how these pollutants disperse. Regional officials stated applications lacking this information will be returned with Notices of Deficiency.

The three facilities that have been permitted thus far for OB/OD are the Schlumberger facility in Coyanosa, Texas, the NASA Yellow Creek Facility in Mississippi and the U.S. Naval Weapons Center in McGregor, Texas.

Schlumberger Well Services, located seventeen miles from Fort Stockten, Texas, is permitted to burn up to 5 tons of RDX (cyclotrimethylenetetranitramine) per year. Air emission estimates for OB/OD of RDX contained in their Part B Application were based upon data from the literature. The facility is permitted to burn only hazardous wastes generated on-site.[1]

The NASA Yellow Creek Facility in Mississippi is permitted to burn 600 tons per year of waste solid rocket fuel. The facility may also include various contaminated items (clothing, tools, etc.) in the burn. These items may not constitute more than 10% of the total waste mass. In its permit application the facility estimated its air emissions from the solid rocket fuel by using a NASA-developed computer program for simulating combustion of solid rocket propellant. They also consulted an EPA publication, "Compilation of Air Pollution Emission Factors (AP-42)",[2] for air pollution data for burning of clothing and other items. The facility will begin treating its wastes when it completes construction of its open burning facilities.[3]

The U.S. Naval Weapons Industrial Reserve Plant operated by Hercules, Inc., in McGregor, Texas is permitted to burn 246 tons/year of solid rocket fuel and miscellaneous manufacturing wastes contaminated with the propellant. These may include paper, wood, rags, solvents and clothing such as gloves, etc. Emissions were estimated by combining emissions from the miscellaneous items using the USEPA AP-42 factors and emissions from the rocket fuel using applicant supplied emission estimates.[4]

A SURVEY OF IME MEMBERS REGARDING OB/OD OF THEIR WASTES

Eighteen members of the IME were contacted in our telephone survey. All respondents stated they had applied for RCRA Part B permits for treatment of their explosive hazardous wastes. All are presently disposing of these wastes by OB/OD under interim status authority. The three permitted facilities identified above were not members of the IME at the time of our phone survey.

Our impression was that the IME members were having difficulty in obtaining estimates of emissions from the OB/OD of their wastes explosive. There was also considerable uncertainty regarding appropriate computer models for use in assessing dispersion of emissions. Only four facilities had included air risk assessments in their Part B Permit Applications. One company used USEPA AP-42 to obtain estimates of air emissions. One facility used Army emission data generated in 1978, but was unable to provide us with a reference for the data. Four facilities attempted computer modelling of the emission dispersion but none were comfortable with the selection of the models nor the inputs used in the models.

We noted that there is a rating of the emission factors for the many processes compiled in USEPA AP-42. The rating for OB/OD of explosive wastes is a "D", which means the emission factor was extrapolated from a related process and therefore must always be used with considerable caution. Thus we would conclude the IME members did not have reliable emission factor data when they prepared their Part B Applications.

DETERMINATION OF EMISSIONS FROM OB/OD OF EXPLOSIVE WASTES

Little data have been published on emissions from explosive materials. Laboratory studies are difficult to conduct because they must take place in relatively small enclosures which severely limit the amount of explosive that can be studied. Hence the initiator or the blasting cap etc., used to ignite the explosive also contributes to the emission products and may bias the data. Laboratory bench type chambers used in past studies have been under an inert or vacuum background. This does not replicate the field parameters because it starves the detonation of O_2. A true evolution of emission products is therefore highly suspect.[5]

Field studies are hard to conduct because the plume usually disperses quickly and the concentrations of many key pollutants become difficult to detect. Also, pollutants are not necessarily distributed throughout the plume in a homogeneous manner, making

representative samples difficult to obtain. The plume's ill-defined shape makes it difficult to accurately determine its volume and hence to compute the total quantity of a given pollutant present from a sample taken at a given point.[3]

EMISSION ESTIMATES IN THE ARMY'S BANGBOX STUDIES

Dugway Proving Grounds in Utah has developed facilities for measuring pollutants released from explosives. Principle among these is the "BangBox", an enclosed hemisphere of about 1000 cubic meters. The goal of the BangBox studies is to provide an enclosed structure in which the air pollutants resulting from an explosion are contained and analyzed with the same precision expected in laboratory studies, while simulating field conditions as closely as possible due to the box's very large volume. A second goal was to develop the methodology needed for testing emissions from similar OB/OD treatments in the field.

The BangBox studies[4] are the first which enable a precise measurement of trace quantities of possible toxic and carcinogenic emissions from the OB/OD of explosive wastes. Test strategy had been developed in July 1988 by a technical steering committee comprised of authorities from governmental, academic and private research organizations. The committee formulated a list of 71 target analytes to be sought in the emissions from the Dugway explosives tests. This list includes many possible products of incomplete combustion (PIC's) as well as carbon dioxide, sulfur dioxide, oxides of nitrogen, and other species.

The USEPA is conducting a critical audit of the initial BangBox data at this time. A draft of this audit report was completed on November 5, 1992. Additional information on the draft audit can be obtained from Terry Brown of USEPA Region VIII.

A DISCUSSION OF EMISSIONS FROM TNT DETONATIONS IN THE BANGBOX

As regulators, we were especially interested in whether the BangBox list of 71 target analytes is comprehensive. In other words, has an accurate accounting been made of all pollutants, or are significant amounts of additional products of incomplete combustion being released as well. If the latter situation is the case, then the experimental data would not permit a clear evaluation of the environmental risks associated with the OB/OD of explosive wastes. For these reasons, we looked for carbon balances in the BangBox data. We also discussed this issue in detail with Dr. Smith Broadbent, a leader in the BangBox studies.

The Army workers attempted a total carbon mass balance for eight TNT detonations in the Bangbox. For convenience of discussion these data are reproduced in Table II. In every case the total carbon recovered exceeded the original carbon of the TNT. The range was from one to seventeen percent excess with an average of seven to nine percent excess.

We believe this attempted mass balance is an important aspect of the BangBox studies. The unique feature of the BangBox is that conditions are similar to the field situation and yet the total plume is contained and available for analysis. This makes it possible to conduct a total carbon mass balance as a verification of the overall experimental design. For example, if the total carbon had been underestimated, by a range of -1 to -17 percent, the entire data base would be in doubt until the missing mass had been accounted for. Conversely, in this case, the carbon in the CO_2 emissions alone exceeded the original carbon content of the TNT. The temptation is to feel comfortable with this result and not consider further whether or not the mass of the other components of the mass balance are underestimated.

We presented our concerns to Dr. Broadbent and he agreed that the study would be stronger if a closer mass balance of the carbon had been achieved. He indicated that a possible source of extra carbon might be due to exhalation of workers in the BangBox prior to tests. He agreed that such a source of error in total mass should have cancelled out when real time CO_2 analyzers data prior to the detonation were subtracted from observations after the denotation; however, there is some uncertainty in this due to the +/- 2 ppm sensitivity of the CO_2 analyzer.

We noted that in the preparation of the TNT blocks some graphite was added to the TNT sample. Also PETN and RDX were used in the initiator of the detonation of the TNT. We asked if these materials could be responsible for the excess carbon recovered in the TNT detonations. Dr. Broadbent replied that the mass of the graphite and the detonator was only about one percent each of the mass of the TNT block and that these materials would not account for the recovery of excess carbon.

Dr. Broadbent concluded his thoughts on the total carbon mass balance by saying that the new BangBox which has recently been constructed will be more air tight and this might improve the carbon mass balance. The BangBox used for the studies of Table III, had a ventilation rate of about one half the total BangBox volume every 25 minutes. The ventilation rate should be greatly reduced in the new BangBox and this will increase the accuracy of the analytical measurements.

The importance of a good total carbon mass balance is also considered in the USEPA Draft Audit of the BangBox studies. The auditors expressed concern that the use of the overestimated CO_2 concentrations in the calculations of the emission factors of organic emissions will result in an underestimation of the organic emission factors. While this is a correct conclusion, we would agree with Dr. Broadbent in that such errors will be too small to have significance when health risks from the organic emissions are considered.

In a second approach to a mass balance review, we compared the total organic carbon or the "OC" column of Table II with the mass

of organic carbon of specific chemicals which were identified in the BangBox studies. In our discussions with Dr. Broadbent it was clarified that the "OC" column of Table II was actually only semivolatile organic carbon. The "OC" carbon was determined as the total mass of organic carbon released by heating the quartz filter of the semi-VOST sampling system without a determination of actual organic compounds. We attempted to compare this mass with the mass of specific semivolatile organic chemicals which were quantitatively determined in a second measurement using either a gas chromatograph mass spectrometer system or a super critical fluid mass spectrometer system.

The first step in the calculation is to estimate the total grams of organic carbon released per gram of TNT based upon the reported emission factors. As an upper estimate of total organic carbon released, one could simply total the emission factors of all the identified analytes. Since each compound is composed of atoms other than carbon, the actual carbon released per gram of TNT detonated must be less than the summation of the emission factors. This summation is presented on line W of Table III.

The second step in the calculation is to convert the estimate of carbon released per gram of TNT to carbon released per gram of carbon detonated. This is accomplished by dividing the values of line W by 0.3701 or the theoretical percent carbon in TNT. These values were presented in line X of Table III.

The third step is to determine the total mass of organic carbon identified in the three trials by multiplying the mass carbon in the TNT detonated as presented in the Theoretical Fuel column of Table II by the grams of organic carbon identified per gram of carbon detonated of line X. This product is reported in line Y of Table III.

The "OC" is taken from Table II and presented again on line Z of Table III for comparison with line X of Table III. The ratio of organic carbon recovered, OC, to organic carbon identified is then presented as line zz.

These considerations suggested to us that there was a substantial quantity of unidentified products of incomplete combustion in the BangBox trials. As shown on line zz of Table III, the quantity of semivolatile organic carbon measured exceeded the quantity of semivolatile organic carbon quantitatively identified by more than 31 to 13,244 times.

We discussed this observation with Dr. Broadbent and he assured us that large quantities of semivolatile organics had not been missed. The semivolatile organics were analyzed using either a gas chromatograph mass spectrometer system or a super critical fluid mass spectrometer system. Over 100 organic chemicals were discretely detected, but the experimenters considered it impractical to identify each one in a quantitative manner. Instead, they elected to seek and identify quantitatively only compounds which might present a health risk if released in emissions. In addition to the compounds listed in Table III, they

also looked for, but did not find, 1,6-dinitropyrene, 2-naphthalamine, Bens[c]acridine, and a major unknown.

As another consideration of the possibility of underestimation of semivolatile organic emissions from TNT detonations in the BangBox we asked Dr. Broadbent if these might have condensed on the surfaces of the BangBox and as a result escaped detection in the semi-VOST system. Dr. Broadbent replied that he was also concerned about this possibility. Therefore, he had taken wipe samples from the walls of the BangBox and also from the blades of the circulation fans within the BangBox. In all cases the semivolatile organics in these tests were below detectable limits.

Our conclusions regarding the possibility of unidentified organic mass in the BangBox studies are as follows. First it must be recognized that the BangBox studies are the only studies which are very close to field conditions and still provide the opportunity for the quantitative measurement of trace organic constituents in the detonation emissions. Other studies, such as the literature cited in the Schlumberger Permit application suggest emissions from TNT detonations in air would only be CO_2, N_2, and H_2O. The BangBox studies not only showed traces of many organic chemicals, but also showed a small quantity of soot in the emissions. Clearly, the BangBox is a significant advancement in attempts to determine emissions from the OB/OD of waste explosives.

Secondly, we would agree with Dr. Broadbent's position that it is not practical to quantitatively identify every constituent of the emissions. Selection of target analytes based upon health risk considerations is certainly the only reasonable way to proceed with these studies. However, our suggestion for future studies with the BangBox would be for Dr. Broadbent and his colleagues to write the details of how these decisions were reached.

HEALTH RISKS ESTIMATED WITH EMISSIONS OBSERVED IN THE BANGBOX AND ALSO FROM FIELD STUDIES CONDUCTED BY THE ARMY AT DUGWAY UTAH

When one looks at the emissions factors observed in the BangBox studies and also in the Army's field studies at the Dugway Proving Grounds, one is impressed by the low emissions of the target analytes which were observed. Based upon these data it is easy to conclude that health risks associated with most of the target analytes are minimal. We did take a closer look at the cancer risk associated with benzo[a]pyrene which has a cancer potency of $1.7*10^{-3}$ m^3/ug.[7]

Though the emission factors of the benzo[a]pyrene were very small in all of the BangBox and Field studies for all wastes, we felt it important to complete the analysis of cancer risk based upon an assumed annual treatment rate and using a screening air dispersion model. The BangBox TNT detonation study on January 31 had a benzo[a]pyrene emission factor of $3.01*10^{-6}$. This was more than an order of magnitude higher than the benzo[a]pyrene emission factors in all of the other studies. Based upon this emission factor and the cancer potency factor we considered what quantity of

detonation per year would be required before a cancer risk of 100,000 would be approached.

The air dispersion model we used was "Screen Version 1.1", PC l comparison of the screen procedures document, EPA-450/4-08- This model may not be optimum for the OB/OD situation since ssumes a steady flow of emissions and of course we had to use engineering judgement in the selection of some of the input neters. However, we felt the model was adequate for an oximate calculation and we note that the USEPA Subpart X group has not yet recommended an optimum OB/OD dispersion l.

The calculation indicated that about 500 tons of TNT treatment B/OD per year would be required to approach a cancer risk of 1 00,000. Noting again that the benzo[a]pyrene emission factors all other tests were at least an order of magnitude less than of the January 31 TNT trial, it must again be concluded that BangBox and associated Field Studies suggest that health risks OB/OD of the explosives are minimal for the wastes tested.

We also noted that benzidine ($C_{12}H_{12}N_2$) which has one of the r cancer potency factors ($6.7*10^{-2}$ m^3/ug) was not included in ist of target analytes.[7] This also points to the need for Dr. bent and his colleagues to discuss in more detail how the t analytes were selected. We did not ask Dr. Broadbent why was not one of the target analytes. Perhaps it is not stable h to survive a detonation. However, because of its cancer cy we do believe that it should be given consideration in tion of the target analytes.

IONS FACTORS CALCULATED BY COMPUTER MODELS

A draft USEPA Permit for OB/OD treatment was issued to the Military Reservation in Hawaii by Region IX, based upon ion estimates obtained with the Navy's Pollu-II computer .[8] The program simulates the OB/OD process and predicts ions of products of combustion and incomplete combustion. as noted above, the NASA Yellow Creek Facility in Mississippi ned an OB/OD treatment permit with emission estimates based a NASA computer program.

We do not feel qualified to comment on these models other than y that we are not comfortable in using estimates of emission rs generated by computer simulations. Especially, in light of uccess with the BangBox and the associated field studies at igway Proving Grounds, we believe the developers of these two ter programs should also complete a BangBox study or something ar to obtain data for the verification of the programs.

NATIVES TO OB/OD - THE ARMY'S EXPLOSIVE INCINERATORS

The Army presently has 18 incinerators for treating explosive s. Twelve units are presently being upgraded to meet the air

emission standards of 40 CFR 264.343. The remaining incinerators will be decommissioned. The upgrade program began in 1987 and is likely to continue into 1994.[9,10]

All the Army's explosive incinerators are modelled after the Army Peculiar Equipment (APE) 1236 rotary kiln. This unit consists of 4 cylindrical "retorts" bolted together which rotate to afford maximum mixing of the explosive materials and air. Each retort is 5 feet long and 3 feet in diameter. Feed is propelled through the retorts using a conveyor system.

The two design features of this incinerator which enable it to withstand explosive fragments and pressures are its exceptionally thick steel walls (2.5 to 3.25 inches) and its lack of refractory. The APE 1236 is also restricted to relatively small quantities of explosives (400 lbs. per hour max.), since large detonations can rupture its walls.

It is Department of Defense policy that these incinerators are to be used only to treat wastes generated on-site. They are not available to commercial explosive users or manufacturers.

COMMERCIAL EXPLOSIVE INCINERATORS

Through our telephone survey we only found one commercial company (ICI Explosives Environmental Co.) that is presently permitted for incineration of explosive wastes. According to Robert Morehard, Vice Present of ICI, tentative plans are to build one such unit in Joplin, Missouri beginning in 1993, pending the outcome of a local citizen's appeal. The unit would be designed much like the Army's APE 1236 incinerator but with additional retorts and with air pollution control equipment as required to comply with 40 CFR 264.343. The total cost of such an incinerator is approximately $15 million.

We did not find any other commercial company planing to build such an incinerator. While some other IME members are investigating incinerators they view them as possible long-range replacements for open burning rather than as immediate alternatives.

OTHER ALTERNATIVES TO OB/OD

Information on current research into new disposal procedures was obtained via the Alternative Treatment Technology Information Center (ATTIC) in Washington, D. C.. ATTIC stores abstracts of more than 1,600 research papers on potential treatment methods for many kinds of hazardous wastes. Abstracts were sought for the four common explosives TNT, RDX, HMX and PETN.

This search revealed two potential alternate treatment methods. The Oak Ridge National Laboratory[11] has shown that explosive wastes might be used as fuel additives. Bench scale tests have verified the feasibility of using TNT and RDX as supplements

to-fuel in boiler plants. Pilot scale testing has yet to be carried out. The Army cautions that only small amounts of materials could be disposed of in this manner, and that "overall safety and risk considerations will make it difficult to field this technology."

In a related study, Oak Ridge National Laboratory has investigated the use of TNT and RDX as co-firing fuels for cogeneration furnaces. Their bench-scale tests indicate that this practice is safe and feasible within certain guidelines. No pilot-scale testing has yet been performed.[12]

CONCLUSIONS

Although 40 CFR 265.382 specifically prohibits the open burning of most hazardous wastes, we feel that OB/OD will likely remain the primary treatment for waste explosives. Alternatives such as explosive wastes incinerators are prohibitive in cost for many explosive users and manufacturers. Also, there is a nationwide lack of commercial incineration capacity for the off-site generator. This situation is likely to persist into the future.

The Dugway results suggest that OB/OD is an environmentally safe practice for the wastes which were studied. However, these studies only considered emissions from a few of the many possible explosive compounds and propellants. Also, many explosive manufacturers and users generate explosive wastes which may contain substantial quantities of scrap detonating cords, contaminated packaging materials, etc. Further studies are necessary to consider the possible emissions from other wastes compositions. There is also a need for the Dugway workers to present a discussion on how they selected target analytes in their studies.

Given the success of the BangBox and associated studies at Dugway Proving Grounds, we would prefer that applications submitted to the Ohio Hazardous Waste Facility Board contain actual emissions data if at all possible, rather than emission estimates based upon computer simulations of the OB/OD treatment.

1) Permit application submitted by Schlumberger Well Services, Rosharon, Texas, to the Texas Water Commission, Hazardous and Solid Waste Division, Austin, Texas, February 1990, p. 66A

2) "Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources", AP-42, Fourth Edition, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, September 1985

3) Telephone conversation with Jay Barkley, permit writer for NASA Yellow Creek Facility, Mississippi Department of Environmental Quality, Bureau of Pollution Control, Jackson, Mississippi, January 20, 1993

4) Telephone conversation with John Gott, permit writer for US Naval Weapons Center, Texas Water Control Board, January 21, 1993

5) Telephone conversation with Mr. MacDonald B. Johnson, Project Officer, Environmental/Explosive Hazards, Dugway Proving Grounds, Dugway, Utah, February 4, 1993

6) M. B. Johnson, Final Report: Development of Methodology and Technology for Identifying and Quantifying Emission Products from Open Burning and Open Detonation Thermal Treatment Methods: U.S. Army Armament, Munitions and Chemical Command, Maintenance Management Division, Demilitarization and Technology Branch, Rock Island, IL, 1992

7) Health Effects Assessment Summary Tables, Annual FY 1991,OERR 9200.6-303(91-1), Office of Research and Development of the Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC, 1991, pg. B-3.

8) Permit application submitted by Makua Military Reservation, Hawaii, to USEPA Region 9, Permit and Solid Waste Branch, San Francisco, CA

9) "Response to the U.S. EPA Notice of Deficiency for Department of Defense RCRA Part B, Subpart X, Permit Application Submitted in Region IV," Department of the Army, Office of the Assistant Secretary, Washington, D. C., 1991

10) Telephone conversation with Jerry Miller, Chief of APE Engineering, Tooele Army Depot, Tooele, Utah, February 14, 1992

11) M.E. Lackey, "Testing to Determine Chemical Stability, Handling Characteristics, and Reactivity of Energetic-Fuel Mixtures," ORNL 6426, Engineering Technology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1988, p. 1-85

12) W.M. Bradshaw, "Pilot-Scale Testing of a Fuel Oil - Explosives Cofiring Process for Recovering Energy from Waste Explosives," Report No. AMXTH-TE-CR;88272, ORNL/TYM-10921, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 37831, 1988, p. 1-123.

Table I. EPA regional officials contacted in phone survey.

Jim Gaffey, Chemical Engineer, Connecticut Waste Regulation Section, USEPA Region I
John Brogard, P. E., Environmental Engineer, USEPA Region II
Mary Beck, RCRA Permitting Engineer, USEPA Region III
Elizabeth Bartlett, Environmental Engineer, RCRA Permitting Section, USEPA Region IV
Carol Witt-Smith, Corrective Action Expert, USEPA Region V
William Hurlbut, Geologist, Environmental Scientist, USEPA Region VI
Deborah Kennedy, Regional Subpart X Contact, USEPA Region VII
Terry Brown, Chemical Engineer, Subpart X Contact, USEPA Region VIII
Larry Bowerman, Section Chief, Alternate Technology Permitting, USEPA Region IX
David Croxton, Environmental Scientist, RCRA Permit Writer, USEPA Region X

Table II. Carbon mass from bang box TNT detonation[a].

DATE	SOURCE	MASS OF CARBON MEASURED				TOTAL CARBON MEASURED	THEORETICAL FUEL CARBON[c] (g)	RATIO[d]	ELEMENTAL ANALYSIS CARBON (g)	RATIO[e]
		CO_2 (g)	CO (g)	OC[b] (g)	EC[b] (g)					
31 JAN 89	TNT	94.96	0.6688	0.4161	1.0331	97.08	82.90	1.17	84.22	1.15
2 FEB 89		82.18	0.4093	0.6495	1.5160	84.75	82.13	1.03	83.43	1.02
6 FEB 89		82.92	0.3384	0.4685	2.0492	85.78	83.22	1.03	84.54	1.01
8 FEB 89-2[f]		90.34	0.4578	0.5150	1.5426	92.86	82.99	1.12	84.31	1.10
8 FEB 89-3		90.26	0.4578	0.5150	1.5426	92.77	83.25	1.11	84.58	1.10
8 FEB 89-4		87.43	0.4578	0.5150	1.5426	89.95	82.62	1.09	83.93	1.07
8 FEB 89-5		87.15	0.4578	0.5150	1.5426	89.66	82.71	1.08	84.03	1.07
8 FEB 89-6		87.92	0.4578	0.5150	1.5426	90.43	82.42	1.10	83.74	1.08
8 FEB 89-7		86.74	0.4578	0.5150	1.5426	89.26	82.47	1.08	83.78	1.07
8 FEB 89-8		85.86	0.4578	0.5150	1.5426	88.37	81.87	1.08	83.17	1.06
15 FEB 89		83.78	0.3813	0.4751	1.4229	86.06	81.88	1.05	83.19	1.03
AVERAGE								1.09		1.07
STANDARD DEVIATION								0.04		0.04

[b] OC - Semivolatile organic carbon.

EC - Elemental carbon.

[a] 97.01 Percent of actual mass of TNT detonated on specific trial.

[d] Ratio of total carbon mass measured to theoretical carbon mass in fuel carbon.

[e] Ratio of total carbon mass measured to independent laboratory mass of carbon.

[f] Number following date is detonation number of multi-detonation trial.

Table III. A comparison of the summation of the mass of semivolatile and n volatile organic carbon identified by chemical form in the TNT detonation in t Bang Box with the total mass of organic carbon (OC) observed in Table II.

Source Table*	compound	EF on Jan. 31	EF on Feb. 2	EF on Feb. 6
5.17	2,6-dinitrotoluene	3.27E-7	9.15E-8	1.02E-7
5.18	4-nitrophenol	4.52E-7	0	5.05E-7
5.19	2,4-dinitrotoluene	9.43E-8	0	8.43E-8
5.20	2-Nitronaphthalene	2.18E-7	1.18E-8	2.1E-7
5.21	2,4,6-Trinitrotoluene	1.18E-6	0	7.35E-7
5.22	1-Nitropyrene	0	0	0
5.23	Phenol	2.84E-6	-	4.57E-6
5.24	Dibenzofuran	1.02E-7	6.49E-9	0
5.25	Benz{a}anthracene	0	0	0
5.26	Benzo[a]pyrene	3.01E-6	0	2.7E-7
5.27	Dibenz[a,h]anthracene	0	0	0
5.28	N-Nitrosodiphenylamine	3.42E-7	0	0
5.29	Naphthalene	1.18E-5	1.89E-8	2.35E-5
5.30	1&2- Methylnaphthalene	1.67E-6	0	3.0E-5
5.31	1,3,5-Trinitrobenzene	0	0	1.28E-9
5.32	Biphenyl	0	0	0
5.33	Phenanthrene	1.85E-7	0	0
5.34	2,5-Diphenlyoxazole	1.42E-5	2.95E-8	8.56E-6
5.35	1,1,3-Trimethyl-3-Phenylindane	1.6E-7	7.7E-8	6.39E-9
5.36	Pyrene	2.0E-7	0	8.27E-8
		-------	-------	-------
(W) Grams of identified organic carbon per gram of TNT detonated		< 3.7E-5	< 0.23E-5	< 6.8E-5
(X) Conversion to per gram carbon detonated basis		< 1.0E-4	< .006E-4	< 1.8E-4
(Y) Total identified organic carbon (grams) per trial		< .0083	< 4.9E-5	< .015
(Z) Total organic carbon recovered		0.416	0.649	0.4685
(ZZ) Ratio of mass of organic carbon recovered to mass of organic carbon identified.		> 50	> 13244	> 31

* Source tables referes to tables in reference six.

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Exhibit 3

HEADQUARTERS
U.S. ARMY ARMAMENT, MUNITIONS AND CHEMICAL COMMAND

FINAL REPORT

DEVELOPMENT OF METHODOLOGY AND TECHNOLOGY FOR IDENTIFYING AND QUANTIFYING EMISSION PRODUCTS FROM OPEN BURNING AND OPEN DETONATION THERMAL TREATMENT METHODS.

BANGBOX TEST SERIES

VOLUME 1
TEST SUMMARY

JANUARY 1992

Maintenance Management Division
Demilitarization and Technology Branch
Rock Island, Illinois 61299-6000
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The report addresses the gaseous and particulate sampling of TNT detonations and double-base and manufactures residue propellant burns. All trials were accomplished in an air supported building (BangBox). Sampling was accomplished with real time instruments for CO_2, CO, NO_x, O_3, and SO_2; canister samplers for SF_6, CO_2, CO, and volatile hydrocarbons; Quartz fiber filters with backup XAD-2™ resin cartridges for semivolatile organics, and various instruments for size and mass of particles. For each analyte measured an emission factor was calculated by the concentration times volume of the building and by the carbon balance method. The carbon balance method is based on the conservation of carbon in the detonation or burn and thus becomes the trace element used as the basis for determining emission factors. The mass balance of carbon in the TNT detonation was established in the BangBox with CO_2 contributing 97 percent of the total carbon, CO carbon (0.50 percent), semivolatile and non volatile organics carbon (0.57 percent), and soot (1.7 percent).
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18. (Cont'd)

supercritical fluid chromatography; SFC; demilitarization; munition disposal; explosive disposal; environment; BB; air building

19. (Cont d)

The tracer method (carbon balance) permits an emission factor estimate from every parcel of sampled air regardless of the homogeneity of the cloud whereas the concentrations times cloud volume method is only good when the concentration is constant throughout the entire cloud volume and the cloud volume can be measured. The test was successful in providing a method for obtaining emission factors in field testing, providing data to select samplers, and the effectiveness of the supercritical fluid chromatography assay for field detonations and burns of PEP material.

FOREWORD

A test planning directive to conduct the OB/OD test in support of U.S. Army Armament, Munitions and Chemical Command (AMCCOM) was issued by U.S. Army Test and Evaluation Command (TECOM) on 28 April 1988[1]. This test was conducted following the Technical Steering Committee Symposium which was convened in July 1988. The requirement for identifying and quantifying emissions from the open detonation of explosives and open burning of propellants was discussed in detail by authorities from throughout the military, academic, and commercial communities. Conclusions and recommendations developed during the symposium are reported in proceedings of the symposium[2].

The BangBox Test series report includes three volumes:

Volume 1. A summary which describes the planning phase, the conduct of trials, sample analyses and results, and the conclusions and recommendations. It is useful for those who need the background, synopsized results, conclusions, and recommendations without the complete details with the supporting data and information.

Volume 2. A stand-alone document which covers the detail of the complete test. It describes the test development, description of the test materiel, and the trial results as they relate to the test objectives and the explosives and propellants tested.

Volume 3. The quality assurance/quality control (QA/QC) report covers the QA/QC plan, detailed test plan, the letters of instruction (prepared for procedural instruction), the quality audits, the reports of the quality audits, and the results of the blind spikes analyzed by the laboratories.

---

[1]Letter, AMSTE-TA-F, Headquarters, U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland, 20 April 1988, subject: Test Planning Directive for Special Study of Open Burning/Open Detonation (OB/OD), Phase II, TECOM Project No 2-CO-210-000-017.

[2]*Proceedings of the Technical Steering Committee Symposium 6-8 July 1988*, Headquarters, United States Army Armament, Munitions and Chemical Command, Rock Island, Illinois, August 1991.

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ABSTRACT

Open burning (OB) and open detonation (OD) are currently the primary means of demilitarization employed by the Department of Defense (DoD) for the treatment of explosive residue, propellants, and munitions as they become unsafe, excess, obsolete, or unrepairable. Increasingly stringent requirements for environmental documentation of potential pollution/contamination from combustion products under such acts as the Clean Air Act, Clean Water Act, and Resource Recovery Act have resulted in a critical need for a test program to collect data to be used as a basis for informed decisions concerning the limitations/restrictions of OB/OD, the need for alternative methods where required, and maintaining an effective, economical, and environmentally safe means of accomplishing the required demilitarization/treatment.

Under the sponsorship of the Single Manager for Conventional Ammunition within the DoD, a symposium was conducted in July 1988[3] to develop planning concepts necessary to address the technical problems associated with an accurate environmental characterization of the OB/OD processes. Authorities from governmental, academic and private research organizations discussed the technical issues and concepts of testing, and the associated sampling and sample analysis technologies, data analysis processes, test organization, and preparation of reports that would be accepted by Federal and State regulatory agencies. Expertise represented included field sampling, instrumentation, field and laboratory analysis, environmental documentation, atmospheric dispersion, data processing, combustion and explosive phenomenology, and quality assurance/quality control. A technical steering committee (TSC) composed of recognized experts in their respective disciplines was formed under the leadership of the U.S. Army Armament, Munitions and Chemical Command Program Manager.

A list of volatile and semivolatile organic compounds and metals which are potential contaminants in either the soil or atmosphere from OB/OD processes was developed. A chamber (BangBox (BB)) test was conducted at Sandia National Laboratories to check out instrumentation, technology, methodology, and analytical procedures that were proposed for follow-on field tests to

[3] *Proceedings of the Technical Steering Committee Symposium 6-8 July 1988*, Headquarters, United States Army Armament, Munitions and Chemical Command, Rock Island, Illinois, August 1991.

be sampled by the tested instrumentation placed on a fixed-wing aircraft flying through the plume. The field tests are required to obtain data to validate the technology and methodology for characterizing full scale OB/OD operations and establish correlations between the BB and full scale operations. If correlations can be established the less expensive BB type of testing may be used for emission characterization of various munitions and explosives in the demilitarization inventory. The U.S. Environmental Protection Agency (EPA) provided technical guidance and support during test planning and execution phases of test, review of data collection and analytical procedures, and assurance of instrument accuracy. Real time and near real time particulate and gaseous concentration measurements were achieved. These data were correlated with the samples collected on filters and gaseous containers and held for subsequent laboratory analysis. A methodology of using carbon balance to calculate more accurate emission factors of combustion products in diffusing clouds was verified.

The BB tests evaluated emission factors from 2,4,6-trinitrotoluene, OD and double- and composite-based propellants, OB. The tests confirmed the technologies, methodologies, and analytical procedures employed. These processes will be the basis for collecting and analyzing the data from the followon large-scale open-air tests scheduled for Phases A, B, and C to be conducted between June 1989 and September 1990. Further refinements will be made as required and approved by the TSC.

SECTION 1. INTRODUCTION

1.1. Open burning (OB) and open detonation (OD) are currently the primary means of demilitarization employed by the Department of Defense (DoD) for the treatment of explosive residue, propellants, and munitions as they become unsafe, excess, obsolete, or unrepairable.

1.2. The increasing need for data on OB/OD combustion products to support environmental documentation requirements, such as those of the Clean Air Act (CAA), Clean Water Act (CWA), and Resource Conservation and Recovery Act (RCRA) resulted in a critical need for a test program to collect data to be used as a basis for informed decisions concerning the limitations/restrictions of OB/OD, the need for alternative methods where required, and maintaining an effective, economical, and environmentally safe means of accomplishing the required demilitarization/treatment. The Single Manager for Conventional Ammunition within the DoD began to address this need in the early 1980's, and to provide scientific data to answer the question of environmental acceptability of OB/OD thermal treatment methods.

1.3. Although limited data are available from past studies on the generation of particulates and criteria pollutants from small-scale laboratory and field OB/OD operations, little field data are available on the levels of semivolatile organic emissions that result from unconstrained combustion of propellants by open-air burning or of explosives by open-air detonation. These compounds are difficult to collect and identify when produced in low concentrations. Thus, prior to the conduct of full-scale OB/OD field testing operations involving large quantities (thousands of kilograms) of explosives and propellants, a limited number of small-scale explosive detonation and burning trials were conducted within a controlled, ambient air environment. The test chamber used to provide this controlled environment was that operated by Sandia National Laboratories (SNL), Kirtland Air Force Base (AFB), New Mexico, and is locally known as the BB.

1.4. The purpose of this report is to describe the BB test technical issues, objectives, methodology development, conduct, data collection, analysis procedures, quality assurance/quality control procedures, results, and conclusions. At various places within the report or its appendices, this test is referred to as the BB, preliminary, or chamber test; these terms are considered equivalent.

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SECTION 2. TECHNICAL ISSUES

2.1. The Symposium

2.1.1. Background

OB/OD operations are conducted at a large number of DoD installations and activities. Each location has unique conditions of soil type, groundwater depth, vegetative cover, terrain, sensitivity to noise or airborne particulate levels, proximity to urban areas, and types of materials requiring demilitarization. Because of the common need of these installations and activities for high-quality data on combustion products to support permit applications and environmental documentation, the U.S. Army Armament, Munitions and Chemical Command (AMCCOM) OB/OD program manager established a technical steering committee (TSC) to provide advice and guidance on test planning, test conduct, and data analysis. In July 1988, a symposium was conducted in Salt Lake City, Utah, to develop the planning concepts necessary to address the many technical problems associated with conduct of a successful OB/OD test program. Authorities from governmental, academic, and private organizations discussed data requirements, sampling and sample analysis technologies, data analysis processes, test organization, and preparation of reports that would be accepted by Federal and State regulatory agencies. Disciplines represented at this symposium included test planning; field sampling; instrumental, field, and laboratory analysis; environmental documentation; atmospheric dispersion; data treatment; combustion and explosive phenomenology; and quality assurance/quality control (QA/QC). It was at this time that the TSC, composed of recognized experts in their respective disciplines, was formed. The results of this symposium are outlined in a separate report[4] and briefly summarized below.

2.1.2. Results.

2.1.2.1. The symposium recognized that open-air, surface detonations of explosives produce a short-term, high-temperature buoyant fireball of oxidizing gases which may entrain soil and which

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[4]*Proceedings of the Technical Steering Committee Symposium 6-8 July 1988*, Headquarters, United States Army Armament, Munitions and Chemical Command, Rock Island, Illinois, August 1991.

disperses rapidly downwind after reaching the cloud stabilization height (Figures 2.1 through 2.3). Typical propellant burns (Figures 2.4 and 2.5) produce extremely luminous, hot plumes over several seconds and with little soil involvement. They also permit more entrainment of ambient oxygen to assist in oxidation; however, they generate a less well-defined cloud, than surface detonations.

2.1.2.2. Because of the differences in explosive and propellant composition, geometry, and combustion phenomenology, it was suggested that chamber trials be conducted first using the following explosive and propellants:

2.1.2.2.1 The explosive 2,4,6-trinitrotoluene (TNT), the most oxygen-deficient (-74 percent) of the military explosives, and therefore the most likely to produce significant amounts of the products of incomplete combustion.

2.1.2.2.2 A double-base propellant containing primarily nitrocellulose and nitroglycerin with added ethyl cellulose.

2.1.2.2.3 A composite propellant containing ammonium perchlorate.

2.1.2.3. Product compositions and concentrations could then be compared with widely variable results reported in earlier computer-modeled combustion product studies and with laboratory-scale and less-controlled open-air detonation and burn studies reported in the literature.

2.1.2.4. To assess the effect that soil might have on product composition by its quenching of complete oxidation during TNT detonation, without puncturing the chamber's fabric walls, it was suggested that a surrogate fireball-mitigating material (aqueous foam) should be used to surround the TNT block on one of the detonation trials.

2.1.2.5. The air building chamber (the BB) at SNL (Figure 2.6) was chosen as the test facility because it offered several advantages over other facilities and devices designed to contain explosions. These advantages are as follows:

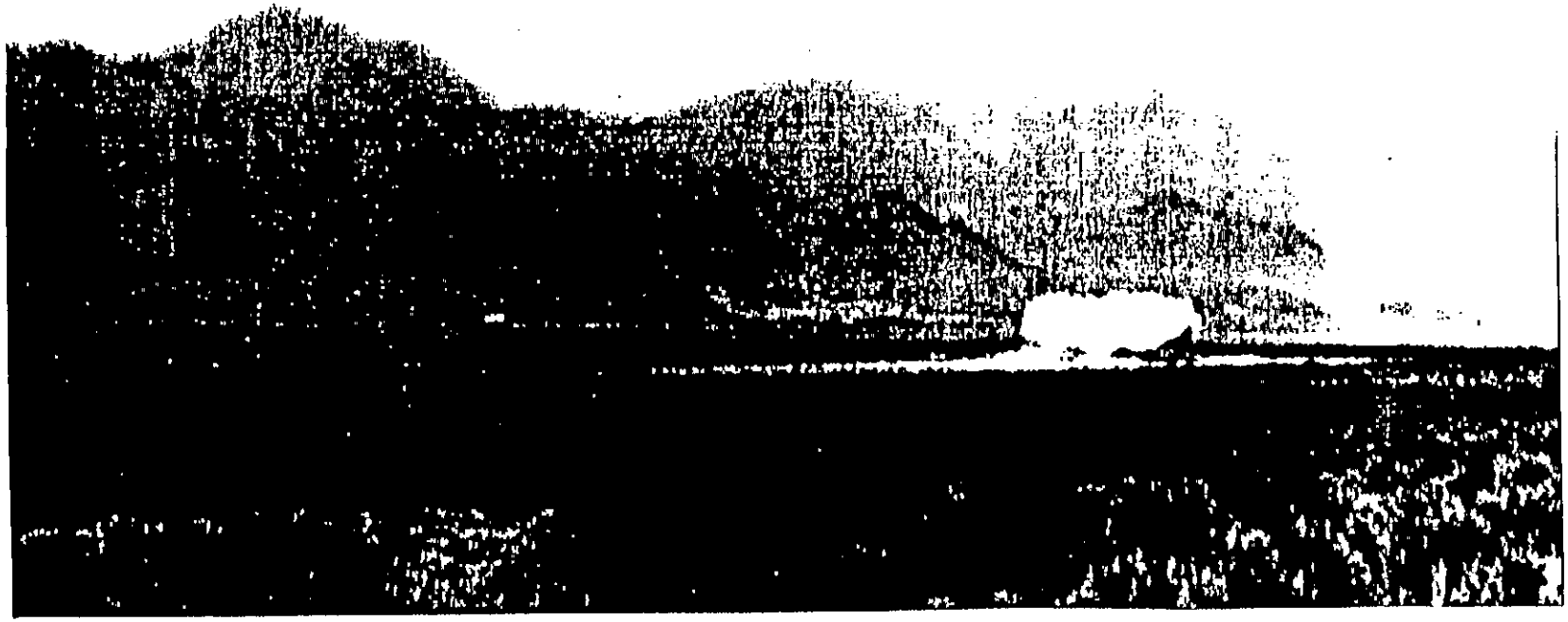


Figure 2.1 Typical Initial Fireball Formation, 907-kg (2000-lb) TNT QD Test



Figure 2.2 Typical Cloud Formation With Entrained Soil, 907-kg (2000 lb) TNT Open Detonation Test

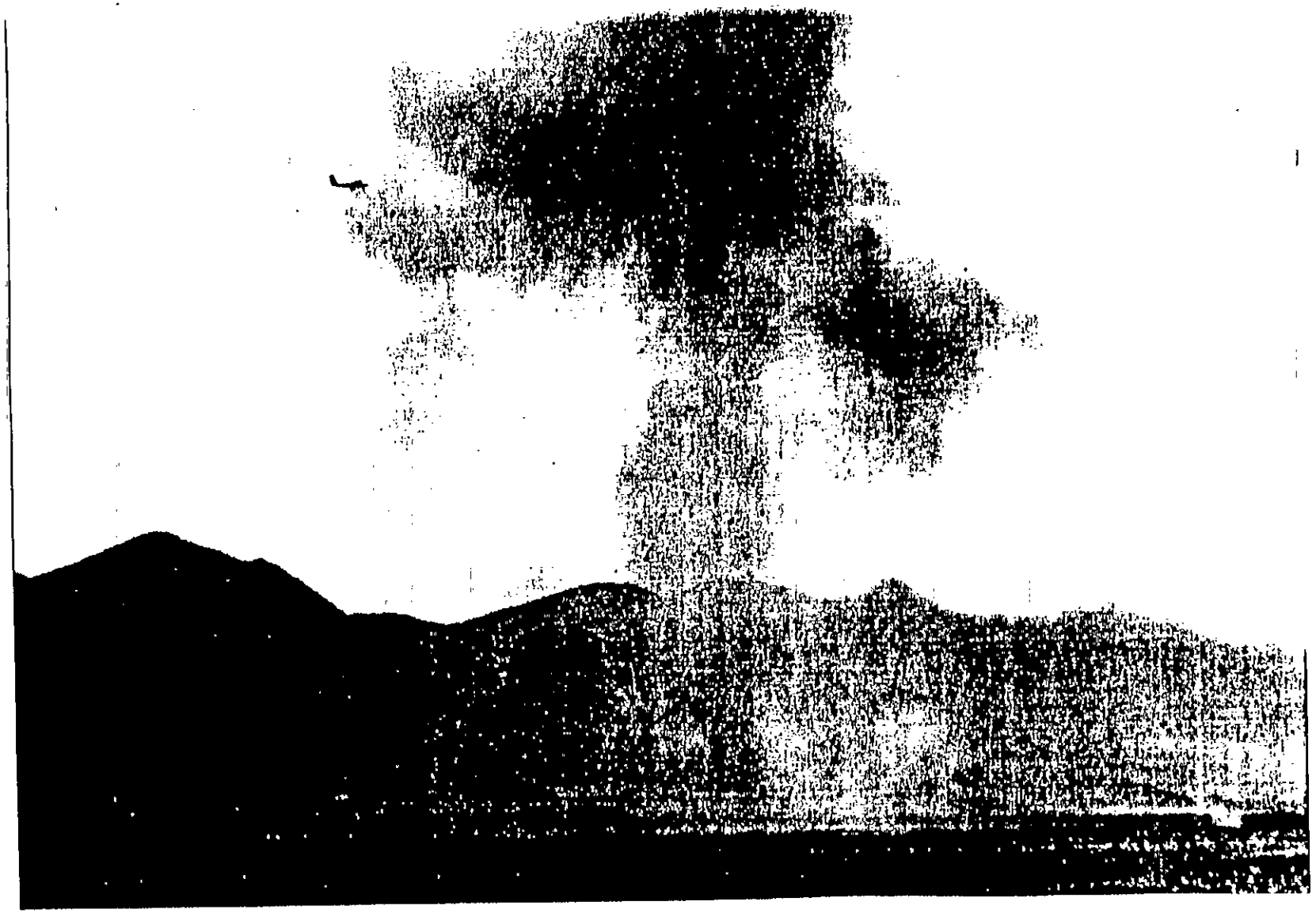


Figure 2.3 Typical Stabilized Cloud Formation Prior to Downwind Dispersal, 907-kg (2000-lb) TNT Open Detonation Test

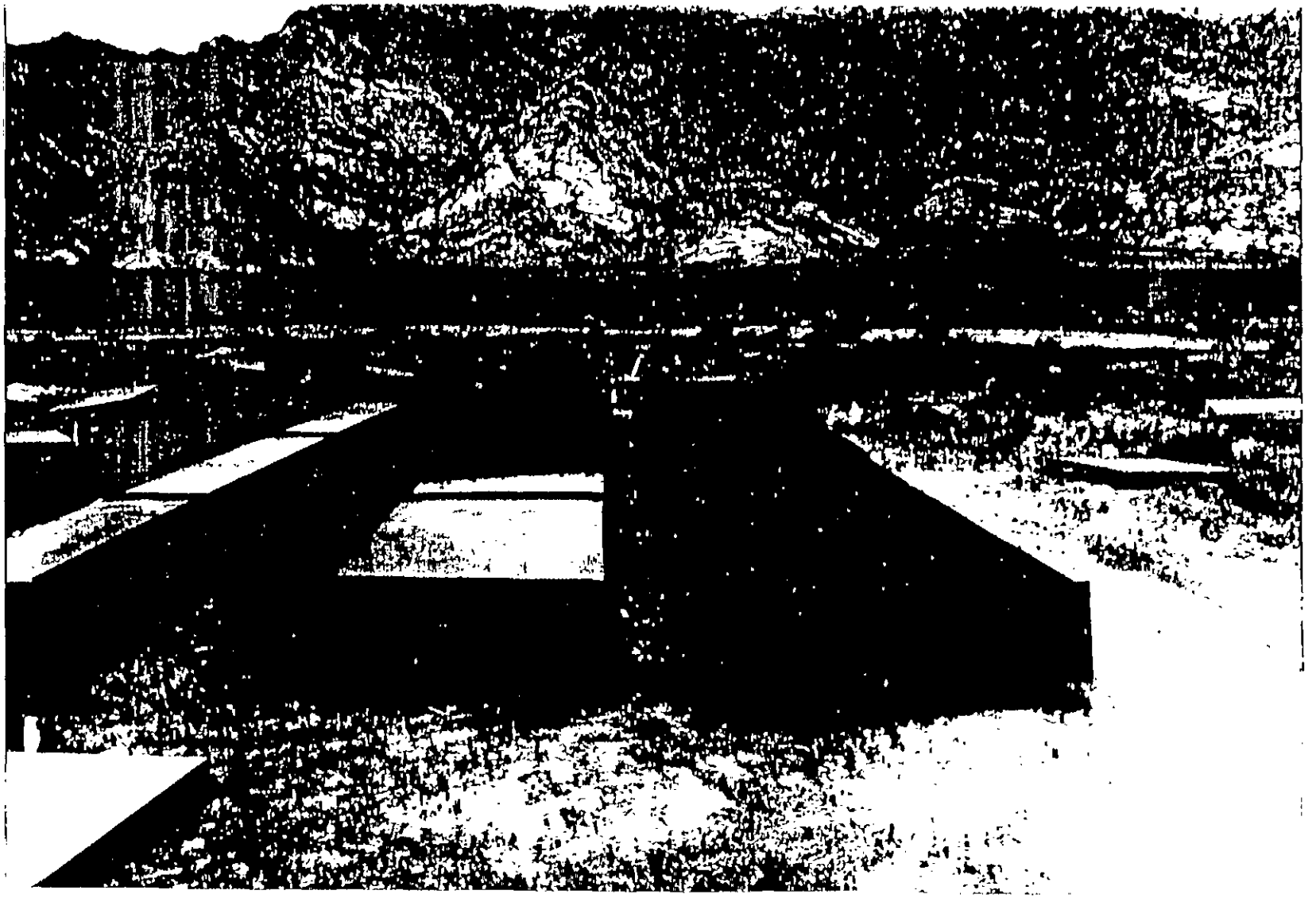


Figure 2.4 Partially-Filled Burn Pans, 3175-kg (7000 lb) Propellant Open Burn Test

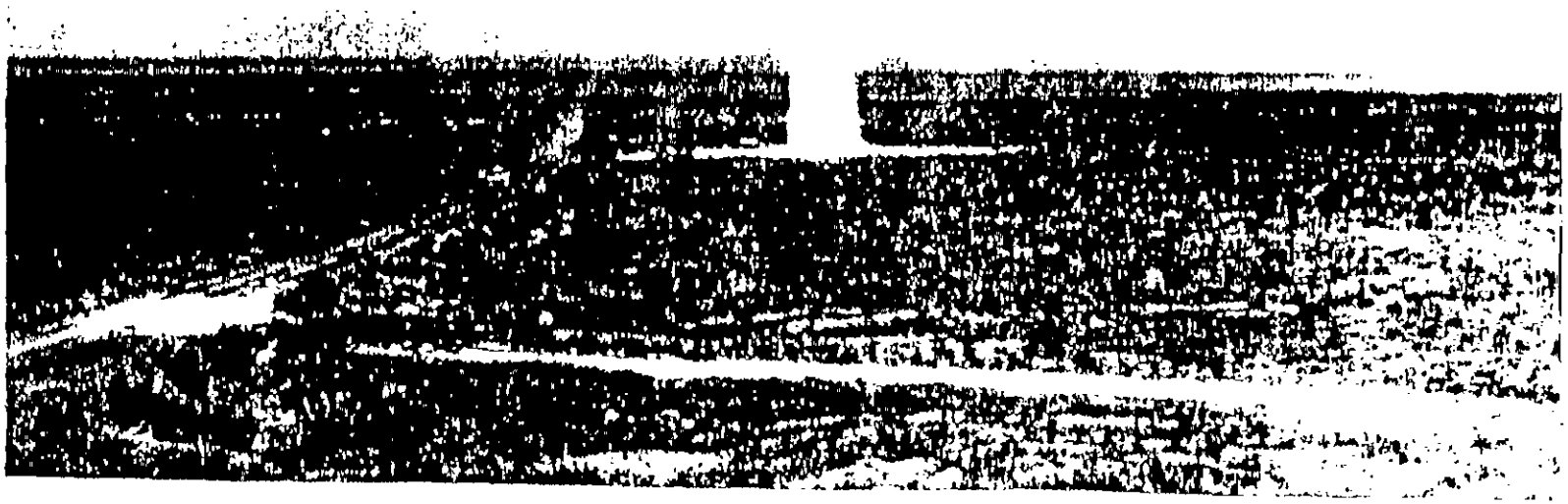


Figure 2.5 Typical Plume, 3175-kg (7000-lb) Propellant Open Burn Test

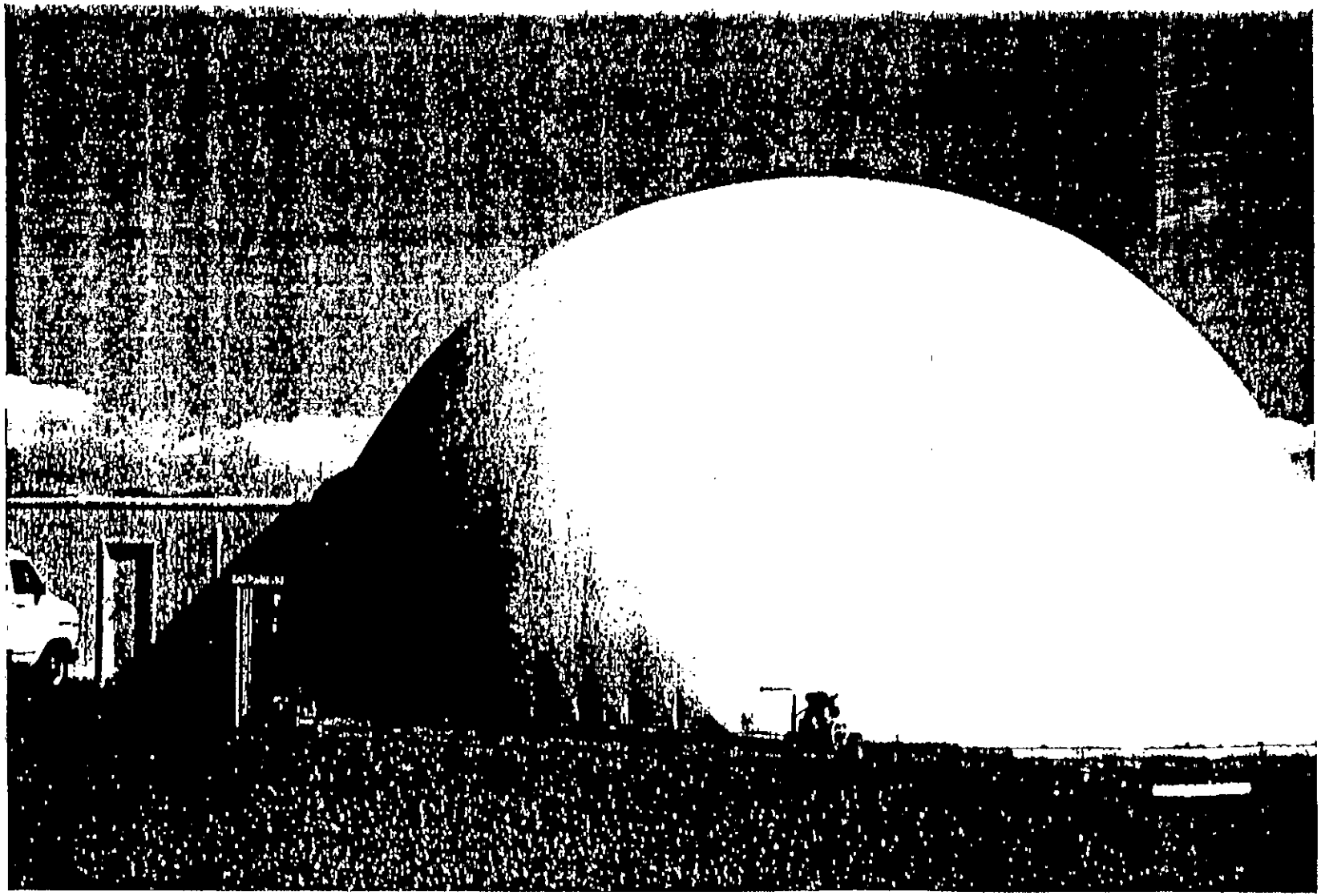


Figure 2.6 SNL BangBox Test Facility Containing Sampling and Real-Time Analysis Equipment

2.1.2.5.1 It was large enough to permit complete combustion and containment of the product clouds from 227 grams (0.5 lb) of explosive and similar quantities of burning propellants.

2.1.2.5.2 There would be no significant spall from the aluminum-covered concrete floor to interfere with sample collection and analysis.

2.1.2.5.3 The same instruments, samplers, and data handling equipment that were proposed to be mounted in a fixed-wing aircraft (FWAC) to sample outdoor OB/OD clouds during later study phases could be completely checked under the controlled conditions of the BB trials. The FWAC planned for use is shown in Figures 2.7 and 2.8.

2.1.2.6. Characterization of the BB test facility included a determination of ventilation rate (using tracer gas) and a determination of the ability to achieve internal atmospheric homogeneity in the chamber using mixing fans. Sulfur hexafluoride (SF_6) and CO_2 would be used as tracer gases.

2.1.2.7. A list of target analytes would be developed covering gaseous criteria pollutants, volatile and semivolatile organic compounds, unreacted explosive/propellants and their manufacturing by products/contaminants, regulated metals and nonmetals, and other potentially detrimental organic compounds. The concentrations of these OB/OD products would then be determined by applying the most sensitive, reproducible, and versatile analytical methods available. Competing analytical technologies, such as gas chromatography-mass spectrometry (GC/MS) and supercritical fluid chromatography-mass spectrometry (SFC/MS), would be evaluated.

2.1.2.8. Sampling equipment and techniques would be evaluated for possible later use in the SNL FWAC during large-scale outdoor trials.

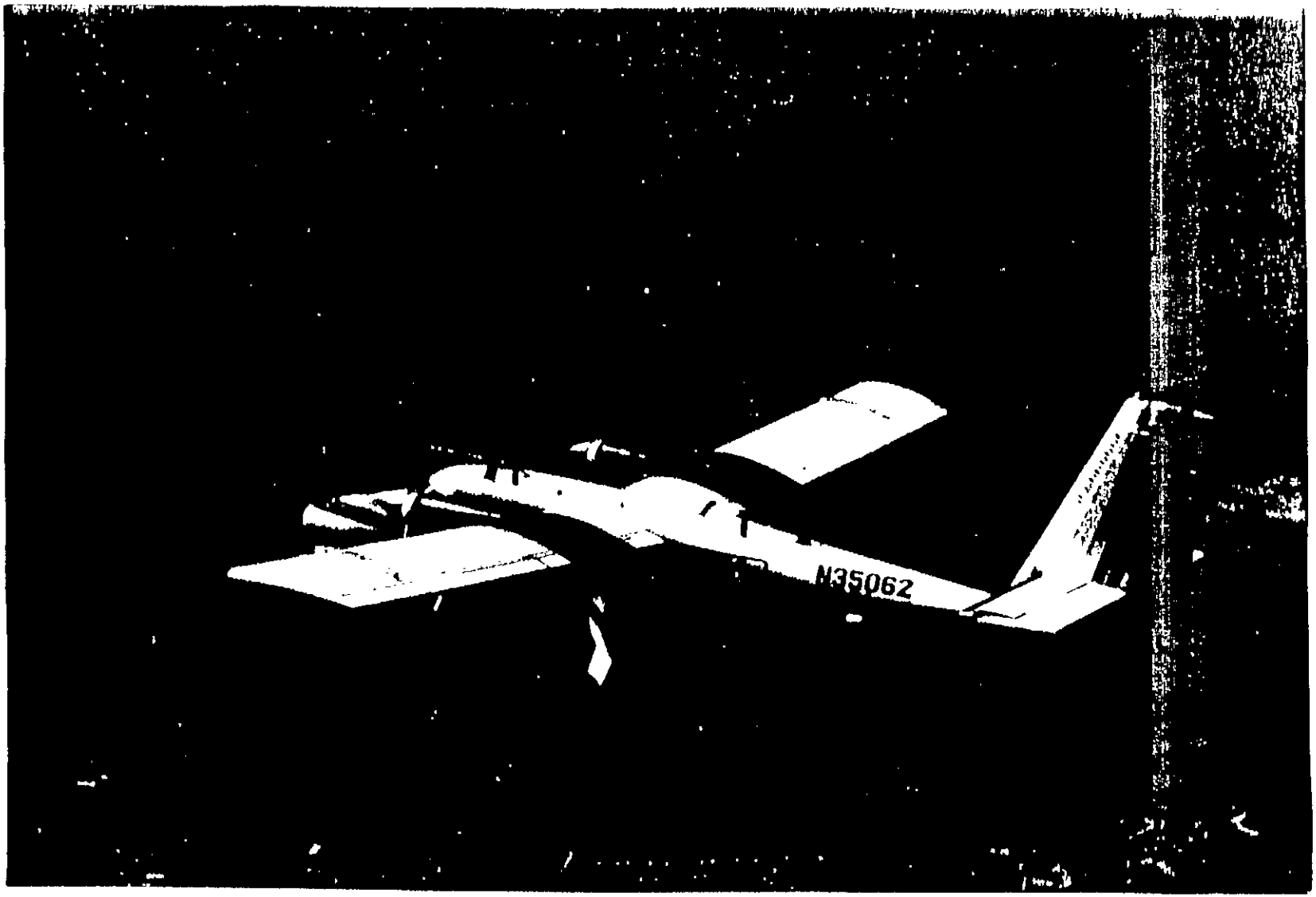


Figure 2.7 SNL Twin Otter Instrumented Fixed Wing Aircraft for Open Air OH-VOC Sampling and Real Time Gas Analysis

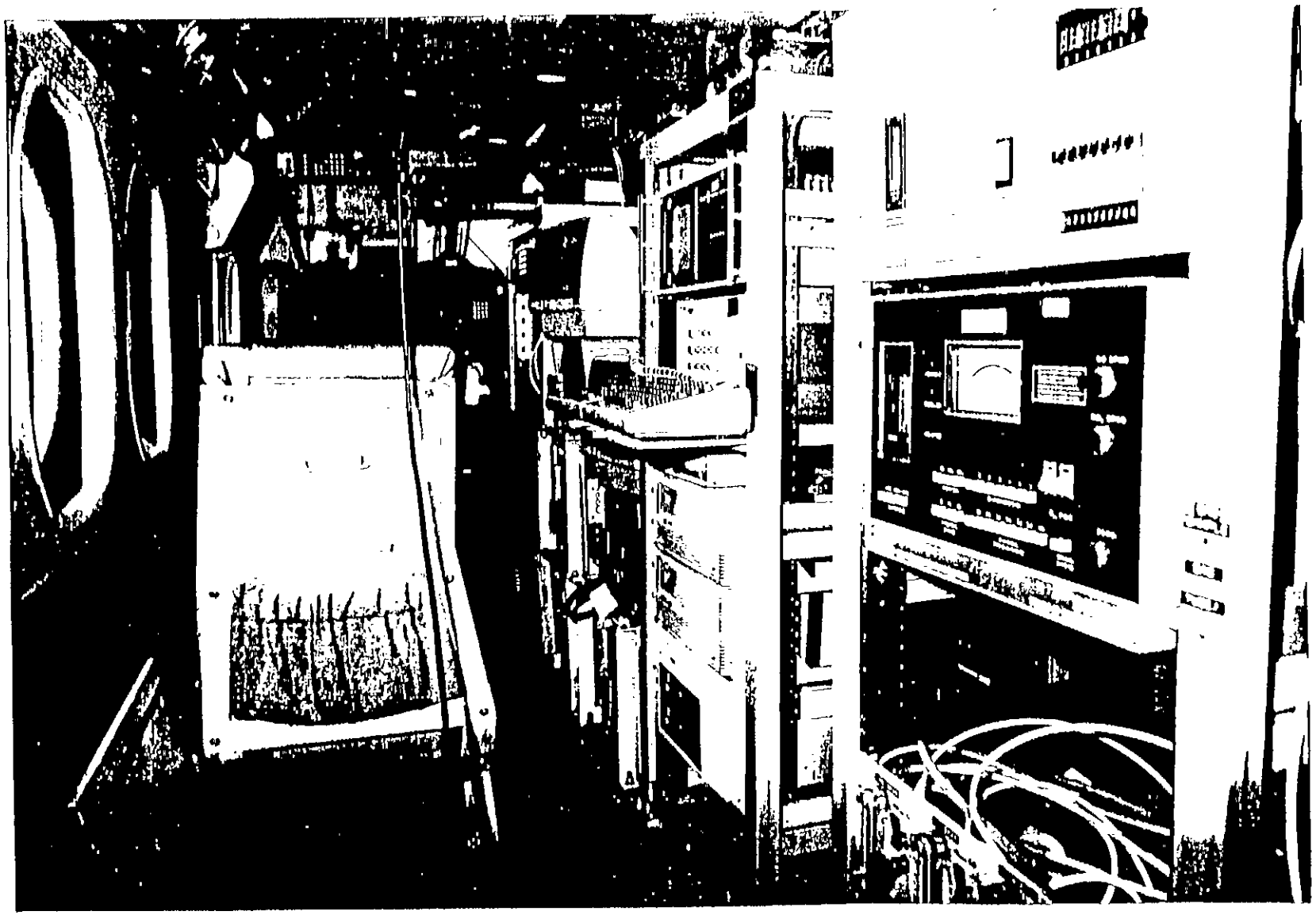


Figure 2.8 Interior View, Partial Instrument Array, SNL Fixed-Wing Aircraft.

2.1.2.9. The widely used method of estimating initial source strengths of emissions within OB/OD clouds yields extremely variable results, because the ultimate accuracy of the estimate depends not only on difficult-to-measure very low concentrations of compounds in the elevated, diffusing cloud, but also on very speculative estimates of the cloud's volume. SNL proposed an alternative method (the carbon balance method) to be evaluated during the chamber trials that did not depend on making a cloud volume estimate. This method would permit a more accurate calculation of emission factors of combustion products in diffusing clouds especially when the fuel's carbon content is well-characterized, and the concentrations of the major carbon-containing products can be accurately measured.

2.1.2.10. Adequate QA/QC procedures for use in sample collection, handling, analysis, and data treatment would need to be developed, checked, approved, and revised (where necessary) before conducting the expensive large-scale outdoor OB/OD trials.

2.2. Test Design Plan

After proposed solutions to technical issues were identified by the TSC, an AMCCOM test design plan was prepared. Formal BB testing began on 7 December 1988.

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SECTION 3. STUDY OBJECTIVES

ırpose is to supply waste characterization data for OB/OD permit
part X.

evelop sampling and analytical technology, instrumentation, and
RCRA subpart X data characterization.

y emissions and residues produced by OB/OD thermal treatment

elopment and validation of an OB/OD dispersion model.

that can be treated by OB/OD thermal treatment methods without

vas designed to develop, verify and confirm the OB/OD thermal
ogy/methodology.

chamber volume, ventilation rate, and combustion product cloud

equipment, procedures.
ır air homogeneity, volume,
ıd outside BB.
)D data trials: provided
trial.
simultaneous air sample

is an air-supported, rubber-
uilding was through a plywood
positive air pressure supplied
tment of inflation airflow rate
anually adjusted to achieve an

nstalled on the FWAC, were
rmances. Gas and particulate
diameter aluminum tube that
that normally installed on the
all particulate and gas samples

3.2.2.2. Develop and improve proposed air sampling equipment and sample analysis procedures to be used in later phases on the FWAC, for sampling product clouds from large-scale follow-on field OB/OD trials.

3.2.2.3. Refine, standardize, and compare supercritical-fluid chromatography (SFC) and gas chromatography (GC) techniques for extracting and analyzing resins, filters, and soils for trace quantities of semivolatile organic OB/OD combustion products and residues, using mass spectrometer (MS) detectors.

3.2.2.4. Verify adequacy of other standard analytical methods to be used for analyses of gases, particulates, volatile organic compounds, metals, and nonmetals.

3.2.2.5. Identify and quantify specific target analytes for TNT, a double-base propellant, and a composite propellant.

3.2.2.6. Assess polychlorinated dibenzodioxins (PCDD) and dibenzofurans (PCDF) levels generated from burning the composite propellant containing high concentration of NH_4ClO_4.

3.2.2.7. Provide information on the morphology, composition, and size distributions of airborne particulate material generated by OB/OD operations in the BB.

3.2.2.8. Examine, using data produced under controlled conditions, the validity of the proposed Carbon Balance method of calculating emission factors; compare the results with those calculated using the more-conventional cloud volume times concentration method.

3.2.2.9. Identify or develop appropriate program-specific QA/QC procedures.

3.2.2.10. Develop and establish procedures for transport and storage of sample specimens.

are collected during flight. A matrix of instruments and equipment used in each trial is shown in Tables 4.2a and 4.2b.

4.1.1.3. The schematic layout of sampling equipment mounted in the BB airlock and used on trials subsequent to 7 December, 1989, is shown in Figure 4.1. The airflow from the interior chamber was routed through a pneumatically driven 10-cm diameter gate valve into a 1.5-m^3 carbon-impregnated polyethylene (Velostat™) sampling bag. The bag, which was constructed of electrically conductive plastic material to minimize wall loss effects of charged particles, fills with air from the chamber interior in approximately 40 seconds.

4.1.1.3.1 Stainless steel sampling lines led to a series of filters, vapor collection systems, and gas monitors. Particulate and semivolatile compounds were collected on two semivolatile organic sampling trains (SEMI-VOSTs), which consisted of a prefired quartz-fiber filter, followed by two sections containing XAD-2™ resin. The front and backup sections contained approximately 65 and 20 grams of resin, respectively. Other filters connected to the bag outlet manifold included a Teflon™ filter, used for gravimetric analysis and X-ray fluorescence (XRF) measurements, and a Nuclepore™ polycarbonate filter used for scanning electron microscopy (SEM). A pump provided airflow through the filters at a rate of approximately 200 L/min. Mass flowmeters enabled determination of air sample volumes.

4.1.1.3.2 Real-time continuous monitors used to provide data for this report are listed in Table 4.3. In-line Teflon™ filters were provided for all these monitors to prevent particulate contamination of the instrument optics. A differential mobility particle sizer (DMPS) was used to measure particle size distributions in the 0.01- to 0.5-μm diameter range. Grab samples of air were collected in electropolished stainless steel canisters directly from the sampling duct, and indirectly from the 1.5-m^3 sampling bag, by Oregon Graduate Center (OGC) personnel. The grab samples were analyzed by OGC for H_2, CO, CO_2 and C_1 - C_{10} hydrocarbon concentrations, using (GC) with thermal conductivity detector (TCD), flame ionization detector (FID) (for SF_6), and electron capture detector (ECD). Hereafter, all samples collected and analyzed from the bag will be referred to as indirect samples.

Table 4.2a **Matrix** of Instrument, Sampler, and Collector Used During the OB/OD Detonation BangBox Test.

	Trial Number[a]									
Item	1	2	3	4	5	6	7	8	9	10
PARTICLE SIZERS										
DMPS[b]	X	X	X		X	X	X	X		
APS[c]	X		X	X		X	X	X	X	X
FILTERS										
Teflon™			X	X			X	X		X
Nuclepore™			X	X			X	X		X
XAD-2™			X	X	X	X	X			X
Porapak-R™			X							
Quartz-fiber			X	X	X	X	X	X		X
DETECTORS										
Nephelometer			X	X		X	X	X	X	X
FID[d]			X					X		
PID[e]	X		X	X		X	X	X	X	X
ANALYZERS										
CO_2	X	X	X	X		X	X	X	X	X
CO	X	X	X	X		X	X	X	X	X
SO_2	X	X	X	X		X	X	X	X	X
O_2	X	X	X	X		X	X	X	X	X
NO_x	X	X	X	X		X	X	X	X	X
SF_6	X	X	X	X		X	X	X	X	X
BUBBLERS										
HCN			X	X		X	X			X
NH_3			X	X		X	X			X
HCl										X
BAG										
1-m^3	X		X	X			X	X		X

NOTE: Footnotes identified on next page.

Table 4.2b Matrix of Instrument, Sampler, and Collector Used During the OB/OD Detonation BangBox Test.

	Trial Number[a]									
Item	1	2	3	4	5	6	7	8	9	10
TANKS/CANISTERS										
0.85-L	X	X	X	X			X		X	X
6-L	X		X	X			X	X	X	X
32-L	X		X	X					X	
CAMERAS										
Color Video	X	X	X	X		X	X	X		X
HS[f]							X	X		X
HS Film	X		X							
MISCELLANEOUS										
Thermometer	X	X	X	X	X	X	X	X	X	X
Barometer	X	X	X		X	X	X	X	X	X
DP[g] Gauge	X	X	X	X		X	X	X	X	

[a]Trial: 1 - Homogeneity and BB Chamber Volume (1 Dec 88).
2 - Ventilation Rate (5 Dec 88).
3 - Single-Charge TNT OD (7 Dec 88).
4 - Single-Charge TNT ODs (31 Jan 89, 2 and 6 Feb 89).
5 - Extended Background Air Sampling (7 Feb 89).
6 - Multiple Detonation (8 Feb 89).
7 - Double-Base Propellant OB (9 Feb 89).
8 - Foam-Attenuated TNT Detonation (13 Feb 89).
9 - Multiple Tank Sampling ("Big Gulp") OD Trial (15 Feb 89)
10 - Composite Propellant Burn (16 Feb 89).

[b]Differential mobility particle sizer.
[c]Aerodynamic particle sizer
[d]Flame ionization detector.
[e]Photoionization detector.
[f]High-speed.
[g]Differential pressure.

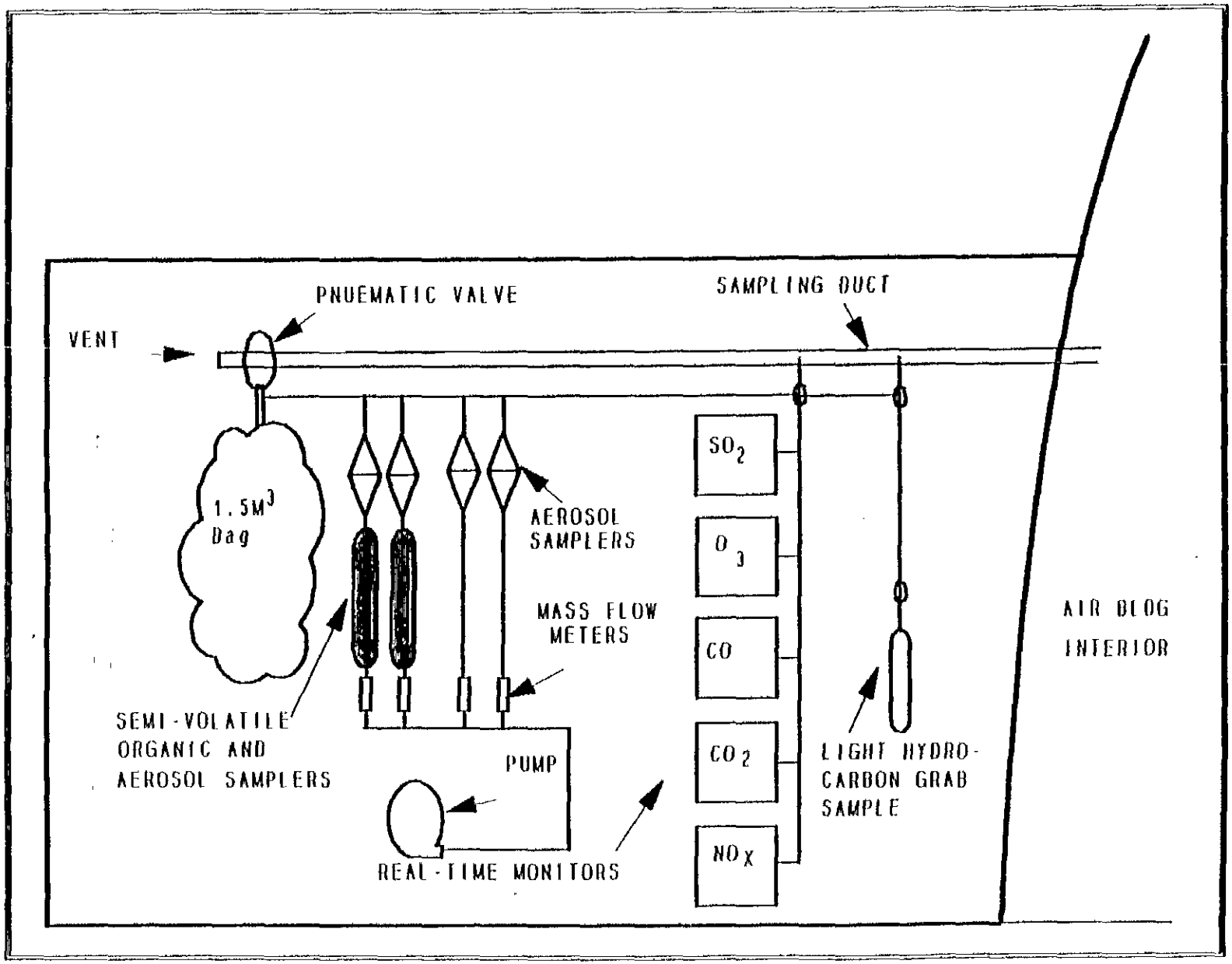


Figure 4.1 BangBox Airlock Instrumentation and Sampling Equipment.

Table 4.3 OB/OD Real-Time Continuous Monitors Positioned in the SNL BangBox Airlock.

SPECIES	INSTRUMENT	MEASUREMENT PRINCIPLE	DETECTION LEVEL[a]
CO_2	TECO Model 41H	Gas Filter Correlation	1.2 ppmv
CO	TECO Model 48	Gas Filter Correlation	0.1 ppmv
SO_2	TECO Model 43	Pulsed UV Fluorescence	2 ppbv
O_3	TECO Model 49	UV Absorption	5 ppbv
NO_x	CSI Model 1600	Chemiluminescence	6 ppbv
THC	Century OVA-128	Flame Ionization	2 ppmv
THC[b]	HNU Model PI-101	Photoionization	0.1 ppmv

[a]Detection level defined as two times the standard deviation of the instrument noise.
[b]The photoionization detector responds to other gaseous species in addition to hydrocarbons. No attempt is made in this study to correct for the non-specificity of this instrument. Hydrocarbons detected were quantitated separately by GC methods outlined elsewhere in this report.

4.1.1.3.3 In order to make direct measurements of interior chamber air following a detonation or burn, additional instruments and samplers were positioned inside the BB facility, as shown schematically in Figure 4.2. The various instruments included are listed in Table 4.4.

4.1.1.3.4 Two laser particle spectrometers that are normally installed in the SNL FWAC were used to make particulate measurements in real-time. Particles in the 0.15- to 3-μm diameter range were measured with an active scattering aerosol spectrometer probe (ASASP). Particles in the 2- to 47-μm diameter range were measured with a forward scattering spectrometer probe (FSSP). The FSSP probe is designed to incorporate true *in situ* measurement principles and, as such, requires no correction for particle transmission or sampling losses. Both the FSSP and ASASP probes provided records of total particle counts at 1-minute intervals.

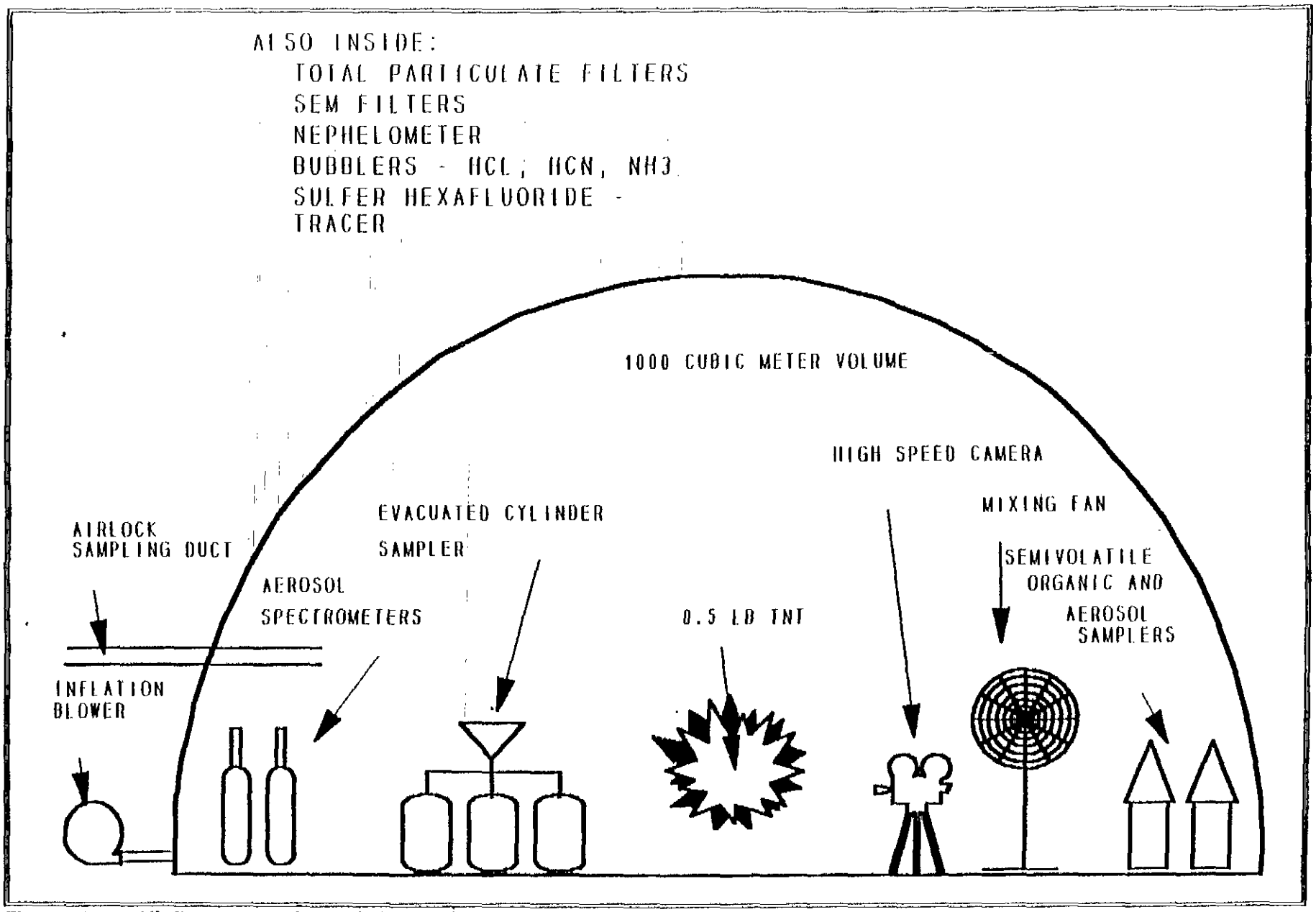


Figure 4.2 SNL BangBox Interior OB/OD Sampling Instrumentation and Equipment.

Table 4.4 Samplers Located Inside the BangBox.

Instrument - Parameter Measured	Model (Characteristics)
Aerosol spectrometer - particle size distribution	PMS ASASP-100X (0.15 - 3 μm diameter)
Aerosol spectrometer - particle size distribution	PMS FSSP-100-X (2 - 47 μm diameter)
Integrating nephelometer - particulate concentration	Belfort Ind. Model 1590 (0 - 3 μm diameter)
Nephelometer - particulate concentration	MIE Model RAM-1 (0 - 3 μm diameter)
Video camera - photometric record	NAC Model HSV-200 (200 frame/s)
Fast frame camera - photometric	NAC Model E-10 (500 - 10000 frame/s)
semi-VOST[a] (2) - trace organics	GMW Model PS-1 (≈ 100 L/min)
Teflon™ filter sampler - total particulate and metals.	GAST Model 30 (30 L/min)
Polycarbonate filter sampler - particle morphology	GAST Model 30 (3 L/min)
Bubbler sampler - Hydrogen cyanide	Gillian Model 113FS (2 L/min)
Bubbler sampler - Ammonia	Gillian Model 113FS (2 L/min)
Bubbler sampler - Hydrogen chloride[b]	Gillian Model 113FS (2 L/min)
Evacuated stainless steel canisters - volatile organics	OGC special design (6-L)
Evacuated stainless steel tanks - volatile and semivolatile organics	OGC special design (32-L)
Evacuated stainless steel canister - SF_6	OGC special design (0.85-L)

[a]semiVOST - semivolatile organic sampling train.
[b]Hydrogen chloride bubblers were used only on the composite propellant burn trial.

4.1.1.3.5 A flash-lamp integrating nephelometer and a portable forward light scattering particulate detector provided continuous measurement of particulate concentration inside the chamber during each test. Photographic coverage of detonation and burn trials was provided by video cameras and recorders and with a high-speed camera run at 5,000 frames per second. Two 1-meter diameter fans with approximate airflow rates of 250 m^3/minute were used to rapidly mix the BB chamber air prior to collection of "homogeneous" air samples. Samples collected from the chamber interior immediately after detonation or burn and before turning on the mixing fans are considered to be nonhomogeneous.

4.1.1.3.6 Semivolatile and organic particulate species were collected directly from the chamber interior by two modified semiVOSTs operating at flow rates of approximately 100 L/min. The filter and cartridge units used in these semiVOSTs were identical to those used for collection of air drawn from the 1.5-m^3 sampling Velostat bag mounted in the airlock. Standard high-volume sampler blowers were used to pull air through these direct semiVOST units.

4.1.1.3.7 As a result of these sampling arrays, data from both direct (chamber) and indirect (bag) sampling during both nonhomogeneous and homogeneous air sampling periods could be compared. Glass impingers (bubblers) filled with appropriate absorbing solutions were used to collect ammonia and hydrogen cyanide product gases.

4.1.1.3.8 An audit of criteria gas and mass flow instrument performance was conducted by personnel from the U.S. Environmental Protection Agency (EPA), Atmospheric Research and Exposure Assessment Laboratory, Quality Assurance Division, Research and Monitoring Evaluation Branch, Research Triangle Park (RTP), North Carolina. Results of the audit were excellent.

4.1.1.3.9 Teflon™ filter particulate sample weights were determined gravimetrically by precision electrobalance. The Teflon™ filters were then analyzed by XRF spectroscopy (for elements with atomic mass units in excess of 12) by Lawrence Berkeley Laboratory (LBL). Particulate carbon speciation was done by Sunset Laboratory (SSL) on 1-cm^2 punches taken from SEMI-VOST quartz-fiber filter samples. This thermo-optical analysis involves a two-step volatilization and combustion process to differentiate between organic, elemental, and inorganic carbon on the filter. Bubbler samples were analyzed by National Institute for Occupational Safety and Health (NIOSH) method 205 (colorimetric) for NH_3 and NIOSH method 116 (cyanide-specific ion electrode) for HCN. Trace-level semivolatile organic compounds from semiVOST filters, XAD-2™ resins, cartridges, swab samples, and 32-L tanks were identified, separated, and quantified by both Battelle Columbus Division (BCD) and by Alpine West Laboratories (AWL). Battelle used GC/MS and AWL used SFC/MS for analysis of solutions prepared by extraction of sample media with methylene chloride followed by concentrating by rotary evaporation.

4.1.1.3.10 During the composite propellant burn, high-volume air samplers sampling at 283 L/min were also used to take duplicate samples on quartz-fiber filters. The filters were backed up by pre-cleaned polyurethane foam-filled cartridges. Analyses were made for PCDD and for PCDF by BCD. The analyses included determination of total hepta-, hexa-, penta-, and tetra-chlorinated dibenzodioxin (CDD) and -chlorinated dibenzofuran (CDF) congeners, as well as octa- and 2,3,7,8-tetra-CDD and - CDF concentrations. Taking into account the relative toxicities of the congeners and converting the results to an equivalent quantity of the most toxic, only 2 ng of PCDD and 3.3 μg of PCDF were detected per ton of composite propellant.

4.2. Chronology

A typical chronology of events for a TNT detonation trial is shown in Table 4.5. The chamber was washed and the floor vacuumed before detonation trials began. Event chronology for the propellant burn and foam-attenuated TNT detonation trials was similar, except for fuel setup configurations and modifications of sampling procedures because of unique data requirements for those trials. A typical detonation of a suspended rectangular 227gram (0.5 lb) TNT block is shown in Figure 4.3. On completion of each trial, samples were collected, sealed, stored at ambient temperatures (usually 0 to 5°C), and subsequently transported to the various laboratories for extraction.

Table 4.5 Typical Chronology of Events for a TNT Detonation Trial.

Time[a] (min)	Event
t-75	Install background filters, SEMI-VOST cartridges, bubblers. Record initial flow rates on all samplers. Check zero and span on all continuous monitors.
t-60	Clear all personnel from chamber interior. Begin background sampling with all instruments and samplers.
t-30	Complete background sampling. Record final flow rates on all sampiers. Remove background sampling media. Install all test filters, SEMI-VOST cartridges, bubblers, etc. Record initial flow rates on all sampiers.
t-15	Hang 227-g (0.5-lb) TNT charge in test fixture.
t-5	Start data acquisition on all continuous instruments. Clear all personnel to safe bunker. Connect detonator cable to charge and arm.
t-0	Detonate charge.
t+3	Remotely start all filter and SEMI-VOST samplers inside chamber. Collect nonhomogeneous sample No. 1 from sampling bag. Pump bag sample through sampling media in airlock. Switch criteria gas monitors to sample directly from bag for 3 minutes. Fill 6-L evacuated cylinder from interior of chamber.Fill 6-L evacuated cylinder from bag.
t+5	Switch mixing fans on for 3 minutes.
t+10	Change sampling media on bag system.
t+15	Collect homogeneous (mixed) air sample No. 1 in sampling bag. Pump bag sample through sampling media. Switch criteria gas monitors to sample directly from bag for 3 minutes. Fill 6-L evacuated cylinder from interior of chamber. Fill 6-L evacuated cylinder from bag.
t+25	Change sampling media on bag system.
t+30	Collect homogeneous sample No. 2 from sampling bag. Pump bag sample through sampling media. Switch criteria gas monitors to sample directly from bag for 3 minutes. Fill 6-L evacuated cylinder from chamber interior. Fill 6-L evacuated cylinder from bag.
t+35	Stop direct SEMI-VOST, filter, and bubbler samplers. Reenter chamber and measure final sampler flows.
t+45	Check zero and span on all continuous monitors. Retrieve and back-up all test data. Collect and preserve all sampling media.

[a]t = time of detonation.

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Figure 4.3 Detonation Fireball from Suspended 227-g (0.5-lb) TNT Block Detonation in BangBox

SECTION 5. SAMPLE ANALYSIS AND ANALYSIS RESULTS

5.1. Sample Handling and Analysis

Sample handling and analysis procedures are outlined in individual laboratory Letters of Instruction (LOIs) (See Volume 3).

5.2. Chemical Compounds Targeted for Analysis

5.2.1. Potentially hazardous substances for which present data was most lacking relative to OB/OD operations were the trace organic compounds, sometimes called products of incomplete combustion (PIC), formed in any combustion process that is less than ideal. The application of the term PIC to OB/OD operations is somewhat misleading, because it may imply that these organic substances occur as a part of the original mass of uncombusted material that happens to escape complete oxidation. In actuality, the OB/OD PIC are formed by pyrolysis of organic matter at flame temperatures. They occur in the combustion effluent because insufficient oxygen is present and/or thermodynamic equilibrium with the environment is not achieved because of premature quenching. Because of electron delocalization, these exotic organic compounds have large atomic bonding energies, and are thermodynamically stable at high temperatures. Furthermore, certain polycyclic aromatic hydrocarbons, along with their nitrogen or oxygen heterocyclic counterparts and their nitro and/or amino derivatives, are among the most mutagenic of known organic compounds. Consequently, such compounds received major attention when targeting certain semivolatile organic compounds for specific analysis. The PIC of greatest interest to OB/OD activities can be placed in eight main groups: (1) residual primary explosives, (2) propellants and their contaminants; (3) inorganic gases, (4) particulates, (5) volatile and semivolatile (exotic) organics, (6) other pyrolysis/combustion products, (7) metals, and (8) anions. Target compounds for detailed analysis from each of these groups were selected by the technical steering committee in July 1988; the target analyte lists were modified slightly after preliminary results were studied.

5.2.2. A consolidated list of chemical compounds targeted for analysis (target analytes), together with a notation as to whether or not they were detected above background levels by detailed sample analysis, is shown in Tables 5.1a, b, c, d, e, and f.

Table 5.1a Target Analytes Detected Above Background Levels for TNT Detonations, Double-Base Propellant Burn, and Composite Propellant Burn in the BangBox Test.

Species	TNT	Double-Base	Composite
Carbon dioxide	X[a]	X	X
Carbon monoxide	X	X	X
Nitrogen dioxide	X	X	X
Nitric oxide	X	X	X
Sulfur dioxide	X	X	X
Ozone	-[b]	X	ND[c]
Methane	X	X	X
Acetylene	X	X	X
Benzene	X	X	X
PARAFFINS			
n-Heptane	X	X	X
2,4-Dimethylhexane			
2-Methylheptane	X	X	X
2-Methylpentane	X	X	
3-Methylpentane	X	X	
Ethylcyclohexane			
n-Hexane	X	X	X
i-Butane	X	X	
Methylcyclopentane	X	X	X
n-Butane	X		
2,4-Dimethylpentane	X		
2,2-Dimethylpropane			
Cyclohexane	X	X	
n-Pentane	X	X	
2,3-Dimethylpentane	X	X	X
Cyclopentane	X	X	X
3-Methylhexane	X		X
n-Octane	X	X	X
Ethane	X	X	X
2,3-Dimethylhexane	X		
Methylcyclohexane	X	X	X
2,3,4-Trimethylpentane	X	X	
n-Nonane	X	X	X

See Table 5.1f for notes.

Table 5.1b **Target Analytes Detected Above Background Levels for TNT Detonations, Double-Base Propellant Burn, and Composite Propellant Burn in the BangBox Test.**

Species	TNT	Double-Base	Composite
PARAFFINS (cont'd)			
2,3-Dimethylbutane	X	X	X
2,2,3-Trimethylpentane			
i-Pentane	X	X	X
Propane	X	X	X
2,3-Dimethylbutane	X		X
3-Ethylhexane	X	X	X
OLEFINS			
Ethylene	X	X	X
2-Methyl-1-pentene			
Propene	X	X	X
1-Butene	X	X	X
trans-2-Hexene			
3-Methyl-1-butene			
Mycrene			
Isoprene			
1,3-Butadiene	X	X	X
trans-2-Pentene			
cis-2-Butene		X	X
cis-2-Hexene			X
1-Pentene	X		
2-Methyl-2-butene			
1-Hexene			
4-Methyl-1-pentene			X
trans-2-Butene		X	X
i-Butene	X	X	X
2-Methyl-2-pentene			
2-Methyl-1-butene	X	X	
cis-2-Pentene			
Cyclopentene		X	X

See Table 5.1f for notes.

Table 5.1c Target Analytes Detected Above Background Levels for TNT Detonations, Double-Base Propellant Burn, and Composite Propellant Burn in the BangBox Test.

Species	TNT	Double-Base	Composite
NONBENZENE AROMATICS			
Toluene	X	X	
3-Ethyltoluene	X	X	
1,3,5-Trimethylbenzene			
n-Propylbenzene		X	
1-Ethyltoluene			
Styrene	X	X	X
i-Propylbenzene			
2-Ethyltoluene			
Ethylbenzene	X	X	X
o-Xylene	X	X	X
p-Xylene	X	X	X
m-Xylene			
1,2,4-Trimethylbenzene & sec-Butylbenzene			
TERPENES			
β-Pinene			
α-Terpinene			
d-Limonene			
α-Pinene			
Δ^3-Carene			
γ-Terpinene			
Terpinolene			
SEMIVOLATILE ORGANICS			
2,6-Dinitrotoluene	X	X	X
4-Nitrophenol	X	X	X
2,4-Dinitrotoluene	X		X
2-Nitronaphthalene	X	X	X
2,4,6-Trinitrotoluene	X	X	
1-Nitropyrene	X		X
1,6-Dinitropyrene			
Phenol	X	X	X
Dibenzofuran	X	X	X

See Table 5.1f for notes.

Table 5.1d Target Analytes Detected Above Background Levels for TNT Detonations, Double-Base Propellant Burn, and Composite Propellant Burn in the BangBox Test.

Species	TNT	Double-Base	Composite
SEMIVOLATILE ORGANICS (cont'd)			
2-Naphthalenamine			
Diphenylamine			
Benz[c]acridine			
Benz[a]anthracene	X		
Benzo[a]pyrene	X	X	
Dibenz[a,h]anthracene	X		
N-Nitrosodiphenylamine	X	X	X
Naphthalene	X		X
1-& 2-Methylnaphthalene	X	NA[a]	NA
1,3,5-Trinitrobenzene	X	NA	NA
Biphenyl	X	NA	NA
Phenanthrene	X	NA	NA
2,5-Diphenyloxazole	X	NA	NA
1,1,3-Trimethyl-3-phenylindane	X	NA	NA
Pyrene	X	NA	NA
4-Nitrosodiphenylamine	NA		NA
2-Nitrodiphenylamine	NA		NA
4-Nitrodiphenylamine	NA		NA
Nitroglycerin	NA		NA
Resorcinol	NA		NA
Di-n-propyl adipate	NA		NA
Triacetin	NA		NA
Salicylic acid	NA		NA
2,2-Methylene bis(4-methyl)-t-butylphenol	NA	NA	
Phenyl di-isodecyl phosphite	NA	NA	
5-ethyl-1,3-diglycidyl-5-methyl hydantoin diepoxide	NA	NA	
Diethylenetriamine	NA	NA	
Dioctyl sebacate	NA	NA	
Isophorone di-isocyanate	NA	NA	

See Table 5.1f for notes.

Table 5.1e Target Analytes Detected Above Background Levels for TNT Detonations, Double-Base Propellant Burn, and Composite Propellant Burn in the BangBox Test.

Species	TNT	Double-Base	Composite
METALS			
Aluminum	X		X
Silicon	X		X
Sulfur	X		X
Chlorine	X		X
Potassium	X		X
Calcium	X		X
Titanium			
Vanadium			X
Chromium	X		X
Magnesium	X		X
Iron	X		X
Nickel	X		X
Copper	X	X	X
Zinc	X		X
Gallium	X		X
Germanium	X		
Arsenic			
Selenium	X		
Bromine	X		
Uranium	X		
Strontium	X		
Lead	X	X	X
Zirconium	X		
Molybdenum	X		
Silver	X		
Cadmium	X		
Tin	X		X
Antimony	X		X
Iodine	X		
Barium	X		X

See Table 5.1f for notes.

Table 5.1f Target Analytes Detected Above Background Levels for TNT Detonations, Double-Base Propellant Burn, and Composite Propellant Burn in the BangBox Test.

Species	TNT	Double-Base	Composite
BUBBLERS			
Ammonia	X		
Hydrogen Cyanide[e]			
Hydrogen Chloride			X

BLANK SPACE - analyzed - not detected above background levels.
[a]X-detected above background levels.
[b]Ambient ozone reduced to below background levels immediately after the detonation.
[c]ND denotes no data.
[d]NA denotes not targeted for analysis for that type of trial.
[e]Analysis of bubbler samples enabled estimation of the CN- anion (as HCN).

5.3. Emission Factor Calculations

5.3.1. Parameter Values

Before EFs for each BB OB/OD product could be calculated for the concentration times volume method and the carbon balance method, several important parameter values were needed: BB volume, BB ventilation rate, total quantity of carbon in the fuel (TNT and propellants), total (combined) carbon content of the compounds generated from the detonation or burn, and the concentrations of the compounds in the samples collected.

5.3.2. BangBox Volume and Ventilation Rates

Volume of the BB for each trial was determined by analyzing data from release of known amounts of SF_6, a tracer gas whose concentration was then carefully measured. These volumes varied (from trial to trial) between 759 and 1078 m^3. The appropriate value, pertinent to the specific trial day, was used in analyzing each trial's data. Trial-specific BB ventilation rates were also determined and served as the bases for determining the "time zero" values for target analyte air concentrations; i.e., the initial postdetonation source strengths of each product. These ventilation rates were extremely well-characterized because of the high quality (accuracy and precision) of the SF_6 data collected. A typical plot of instrument voltage versus time for the CO_2 monitor (Figure 5.1) shows that

homogeneity is achieved after 3 minutes of mixing with fans (generally fans are turned on 3 to 5 minutes after detonation) and then the chamber air containing combustion products is slowly diluted (ventilation) as makeup air is brought into the chamber to keep it inflated. Typical plots of net CO_2 concentration above background levels (including 95-percent confidence limits), as measured by real-time instruments during the homogeneous period of sampling after one of the 8 February 1989 227-gram TNT detonations, are shown in Figure 5.2.

5.3.3. Concentrations of Target Analytes in Air Samples

5.3.3.1. Target analyte concentrations in the bangbox air immediately after OB or OD were determined by the variety of sensitive analytical methods listed in Table 5.2. The most unique of these methods was application of the relatively new technique of supercritical fluid chromatography (SFC) for separation of semivolatile organic compounds in extract solutions of filter- and canister-collected samples of BB air. SFC was chosen for use in the OB/OD program, because certain thermally unstable OB/OD products that are converted to other compounds *during analysis* by GC remain stable when separated by SFC. An example is N-nitrosodiphenylamine, which is specifically identifiable by SFC but converts to diphenylamine when subjected to GC. However, certain volatile compounds, such as phenol, are not easily detected by SFC when supercritical CO_2 is used; these compounds *are* easily detected by GC. Other detection methods such as HPLC, were not considered sensitive enough for the scope and detection limits needed.

5.3.3.2. The extremely sensitive methods of chemical ionization negative and positive selective ion monitoring by mass spectrometry were used for product quantification with both SFC and GC separation techniques. Semivolatile organic compound assay results by SFC/MS and GC/MS showed that *both* separation techniques are applicable and that MS detection and quantification are extremely sensitive. For example, the laboratory responsible for the SFC/MS analyses reported typical lower detection limits (signal-to-noise >3) for compounds in methylene chloride solution of 0.03 to 2.3 ng/mL, depending on the specific analyte being assayed.

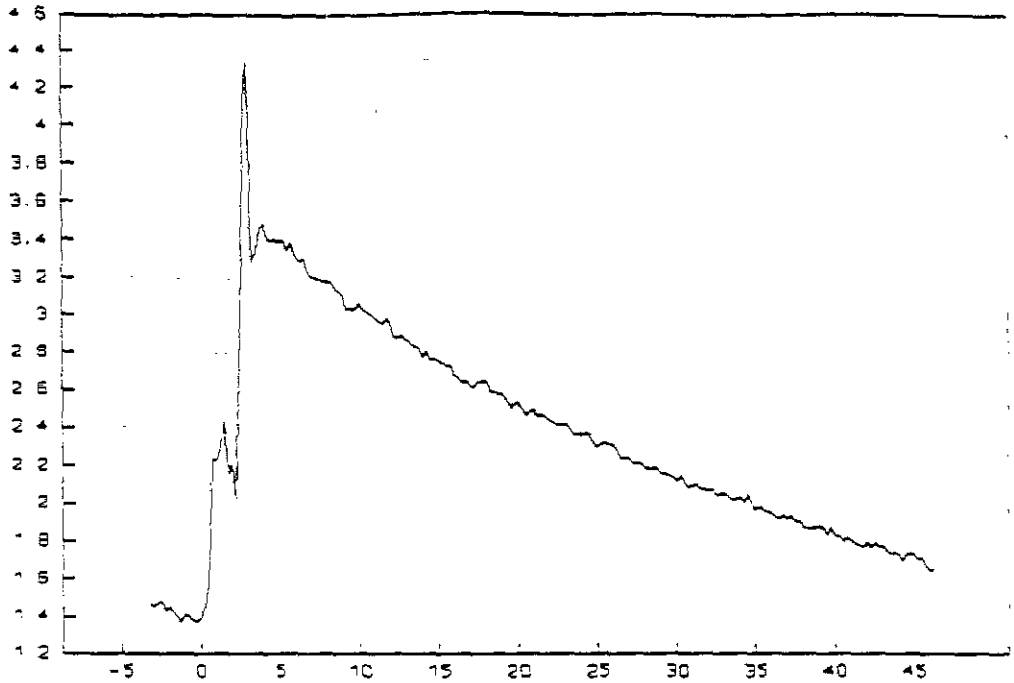


Figure 5.1 CO_2 Instrument Voltage Trace, TNT Detonation Number 2, 8 February 1989.

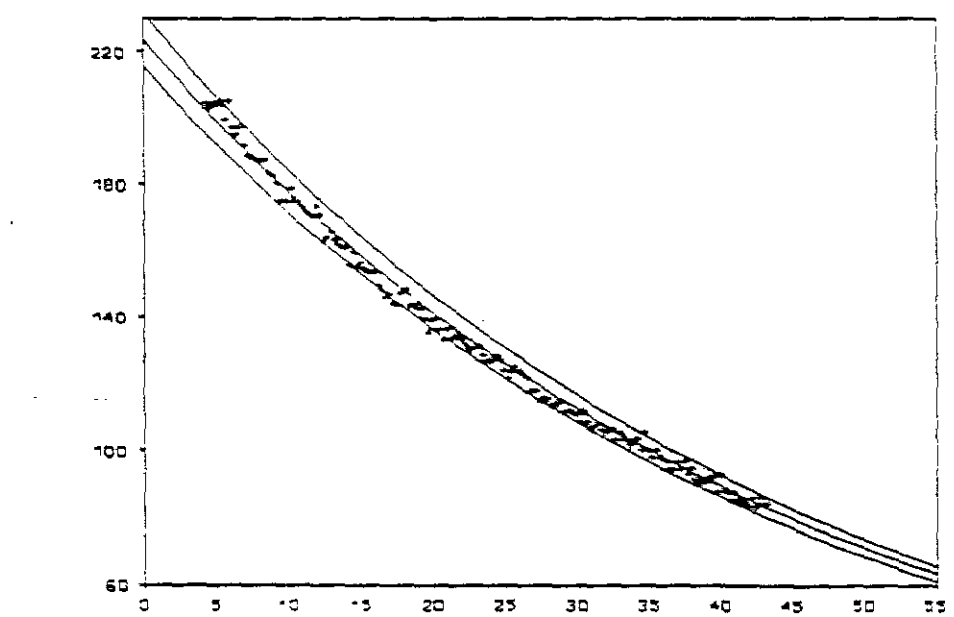


Figure 5.2 CO_2 Concentration and 95 Percent Confidence Limits During the Homogeneous Period of Direct Sampling From the BangBox TNT Detonation Number 2, 8 February 1989.

Table 5.2 Summary of OB/OD BangBox Sample Analysis Program.

TYPE	TARGET SPECIES	ASSAY METHOD	ASSAY LAB
Exotic organics	Approx 33 compounds	SFC-MS[a]	AWL[b]
Exotic organics	Approx 15 compounds	GC-MS[c]	BCD[d]
Inorganic (metals)	7	XRF[e]	LBL[f]
Total particulate carbon	Organic, elemental, and inorganic carbon	Thermooptical	SL[g]
Volatiles	THC[h], CH_4, H_2, C_2-C_{10}, C_6H_6, CO, CO_2	GC[i]	OGC[j]
Particle characterization	NA[k]	SEM[l]	SNL[m]
Near-real-time	SF_6	GC/ECD[n]	OGC
Real-time	CO, CO_2, NO_x[o], SO_2, O_3, THC	Gas and total hydrocarbon analyzers	SNL
Bubbler	HCN, HCl, NH_3	NIOSH standard methods	SNL
Particle size/mass	Particulate	DMPS[p], APS[q], ASASP[r], FSSP[s]	SNL
Dibenzodioxin compounds Dibenzofuran compounds	Specified	GC-MS	BCD

[a]Supercritical fluid chromatography-mass spectrometry.
[b]Alpine West Laboratory.
[c]Gas chromatography-mass spectrometry.
[d]Battelle Columbus Division.
[e]X-ray fluorescence.
[f]Lawrence Berkeley Laboratory.
[g]Sunset Laboratory.
[h]Total hydrocarbons.
[i]Gas chromatography.
[j]Oregon Graduate Center.
[k]Not applicable.
[l]Scanning electron microscopy.
[m]Sandia National Laboratories.
[n]Electron capture detector.
[o]Nitrogen oxides.
[p]Differential mobility particle sizer.
[q]Aerodynamic particle sizer.
[r]Active scattering aerosol spectrometer probe.
[s]Forward scattering spectrometer probe.

5.3.4. Audit samples

Audit samples in the form of spiked canisters were provided by the EPA, RTP NC. These samples were successfully analyzed (as ascertained by EPA auditors) by laboratories involved in both volatile and semivolatile organic compound analyses (AWL, BCD, and OGC).

5.4. Carbon Mass Balance.

5.4.1. Analysis

Analysis of the aerosol and particulate samples taken during a given trial provided an estimate of carbon mass released, based on the combined carbon mass contained in generated CO_2 and CO, the organic particulate/semivolatile carbon, volatile organic compound (C_1-C_{10} hydrocarbons), elemental carbon (soot), HCN, and inorganic carbon (as carbonate). The carbon from CO_2 was estimated from the real-time continuous monitor, with extrapolation of the fitted exponential curve (fit to the data from the homogeneous period of sampling) to detonation time zero ($t = 0$). As noted earlier, the carbon from CO and volatile C_1-C_{10} hydrocarbons was estimated from the results of 6-L canister sampling, with extrapolation of the fitted exponential curve to detonation time zero. Total particulate organic carbon, elemental carbon (soot), and inorganic carbonate were estimated from thermal analysis of 1-cm^2 samples taken from quartz-fiber filters. This latter analysis incorporates a two-step volatilization and combustion process that permits estimation of the contributions by each of these carbon sources.

5.4.2. Carbon Mass

Table 5.3 shows the carbon mass derived from each source during 11 TNT detonations, as well as ratios of total carbon detected to that predicted as available from the TNT fuel (37.01 percent). The carbon mass determined by the analysis of sampled aerosol and particulate carbon sources overaccounts for the (theoretical) mass of carbon available in bulk TNT by about 9 percent. Results showed that the total carbon amounts contributed by volatile organics (C_1-C_{10}), HCN, and inorganic carbonate are negligible (<0.01 percent), while CO_2 contributes the vast majority of carbon measured (97.2 percent). Minor amounts of CO (0.50 percent) carbon, carbon from semivolatile

principally to CO_2 upon detonation in ambient air. Table 5.3 also shows the carbon mass derived from the foam-attenuated TNT detonation, the double-base propellant burn and the composite propellant burn. The overestimate of the carbon mass (0.29) in the composite propellant burn could easily be the result of uncertainty in the carbon content of the composite propellant. Three composite propellant samples assayed for elemental carbon gave percentages of carbon ranging from 12.67 to 21.26.

5.4.2.1. These results are in sharp contrast to those predicted by certain theoretical models or determined during experiments involving limited available oxygen from surrounding air. The results

Table 5.3 Measured Carbon Mass Derived From Each Source Resulting From TNT Detonation or Propellant Burn.

DATE	SOURCE	CARBON MASS MEASURED (g)				Total Carbon (g)		
		CO_2	CO	OC[a]	EC[b]	MEASURED[c]	THEORETICAL	RATIO[d]
31 JAN 89	TNT	94.96	0.6688	0.4161	1.0331	97.08	82.90	1.17
2 FEB 89		82.18	0.4093	0.6495	1.5160	84.75	82.31	1.03
6 FEB 89		82.92	0.3384	0.4685	2.0492	85.78	83.22	1.03
8 FEB 89-2[e]		90.34	0.4578	0.5150	1.5426	92.86	82.99	1.12
8 FEB 89-3		90.26	0.4578	0.5150	1.5426	92.77	83.25	1.11
8 FEB 89-4		87.43	0.4578	0.5150	1.5426	89.95	82.62	1.09
8 FEB 89-5		87.15	0.4578	0.5150	1.5426	89.66	82.71	1.08
8 FEB 89-6		87.92	0.4578	0.5150	1.5426	90.43	82.42	1.10
8 FEB 89-7		86.74	0.4578	0.5150	1.5426	89.26	82.47	1.08
8 FEB 89-8		85.86	0.4578	0.5150	1.5426	88.37	81.87	1.08
15 FEB 89		83.78	0.3813	0.4751	1.4229	86.06	81.88	1.05
							Average	1.09
							Std. Dev.	0.04
13 FEB 89	TNT w/foam	24.13	2.7154	NS[f]	NS	26.85	82.00	0.33
9 FEB 89	Double base	131.66	0.1950	0.2725	0.0000	132.13	125.17	1.06
16 FEB 89	Composite	66.05	0.0706	0.0000	0.0065	66.12	51.16	1.29

[a]OC-Organic carbon: includes carbon from semivolatile organics.
[b]EC-Elemental carbon.
[c]Carbon in HCN, volatile HC(C_1-C_{10}) and inorganic carbonate account for less than 0.01 percent, when combined.
[d]Ratio of total carbon mass measured to carbon mass in fuel.
[e]Number following date is detonation number of multidetonation trial.
[f]NS - not sampled.

5.4.2.1. These results are in sharp contrast to those predicted by certain theoretical models or determined during experiments involving limited available oxygen from surrounding air. The results of the BB TNT detonation tests are included, with some of these literature values, in Table 5.4. Clearly, OD of even the most oxygen-deficient of the common military explosives, TNT, yields a much higher fraction of CO_2 and lower fractions of CO and other carbonaceous products than models or earlier small-scale laboratory experiments have predicted (most of these assume oxidant is available only from the molecule and not from ambient air entrainment).

Table 5.4 Comparison of Carbon-Containing TNT Detonation Product Levels as Predicted by Literature and Determined by Experiment (kg/ton).

SPECIES	OB/OD[a]	COOK[b]	HAID/SCHMIDT[c]	ORNELLAS[d]	ORNELLAS[e]
Carbon dioxide	1.20 x 10^{2}	399.00	220.00	220.00	11.2
Carbon monoxide	4.07	25.40	239.00	221.00	658.00
Hydrogen cyanide	0.00	27.00	7.85	2.21	2.70
Carbon (soot)	5.77	154.70	159.00	175.40	47.9
Methane	2.45 x 10^{-1}	43.6	6.11	6.40	0.58
Ethane	-[f]			0.55	
Nonmethane HC	5.72 x 10^{-2}				
Semivolatile OC[g]	1.93				

[a]Present BB TNT OB work (density ≈ 1.4 g/cm^3). Values are estimates derived from mean emission factor data.
[b]Computed data for TNT (density = 1.59 g/cm^3).
[c]Experimental data from TNT detonation (density = 1.59 g/cm^3) from Haid and Schmidt (1931).
[d]Experimental data from confined TNT (density = 1.54 g/cm^3) under vacuum from Ornellas (1982).
[e]Experimental data from unconfined TNT (density = 1.54 g/cm^3) under vacuum from Ornellas (1982).
[f]C_2H_6 included in NMHC value of 5.72 x 10^{-2} kg/ton.
[g]Organic carbon from thermooptical analysis of aerosol/particulate collected on quartz-fiber filters.

5.5. Carbon-Balance Method

5.5.1. Calculating EF's

The carbon balance method of calculating EFs depends on two assumptions: (1) the mass of carbon available in the TNT can be accounted for in the masses of the various carbon-containing product species, and (2) the proportional distribution among carbon-containing products within individual microregions of the cloud remains relatively constant, even though the actual values for individual concentrations may be considerably different within different macroregions of the cloud.

5.5.1.1. Based on these two assumptions, the total volume of the cloud becomes irrelevant in making EF calculations, and the EF of any individual product i can be estimated by the equation:

Equation 5.1 Carbon Balance Emission Factor Determination.

$$EF_i = (f_c)\,\frac{[D_{ij}]}{[C_j]}$$

where, f_c = mass fraction of carbon in the fuel (0.3701 for TNT),
$[D_{ij}]$ = average concentration of product i over any specific volume element j of the cloud, and
$[C_j]$ = concentration of all forms of carbon in the sample taken from volume element j.

5.5.1.2. For example, the maximum EF value calculated for 2,4-dinitrotoluene from analyses of 11 OD samples was 1.05×10^{-6} weight units (e.g., kg) of product per weight unit (e.g., kg) of TNT detonated. (Values used were $f_c = 0.3701$, $[D_{ij}] = 2.2 \times 10^{-4}$ mg/m^3, and $[C_j] = 77.9$ mg/m^3.)

5.5.2. Value in Field Testing

The carbon balance method has great potential for calculating OB/OD combustion product EFs in large-scale field tests, because total volumes of clouds and total concentrations of products over that whole "volume" do not need to be known; only "grab samples" need to be taken within the cloud by aircraft sampling, and CO_2 and target analyte levels above background need to be clearly measured.

5.6. Concentration Times Cloud Volume (C • V) Method.

5.6.1. Calculating EF's

The more traditional method of calculating an EF for product *i* is the C • V method.

Equation 5.2 Cloud Volume Emission Factor Determination

$$EF_i = \frac{[D_i]V}{M}$$

where: $[D_i]$ = average concentration of product *i* over the entire cloud immediately after detonation,
V = volume of the entire cloud, and
M = mass of TNT (or propellant) consumed.

5.6.2. Use of C • V

The use of this method is extremely difficult in the field environment because concentrations of products are not homogeneous over the entire cloud; therefore, many points in the diffusing cloud must somehow be sampled in order to obtain a true average product concentration. Also, it is difficult to accurately measure the actual volume of the diffusing, nonsymmetrical, ill-defined cloud at the precise time at which concentration samples are collected. These difficulties can be readily overcome in a chamber environment in which air concentrations and chamber volumes can be accurately determined as functions of sampling time. Thus, although difficult to apply in the field, this method was successfully used in calculating EFs from BB data. For example, the maximum EF calculated for 2,4-dinitrotoluene by this method was 0.819×10^{-6} weight units (e.g. kg) of the product produced per weight unit (e.g. 1 kg) of TNT detonated. (Values used were $[D_i] = 2.2 \times 10^{-4}$ mg/m^3, V = 833.8 m^3, and M = 0.224 kg or 224 g.)

5.6.2.1. Thus, the calculated carbon balance method EF (1.05×10^{-6}) for this compound compares extremely well with the C • V method EF of 0.819×10^{-6}.

5.6.2.2. As noted earlier, conducting these tests in an enclosed chamber environment allowed comparison of a proposed method of calculating these EFs (the carbon balance method) with the more traditional method involving multiplication of air emission concentration by the cloud volume (the C • V method). Results showed clearly that the proposed-carbon balance method, which is not dependent on cloud volume and therefore can be applied to cases in which the cloud volume is extremely difficult to estimate (such as after outdoor OD), gave EFs which were not statistically different from those obtained by the C • V method. This is certainly true when the cloud is homogeneous and its volume is accurately known (as in the BB). Even when the emission concentrations are nonhomogeneous (a condition which exists in outdoor OB/OD operations) in the chamber EFs from the carbon balance method were not different from the EFs obtained during the homogeneous period of sampling. The C • V method did not provide a good estimate of EFs when the emission concentrations are nonhomogeneous in the chamber. As a result, it was concluded that the carbon-balance method should be further evaluated in large-scale outdoor OB/OD operations. This assessment will determine the degree to which the principal carbon-containing species (CO_2) are above ambient background levels when the OB/OD clouds are sampled by FWAC, and the degree to which dilute, measurable concentrations of the volatile and semivolatile combustion products can be detected by analysis of FWAC samplers mounted on FWAC. If above-background CO_2 concentrations and detectable emission concentrations can be measured by analysis of FWAC-mounted samplers, then EFs can be calculated more accurately than by using methods requiring careful cloud volume estimations.

5.7. Emission Factors.

5.7.1. Calculations

After sample analysis concentrations, BB volumes, BB ventilation rates, fuel carbon contents, and total product carbon contents became known, EFs for each combustion product were calculated. These EFs are expressed as weight (e.g., kg) of each combustion product produced per unit weight (e.g., 1 kg) of explosive or propellent consumed. The maximum EFs detected are summarized in Tables 5.5a through 5.5d.

5.7.2. Carbon Dioxide

Tables 5.3 and 5.4 indicate that CO_2 was by far the dominant product in both TNT detonations and double-base and composite propellant burns.

5.7.3. Carbon Monoxide and Other Organic Compounds

The proportion of carbon monoxide, volatile organic hydrocarbons (C_1-C_{10}), total organic carbon, and elemental carbon decreases when the two types of propellants are burned. Emission factors for the exotic semivolatile organics rarely reached levels of 10^{-4} kg of emissions per kilogram of fuel; most are generated in quantities approximating 10^{-6} to 10^{-9} kg per kg of fuel. For this latter range of values, initial source strengths of emitted compounds would be in the range of 0.05 to 50 grams (10^{-3} to 10^{-6} lb) for a 907-kg (2000-lb) OB/OD operation. These source strengths, once dispersed by atmospheric meteorological conditions, even at short downwind distances, are not expected to create measurable quantities of the analytes at downwind receptor populations/locations.

5.7.4. Metals and Nonmetals

After TNT detonations or propellant burns, metals and nonmetals were rarely detected in concentrations high enough for EFs to exceed 10^{-4}, except in cases where the element was traceable directly to the fuel mixture (Al, Cu), igniter, chamber pan, or floor material, or previous, unrelated SNL test activities conducted in the BB.

Table 5.5a Maximum Emission Factors (kg/kg) and ppmw for Species Found for TNT Detonations, Double-Base, and Composite Propellant Burns.

Species	TNT Detonation		Double-Base Burn		Composite Burn	
	EF (kg/kg)	ppmw	EF	ppmw	EF	ppmw
Carbon dioxide	1.33	$1.33 \times 10^{+6}$	9.7×10^{-1}	$9.7 \times 10^{+5}$	4.18×10^{-1}	4.18
Carbon monoxide	7.17×10^{-3}	7170	9.54×10^{-4}	954	4.28×10^{-4}	4.28
Nitrogen dioxide	2.60×10^{-3}	2600	2.81×10^{-3}	2810	1.57×10^{-3}	1570
Nitric oxide	1.46×10^{-2}	14600	2.47×10^{-2}	24700	5.37×10^{-3}	5370
Sulfur dioxide	2.23×10^{-4}	223	3.60×10^{-4}	360	1.44×10^{-4}	144
Ozone[a]						
Methane	1.31×10^{-4}	131	7.26×10^{-5}	72.6	7.99×10^{-5}	79.9
Acetylene	1.82×10^{-5}	18.2	2.18×10^{-5}	21.8	5.27×10^{-5}	52.7
Benzene	8.67×10^{-6}	8.67	1.27×10^{-5}	12.7	3.02×10^{-5}	30.2
Paraffins[b]	1.45×10^{-4}	145	6.98×10^{-5}	69.8	6.95×10^{-5}	69.5
Olefins[b]	3.03×10^{-5}	30.3	7.94×10^{-5}	79.4	$3.93 \times 10_{5}$	39.3
Non-benzene aromatic	2.99×10^{-5}	29.9	9.8×10^{-5}	98.5	1.98×10^{-5}	19.8
SEMIVOLATILE ORGANICS						
2,6-Dinitrotoluene	4.39×10^{-7}	0.439	1.43×10^{-8}	0.0143	3.72×10^{-9}	0.00372
4-Nitrophenol	2.59×10^{-6}	2.59	6.87×10^{-7}	0.687	4.08×10^{-7}	0.408
2,4-Dinitrotoluene	1.05×10^{-6}	1.05	$< 1.75 \times 10^{-10}$	<0.000175	1.04×10^{-8}	0.0104
2-Nitronaphthalene	6.43×10^{-7}	0.643	5.43×10^{-9}	0.0543	2.03×10^{-8}	0.0203
2,4,6-Trinitrotoluene	3.38×10^{-6}	3.38	5.01×10^{-8}	0.0501	$< 1.37 \times 10^{-9}$	<0.00137
1-Nitropyrene	1.06×10^{-6}	1.06	$< 1.66 \times 10^{-8}$	<0.0166	$1.98 \times 10_{8}$	0.0198
1,6-Dinitropyrene	ND[c]	ND	ND	ND	ND	ND
Phenol	2.52×10^{-5}	25.2	4.39×10^{-6}	4.39	3.78×10^{-6}	3.78
Dibenzofuran	1.32	1.32	2.25×10^{-7}	0.225	2.79×10^{-7}	0.279

See Table 5.5d for notes

Table 5.5b Maximum Emission Factors (kg/kg) and ppmw for Species Found for TNT Detonation, Double-Base, and Composite Propellant Burns.

Species	TNT Detonation		Double-Base Burn		Composite Burn	
	EF (kg/kg)	ppmw	EF	ppmw	EF	ppmw
SEMIVOLATILE ORGANICS (cont'd)						
2-Naphthylamine	ND	ND	ND	ND	ND	ND
Diphenylamine	ND	ND	ND	ND	ND	ND
Benz[c]acridine	ND	ND	ND	ND	ND	ND
Benz[a]anthracene	$< 3.30 \times 10^{-8}$	<0.033	$< 1.83 \times 10^{-9}$	<0.00183	$< 1.66 \times 10^{-8}$	<0.0166
Benzo[a]pyrene	3.01×10^{-8}	3.01	8.96×10^{-7}	0.896	5.23×10^{-8}	<0.0523
Dibenz[a,h]anthracene	1.73×10^{-8}	1.73	ND	ND	ND	ND
N-Nitrosodiphenylamine	1.23×10^{-8}	1.23	1.45×10^{-6}	1.45	3.45×10^{-9}	0.0345
Naphthalene	1.50×10^{-6}	150	$< 1.55 \times 10^{-9}$	<0.00155	1.44×10^{-8}	1.44
1-& 2-Methylnaphthalene	3.00×10^{-5}	30				
1,3,5-Trinitrobenzene	2.75×10^{-9}	0.00275				
Biphenyl	$< 5.20 \times 10^{-8}$	<0.052				
Phenanthrene	1.85×10^{-7}	0.185				
2,5-Diphenyloxazole	7.23×10	72.3				
1,1,3-Trimethyl-3-phenylindane	5.70×10^{-7}	0.57				
Pyrene	2.02×10^{-7}	0.202				
4-Nitrosodiphenylamine	---[4]		ND	ND		
2-Nitrodiphenylamine			ND	ND		
4-Nitrodiphenylamine			ND	ND		
Nitroglycerin			ND	ND		
Resorcinol			ND	ND		
Di-n-propyl adipate			ND	ND		

See Table 5.5d for notes

Table 5.5c Maximum Emission Factors (kg/kg) and ppmw Found for TNT Detonation, Double-Base, and Composite Propellant Burns.

Species	TNT Detonation		Double-Base Burn		Composite Burn	
	EF (kg/kg)	ppmw	EF	ppmw	EF	ppmw
SEMIVOLATILE ORGANICS (cont'd)						
Triacetin			ND	ND		
Salicylic acid			ND	ND		
2,2-Methylene bis(4-methyl)-6-t-butylphenol					ND	ND
Phenyl di-isodecyl phosphite					ND	ND
5-ethyl-1,3-diglycidyl-5-methyl hydantoin diepoxide					ND	ND
Diethylenetriamine					ND	ND
Dioctyl sebacate					ND	ND
Isophorone di-isocyanate					ND	ND
METALS						
Aluminium					1.33×10^{-4}	133
Chromium	3.52×10^{-6}	3.52	BD	BD	4.77×10^{-6}	4.77
Iron					6.04×10^{-4}	604
Nickel	2.54×10^{-6}	2.54	BD	BD	1.59×10^{-6}	1.59
Copper			3.71×10^{-3}	3710		
Arsenic	BD	BD	BD	BD	BD	BD
Lead	1.97×10^{-5}	19.7	1.27×10^{-2}	12700	9.39×10^{-5}	93.9
Cadmium	2.86×10^{-6}	2.86	BD	BD	BD	BD
Antimony	1.06×10^{-6}	1.06	BD	BD	4.77×10^{-6}	4.77
Barium	9.31×10^{-4}	931	BD	BD	1.59×10^{-7}	159

See Table 5.5d for notes

Table 5.5d Maximum Emission Factors (kg/kg) and ppmw for Species Found for TNT Detonation, Double-Base, and Composite Propellant Burns.

Species	TNT Detonation		Double-Base Burn		Composite Burn	
	EF (kg/kg)	ppmw	EF	ppmw	EF	ppmw
BUBBLERS						
Ammonia	2.92×10^{-4}	292	BD	BD	BD	BD
Hydrogen cyanide	BD	BD	BD	BD	BD	BD
Hydrogen chloride					9.43×10^{-2}	94300

[a]Ambient ozone was reduced to near zero at detonation by reacting with the detonation products.

[b]For a full listing of compounds included within these groupings as analyzed by Oregon Graduate Center, refer to Table 3.4.4, this report.

[c]ND - detection limit was not determined.

[d]Blank Cell - not a target analyte during the cited detonation or burn.

[e]BD - target analyte not found in concentrations above detection limits. Detection limits (approximately 0.5 $\mu g/m^3$ for the elements corresponds to an EF of 2×10^{-6} for TNT and 1×10^{-6} for double-base and composite propellant). Detection limits (approximately 10 $\mu g/m^3$) for ammonia and hydrogen cyanide corresponds to an EF of 4×10^{-5} for TNT and 2×10^{-5} for double-base and composite propellant.

5.7.5. HCN, NH_3, and HCl

HCN was never detected during analysis of bubblers. NH_3 concentrations were detected slightly above background levels in only two TNT OD samples. These detections were also characterized by abnormally low values in the applicable background samples and are therefore speculative. As expected, HCl was measured in significant concentrations during air sampling from the composite fuel burn, however because of significant problems encountered with the HCL bubbler during sampling the data is considered unreliable.

5.7.6. Dioxins/Furans

A team from BCD specializing in sampling for polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF) sampled the chamber air following the burn of the composite propellant (the only propellant, explosive, and pyrotechnic (PEP) material containing chlorine tested in the BB), (Volume 2, Appendix B). The tetrachloro derivatives, particularly the symmetrically substituted 2,3,7,8-tetrachlorodibenzofuran and 2,3,7,8-tetrachlorodibenzodioxin isomers are of particular concern as toxicants. None of the most toxic 2,3,7,8-tetrachlorodibenzodioxin was detected and only one of two samples showed a barely marginal value for the less toxic 2,3,7,8-tetrachlorodibenzofuran showing that even its presence is problematical. Small amounts of some of the other, much less toxic, chlorinated derivatives were detected. The hepta-, and octa-CDD were detected in concentrations of 2.6 pg/m^3 and 15 pg/m^3 respectively. These concentrations result in EFs of 5.3×10^{-12}, and 30×10^{-12}. Using these EFs a similar mix of 10 metric tons of an AP composite propellant, when burned, would yield 53 μg of hepta-CDD, and 300 μg of octa-CDD.

5.7.7. Foam-Attenuated TNT Test

As might be expected, the foam-attenuated TNT detonation conducted 13 February 1989 produced generally lower concentrations of CO_2 and greater concentrations of CO, NO_2, NO, and volatile organics than did the various non-attenuated TNT detonations. The main effects of the foam were mitigation of the blast and noise, reduction of the total carbon mass recovery accounted for as CO_2, and the spreading of viscous, sulfonate-glycol/ether-xanthan polymer residue widely about the chamber floor.

SECTION 6. SAMPLE DISPERSION MODEL CALCULATION

6.1. The Volume Source Diffusion Model

The volume source diffusion model (VSDM) was used by the DPG Meteorology Division to estimate concentrations of emissions downwind from the detonation site. The dispersion model was applied to nominal source strengths of the combustion products as calculated from the maximum EF's determined from BB testing. Typical meteorological input parameters were chosen, based on conditions that provide a clearing index of at least 500 (a State of Utah test conduct requirement at DPG). The cloud height at stabilization for 907-kg (2000-lb) TNT detonations was calculated from the instantaneous cloud rise equations developed by National Aeronautic and Space Administration (NASA). The stabilization height is the calculated point relative to detonation at which the energy input from the detonation has been expended and the cloud growth and movement are thereafter only influenced by the ambient environment meteorological conditions.

6.2. Sample Calculations

The following sample calculations use the maximum EF for 2,4-dinitrotoluene, a TNT OD combustion product of interest. The maximum EF calculated for this compound, based on BB results, was 1.05×10^{-6}. Multiplying the EF by the weight of TNT to be detonated yields the maximum total source strength of that compound. Thus, the amount of 2,4-dinitrotoluene resulting from a 907-kg (2000-lb) TNT detonation would be approximately 1 gram (1×10^{-3} kg). Figure 6.1 shows that the maximum momentary peak ground-level 2,4-dinitrotoluene concentration (1.1×10^{-5} $\mu g/m^3$) would be detected approximately 2.5 km downwind from the detonation site and should not have persisted for more than a few minutes. The maximum ambient air concentration limits for 2,4-dinitrotoluene exposure to the general population have been set by several states. One of the most restrictive is presently 15 $\mu g/m^3$, set by North Dakota for an 8-hour exposure. Thus, for the 2,4-dinitrotoluene expected from a 907-kg (2000-lb) TNT open detonation, there would be essentially no risk to the receptor site/general population since the peak concentration at ground level (at approximately 2.5 km downwind) would be 14,000 times less than the North Dakota ambient air standard.

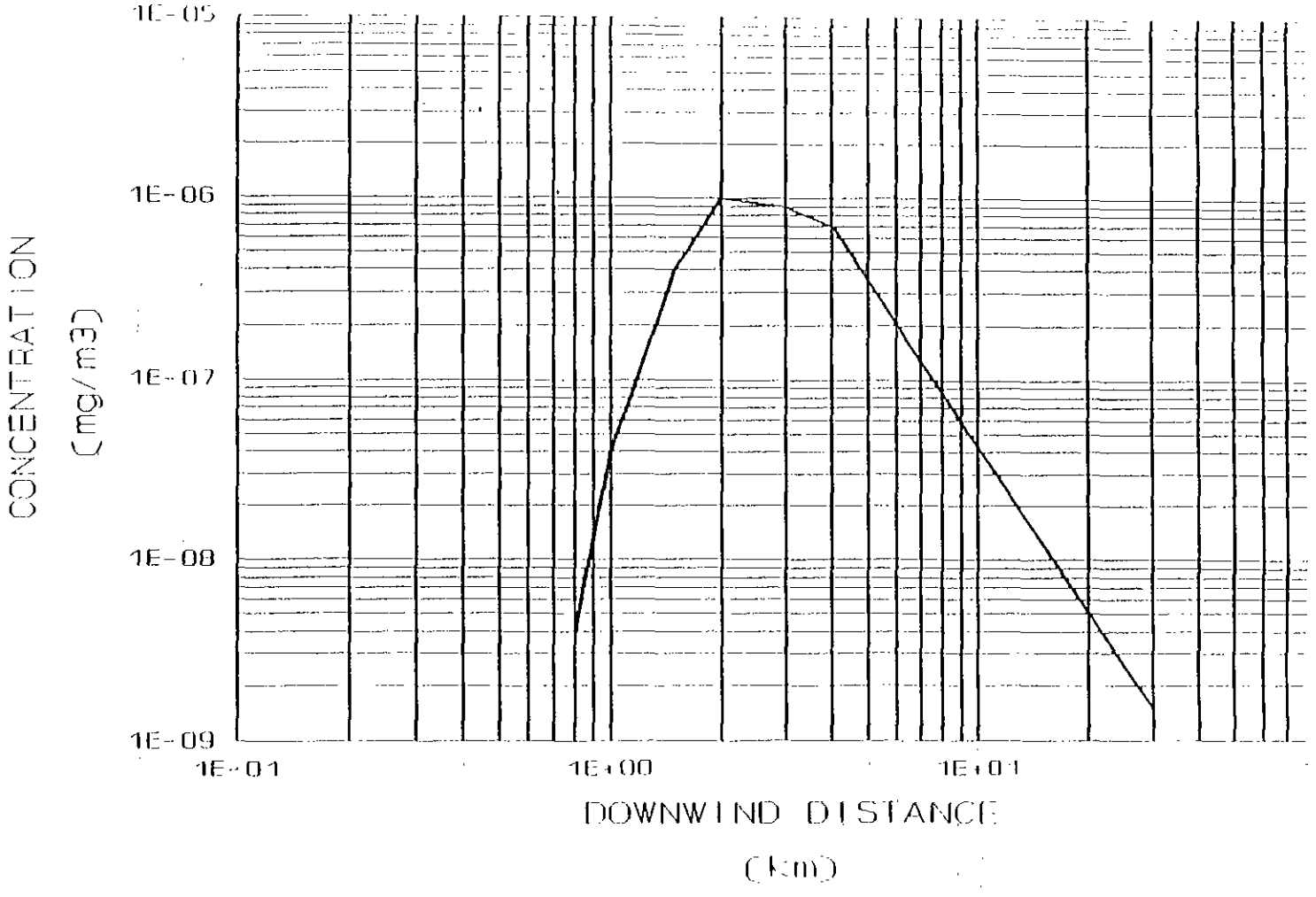


Figure 6.1 *Calculated Profile of Peak Concentration at Ground Level Versus Downwind Distance for* 2,4-DNT

6.2.1. Calculation Method

6.2.1.1. Criterion/Restriction: 15 $\mu g/m^3$ ambient air concentration limit for an 8-h time period for the general population, North Dakota.

6.2.1.2. Maximum EF for 2,4-dinitrotoluene: 1.05×10^{-6} kg/kg for TNT detonation.

6.2.1.3. Maximum peak 2,4-dinitrotoluene concentration calculated from application of the VSDM for a 1×10^{-3} kg source: approximately 1.1×10^{-6} mg/m^3 (1.1×10^{-3} $\mu g/m^3$).

Equation 6.1 Equation Used To Calculate Safety Factor for 2,4-DNT.

$$\frac{15\ \mu g/m^3\ (\textit{general population concentration limit, ND})}{1.1\ x\ \mu g/m^3\ (\textit{momentary peak concentration max at ground level 2.5 km det.})} = 1.4x10^4\ (\textit{about 14,000 x less than allowable ND standards})$$

6.3. Risk Assessments

No attempt has been made in this report to prepare detailed, formal risk assessments based on the source strengths of each projected product derived from the BB data. However, there appears to be sufficient data here to support such analyses by applying concepts similar to those outlined in the November 1988 EPA Report, Risk Assessment Guidelines and Information Directory, the October 1989 EPA Draft Final Report, Background Information Document for the Development of Regulations for PIC Emissions from Hazardous Waste Incinerators, and other similar documents pertinent to implementation of ambient air quality standards.

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SECTION 7. CONCLUSIONS

7.1. Conclusions (Addressed by Study Objectives)

7.1.1. Objective 1 - BangBox Characterization: Characterize the BB chamber volume, ventilation rate, and combustion product cloud homogeneity level.

The chamber volume, ventilation rate, and cloud homogeneity were successfully determined, and found satisfactory for subsequent use throughout the data evaluation/analysis processes.

7.1.2. Objective 2 - Sampling and Analyses: Develop and improve proposed air sampling equipment and sample analysis procedures to be used in later phases on the FWAC, for sampling product clouds from large-scale follow-on outdoor OB/OD trials.

7.1.2.1. Samplers and detectors used in the BB tests that were felt to have performed well enough to be used for FWAC sampling of open-air clouds of OB/OD products included 0.85-L evacuated canisters; 6-L evacuated canisters; 32-L evacuated tanks; CO_2, CO, SO_2, and NO_x real-time gas monitors; quartz-fiber particulate filters; Teflon™ particulate filters; the Belfort integrating nephelometer; the RAM nephelometer; and DMPS, ASASP, and FSSP aerosol spectrometers.

7.1.2.2. Samplers used in BB tests that were felt to have performed marginally included the resin filters (both Porapak-R™ and XAD-2™) which were an integral part of the semi-VOST system and the Velostat™ bag. The resin filters greatly constricted airflow, thus limiting their suitability for FWAC grab sampling. The bag proved inadequate for some volatile and semivolatile organic compounds, because of absorption and subsequent off-gassing.

7.1.2.3. The CO real time instrument did not perform properly. The CO data was obtained from the 6-L canister analysis.

7.1.3. Objective 3 - Comparison of SFC/MS and GC/MS: Refine, standardize, and compare SFC and GC techniques for extracting and analyzing resins, and filters, for trace quantities of semivolatile organic OB/OD combustion products and residues, using MS detectors.

Both SFC/MS and GC/MS are sufficiently sensitive analysis techniques to detect and quantify semivolatile organic (exotic) target analytes collected from chamber air by quartz-fiber filters, resin-filled canisters, and evacuated stainless steel cylinders. SFC is superior for some of the less thermally stable exotic species of interest, e.g. N-nitrosoamines, and some of the nitro compounds.

7.1.4. Objective 4 - Other Standard Analytical Methods: Verify adequacy of other standard analytical methods to be used for analyses of gases, particulates, volatile organic compounds, metals, and nonmetals.

7.1.4.1. The Velostat™ bag sampler proved inadequate for some volatile and semivolatile organic compounds because of absorption and subsequent off-gassing problems.

7.1.4.2. The liquid impingers (bubblers) used for measuring HCN, NH_3, and HCL in the cloud were adequate for the BB.

7.1.4.3. The extraction and analytical procedures (GC/FID) used for analysis of the volatile organics (VOC's) and the SF_6 (GC/ECD) proved to be highly successful.

7.1.4.4. Elemental analysis proved successful using XRF techniques.

7.1.5. Objective 5 - Identify and Quantify Specific Target Analytes: Identify and quantify specific target analytes for TNT, a double-base propellant, and a composite propellant.

7.1.5.1. TNT Detonation

7.1.5.1.1 The maximum EF values calculated from TNT detonation data are given in Table 7.1.

Table 7.1 Maximum Emission Factors From TNT Detonation by the Carbon Balance Method.

Species	Emission Factor (kg/kg)
Methane	1.3×10^{-4}
Acetylene	1.8×10^{-3}
Benzene	8.7×10^{-4}
Selected C_2-C_{10} non-methane paraffins	1.5×10^{-4}
Selected C_2-C_{10} olefins	3.0×10^{-3}
Selected non-benzene aromatics	3.0×10^{-3}
Phenol	2.5×10^{-3}
Naphthalene	1.5×10^{-4}
Other individual semivolatile (target analyte exotic) aromatics varied from	3×10^{-9} to 7×10^{-5}

7.1.5.1.2 Open detonation is an extremely efficient TNT thermal treatment method. Carbon-containing species measured from 227-gram (0.5-lb) TNT detonations were generally distributed as shown in Table 7.2.

Table 7.2 Distribution from Carbon-containing Species Measured From TNT.

Species	Percent
Carbon Dioxide	97.20
Carbon Monoxide	0.50
C_1 to C_{10} volatile hydrocarbons and other organics	0.57
Elemental carbon (soot)	1.71

7.1.5.2. Propellant Burn

7.1.5.2.1 Propellant burn maximum EFs were generally one to two orders of magnitude lower than those for the corresponding TNT detonation product.

7.1.5.2.2 Based on propellant carbon conversion to CO_2, open burning of double-base and composite propellants is an extremely efficient thermal treatment method. However, further work is needed to determine the fate of chlorine in the combustion products. Carbon-containing species measured from burning these fuels are distributed as shown in Table 7.3.

Table 7.3 Carbon-containing Species Measured from Propellant Burns.

Species	Percent	
	Double-Base	Composite
Carbon Dioxide	99.64	99.88
Carbon Monoxide	0.15	0.11
Organic Carbon	0.21	0.00
Elemental carbon (soot)	0.00	0.01

7.1.6. Objective 6 - PCDD's and PCDF's: Assess polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) levels generated from burning the composite propellant containing high concentration of NH_4ClO_4.

None of the most toxic PCDDs were detected, and only one of two samples had a marginal value for the less toxic PCDFs indicating that their source was not derived from the composite propellant.

7.1.7. Objective 7 - Morphology, Composition and Size Distribution of Particulate: Provide information on the morphology, composition, and size distributions of airborne particulate material generated by OB/OD operations in the BB.

Particulate morphology and composition was accomplished by SEM and optical microscopy. The results showed that over 90 percent of the particulate was soot (carbon) with small amounts of calcium carbonate and non-asbestos insulating material.

7.1.8. Objective 8 - Carbon Balance Method: Examine, using data produced under controlled conditions, the validity of the proposed carbon balance method of calculating emission factors; compare the results with those calculated using the more-conventional cloud volume times concentration method.

7.1.8.1. The proposed carbon balance method of calculating emission factors of products of combustion resulting from OD of TNT and double-base and composite propellant burns has been verified under conditions which permit a careful comparison with the cloud-volume method.

7.1.8.2. EFs calculated by the carbon balance-method agreed within experimental uncertainty with those calculated by the more traditional concentration times cloud volume method. During periods of nonhomogenity of cloud concentration the carbon balance-method provided better estimates of the EF.

7.1.8.3. Sufficient CO_2 concentrations (above background ambient levels) must be measurable to be able to apply the carbon balance method of calculating EFs during followon, large-scale outdoor OB/OD tests.

7.1.9. Objective 9 - QA/QC Procedures: Identify or develop appropriate program-specific QA/QC procedures.

A QA/QC program was developed specifically to address BB testing and subsequent analyses. This program, along with its findings and conclusions, is delineated in Volume 3 of this report.

7.1.10. Objective 10 - Sample Storage/Transport Procedures: Establish procedures for transport and storage of sample specimens.

Procedures were established to ensure that, during transportation and storage, semivolatile compounds would be retained by their respective sampling media, and that sample identity and integrity would be maintained. These procedures are described in Volume 3 of this report.

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SECTION 8. RECOMMENDATIONS

8.1. Particulate Counting and Sizing Measurements and Data Handling Procedures

Further review particulate counting and sizing measurements and data handling procedures for adequacy before conducting full-scale, field OB/OD operations.

8.2. Bag Sampling for the FWAC

Find a more suitable bag for FWAC use during later phases of the OB/OD program. Absorption and off-gassing properties of this replacement bag should be well-characterized. If this is not available, replace the bag with another collection media.

8.3. Semi-VOST Resin Media Sampling

Replace the semi-VOST resin media with another collection media.

8.4. SFC/MS Analytical Methods

Expand the SFC/MS method of analysis to embrace samples derived from soil.

8.5. HCL, HCN, and NH_3

Define and authenticate a means of adequately measuring HCL, HCN, NH_3 in field OB clouds from a FWAC platform before conducting large-scale composite propellant burns.

8.6. Carbon Balance Method

Conduct large scale field tests of OB/OD PEP material to obtain EFs based on the carbon balance technique proven in the BB test.

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APPENDIX A - CONSOLIDATED ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AEHA	U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland
AFB	Air Force Base
AMC	U.S. Army Materiel Command, Alexandria, Virginia
AMCCOM	U.S. Army Armament, Munitions and Chemical Command, Rock Island, Illinois
amino-PAH	aminopolycyclic aromatic hydrocarbons
ANOVA	analysis of variance
AP	ammonium perchlorate
APS	aerodynamic particle sizer
ASASP	active scattering aerosol spectrometer probe
AWL	Alpine West Laboratories, Provo, Utah
BB	BangBox
BCD	Battelle Columbus Division, Columbus, Ohio
BD	target analyte not found in concentrations above detection limits
BYU	Brigham Young University, Provo, Utah
CAA	Clean Air Act
CDD	chlorinated dibenzodioxin
CDF	chlorinated dibenzofuran
CI-SIM	chemical ionization, selective-ion monitoring
CSI	Columbia Scientific Instruments
C•V	concentration times cloud volume method
CWA	Clean Water Act
DMC	Data Management Center
DMPS	differential mobility particle sizer
DoD	Department of Defense
DPG	U.S. Army Dugway Proving Ground, Dugway, Utah
EC	electron capture *or* elemental carbon
ECD	electron capture detector
EDAX	energy-dispersive X-ray analysis
EER	Energy and Environmental Research Corporation, Irvine, California

EF	emission factor(s)
EI	electron impact
EI-MS	mass spectrometer used in the electron impact ionization mode
EI/MS	electron impact ionization/ mass spectrometry
EIS	environmental impact statement
ELI	Environmental Labs, Incorporated, Provo, Utah
EOD	explosive ordnance disposal
EPA	U.S. Environmental Protection Agency
EPO	Environmental Protection Office, U.S. Army Dugway Proving Ground, Dugway, Utah
ER	expansion ratio
FID	flame ionization detector
FSSP	forward scattering spectrometer probe
FTIR	Fourier Transform Infrared Spectrometry
FWAC	fixed-wing aircraft
GC	gas chromatograph(y)
GC-ECD	gas chromatography with an electron capture detector
GC-FID	gas chromatography with a flame ionization detector
GC/MS	gas chromatography-mass spectrometry
GLP	good laboratory practices
HE	high explosive
HMX	octamethylenehexanitramine
HNBB	hexanitrobibenzyl
HRGC/HRMS	combined capillary column gas chromatography/high resolution mass spectrometry
HS	high-speed
LASD	Los Angeles Sheriff Department
LBL	Lawrence Berkeley Laboratory, Berkeley, California
LC	liquid chromatography
LOD	limit of detection
LOI	letter(s) of instruction
NO_x	nitrogen oxide (s)

MR	multiple range
MRI	Midwest Research Institute, Kansas City, Kansas
MS	mass spectrometry (or mass spectrometer)
MSA	Mine Safety and Appliance Company
NA	not targeted for analysis *or* not applicable
NASA	National Aeronautical and Space Administration
NATICH	National Air Toxics Information Clearinghouse
NBS-SRM	National Bureau of Standards (now NIST)- Standard Reference Material
ND	no data *or* detection limit not determined
NEPA	National Environmental Policy Act
NF	not found in the sample matrix *or* not determined
NIST	National Institute of Science and Technology
nitro-PAH	nitropolycyclic aromatic hydrocarbons
NIOSH	National Institute for Occupational Safety and Health
NOSIH	Naval Ordnance Station, Indian Head, Maryland
NO_x	nitrogen oxides
NS	not sampled
OB	open burning
OB/OD	open burning/open detonation
OC	organic carbon
OD	open detonation
OGC	Oregon Graduate Center, Beaverton, Oregon
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbons
PANH	polycyclic aromatic nitrogen heterocycles
PAOH	polycyclic aromatic oxygen heterocycles
PCDD	polychlorinated dibenzodioxins
PCDF	polychlorinated dibenzofurans
PETN	pentaerythritol tetranitrate
PEP	propellants, explosives, and pryotechnics
PIC	products of incomplete combustion
PICI/SIM	Positive ion chemical ionization/selective ion monitoring

PID	photoionization detector
PIP	product improvement program
PM	program manager
PMS	Particle Measuring Systems, Inc.
PUF	polyurethane foam
QA	quality assurance
QA/QC	quality assurance/quality control
QC	quality control
QAA	quality assurance agency
QAPP	quality assurance project plan
QAU	quality assurance unit
RCRA	Resource Conservation and Recovery Act
RDX	hexamethylenetrinitramine
RFD	Reno (Nevada) Fire Department
RIC	relative ion count
RSD	relative standard deviation
RTP	Research Triangle Park, North Carolina
SDPDA	Special Defense Property Disposal Account
semi-VOST	semivolatile organic sampling train
SEM	scanning electron microscope/microscopy
SFC	supercritical fluid chromatography
SFC/MS	supercritical fluid chromatography/mass spectrometry
SF_6	sulfur hexafluoride
SIM	selected-ion monitoring (or selective-ion monitoring)
SNL	Sandia National Laboratories, Albuquerque, New Mexico
SOP	standing operating procedures
SS	stainless steel
SSC	stainless steel canister
SSL	Sunset Laboratory, Forest Grove, Oregon
STEL	short-term exposure limit
STP	standard temperature and pressure (25°C and 760 torr)
TCD	thermal conductivity detector

TDP	test design plan
TEAD	U.S. Army Tooele Army Depot, Tooele, Utah
TECO	Thermo Electron Instruments (Company)
TECOM	U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland
THC	total hydrocarbon
TLV	threshold limit values
TNT	2,4,6-trinitrotoluene
TSC	technical steering committee
TSP	total suspended particulate
TWA	time-weighted average
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland
UV	ultraviolet
VOC	volatile organic compounds
VSDM	Volume Source Diffusion Model
XRF	X-ray fluorescence *or* X-ray fluorescence spectrometer

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FINAL REPORT

DEVELOPMENT OF METHODOLOGY AND TECHNOLOGY FOR IDENTIFYING AND QUANTIFYING EMISSION PRODUCTS FROM OPEN BURNING AND OPEN DETONATION THERMAL TREATMENT METHODS.

FIELD TEST SERIES A, B, AND C

VOLUME 1
TEST SUMMARY

JANUARY 1992

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The report covers the OB/OD field tests A, B, and C using the methodology and technology developed in the BangBox (BB) test for use on the fixed-wing aircraft (FWAC). Field test A was a checkout of the equipment and sampling selected from the BB test, and the development of procedures for sampling the TNT detonation crater soil, and the particle fallout in the surrounding area. Triple-base propellant was also burned in pans with the area sampled to 30-m with fallout pans. The analytes in both the air emission and the soil were identified and quantified. Field test B used TNT as the explosive and manufacturing residue as the burn material. Air sampling with the FWAC and soil sampling provided estimates of emission factors (EF) and soil contaminates that were detected above background levels. Suspended TNT detonations and manufacturing residue burns were also characterized for emission products. Phase C test using refinements in sampling and analysis from the previous phases provided data for TNT, composition B, explosive D, and RDX detonations and manufacturing residue single-base (M1,M6) propellant burns. The EF data from the TNT field tests were examined and compared with BB data; the results were comparable in the analytes detected and the level of analytes detected. The results indicate an efficiency for the detonation >92 percent (Continued on reverse)

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supercritical fluid chromatography; SFC; demilitarization; munition disposal; explosive disposal; environment; BB; air building; explosive D; composition B; RDX; single-base propellant (M1,M6); triple-base propellant(M30).

19. (Cont'd)

based on the conversion of the carbon in the explosive material to CO_2. The semivolatiles in the soil were identified, quantified and a comparison made between background levels and after detonations levels. Similarity in analyte detected and the levels of analytes measured for TNT, RDX, explosive D, and composition B lead to the conclusion that OB/OD can be and effective means of treatment. Based on TNT the BB EF are comparable to field EF. The propellant burns all resulted in extremely efficient conversion of material carbon into CO_2 >99 percent.

FOREWORD

A test planning directive to conduct the OB/OD test in support of U.S. Army Armament, Munitions and Chemical Command (AMCCOM) was issued by U.S. Army Test and Evaluation Command (TECOM) on 28 April 1988[1]. A Technical Steering Committee Symposium was convened in July 1988. The requirement for identifying and quantifying emissions from the open detonation of explosives and open burning of propellants was discussed in detail by authorities from throughout the military, academic, and commercial communities. Conclusions and recommendations developed during the symposium are reported in proceedings of the symposium[2].

A series of TNT detonations and propellant burns were characterized in a BangBox (chamber) in December 1988 and January 1989 for the purpose of developing methodology and technology for large scale detonations and burns in the field. The BangBox test is reported in a three volume set. The report covers the details of the methods and technology development and would be useful for those desiring more detail on such things as the carbon balance method, the emission factors from a nonhomogeneous and homogeneous detonation or burn cloud, the samplers selected for future use in the fixed wing aircraft, and the techniques used in extracting and assaying samples.

The field tests took place in 1989 and 1990 and are reported in three volumes.

Volume 1. A summary which describes the planning phase, the conduct of trials, sample analyses and results, and the conclusions and recommendations. It is useful for those who need only a quick review (executive summary) and those who need a detailed description of the conduct and results of the Field Tests Phases A, B, and C.

Volume 2, Part A. A stand-alone document which covers the quality assurance and quality control procedures, the blind spiking of samples, the on site challenges of equipment and

---

[1]Letter, AMSTE-TA-F, Headquarters, U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland, 20 April 1988, subject: Test Planning Directive for Special Study of Open Burning/Open Detonation (OB/OD), Phase II, TECOM Project No 2-CO-210-000-017.

[2]*Proceedings of the Technical Steering Committee Symposium 6-8 July 1988*, Headquarters, United States Army Armament, Munitions and Chemical Command, Rock Island, Illinois, August 1991.

personnel, the conclusions, and the recommendations.

Volume 2, Part B. The quality assurance (QA) program plan which was developed specifically to support phase "C" field testing. While directed to phase "C" testing, it also represents the procedures and techniques and QA philosophies which were used during OB/OD field testing phases "A" and "B" and is based on experience gained during these two earlier field tests.

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ABSTRACT

The development, testing, and evaluation of a U.S. Environmental Protection Agency (Office of Solid Waste/Atmospheric Research and Exposure Assessment Laboratory) validated and accepted method for the characterization of emissions from open burning (OB) and open detonation (OD) thermal treatment operations is presented. The methodology utilizes an innovative carbon balance technique to calculate accurate emission factors (Efs) of combustion products in diffusing clouds and a combination of supercritical fluid chromatography (SFC), gas chromatography (GC), and mass spectrometry (MS) to detect and quantify potential air and soil contaminants. These methods were used to achieve maximum sensitivity/identification of volatiles and semivolatile organic compounds. The SFC-MS was able to measure the thermally labile semivolatile organics such as RDX and N-Nitrosodiphenylamine which are subject to breakdown into other compounds with GC-MS. Confirmation of the methodology included closed-chamber tests to check out instrumentation, technology, and analytical procedures proposed for follow-on large- scale open air tests conducted on a fixed wing aircraft flying through the plume. Comparable EFs were obtained from the BangBox (BB) and open air tests for TNT. Because of the similarity in analytes detected, EFs, and concentrations between TNT, composition B, explosive D and RDX, it is reasonable to expect that BB can provide results that will be useful in permit applications.

Materials characterized during the OB/OD study included the explosives TNT, RDX, Explosive D, and Composition B; propellant manufacturing residue; and single-, double-, triple-base, and composite types of propellant. The study and emerging results were briefed as part of a nation-wide EPA-sponsored seminar, on "Incineration and Alternative Treatment of Energetic Compounds to Minimize Effects to Air, Soil and Water Supplies". The seminar was presented to all EPA regions during the period of April-September 1990. The study has confirmed the methodology, technology, and procedures necessary to obtain a portion of data required to obtain permits under provisions of the Resource Conservation and Recovery Act (RCRA), subpart X. Such permitting is required for continuation of all Department of Defense OB/OD operations after 8 November 1992. It is recommended that the methodology and procedures be used in a follow-on program to acquire characterization data on specific munitions, explosives, and propellants that are included in the DoD inventory.

The data obtained will be used to demonstrate that OB/OD units can be operated in a manner so as to meet the environmental performance standards.

EXECUTIVE SUMMARY

Open burning (OB) and open detonation (OD), thermal treatment methods are currently the primary means of demilitarization employed by the Department of Defense (DoD) for the treatment of explosive residue, propellants, and munitions. Increasingly stringent requirements for environmental documentation of potential pollution/contamination from combustion products under such acts as the Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act (RCRA), resulted in a critical need for technology development to be able to collect data to use as a basis for making informed decisions to determine: (1) the limitations/restrictions of OB/OD thermal treatment methods, (2) the development of alternative treatment methods for munitions/propellants for which OB/OD is not acceptable, and (3) developing and maintaining the most effective, economical, and environmentally safe means of accomplishing required demilitarization/treatment.

The objective of this phase (I) of the OB/OD thermal emission study was to develop and demonstrate the utility of the technologies and methodologies needed to provide the data required for these critical decisions. (See Appendix K)

Under the sponsorship of the Single Manager for Conventional Ammunition within the DoD, a symposium was conducted in July 1988 (Reference 1) to develop planning concepts necessary to address the technical problems associated with an accurate environmental characterization of the OB/OD processes. Authorities from governmental, academic, and private research organizations discussed sampling and sample analysis technologies, data analysis processes, test organization, and preparation of reports that would be acceptable to Federal and State environmental regulatory agencies. Expertise represented included field sampling, instrumentation, field and laboratory analyses, environmental documentation, atmospheric dispersion modeling and sampling, data management, combustion and explosive phenomenology, and quality assurance/quality control. A technical steering committee composed of recognized experts in their respective disciplines was formed under the leadership of the U.S. Army Armament, Munitions and Chemical Command Program Manager.

A list of volatile and semivolatile organic compounds and metals which are potentially hazardous contaminants if they were produced in either the soil or atmosphere from OB/OD processes was developed. A closed chamber (BangBox or BB) test was conducted at Sandia National Laboratories (See Reference 2) to check out instrumentation, technology, methodology, and analytical procedures that were proposed for follow-on large scale field tests to be sampled by a fixed-wing aircraft (FWAC) flying through OB/OD-generated plumes. Representatives of the U.S. Environmental Protection Agency (EPA) (Office of Solid Waste at Washington DC, Region VIII at Denver, CO, and the Quality Assurance Division at Research Triangle Park, NC) served as members of the technical steering committee to provide technical guidance and quality assurance/quality control support during test planning and execution phases, and to review data collection and analytical procedures throughout the entire program. In addition, representatives from the Office of Solid and Hazardous Waste from the State of Utah participated throughout the entire planning and testing period. Real-time and near real-time particulate and gaseous concentration measurements were achieved. These data were correlated with the samples collected on filters and gaseous containers and held for subsequent laboratory analysis. A methodology of using carbon balance to calculate EF factors of combustion products in diffusing clouds was developed. Laboratory analyses of samples utilized innovative supercritical fluid chromatography (in addition to gas chromatography) and mass spectrometry, one of the techniques which attain the lowest possible detection limits for the selected semivolatile analytes.

The BB tests evaluated EF from the open detonation of 2,4,6 trinitrotoluene (TNT), and open burning of a double-base and a composite propellant. The tests confirmed the technologies, methodologies, and analytical procedures employed. These processes were further successfully proven during the conduct of large-scale tests during field tests Phases A, B, and C.

Emissions and residues from propellant manufacturing residue, single- and triple-base, and composite propellants; and TNT, explosive D, RDX and composition B were characterized during the field trials conducted at Dugway Proving Ground (DPG) between June 1989 and September 1990.

Emerging results of the current study were briefed as part of a nationwide EPA-sponsored seminar on "Incineration and Alternative Treatment of Energetic Compounds to Minimize Effects to Air,

Soil, and Water Supplies." The seminar was presented to all EPA regions within the continental United States during the period of April to September 1990. The EPA representatives have accepted the methodology, technology, and procedures as an effective approach to obtain data required for permitting of DoD OB/OD thermal treatment operations.

Results of the study that have direct application to critical decisions on future planning and funding of the DOD demilitarization/treatment program are summarized below:

Comparable EFs were found during BB and field testing for TNT. Additional similarities of the EF, combustion products, and combustion product concentration levels resulting from the OD of TNT, composition B, explosive D, and RDX were observed during large-scale field testing. These two sets of relationships indicate that small-scale BB-type OD tests may be capable of providing the data needed for characterizing large-scale field OD thermal treatment operations and supporting permit applications.

The study also suggests that the bulk explosives and propellants examined during field testing may be treated in an environmentally safe manner by surface OB/OD methods. While these results are encouraging, site-specific testing is needed to provide data to support risk assessments. Only after these risk assessments are completed may a definitive statement be made concerning the effect (if any) OB/OD operations have on human health and the environment.

The advantages of conducting tests in properly designed chambers as opposed to field testing include:

(1) Costs are reduced and can be more precisely controlled.

(2) The test environment can be standardized.

(3) Results may be obtained rapidly.

(4) Sampling may continue until sufficient quantities of targeted analytes obtained have been collected to meet or exceed minimum quantification level of the analytical methods being used.

(5) Secondary reactions and the decay rate of primary and secondary products of combustion can be studied.

(6) The number of samples necessary for calculating statistically valid EFs (and the uncertainty (imprecision) associated with these EFs) can be acquired under repeatable and well controlled conditions. With this information, a very conservative EF such as the maximum probable EF (upper 95% tolerance level) can be calculated.

(7) Testing delays caused by adverse weather conditions will be minimized.

(8) PEP materials requiring alternative treatment technologies can be rapidly identified.

For those materials that cannot be safely treated by other modes of treatment, the results obtained from chamber testing can be combined with dispersion modeling and health risk assessment information to determine the following:

(1) The type and quantities of pollutants that will be released to the environment from specific PEP items.

(2) Identification of PEP materials for which OB/OD thermal treatment methods are environmentally acceptable.

(3) Those PEP materials that cannot be safely treated in an environmentally safe manner by OB/OD thermal treatment methods, require the development of alternative technologies.

(4) Effective focussing of alternative technologies development.

(5) The design and placement of the monitoring systems that will be required to ensure that the quantities of pollutants released to the environment from permitted OB/OD thermal treatment operations remain at or below the levels specified in the OB/OD permit.

(6) The types of monitoring equipment that must be used and the number of samples of each type that must be taken and the target analytes that must be measured, when chamber studies are inconclusive and an assessment must be made through field testing.

(7) The kinds and quantities of pollutants released from OB/OD thermal treatment operations as the type, quantity, configuration (buried/surface), physical condition (bulk, munition type, old, new), and composition (supplemental oxidants added/not added) is varied.

This combination of testing and modeling will provide the data required to improve/optimize the current OB/OD technology and the environmental sampling and analysis methods employed for monitoring pollutant releases.

The EFs obtained from the BB tests and from the field tests for OD of explosives and OB of propellants is presented in Tables 1, 2, 4, and 5.

Table 1 presents the average EFs for inorganic gases, and volatile organic compounds; Table 2 presents the maximum EFs for semivolatile organic compounds obtained when 225 gram quantities of bulk TNT were detonated in a 1000-m^3 BangBox chamber, and results from the trials of three field tests in which 4000 to 10000 lb of bulk TNT, composition B, explosive D, or RDX were detonated on soil at DPG.

The TNT data show that the BB generated EFs are comparable to those obtained in the field. All TNT tests show a very efficient conversion of carbon to CO_2 (>92 percent).

The striking thing about the data in these tables is the very efficient conversion of carbon to CO_2 for all four explosives and the comparable low level of the volatiles and semivolatiles.

A summary of the semivolatile analytes detected in the ejecta soil from the detonations is presented in Table 3. The analytes that were measured after detonation in concentrations greater than those observed in the pretest background are marked with an asterisk. The data shows very few of the analytes detected above background. The parent compound TNT showed elevated levels after the detonations of TNT and composition B.

The results are encouraging because:

(1) they document the utility of the BB in estimating air emissions in large scale field tests, and

(2) they indicate that the concentrations of inorganic compounds, volatile organic and semivolatile compounds generated from OD operations may be more predictable than previously supposed.

(3) they indicate that soil contamination from large-scale high order detonations are very small.

The comparability of EFs obtained for propellants burned in trays at the BB and at DPG parallels the degree of comparability between BB and field detonations. The BB testing of double-base and composite propellants generally yielded EFs that approximated or exceeded those obtained in the field tests, and EFs generated during the OB field testing did not substantially differ from each other. Over 99 percent of the total carbon contained in tested propellants was accounted for in the form of carbon dioxide following the burn event. The semivolatile organics detected were propellant specific, e.g., no semivolatile organic were detected for the M30 (triple-base) propellant burn, but nine semivolatile compounds were detected for the phase B propellant manufacturing residues.

The analyses of samples collected in the fallout and the sputter pans (burns) indicate that the propellants used in this program did not add measurable levels of contamination to the soil beyond 12 m from the propellant burns. The analytes detected and the maximum concentration level of the analyte in the fallout material are shown in Table 6.

The DPG real time volume source dispersion model (RTVSM) was used to estimate ground-level concentrations of selected analytes that would be expected from a 1 metric ton (1000 kg) surface detonation of TNT. Test cases run for typical EFs measured for surface detonated TNT such as CO (EF = 50×10^{-3}), benzene (EF = 0.1×10^{-3}), and benzo[a]pyrene (EF = 0.1×10^{-6}) reveals that maximum ground level peak and 15-minute average concentrations would be indistinguishable from background levels of these pollutants.

The follow on program will obtain emission characterization data for specific munitions and other PEP items in the DoD inventory. Obtaining these critical data and the required permits will eliminate the potential for costly and time consuming litigious actions, and will ensure the continuation of an effective integrated PEP demilitarization/treatment program.

Table 1 Explosive Detonations: Average Emission Factors[a] for Inorganic, and Volatile Analytes.

Analyte	TNT BangBox	TNT Surface Detonations			Phase C Surface Detonations		
		Phase A	Phase B	Phase C	Comp B	Exp D	RDX
Percent Carbon Converted to CO_2	97.1	92.6	94.9	94.1	94.5	92.5	96.6
Carbon dioxide (Theoretical EF[b])	1.36	1.36	1.36	1.36	0.921	1.07	0.59
INORGANIC COMPOUNDS							
Carbon dioxide (Empirical EF)	1.32	1.26	1.29	1.28	0.87	0.99	0.57
Carbon monoxide	4.9×10^{-3}	61×10^{-3}	42×10^{-3}	49×10^{-3}	31×10^{-3}	53×10^{-3}	31×10^{-3}
Nitrogen oxide	11×10^{-3}	0.70×10^{-3}	1.4×10^{-3}	1.4×10^{-3}	0.8×10^{-3}	0.9×10^{-3}	0.9×10^{-3}
Nitrogen dioxide	0.56×10^{-3}	3.6×10^{-3}	1.1×10^{-3}	1.4×10^{-3}	1.0×10^{-3}	1.1×10^{-3}	0.6×10^{-3}
VOLATILE COMPOUNDS							
Methane	0.025×10^{-3}	1.5×10^{-3}	1.2×10^{-3}	1.5×10^{-3}	0.6×10^{-3}	2.4×10^{-3}	0.2×10^{-3}
Total Nonmethane hydrocarbons	0.057×10^{-3}	1.4×10^{-3}	1.9×10^{-3}	2.1×10^{-3}	1.2×10^{-3}	2.0×10^{-3}	1.3×10^{-3}
Benzene	2.4×10^{-6}	94×10^{-6}	93×10^{-6}	100×10^{-6}	62×10^{-6}	110×10^{-6}	69×10^{-6}

[a]Emission factor--a dimentionless number that, when multiplied by the weight of explosive or propellant material, detonated or burned, results in the weight of analyte expected.
[b]Theoretical EF (emission factor) if all carbon is converted to CO_2.

Table 2 Explosive Detonations: Maximum Emission Factors[a] for Semivolatile Analytes.

Analyte	TNT BangBox	TNT Surface Detonations			Phase C Surface Detonations		
		Phase A	Phase B	Phase C	Comp B	Exp D	RDX
SEMIVOLATILE COMPOUNDS							
2,4-Dinitrotoluene	170×10^{-9}	150×10^{-9}	8400×10^{-9}	BD[b]	450×10^{-9}	590×10^{-9}	210×10^{-9}
2,6-Dinitrotoluene	140×10^{-9}	19×10^{-9}	7100×10^{-9}	BD	24×10^{-9}	80×10^{-9}	41×10^{-9}
2,4,6-Trinitrotoluene	620×10^{-9}	220×10^{-9}	150×10^{-9}	60×10^{-9}	250×10^{-9}	44×10^{-9}	98×10^{-9}
2-Nitronaphthalene	160×10^{-9}	80×10^{-9}	270×10^{-9}	BD	86×10^{-9}	43×10^{-9}	49×10^{-9}
N-Nitrosodiphenylamine	200×10^{-9}	BD	4.4×10^{-9}	BD	36×10^{-9}	58×10^{-9}	BD
1,3,5-Trinitrobenzene	0.45×10^{-9}	BD	BD	BD	59×10^{-9}	18×10^{-9}	44×10^{-9}
2-Nitrodiphenylamine	NA[c]	BD	NA	BD	72×10^{-9}	58×10^{-9}	34×10^{-9}
1-Nitropyrene	BD	BD	39×10^{-9}	BD	56×10^{-9}	11×10^{-9}	50×10^{-9}
RDX	NA	NA	NA	NA	BD	NA	2100×10^{-9}
Picric acid	NA	NA	NA	NA	NA	50×10^{-9}	NA
Naphthalene	28000×10^{-9}	BD	3700×10^{-9}	2600×10^{-9}	420×10^{-9}	630×10^{-9}	200×10^{-9}
Benz[a]anthracene	BD	2.2×10^{-9}	160×10^{-9}	100×10^{-9}	7.4×10^{-9}	19×10^{-9}	93×10^{-9}
Benzo[a]pyrene	360×10^{-9}	BD	240×10^{-9}	BD	14×10^{-9}	38×10^{-9}	140×10^{-9}
Pyrene	32×10^{-9}	BD	NA	220×10^{-9}	210×10^{-9}	180×10^{-9}	220×10^{-9}
Phenol	9900×10^{-9}	BD	5200×10^{-9}	BD	---[d]	---	---
Dibenzofuran	150×10^{-9}	BD	85×10^{-9}	180×10^{-9}	BD	110×10^{-9}	2000×10^{-9}
Diphenylamine	BD	NA	7.7×10^{-9}	170×10^{-9}	66×10^{-9}	19×10^{-9}	310×10^{-9}

[a]Emission factor--a dimentionless number that, when multiplied by the weight of explosive or propellant material, detonated or burned, results in the weight of analyte expected.
[b]BD - below detection limit.
[c]NA - not a target analyte.
[d]Phenol was lost in the extraction of the semivolatile.

Table 3 Explosive Detonations: Semivolatile Analytes Detected and Maximum Recovery in Soil Ejecta (ng/g)[a].

	TNT	Comp B	Exp D	RDX
SEMIVOLATILE COMPOUNDS				
2,4-Dinitrotoluene	8.0	17	1.3	2.0
2,6-Dinitrotoluene	2.3	1.0	0.14	0.90
2,4,6-Trinitrotoluene	360 *[b]	14 *	7.4	0.67
2-Nitronaphthalene	1.8	0.39	0.11	0.90
N-Nitrosodiphenylamine	1.1	0.39	0.090	1.7
1,3,5-Trinitrobenzene	39 *	0.39	0.14	0.77
2-Nitrodiphenylamine	BD[c]	0.60	0.24	0.19
1-Nitropyrene	1.2	0.14	0.12	0.23
RDX	NA[d]	BD	NA	15
Picric acid	NA	NA	BD	NA
Naphthalene	210	13	11	5.3 *
Benz[a]anthracene	11 *	1.9	5.4	2.4
Benzo[a]pyrene	BD	0.55	0.67	0.41
Pyrene	53 *	4.5	5.2 *	5.3 *
Phenol	69 *	—[e]	—	—
Dibenzofuran	18	1.6	1.0	0.95
Diphenylamine	0.79	1.6	0.26	0.48

[a]Represents ng of analyte per g of soil.
[b]The asterisk indicates that the analyte was detected above background level (P >0.95).
[c]BD - below detection limit.
[d]NA - not a target analyte.
[e]Phenol was lost in the extraction of the semivolatile.

Table 4 Propellant Burns: Average Emission Factors[a] for Inorganic and Volatile Analytes.

Analyte	BangBox		Phase A	Manufacturing Residue		Phase C	
	Double Base	Composite	Triple Base	Phase B	Phase C[a]	M-1	M-6
Percent Carbon Converted to CO_2	103	111	102	unknown	99.5	99.1	99.1
Carbon dioxide (Theoretical EF[b])	0.94	0.88	0.65	unknown	1.005	1.11	1.07
INORGANIC COMPOUNDS							
Carbon dioxide (Empirical EF)	0.97	0.42	0.66	0.77	1.0	1.1	1.1
Carbon monoxide	0.91×10^{-3}	0.29×10^{-3}	0.025×10^{-3}	0.49×10^{-3}	0.7×10^{-3}	0.25×10^{-3}	0.095×10^{-3}
Nitrogen oxide	0.14×10^{-3}	3.0×10^{-3}	5.2×10^{-3}	2.8×10^{-3}	2.6×10^{-3}	1.2×10^{-3}	2.4×10^{-3}
Nitrogen dioxide	0.88×10^{-3}	0.61×10^{-3}	2.1×10^{-3}	0.51×10^{-3}	0.15×10^{-3}	0.47×10^{-3}	0.52×10^{-3}
VOLATILE COMPOUNDS							
Methane	67×10^{-6}	20×10^{-6}	BD[c]	BD	750×10^{-6}	8000×10^{-6}	46×10^{-6}
Total nonmethane hydrocarbons	160×10^{-6}	33×10^{-6}	1.5×10^{-6}	45×10^{-6}	560×10^{-6}	460×10^{-6}	13×10^{-6}
Benzene	11×10^{-6}	5.7×10^{-6}	BD	BD	16×10^{-6}	4.8×10^{-6}	1.7×10^{-6}

[a]Emission factor--a dimentionless number that, when multiplied by the weight of explosive or propellant material, detonated or burned, results in the weight of analyte expected.
[b]Theoretical EF (emission factor) if all carbon is converted to CO_2.
[c]BD - below detection limit.

Table 5 Propellant Burns: Maximum Emission Factors[a] for Semivolatile Analytes.

Analyte	BangBox		Phase A	Manufacturing Residue		Phase C	
	Double Base	Composite	Triple Base	Phase B	Phase C[c]	M-1	M-6
SEMIVOLATILE COMPOUNDS							
2,4-Dinitrotoluene	BD[b]	10×10^{-9}	BD	BD	160×10^{-9}	1.2×10^{-9}	1.0×10^{-9}
2,6-Dinitrotoluene	14×10^{-9}	3.7×10^{-9}	BD	BD	140×10^{-9}	BD	0.077×10^{-9}
2,4,6-Trinitrotoluene	50×10^{-9}	BD	BD	BD	64×10^{-9}	BD	BD
2-Nitronaphthalene	54×10^{-9}	13×10^{-9}	BD	3.7×10^{-9}	83×10^{-9}	BD	BD
N-Nitrosodiphenylamine	1500×10^{-9}	35×10^{-9}	BD	19×10^{-9}	27×10^{-9}	BD	0.14×10^{-9}
1,3,5-Trinitrobenzene	NA[c]	NA	BD	NA	5.3×10^{-9}	BD	BD
2-Nitrodiphenylamine	BD	NA	BD	BD	13×10^{-9}	BD	BD
4-Nitrophenol	0.69×10^{-6}	0.41×10^{-6}	BD	BD	NA	NA	NA
1-Nitropyrene	BD	20×10^{-9}	BD	NA	BD	BD	BD
Naphthalene	BD	1400×10^{-9}	BD	1500×10^{-9}	540×10^{-9}	19×10^{-9}	75×10^{-9}
Benz[a]anthracene	BD	BD	BD	38×10^{-9}	140×10^{-9}	BD	BD
Benzo[a]pyrene	900×10^{-9}	BD	BD	23×10^{-9}	81×10^{-9}	BD	BD
Pyrene	NA	NA	BD	71×10^{-9}	320×10^{-9}	BD	BD
Phenol	4400×10^{-9}	3800×10^{-9}	BD	8000×10^{-9}	---[d]	3.4×10^{-9}	1.5×10^{-9}
Dibenzofuran	0.26×10^{-6}	0.28×10^{-6}	BD	0.26×10^{-6}	120×10^{-6}	BD	BD
Diphenylamine	BD	BD	BD	20×10^{-9}	310×10^{-9}	0.11×10^{-9}	0.026×10^{-9}

[a]Emission factor--a dimentionless number that, when *multiplied* by the weight of explosive or propellant material, detonated or burned, results in the weight of analyte expected.
[b]BD - *below detection limit.*
[c]NA - not a target analyte.
[d]---Phenol was lost in the extraction of the semivolatile.

Table 6 Propellant Burns: Semivolatile Analytes Detected and Maximum Recovery in Fallout Pans (ng/g).

Analyte	Phase A	Manufacturing Residue		Phase C	
	Triple Base	Phase B	Phase C[a]	M-1	M-6
SEMIVOLATILE COMPOUNDS					
2,4-Dinitrotoluene	BD	700	58	900	410
2,6-Dinitrotoluene	BD	BD	7.9	36	BD
2,4,6-Trinitrotoluene	BD	BD	120	0.38	1.0
2-Nitronaphthalene	BD	BD	8.8	0.14	0.18
N-Nitrosodiphenylamine	BD	6.7	BD	BD	20
1,3,5-Trinitrobenzene	BD	BD	18	BD	0.009
2-Nitrodiphenylamine	BD	17	BD	0.29	1.1
4-Nitrophenol	BD	BD	NA[c]	NA	NA
1-Nitropyrene	BD	BD	BD	BD	0.009
Naphthalene	BD	390	34	5.5	9.6
Benz[a]anthracene	BD	BD	94	0.51	2.2
Benzo[a]pyrene	BD	BD	8.4	BD	1.1
Pyrene	BD	510	17	BD	0.36
Phenol	190,000	16	---[d]	BD	0.15
Dibenzofuran	BD	29	80	BD	53
Diphenylamine	BD	2.7	21	6.9	26
Ethyl centralite	96,000	NA	NA	NA	NA
Nitroglycerin	43,000	310	BD	NA	NA
Nitroguanidine	55,000	BD	NA	NA	NA

[a]Represents ng of analyte per g of fallout material.
[b]BD - below detection limit.
[c]NA - not a target analyte.
[d]---Phenol was lost in the extraction of the semivolatile.

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SECTION 1. INTRODUCTION

1.1 Demilitarization Stockpile Situation

1.1.1 Size, Storage, and Treatment

The military services possess a massive munitions demilitarization inventory which has reached 200,000 short tons and grows by 25,000 short tons annually, despite ongoing demilitarization operations. The stockpile's growth is expected to accelerate as an expected drawdown of U.S. forces in Europe begins and stocks in our European depots are retrograded. The ammunition logistics support network is presently experiencing several consequences. First, the storage capacity of depot igloo facilities has reached saturation, prompting the need for outdoor storage. Second, many munitions and propellants deteriorate with age and are subject to spontaneous detonation or ignition, with the attendant safety and environmental risks. As the triservice manager for demilitarization, the U.S. Army continues to cope with this problem, traditionally using open burning (OB) and open detonation (OD) thermal treatment procedures. OB and OD have historically proven to be the fastest, safest, most reliable, and least expensive of any demilitarization procedures within existing technology and are well understood by depot munitions specialists.

1.1.2 Environmental Issues and RCRA Permitting

Within the past several years, OB/OD operations have been faced with increasing restrictions. Part of these requirements include the need to obtain permits under provisions of the Resource Conservation and Recovery Act (RCRA), subpart X. Because of the absence of definitive data concerning explosive and propellant combustion products, especially trace organics, RCRA permits have been granted an interim status in many instances, and OB/OD activities closed in others. Unless permitted under RCRA subpart X prior to 8 November 1992, all OB/OD operating sites are subject to closure, and the armed forces may lose their only operating means of reducing a significant part of the demilitarization inventory. Additionally, ordnance manufacturing and processing facilities need OB/OD capabilities to treat their reactive waste streams. Without OB/OD data to support permit application evaluation, these permits will be in jeopardy.

1.1.3 Alternative Methods for Demilitarization

A number of alternative methods have been proposed for demilitarization operations. Some have proven environmentally unsound, e.g., washout which produces contaminated wastewater; others have a low thruput or are severely limited in the quantities or types of ordnance which can be treated; and some are exceedingly expensive or are not technologically mature. Most alternative methods being considered to replace OB/OD will not be operational for at least 5 to 7 years. Until these alternative methods are fully developed, tested, and permitted, stocks will grow to unmanageable proportions, unless OB/OD thermal treatment methods continue at an accelerated pace. It is estimated that OB/OD thermal treatment methods can safely and economically process a large part of the current inventory without serious impact to the environment. Once proven environmentally acceptable, OB/OD thermal treatment methods can work in concert with emerging alternative technologies, to solve the current and future demilitarization problems.

1.2 Background

1.2.1 Interim Study

In 1986, an interim field test was conducted at Tooele Army Depot (TEAD), Utah. The purpose of that test was to evaluate several new testing, sampling, and analysis procedures. A wide variety of material was detonated or burned, ranging from hand grenades to 227 kg (500-lb) bombs to artillery propellants. While most detonations were conducted on the surface, a limited number of buried detonations were conducted. The combustion products of these events were sampled by collectors for subsequent laboratory analyses or analyzed by real-time instruments mounted aboard a UH1-D helicopter. While some valuable data were collected on criteria gases, the real benefit of this test was the evaluation of equipment and procedures. The test revealed that the helicopter was unsuitable as an aerial sampling platform because of the vibration, engine vulnerability to airborne particulate matter, and inability to catch some fast-moving plumes. The test also demonstrated that existing assay technologies were not sufficiently refined to detect the very low levels of emittants desired by environmental regulators.

1.2.2 Symposium - Technical Steering Committee

1.2.2.1 In 1988, the U.S. Army Armament, Munitions and Chemical Command (AMCCOM) convened a technical symposium at Salt Lake City, Utah. This symposium drew internationally recognized authorities from the military services, U.S. Environmental Protection Agency (EPA), academia, not-for-profit organizations, and private enterprise. The symposium included representatives with expertise in analytical chemistry, sampling, modeling, explosives and propellants, statistical analysis, and quality assurance. The technical challenges of the earlier tests were reviewed, and alternate strategies and technologies for the next phases of the study were discussed (reference 1). A Technical Steering Committee (TSC) was formed from selected symposia participants, including the EPA. The initial product of the TSC was the list of target analytes from propellant, explosive, and pyrotechnic (PEP) combustion that were of foremost environmental interest.

1.2.3 The BangBox Test Series

The BangBox test provided the initial assessment of state-of-the-art technologies recommended by the TSC as candidates for use during field testing. These technologies highlighted supercritical fluid chromatography/mass spectrometry (SFC-MS), the carbon balance method for determining combustion product emission factors, micropolished stainless steel (SS) evacuated canisters and tanks for collecting air samples believed to contain volatile organic compounds, a sophisticated reflux-extraction process used to extract volatile organic compounds from the SS tanks/canisters, a high-volume sampling train to trap semivolatile organic compounds, and a fixed-wing aircraft (FWAC) package of real-time analyzers, samplers, and collectors.

1.2.3.1 Test Facility

1.2.3.1.1 The test facility selected to test the samplers, collectors, and real-time analyzers was an inflatable building located at Kirtland Air Force Base, Albuquerque, New Mexico. The facility is operated by the Sandia National Laboratories (SNL) and is known as the BangBox (BB). The flexible nature of the building permitted enclosed detonations of small quantities of explosives (227 g (0.5 lb)) and burns of small quantities of propellants (454 g (1.0 lb)) without violating

structural integrity and allowed any combustion products to be sampled for an extended period of time. Equipment used in the BB was that proposed by the TSC.

1.2.3.1.2 As a permanent fixed facility, the BB facilitated the accurate characterization of combustion products. Test personnel were able to calculate the BB volume and determine background levels of species targeted for individual subtests. Since its size was determined, it permitted precise comparison of the carbon-balance method to the more traditional cloud volume method in calculating emission factors.

1.2.3.1.3 The building was serviced with water and electricity. This permitted technicians to clean the test chamber and prevent cross-contamination between subtests, operate all collection and analytical equipment, and document events with high-speed motion picture cameras and video recorders.

1.2.3.2 Test Results

1.2.3.2.1 The highly satisfactory results of the test were published in a final report (reference 3). In addition to providing data on emission products, several important conclusions were drawn.

a. Those sampling, collecting, and analyzing systems selected for subsequent use are capable of providing complete and accurate data. The semivolatile organic sampling train could not be used for field testing because the throughput was much to low for the short duration of sampling the cloud.

b. Trace organic compounds can be accurately and consistently identified and quantified by the SFC-MS. This was confirmed by spiked samples submitted by the EPA's Atmospheric Research and Exposure Assessment Laboratory and analyzed by the chromatography laboratory.

c. The carbon-balance method performed better than the cloud volume method for calculating emission factors (EF) using samples of homogeneous and nonhomogeneous chamber air.

SECTION 2 SCOPE OF TEST

2.1 Overall Test Program (See Appendix K)

2.1.1 Purpose

Although the individual tests each had their own specific purpose and objectives, the broad overall program purpose is to supply waste characterization data for OB/OD permit applications under RCRA subpart X.

2.1.2 Objectives

2.1.2.1 Identify and validate sampling and analytical technology, instrumentation, and procedures needed to provide RCRA subpart X data characterization.

2.1.2.2 Identify and quantify emissions and residues produced by OB/OD thermal treatment methods.

2.1.2.3 Provide input for development and validation of an OB/OD dispersion model.

2.1.2.4 Identify specific items that can be treated by OB/OD thermal treatment methods without adverse environmental impact.

2.2 BangBox Test

2.2.1 Purpose

The OB/OD BB test series was designed to develop and verify the OB/OD thermal treatment method test methods and technology.

2.2.2 Objectives

2.2.2.1 Characterize the BB chamber volume, ventilation rate, and combustion product cloud homogeneity level.

2.2.2.2 Develop and improve proposed air sampling equipment and sample analysis procedures to be used in later phases on the FWAC, for sampling product clouds from large-scale follow-on outdoor OB/OD trials.

2.2.2.3 Refine, standardize, and compare supercritical-fluid chromatography (SFC) and gas chromatography (GC) techniques for extracting and analyzing resins, filters, and soils for trace quantities of semivolatile organic OB/OD combustion products and residues, using mass spectrometer (MS) detectors.

2.2.2.4 Verify adequacy of other standard analytical methods to be used for analyses of gases, particulates, volatile organic compounds, metals, and nonmetals.

2.2.2.5 Identify and quantify specific target analytes for TNT, a double-base propellant, and a composite propellant.

2.2.2.6 Assess polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) levels generated from burning the composite propellant containing high concentration of NH_4ClO_4.

2.2.2.7 Provide information on the morphology, composition, and size distributions of airborne particulate material generated by OB/OD operations in the BB.

2.2.2.8 Examine, using data produced under controlled conditions, the validity of the proposed Carbon Balance method of calculating emission factors; compare the results with those calculated using the more-conventional Cloud Volume times Concentration method.

2.2.2.9 Identify or develop appropriate program-specific QA/QC procedures.

2.2.2.10 Establish procedures for transport and storage of sample specimens.

2.2.3 Test Matrix

Table 2.1 BangBox Test Schedule

Subtest	Date Conducted
Homogeneity and chamber volume	1 Dec 88
Ventilation rate	5 Dec 88
Equipment and procedure selection	7 Dec 88
Single detonation - 1	31 Jan 89
Single detonation - 2	2 Feb 89
Single detonation - 3	6 Feb 89
Extended background sampling	7 Feb 89
Multiple detonation	8 Feb 89
Double-base propellant burn	9 Feb 89
Foam-attenuated detonation	13 Feb 89
Multiple-tank sampling	15 Feb 89
Composite propellant burn	16 Feb 89

2.3 Field Test Phase A

2.3.1 Purpose

Phase A was designed to be an operational readiness inspection (ORI) conducted under conditions expected during further testing, to verify the field suitability of instruments and procedures selected pursuant to the BangBox test.

2.3.2 Objectives

2.3.2.1 Evaluate the performance of the instrumented FWAC as a sampling platform during large-scale field OB/OD tests.

2.3.2.2 Determine if target species can be adequately sampled and measured above background levels.

2.3.2.3 Evaluate the utility of the carbon-balance method in the field testing environment.

2.3.2.4 Evaluate soil sampling, handling, and assay procedures (e.g. SFC-MS) for field OB/OD tests.

2.3.3 Test Matrix

Table 2.2 Field Test Phase A Test Matrix.

Date (mo-day-yr)	Trial Number[a]	OB or OD Time (MDT)	Amount Fuel (kg-lb)	Length Burn (s)	Comment
06-13-89	M30-OB-O-P1	13:23:00	1424-3140	19	No primer used
	M30-OB-O-P2	15:44:40	1597-3520	17	
06-14-89	M30-OB-1-P1	10:07:19	3144-6980	21	1.4 kg (3.0 lb) M3A1 propellant used as primer
	M30-OB-1-P2	10:20:58	3193-7040	20	
06-20-89	TNT-ODS-O-A	14:28:46	921-2030	NA[b]	Bulk 32-kg (70-lb) blocks
	TNT-ODS-O-B	14:55:24			
06-21-89	TNT-ODS-1-V	09:58:52	898-1980		Flake material
	TNT-ODS-1-II	10:12:12			
	TNT-ODS-1-III	10:22:42			
	TNT-ODS-1-IV	10:43:46			
	TNT-ODS-1-I	10:54:18			

[a]Abbreviations used within trial number:
Group 1 Fuel used.
M30 - Triple-base propellant.
TNT - 2,4,6-trinitrotoluene.
Group 2 Type of trial.
OB - Open burning.
ODS - Open detonation - surface.
Group 3 Trial number.
O - Operational readiness inspection.
1 - Trial number.
Group 4 Site number.
P1, P2 - Burn site number.
A, B, I, II, etc - Detonation site number.
[b]NA - not applicable.

2.4 Field Test Phase B

2.4.1 Purpose

Field Test Phase B was conducted to confirm selections of instruments and procedures made as a result of Phase A, and to determine if there is a relationship between the BB test data and the field test data.

2.4.2 Objectives

2.4.2.1 Sample and analyze the combustion products of large-scale OB/OD operations which were conducted in a manner representing treatment site practices.

2.4.2.2 Sample and analyze the combustion products of large-scale OB/OD operations which were conducted from suspended detonations.

2.4.2.3 Determine if the field test detonation data can be related to the BB test detonation data.

2.4.2.4 Provide the foundation for establishing a database on TNT and selected propellant combustion products.

2.4.3 Test Matrix

Table 2.3 Field Test Phase B Test Matrix.

Date (mo-day-yr)	Trial Number[a]	OB or OD Time (MDT)	Amount Fuel (kg-lb)	Length Burn (s)	Comment[b]
10-16-89	TNT-ODS-O-1	14:44:00	904-1998	NA[c]	1.8 kg (4.0 lb) of TNT used as primer.
10-17-89	TNT-ODS-1-4	12:41:32			
	TNT-ODS-1-6	12:55:36			
	TNT-ODS-1-2	13:13:04			
10-18-89	TNT-ODS-2-5	11:56:00			
	TNT-ODS-2-3	12:13:00			
	TNT-ODS-2-7	12:28:50			
10-19-89	BMR-OB-0-P1	14:03:27	3017-6652	173	ABL casting powder used as primer.
10-25-89	BMR-OB-1-P1	09:26:00	2993-6598	180	Smokeless powder used as primer.
	BMR-OB-1-P2	09:37:00	3000-6614	240	
	TNT-ODA-O-0	11:13:00	907-2000	NA	1.8 kg (4.0 lb) of TNT used as primer.
10-31-89	TNT-ODA-1-3	10:48:58	909-2004		
	TNT-ODA-1-5	11:02:00			
	TNT-ODA-1-1	11:17:00			
	TNT-ODA-2-4	14:55:00			
	TNT-ODA-2-2	15:09:00			
	TNT-ODA-2-6	15:23:00			

[a]Abbreviation used within trial number:

Group 1 Fuel used.
- TNT - 2,4,6-Trinitrotoluene.
- BMR - Propellant manufacturing residue.

Group 2 Type of trial.
- ODS - Open detonation - surface.
- OB - Open burning.
- ODA - Open detonation - suspended.

Group3 Trial number.
- O - Operational readiness inspection.
- 1, 2 - Trial number.

Group 4 Site number.
- P1, P2 - Burn site number.
- 0,1,etc - Detonation site number.

[b]Primer in addition to fuel amount.

[c]NA - not applicable.

2.5 Field Test Phase C

2.5.1 Purpose

Field Test Phase C was conducted to supplement the developing database on TNT and selected propellant combustion products, and to include additional explosives and propellants in the test program.

2.5.2 Objectives

2.5.2.1 Conduct additional TNT detonations to facilitate relating BB test results to field test results.

2.5.2.2 Conduct additional TNT test to establish the reproducibility (between test precision) of TNT OD emissions.

2.5.2.3 Sample and analyze the explosive decomposition products of composition B (comp B) explosive.

2.5.2.4 Sample and analyze the explosive decomposition products of explosive D.

2.5.2.5 Sample and analyze the explosive decomposition products of RDX explosive.

2.5.2.6 Sample and analyze the combustion products of M1 and M6 single-base propellants.

2.5.2.7 Sample and analyze the combustion products of propellant manufacturing residue.

2.5.3 Test Matrix

Table 2.4a Field Test Phase C Test Matrix.

Date (mo-day-yr)	Trial Number[a]	OB or OD Time (MDT)	Amount Fuel (kg-lb)	Length Burn (s)	Comment[b]
08-07-90	TNT-ODS-1-C5	11:41:00	900-1984	NA[c]	1.8 kg (4.0 lb) TNT as primer.
08-08-90	EXD-ODS-O-A0	10:05:53	839-1850		9.1 kg (20 lb) of C4 used as primer.
	TNT-ODS-O-SB	11:36:12	680-1500		1.8 kg (4.0 lb) TNT as primer.
08-09-90	TNT-ODA-1-OA	09:14:21	895-1974		
	TNT-ODA-1-OC	09:26:57			
	TNT-ODA-1-OB	09:41:55			
	TNT-ODS-1-C1	12:53:56	900-1984		
	TNT-ODS-1-C3	13:12:53			
	TNT-ODS-1-CO	15:38:00			
08-13-90	TNT-ODS-2-C6	11:07:53	895-1974		
	TNT-ODS-2-C4	11:24:10			
	TNT-ODS-2-C2	11:35:18			
08-14-90	BMR-OB-1-P1	09:42:30	2253-4968	66	0.23 kg (0.5 lb) Unique[e] powder as primer.
	BMR-OB-1-P2	09:54:55	2184-4814	63	
	EXD-ODS-1-A6	12:28:30	916-2020	NA	9.1 kg (20 lb) of C4 used as primer.
	EXD-ODS-1-A2	12:41:55			
	EXD-ODS-1-A4	12:54:30			

[a]Abbreviations used within trial number:

Group 1 Fuel used.
- TNT - 2,4,6-Trinitrotoluene.
- EXD - Explosive D.
- BMR - Propellant manufacturing residue.

Group 2 Type of trial.
- ODS - Open detonation - surface.
- ODA - Open detonation - suspended.
- OB - Open burning.

Group 3 Trial number.
- O - Operation readiness inspection.
- 1, 2 - Trial number.

Group 4 Site number.
- C5,A0,etc - Detonation site number.
- P1, P2 - Burn site number.

[b]Primer amount in addition to fuel amount.

[c]NA - not applicable.

Table 2.4b Field Test Phase C Test Matrix.

Date (mo-day-yr)	Trial Number[a]	OB or OD Time (MDT)	Amount Fuel (kg-lb)	Length Burn (s)	Comment[b]
08-15-90	BMR-OB-2-P1	08:31:04	2218-4890	67	0.23 kg (0.5 lb) Unique® powder + 1.35 kg (3.0 lb) M2 propellant primers/P1 and P2.
	BMR-OB-2-P2	08:47:57	2218-4890	68	
	EXD-ODS-2-A1	10:52:00	916-2020	NA[c]	9.1 kg (20 lb) C4 as primer.
	EXD-ODS-2-A5	11:03:35			
	EXD-ODS-2-A3	11:24:28			
08-16-90	RDX-ODS-1-D1	09:17:45	871-1920		1.8 kg (4 lb) TNT primer.
	RDX-ODS-1-D5	09:32:55	875-1930		2.27 kg (5.0 lb) C4 primer.
	RDX-ODS-1-D3	09:46:10	880-1940		
	RDX-ODS-2-D6	13:06:35			
	RDX-ODS-2-D2	13:20:45	899-1982		
	RDX-ODS-2-D4	13:42:10	880-1940		
08-27-90	CMB-ODS-1-B1	13:19:20	907-2000		
	CMB-ODS-1-B5	13:35:30			
	BM6-OB-1-P1	15:17:25	3184-7020	ND[d]	1.35 kg (3.0 lb) M1 propellant primer
	BM6-OB-1-P2	15:26:40		17	
	BM6-OB-1-P3	15:38:00		12	
08-28-90	BM6-OB-2-P1	12:04:20		12	
	BM6-OB-2-P2	12:15:20		13	
	BM6-OB-2-P3	12:25:35		13	

[a]Abbreviations used within trial number:

Group 1 Fuel used.
- BMR - Propellant manufacturing residue.
- EXD - Explosive D.
- RDX - 1,3,5-trinitrohexahydro-1,3,5-triazine.
- CMB - Composition B.
- BM6 - M6 propellant.

Group 2 Type of trial.
- OB - Open burning.
- ODS - Open detonation - surface.

Group 3 Trial number.
- 1, 2 - Trial number.

Group 4 Site number.
- P1, P2 - Burn site number.
- A1,A5,etc - Detonation site number.

[b]Primer amount in addition to fuel amount.
[c]NA - not applicable.
[d]ND - no data.

Table 2.4c OB/OD Phase C Test Matrix.

Date (mo-day-yr)	Trail Number[a]	OB or OD Time (MDT)	Amount Fuel (kg-lb)	Length Burn (s)	Comment[b]
08-29-90	BM6-OB-3-P1	09:32:00	3184-7020	18	1.35 kg (3.0 lb) M1 propellant as primer.
	BM6-OB-3-P2	09:44:00		17	
	BM6-OB-3-P3	09:58:00		21	
08-30-90	BM6-OB-4-P1	10:32:30	3320-7320	14	1.35 kg (3.0 lb) M1 propellant as primer.
	BM6-OB-4-P2	10:48:10		12	
	BM6-OB-4-P3	11:01:20		12	
09-05-90	BM1-OB-1-P2	11:38:15	3159-6965	17	0.23 kg (0.5 lb) of Unique[a] powder as primer.
	BM1-OB-1-P1	11:52:25		16	
	BM1-OB-1-P3	12:03:50		16	
09-06-90	BM1-OB-2-P1	12:14:00		19	
	BM1-OB-2-P2	12:28:01		17	
	BM1-OB-2-P3	12:40:00		16	
09-18-90	CMB-ODS-1-B0	10:46:05	907-2000	NA[c]	2.27 kg (5.0 lb) C4 as primer.
	CMB-ODS-1-B3	11:04:00	916-2020		
	CMB-ODS-1-D0	11:18:30	907-2000		
	CMB-ODS-2-B6	15:17:50			
	CMB-ODS-2-B2	15:31:05			
	CMB-ODS-2-B4	15:46:20			

[a]Abbreviations used within trial number:

Group 1 Fuel used.
- BM6 - M6 propellant.
- BM1 - M1 propellant.
- CMB - Composition B.

Group 2 Type of trial.
- OB - Open burning.
- ODS - Open detonation - surface.

Group 3 Trial number.
- 1,2,3,4 - Trial number.

Group 4 Site number.
- P1,P2,P3 - Burn site number.
- B0,B3,etc - Detonation site number.

[b]Primer amount in addition to fuel amount.
[c]NA - not applicable.

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SECTION 3. SPECIFICATIONS

3.1 Description of Facilities/Site

3.1.1 BangBox

The BB consists of two major segments: a test chamber and an airlock (Fig. 3.1). The test chamber is a 16-meter diameter hemisphere constructed of plastic-coated nylon fabric, which is supported on a concrete pad by blower-injected air. The chamber volume is maintained at approximately 927 m^3 by adjusting a damper through which air is provided by the blower. The airlock is constructed of wood and is connected directly to the chamber. Passage to the chamber is through a power-operated garage door, which is closed during testing. Airlock doors to the outside atmosphere are airtight, so that chamber pressure can be maintained when the airlock access door is open. Both the airlock and the chamber have electric service, and the chamber has water connections. Figures 3.2 and 3.3 schematically show test chamber and airlock instrumentation, respectively.

3.1.2 DPG Test Grids

DPG was selected for the test location as a result of its available manpower experience in OB/OD operations, the availability of Michael Army Air Field (MAAF) as a staging area for instrumented aircraft, and the availability of munitions at nearby TEAD. DPG is located in the Great Basin, 129 km (80 mi) southwest of Salt Lake City at an altitude of about 1325 m (4347 ft) above mean sea level. The terrain is similar to that encountered in much of the Great Basin region of the western United States, with large expanses of relatively flat terrain interrupted by occasional rugged mountainous regions. The only conspicuous terrain feature in the immediate vicinity of the test grid (Fig. 3.4) is a mountainous area to the northwest, known as Granite Peak.

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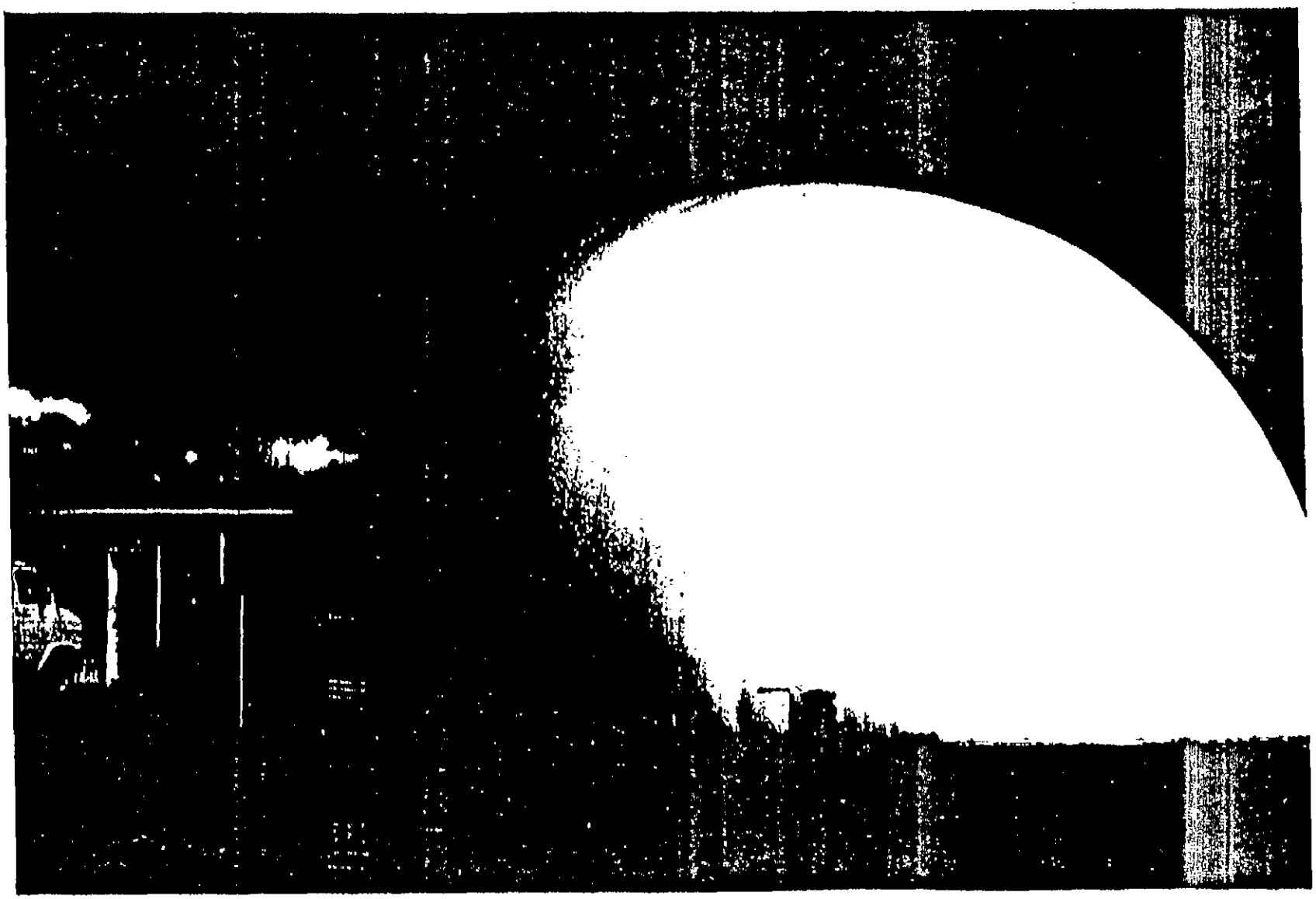


Figure 3.1 SNL BangBox Test Facility Containing Sampling and Real-Time Analysis Equipment.

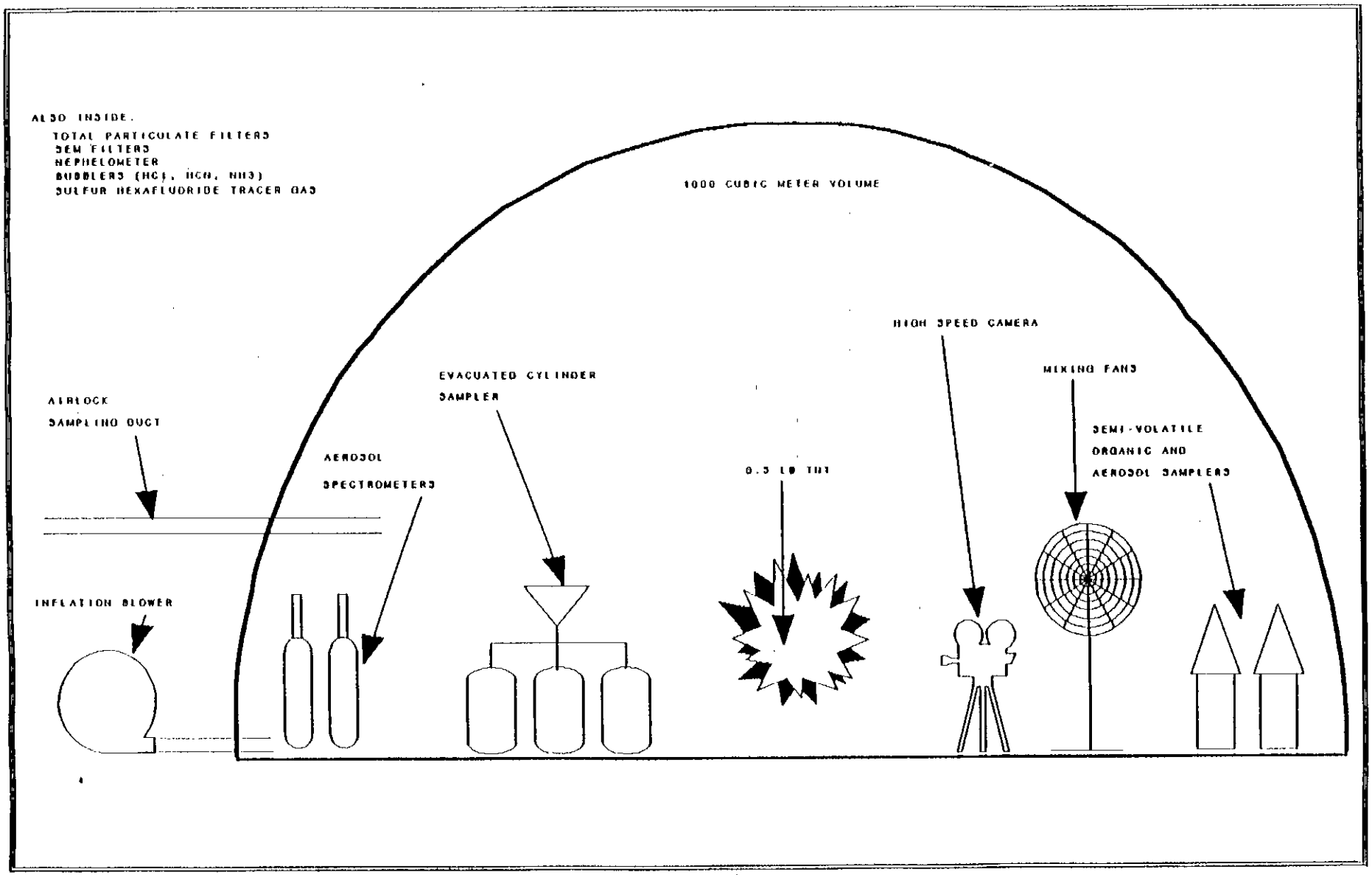


Figure 3.2 SNL BangBox Interior OB/OD Sampling Instrumentation and Equipment.

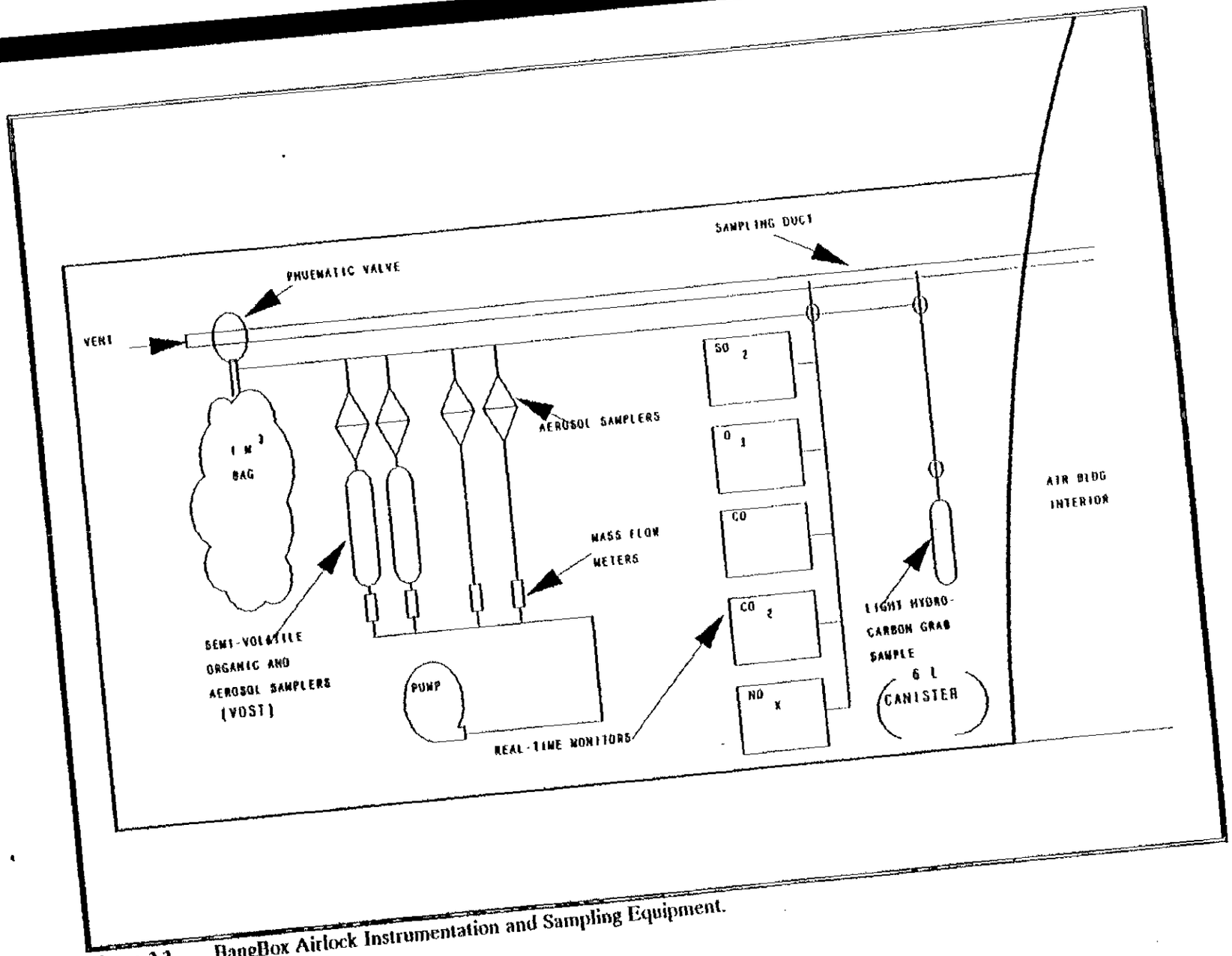


Figure 3.3 BangBox Airlock Instrumentation and Sampling Equipment.

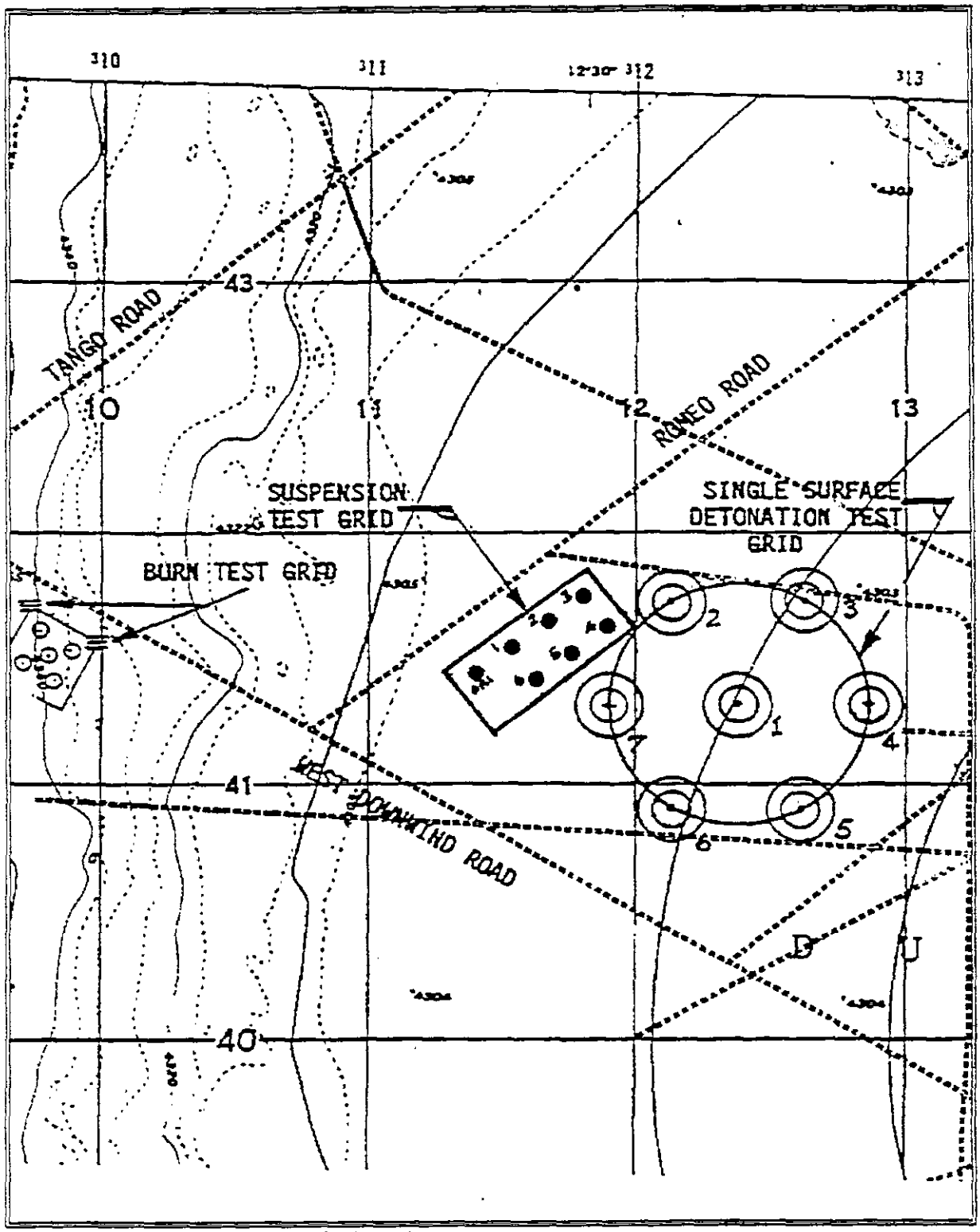


Figure 3.4 OB/OD Test Grid Location.

3.1.2.1 Field Test Phase A

The test grid for the triple-base propellant burn was located in an area southwest of the intersections of Tango Road and Romeo Road with West Downwind Road. The TNT detonations were located east of the intersection of Romeo Road and West Downwind Road. This is approximately 15 km (9 mi) from MAAF. The grid was 300 m^2 (3228 ft^2) with sampler positions for TNT located at coordinate points located 50 m (164 ft) apart. Surface soil was sampled at each fallout sampler pan location (Fig. 3.5). The detonation points and burn sites are shown in Figure 3.4.

3.1.2.2 Field Test Phase B

The test grid, with areas designated for the surface detonations, suspended detonations, and propellant burns is shown in Figure 3.4.

3.1.2.2.1 The location relationship of the seven single TNT surface detonation sites is shown in Figure 3.6. Two pretest core samples were taken within 1 m (3.3 ft) of each other to a depth of 2.1 m (7 ft) at the center of each of the seven detonation sites. The layout of the 1 m^2 (10.8 ft^2) fallout pan samples at each of these sites is shown in Figure 3.7. The sampling on the 150 and 200 m (492 and 656 ft) sampling rings was deleted after the ORI test, because quantities of fallout material too small to be useful were collected at these distances during the ORI. However, sampling on the 150- and 200-meter rings was reinstituted in phase C because the concentrations of pollutants in the more distant rings were higher, even though the quantities of fallout were smaller than for the rings at 50 and 100 meters.

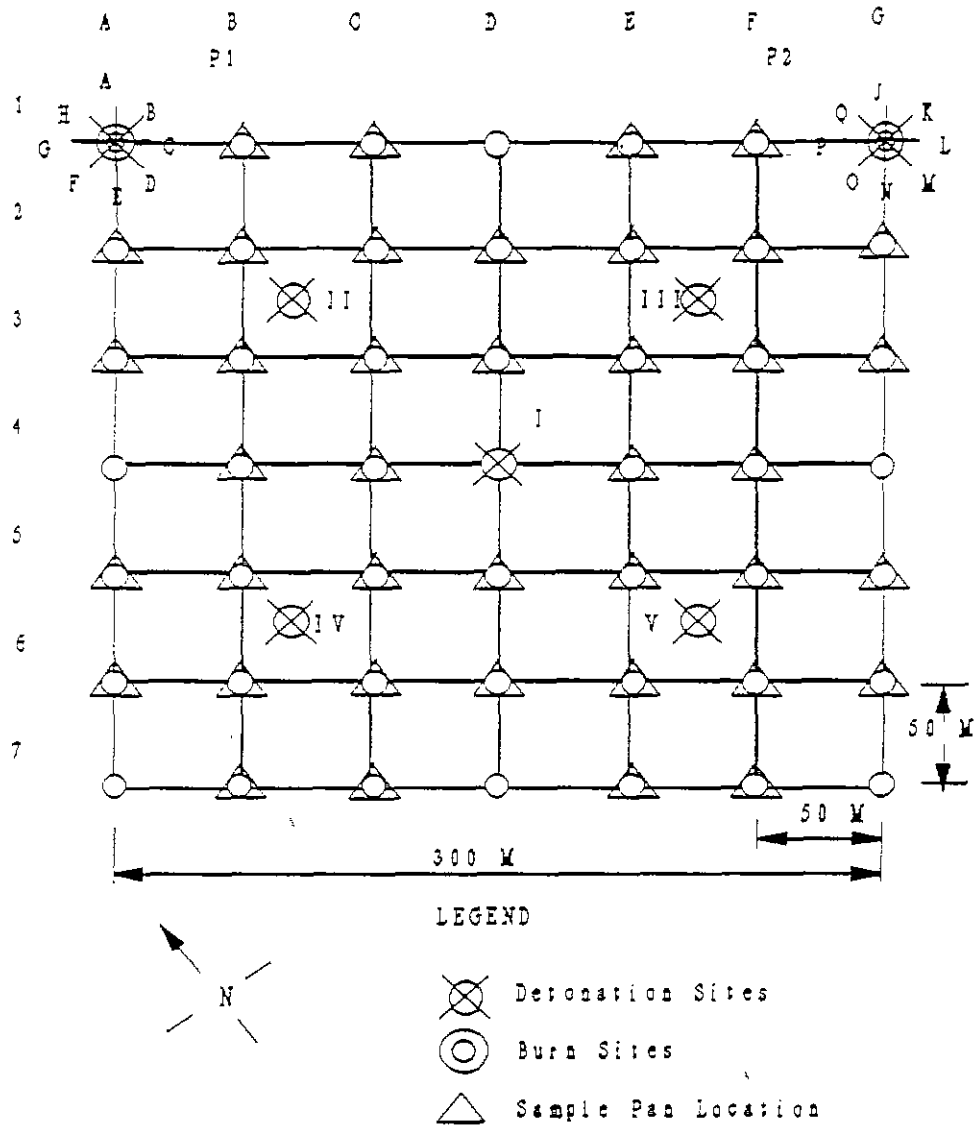


Figure 3.5 OB/OD Phase A Soil and Fallout Sampling Location.

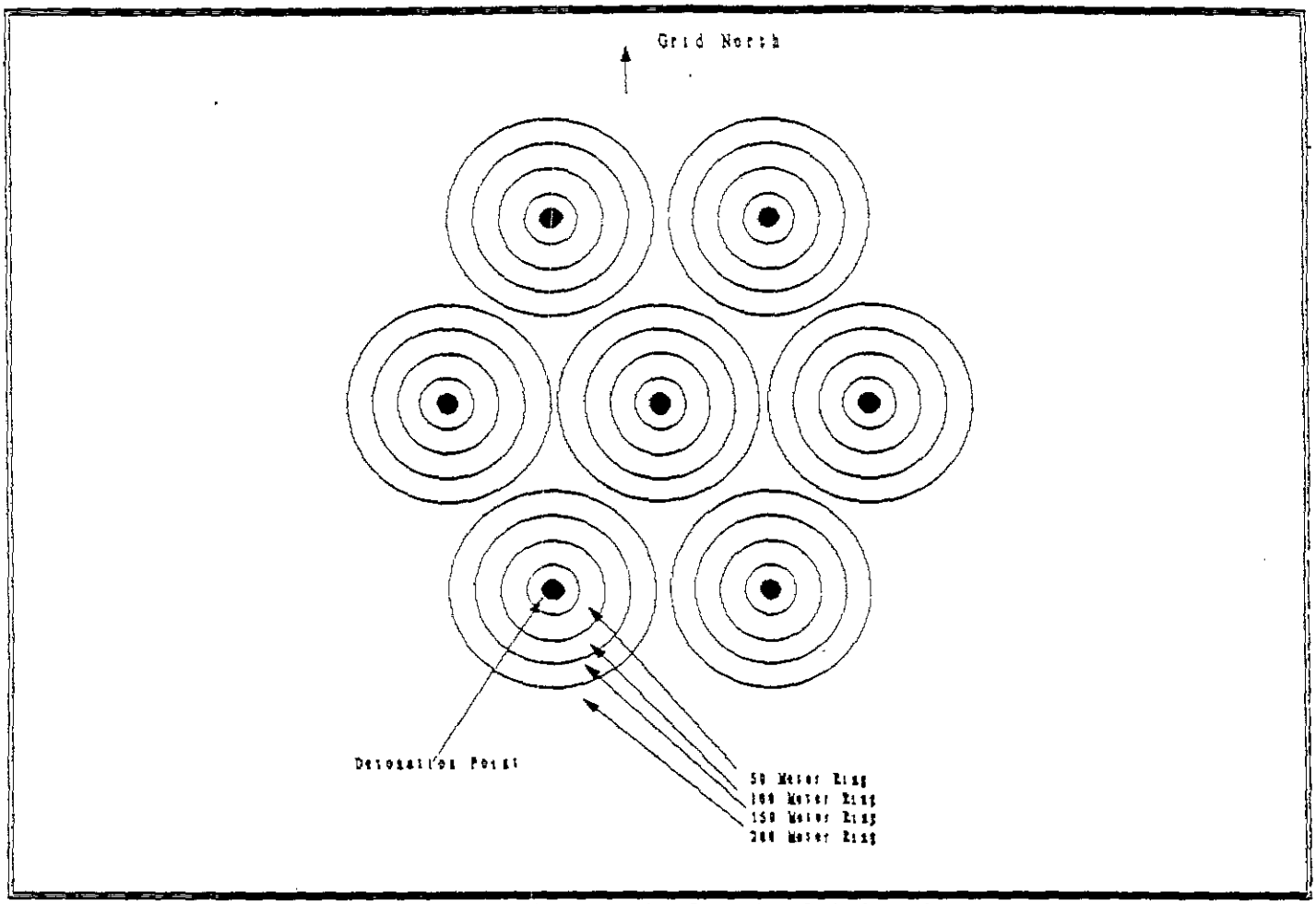


Figure 3.6 OB/OD Phase B Surface TNT Detonation Location Relationships.

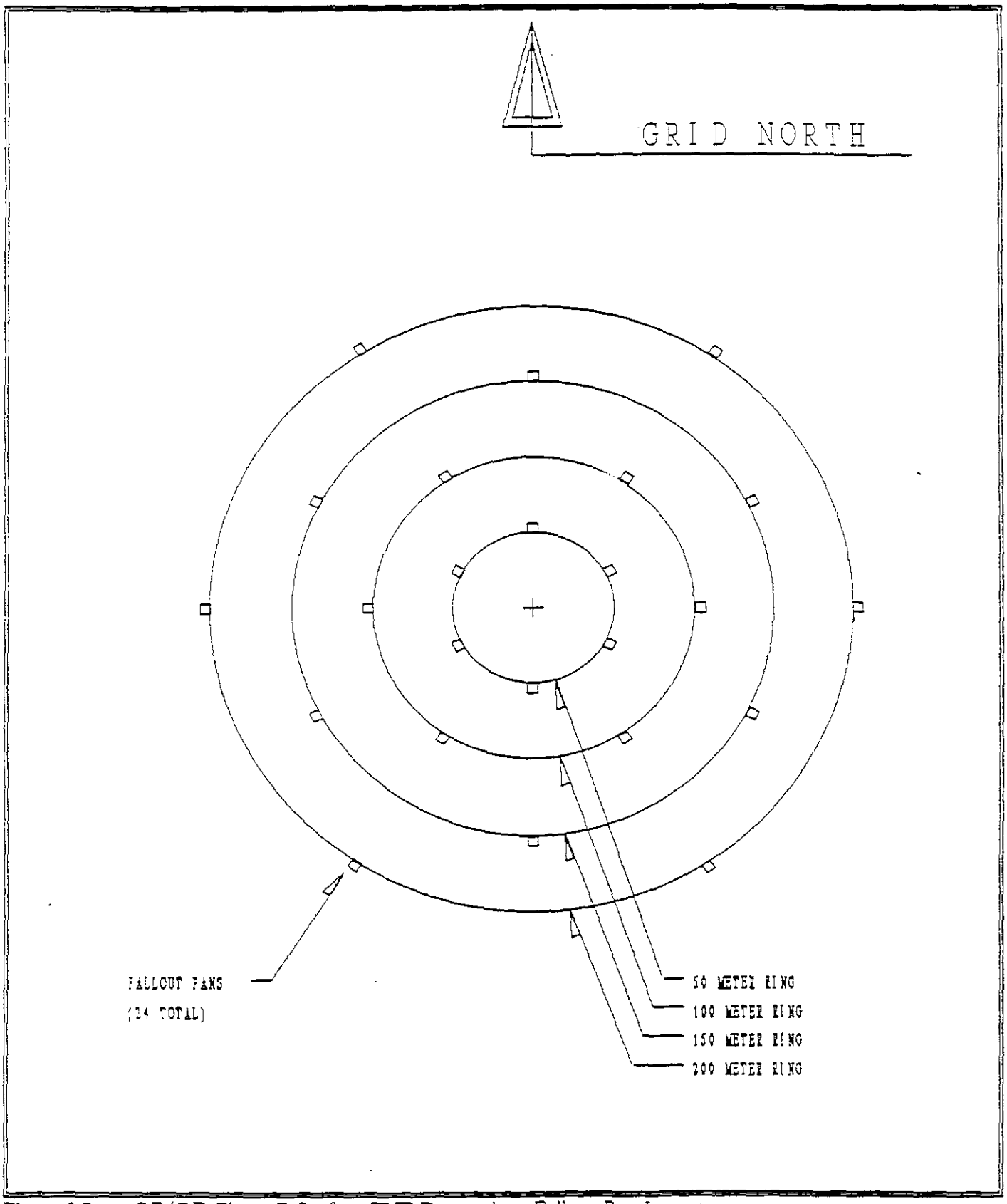


Figure 3.7 OB/OD Phase B Surface TNT Detonations Fallout Pan Layout.

3.1.2.2.2 Posttest samples of the crater and ejecta were taken as follows:

a. Center of the crater (one sample).

b. Three meters (9.8 ft) from the center of the crater on four diagonal lines established at 45-degree intervals from grid north (four samples).

c. One meter (3.3 ft) from the rim of the crater on the diagonal lines (four samples).

d. Four meters (13.1 ft) from the rim of the crater on the diagonal lines (four samples).

3.1.2.2.3 The sites for the seven single TNT suspended detonations are shown in Figure 3.4. The locations of the pretest and posttest sampling for a typical site are shown in Figure 3.8. This figure also shows the suspension pole locations. The 907 kg (2000 lb) of TNT was suspended approximately 12 meters (40 ft) above the ground, centered between the two poles.

3.1.2.2.4 The locations at a burn site of the 1 m^2 sputter pans and fallout pan samples are shown in Figure 3.9. Three burn pans were located at each site, each pan 1.2-m (4-ft) wide by 11-m (36-ft) long, and 0.3-m (1-ft) deep. All three pans of propellant at each site were ignited simultaneously.

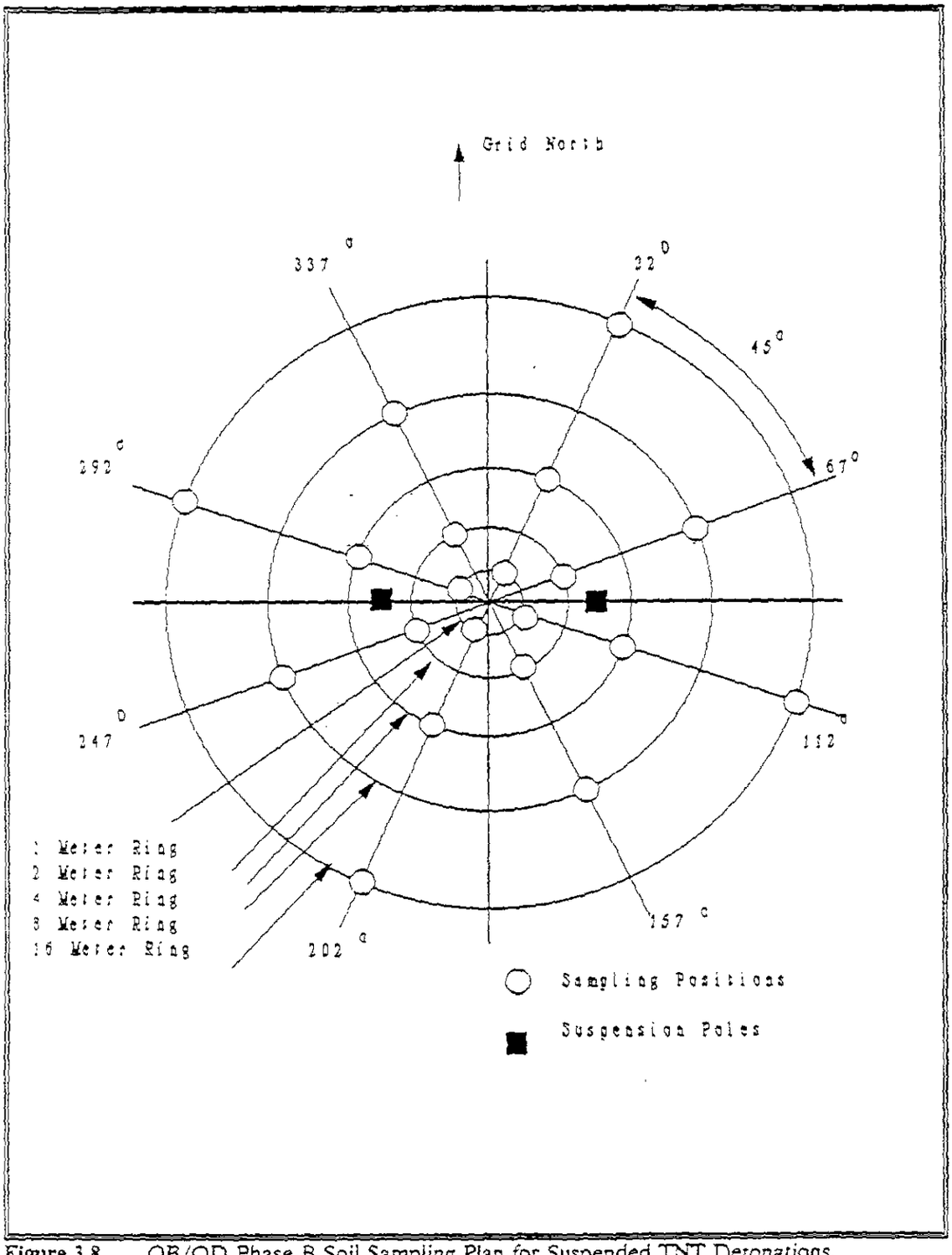


Figure 3.8 OB/OD Phase B Soil Sampling Plan for Suspended TNT Detonations.

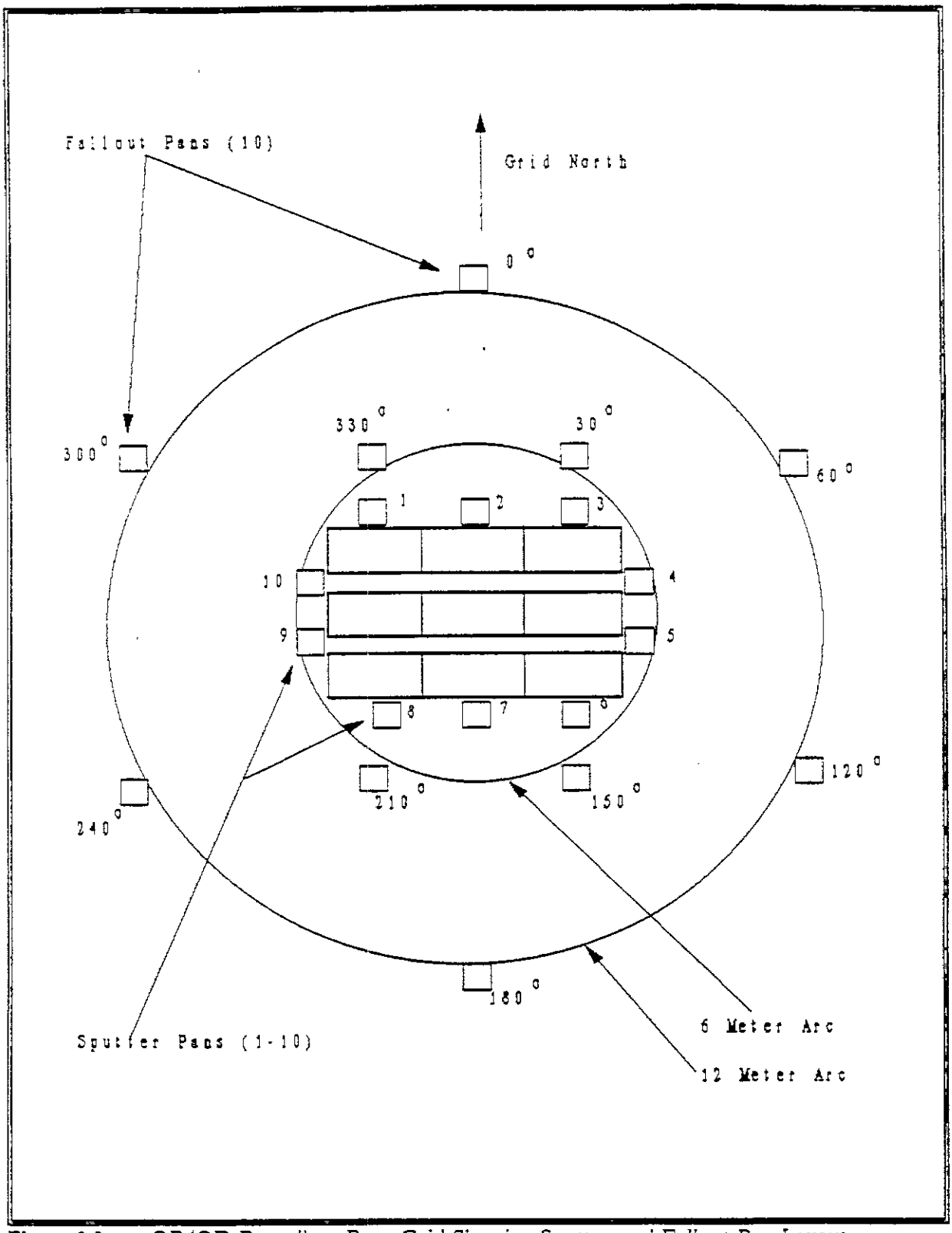


Figure 3.9 OB/OD Propellant Burn Grid Showing Sputter and Fallout Pan Layout.

3.1.2.3 Field Test Phase C.

The test grids for the Phase C trials are shown in Figure 3.10. Surface explosive detonation sites A, B, C, and D were used, respectively, for explosive D, composition B, TNT, and RDX. Only TNT was used at the suspended (aerial) detonation site (Fig 3.10).

3.1.2.3.1 The seven single detonation sites which are in a surface explosive detonation site are shown in Figure 3.11. The fallout pan sampler layout for one of these sites is shown in Figure 3.12.

a. Pretest samples were taken to a depth of 15 cm (6 in), using a 5-cm diameter (2-in) core sampler, as follows:

(1) Four samples were taken 1 meter (3.3 ft) from grid center at 0, 90, 180, and 270 degrees.

(2) Four samples were taken 3 meters (9.8 ft) from grid center at 45, 135, 225, and 315 degrees.

(3) The posttest ejecta sampling of material inside the crater and immediately adjacent to it was taken to a depth where undisturbed soil was encountered.

b. The samples were taken at locations:

(1) Three meters (9.8 ft) from the lowest visible point of the crater at 0, 90, 180, and 270 degrees from grid north.

(2) One meter (3.3 ft) from the rim of the crater at 45, 135, 225, and 315 degrees from grid north.

3.1.2.3.2 The suspended explosive detonations, were in the area shown in Figure 3.10. Three detonations were made, each suspended 12 meters (40 ft) above the ground. No sampling of fallout was planned.

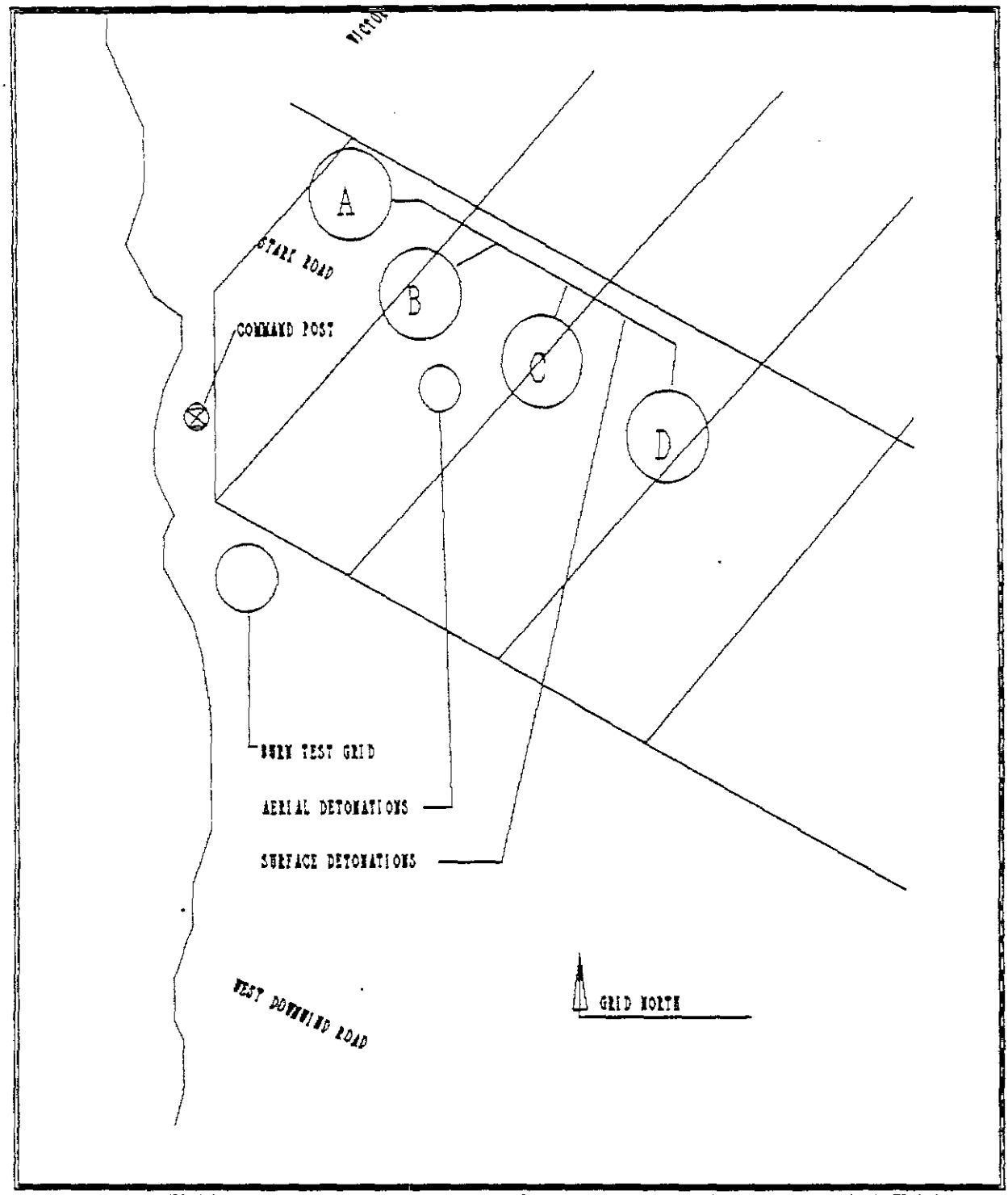


Figure 3.10 Field Test Phase C Locations of Surface Detonations, Suspended Trials, and Propellant Burns.

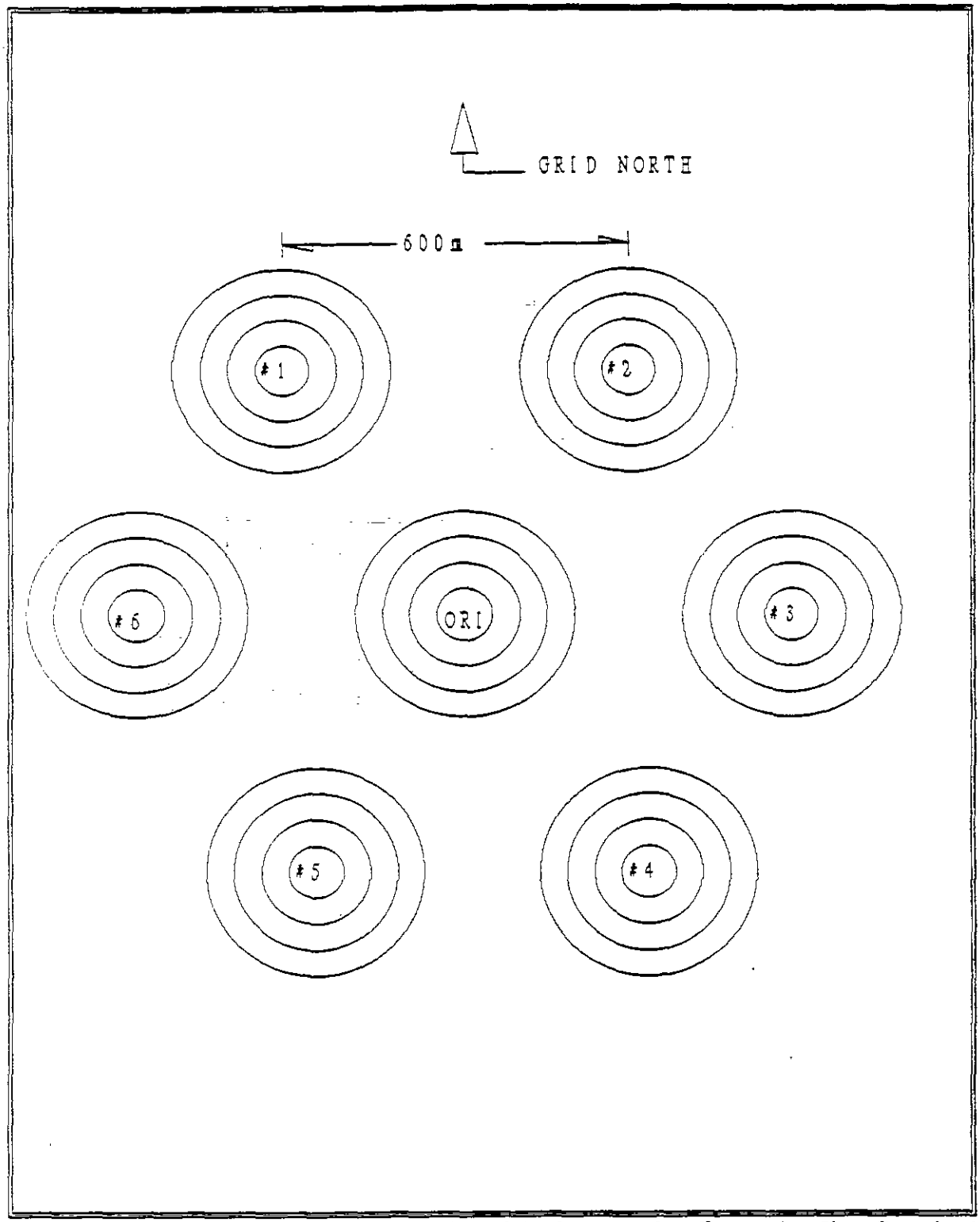


Figure 3.11 Field Test Phase C Relationship of the Seven Surface Detonation Sites Contained in Sites A, B, C, and D of Fig. 3.10.

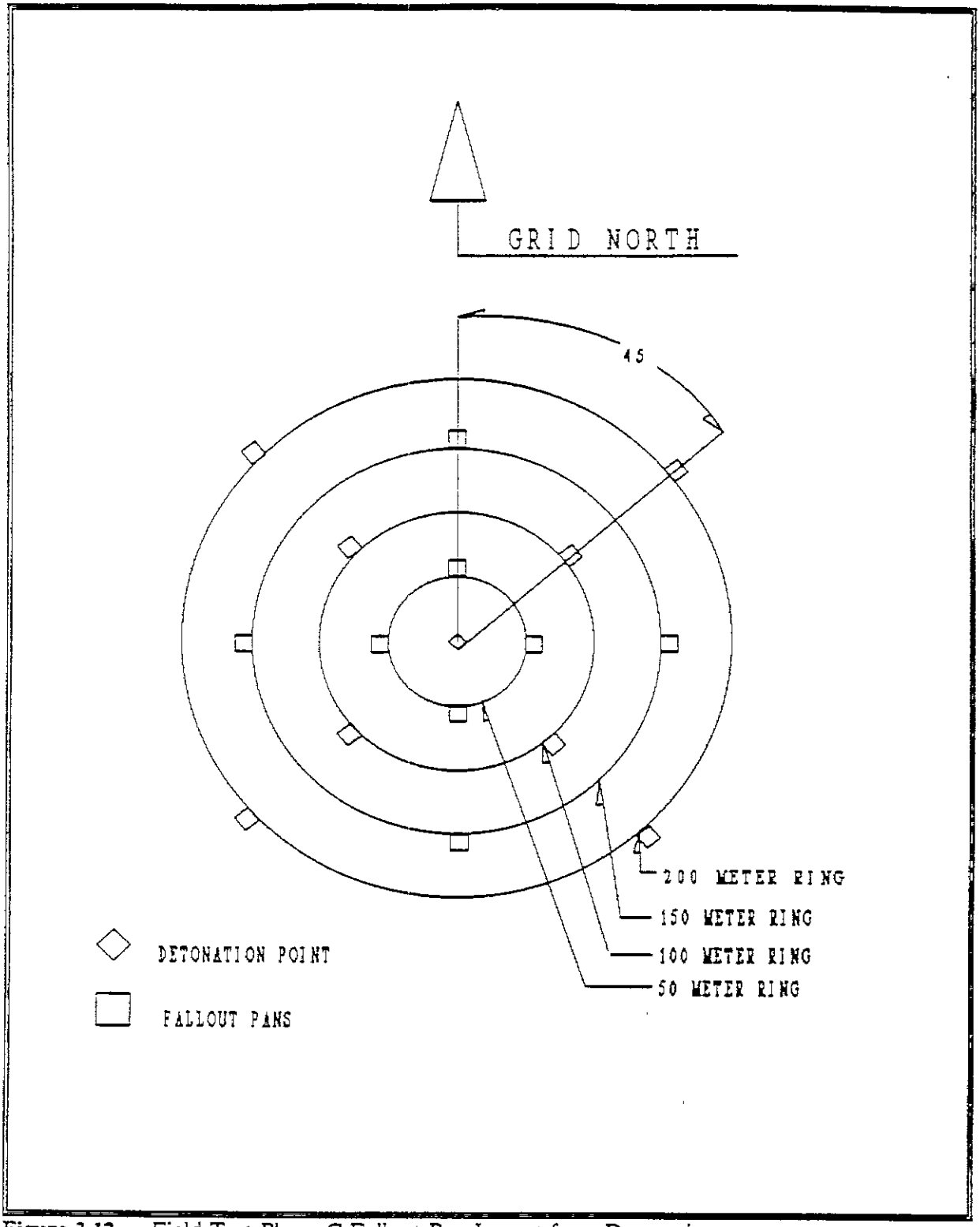


Figure 3.12 Field Test Phase C Fallout Pan Layout for a Detonation.

3.1.2.3.3 The burn test grid area along West Downwind Road had three burn sites, each configured for sampling as shown in Figure 3.9.

3.1.3 Sampling Platform - FWAC

3.1.3.1 Aircraft System Description

The aircraft, instrumented and operated by SNL during this test series, was a Boeing Canada, de Havilland Division, DHC-6 series 300 (Twin Otter) as shown in Fig.3.13. The Twin Otter is a twin-turboprop short take-off and landing, 20-passenger transport aircraft. Maximum take-off weight is 5,670 kg (12,500 lb) and maximum equipment payload, including technical crew, is approximately 1,000 kg (2205 lb). The aircraft has been modified with fastening points to accommodate exterior-mounted instrument packages under both wings and the fuselage. The aircraft is flown with DC-to-AC power inverters onboard, so that conventional instrumentation requiring 115-VAC power can be easily accommodated. Instrumentation is normally carried in up to five standard racks arranged along one side of the aircraft. During the Phase B and C tests, the aircraft was equipped with a "forward-looking" video camera, so that the detonation or burn test and the resulting cloud formation could be recorded during flight. The aircraft accommodates up to five technical-crew members, in addition to a full load of instrumentation and two flight-crew members. A complete description of the various sampling and analysis systems is given below.

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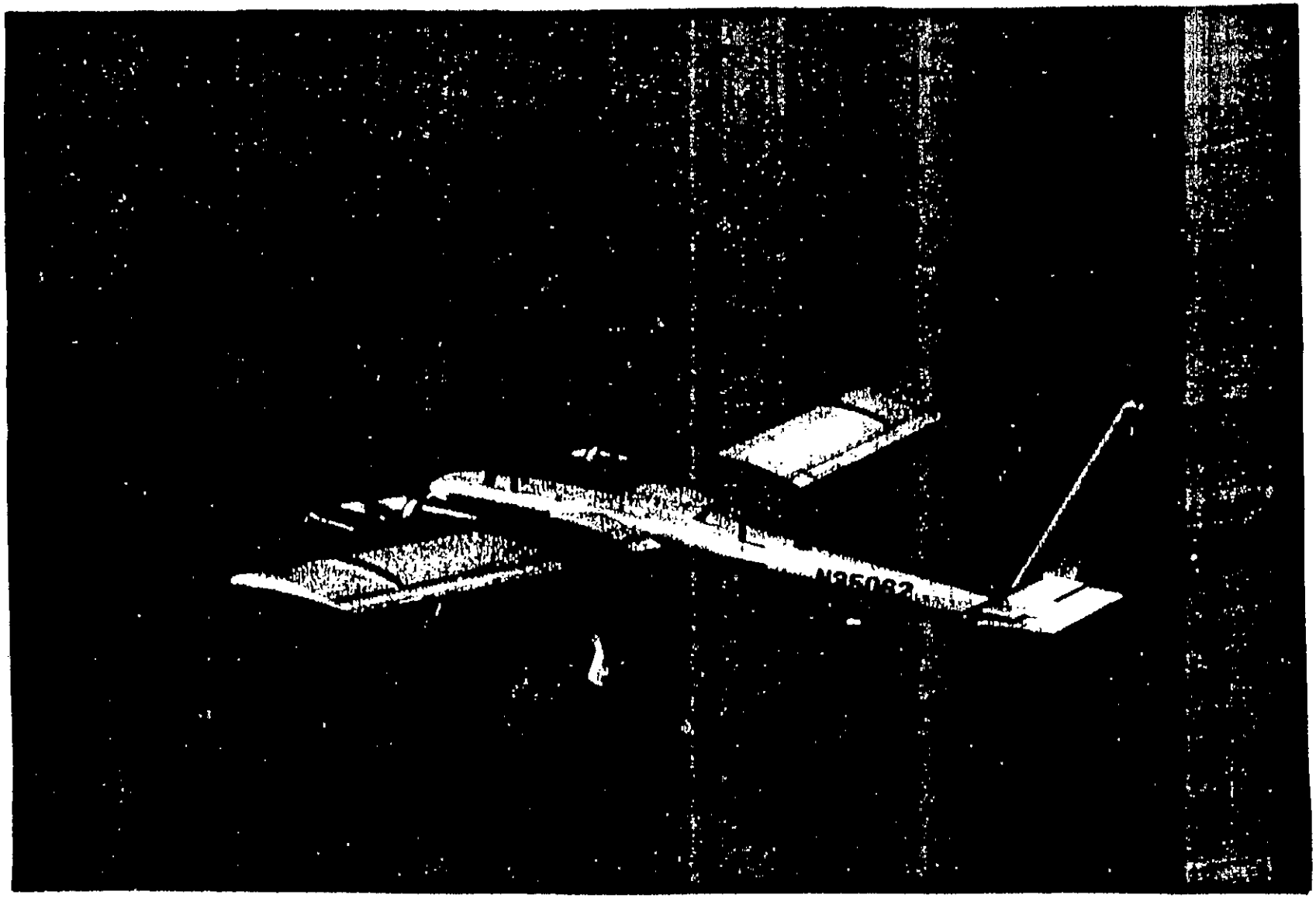


Figure 3.13 SNL Twin Otter Instrumented Fixed-Wing Aircraft for Open-Air OB/OD Sampling and Real-Time Gas Analysis.

3.1.3.2 Aircraft Gas and Aerosol Sampling Probe

The aircraft was equipped with an exterior-mounted inlet sampling probe for collection of both gas and particle samples. The sampling and transport system is shown schematically in Figure 3.14. The probe system was designed to provide a continuous flow of exterior air to the analytical instruments in the aircraft cabin. In addition to supplying the various continuous monitoring instruments, the tube is used to supply input to other sampling systems, such as evacuated canisters, sampling bags, and filter ports. The sampling system consists of five main components: (1) the external probe, (2) the transport tube, (3) the sampling valve, (4) the filter sampling section, and (5) a grab sampling bag. In addition, a transition section joins the probe and transport tube and provides a gradual transition between the different tube diameters of these two components. The sampling probe is an aluminum tube with an 8-cm (3-in) outside diameter and 0.3-mm (1/8-in) walls, that extends outside the aircraft boundary layer at a position forward and above the copilot windshield. A pair of long radius bends are included in the probe section to bring it through the roof of the aircraft and into the passenger cabin, so that particle deposition losses are minimized during air transport through the tube.

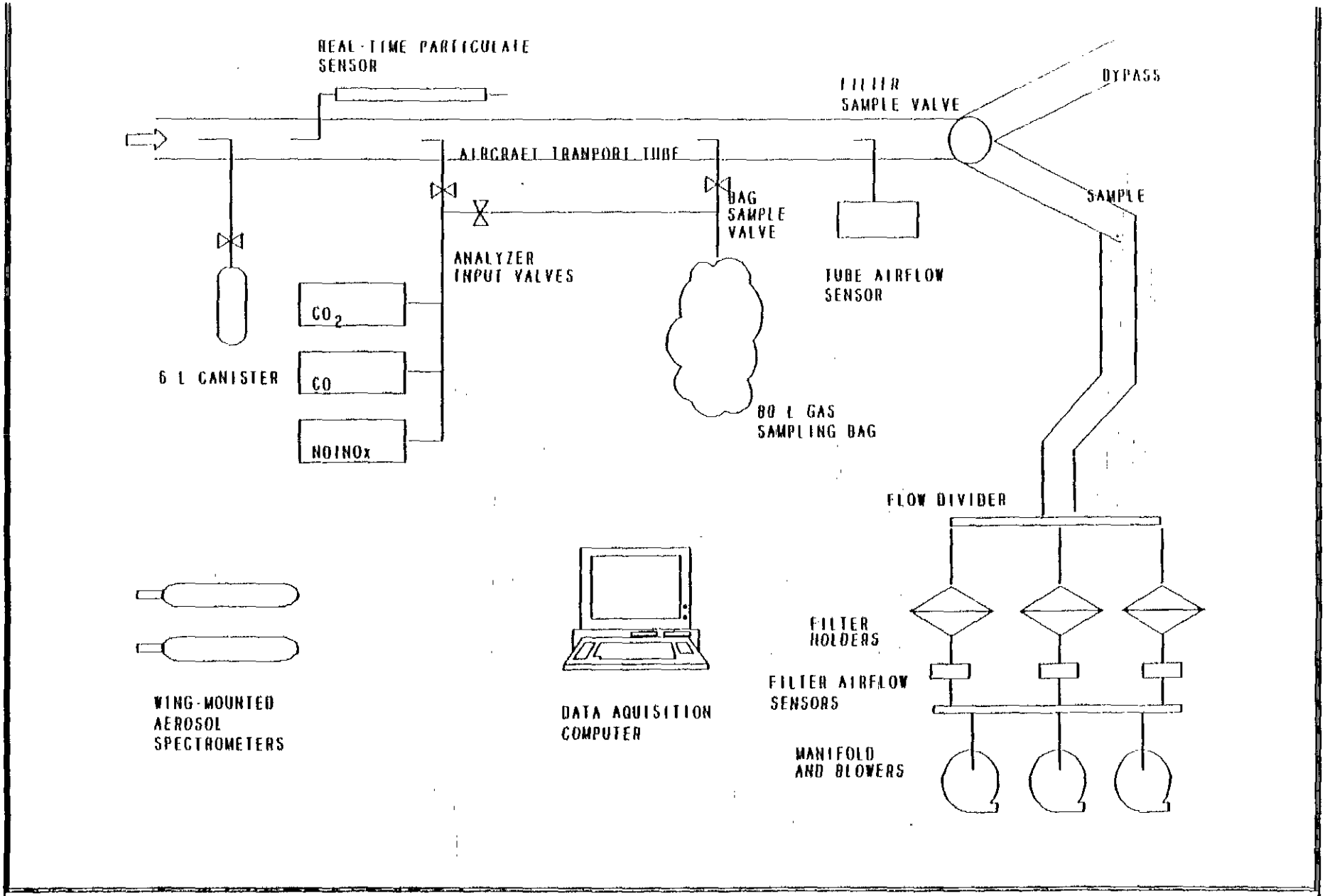


Figure 3.14 Schematic Diagram of Sampling Aircraft Instrumentation.

3.1.3.3 Aircraft Gas and Aerosol Transport Tube

The transport tube, also aluminum, has a 10-cm (4-in) outside diameter and 0.3-mm (1/8-in) walls. It consists of two end-jointed straight sections, each approximately 1.7-m (5.6-ft) long, a total length of 11.2 feet, that terminate in a long-radius 30-degree bend. The straight sections carry the sample flow through the cabin, and the bend leads through the rear cabin bulkhead into the baggage compartment which contains the sampling valve and filter units. The probe, transition, and transport tube sections and valve are joined with compression clamps (Morris Coupling Co., Erie, PA) that provide an essentially smooth interior wall surface from the probe inlet to the sampling valve. Specially designed connections and small probes provide a versatile method for diverting air flow from the transport tube to the analytical instruments and specialized samplers in the aircraft cabin.

3.1.3.4 Aircraft Aerosol Sampling Valve

The sampling valve is a standard 60-degree sliding gate valve (Salina Vortex Corp., Salina, Kansas) and is designed for use in pneumatic conveying applications. The valve body is aluminum, as is the valve plate which slides between nylon pressure plates. The valve position is controlled by a double-acting pneumatic cylinder with quick dump exhaust valves. Control air for the cylinder is supplied through electrically actuated solenoids. One discharge port of the valve is connected to the filter sampling section and the other discharges directly into the rear compartment. The inlet probe and transport tube is continually flushed through a bypass outlet whenever filter sampling is not in progress.

3.1.3.5 Aircraft Filter Port

The filter sampling section consists of three parts: (1) the flow divider, (2) the filter holders, and (3) the vacuum manifold and blowers. The flow divider is attached directly to one port of the sampling valve. It provides for the symmetrical attachment of three 20 by 25-cm (8 by 10-inch) clamshell-type filter holders. These are standard high-volume sampler filter holders (General Metal Works, Village of Cleves, Ohio), except that the inlets have been modified to allow them to be easily connected to and disconnected from the flow divider. The filter holders are constructed of

electro-polished stainless steel and are used with closed-cell urethane foam gaskets and special retaining straps to prevent the closure system from vibrating loose in flight. A vacuum manifold provides uniform suction for the three filters. The manifold is equipped with a bypass inlet, consisting of a pneumatically-actuated ball valve with an inside diameter of 1 cm (0.5 in.) The actuator for this valve is connected in parallel with that for the sampling valve, but with the opposite sense. Thus, when the sampling valve is closed (bypass position), the manifold bypass valve is in the open position. This prevents overloading the blower motors when not sampling, and when sampling is abruptly stopped, it prevents system backflow that could possibly rupture the filters. Air suction is generated by three 0.56 kW (3/4-HP) straight radial blade electric blowers attached to the manifold. (These blowers were manufactured by Gelman Instrument Company, Ann Arbor, Michigan, but they are no longer available from this manufacturer.)

3.1.3.6 Transport Tube Flow Measurement Instrumentation

The total flow through the transport tube was monitored using a Pitot tube mounted well downstream from most of the specialized instrument sampling connections and aligned on the centerline of the transport tube. The differential pressure was monitored on a magnehelic needle gauge (Dwyer Instruments, Inc., Michigan City, Indiana) and was continuously measured with a pressure transducer (Validyne Engineering Corp., Northridge, California) that provided a voltage signal for the analog data collection system. Voltage output from this sensor was proportional to air velocity through the transport tube. The electronic pressure transducer for the Pitot tube was subjected to periodic calibration checks against an inclined manometer pressure standard. A complete description of the calculations made to determine volumetric flow through the transport tube during filter sampling is given in Appendix A.

3.1.3.7 Probe and Transport Tube Sampling Efficiency

Accurate measurement of the concentration and composition of airborne particles from filter samples requires that aerosol properties not be distorted within the sampling system. This requirement offers particular design challenges for any sampling system that is intended to extract particles from a moving airstream. To minimize the distortion of particle size and mass distributions, the air velocity into the probe inlet must be the same as the relative velocity difference

between aircraft and the air being sampled. This is the "isokinetic" sampling condition. A second consideration is the potential loss of particles at the inlet and in the transport tube between the inlet and the collecting filters. Particle losses to the walls of the tube may arise from sedimentation, static attraction, inertial effects, and diffusion. The dominant mechanism of particle loss depends on particle size, tube flow conditions, and tube size.

3.1.3.8 Particle Sampling Losses

A number of experimental and mathematical studies have been completed on particle sampling losses in tubes. Although they provide some insight into the effects in the sampling system used in this work, the conditions in the published studies are not directly comparable to those in the SNL system. The turbulence intensity published in these studies, as indicated by Reynolds number, is typically less than one-quarter of the level encountered in the aircraft tube sampling system under normal flight speeds. Particle transmission efficiency through the probe inlet and tube are calculated from selected parameters from several of these studies and are given in Appendix A. Two cases are considered: one for the case of isokinetic entry into the probe and a second for an entry velocity that is 70 percent of the isokinetic rate. An approximate 70-percent isokinetic sampling rate was measured for the Phase A and B tests that were carried out with quartz filter media. A 100-percent isokinetic sampling rate was measured during the Phase C tests, during which Teflon™-coated glass fiber filters were used. The correction for nonisokinetic conditions is taken from the work of Durham and Lundgren (Reference 3). Deposition losses in the probe and transport tube were estimated as a function of particle size from the work of Liu and Agarwal (Reference 4). Tube flow conditions in the referenced report were not the same as during the AMCCOM tests, but the model has other attractive features. One of these is the inclusion of terms that allow for enhanced penetration of very large particles, rather than assuming that losses increase monotonically with increasing particle size. Details of the calculations are included in Appendix A. The sampling and transport efficiency of particles smaller than 1 μm is unaffected by operating conditions. The increased efficiency for particles larger than 1 μm in the 70-percent isokinetic case results from large-particle oversampling. This oversampling is the result of probe inlet velocity conditions and the lower losses during particle transport down the tube under less turbulent conditions. If the increased sampling efficiencies that result from large-particle reentrainment is disregarded, 70-percent isokinetic sampling conditions result in an approximate 50-percent cut point

for the inlet probe and transport tube at about 5 μm in aerodynamic particle diameter. In other words, an estimated 50 percent of the 5 μm aerodynamic diameter particles that enter the tube are transported to the filter. The other half are deposited on the walls of the transport tube and are not resuspended. Many of the larger ($>10\mu$m) particles that enter the tube are eventually transported down the tube by saltation processes whereby the particles are continually deposited and reentrained down the tube.

3.1.3.9 Aircraft Gas Sampling Bag

A pillow-shaped 125-μm (5-mil) thickness Teflon™ bag (BGI Inc., Waltham, MA) with an approximate capacity of 80-L was positioned upstream from the filters as schematically shown in Figure 3.14. The bag was connected directly into the transport tube through a ball valve and was used to collect a gas sample from the transport tube at the same time an aerosol sample was being collected by the filter system. Gas analyzer input could be selected either directly from the tube or from the bag by a pneumatically controlled three-way valve. This arrangement allowed gas measurements from the bag to be completed in flight immediately after sampling.

3.1.3.10 Real-Time Particle Concentration/Size Measurements

Three instruments were flown on the aircraft to measure aerosol concentrations in real-time. For the Phase A tests, a flash-lamp-type integrating nephelometer (MRI, Model 1550) was connected directly into the transport tube to allow a real-time measurement of aerosol concentration in flight, as schematically shown in Figure 3.14. A flash rate of 8 Hz with an electronics time constant of 10 Hz was used during all cloud penetrations to insure acceptable instrument response. The output of this instrument was continuously recorded with the data acquisition system. For the Phase B tests, a second forward-scattering nephelometer (MIE Instruments, Model RAM-1) was also used in tandem with the integrating nephelometer as a cloud marker. Only the RAM-1 instrument was used during the Phase C tests.

3.1.3.11 Particle Spectrometers

Two laser-type particle spectrometers were externally mounted on the aircraft in a below-wing configuration. Particles in the 0.15 to 3.0 μm diameter range were measured with an active cavity laser system, using both forward- and back-scattered light collection optics (Particle Measuring Systems, model ASASP-100-X). Particles in the 1- to 47-μm diameter range were measured with a similar instrument that uses an external laser beam and forward-scattering light collection optics to measure both particle size and number counts (Particle Measuring Systems, model FSSP-100-X). The FSSP probe is designed so that it incorporates true in situ measurement principles and requires no correction for particle transmission or sampling losses in transport to the particle sensing zone. On the other hand, the ASASP probe is not a true *in situ* instrument. However, since it measures particles less than 3-μm diameter and incorporates a dilution air sheath in the sample route to the measurement chamber, particle transport losses are insignificant. Both probes incorporate extremely fast electronics which enable particle count rates in the range of 10^6 Hz. Data streams from both probes were fed to a digital data acquisition system (Particle Measuring Systems, PDS 400) and then to a portable computer hard disc. Data from each probe were averaged separately over a 5-s interval and recorded continuously during cloud penetrations with the aircraft.

3.1.3.12 Aircraft Data Acquisition Systems

3.1.3.12.1 Phase A

During the Phase A test, two data acquisition systems were used to record in-flight data. One system incorporated a 16-bit (0.01-millivolt resolution) analog-to-digital converter (Hewlett Packard, 3497A) and a computer (Hewlett Packard, 9816) to record all continuous voltage data at a sampling frequency of 2 Hz. A second identical computer was used to record digital data from the wing-mounted aerosol spectrometer probes and a long-range navigation (LORAN) unit. The LORAN receiver indicated aircraft position to an accuracy of about 0.5 km every 5 s.

3.1.3.12.2 Phases B and C

During the Phase B and C tests, all data acquisition was performed using a 386-type 20-mHz personal computer, equipped with Lab Tech Notebook™ data acquisition software that incorporated real-time graphical display during flight. While the aircraft was in ambient air and sampling bag

gas measurements were being taken, the data acquisition rate was at 0.2 Hz. During cloud penetration the data sampling rate was increased to 4 Hz in order to more precisely measure the edges of the clouds. The typical aircraft speed during cloud sampling was 50 m/s. This speed, coupled with the 4-Hz sampling rate, corresponds to a spatial resolution of about 13 meters per data interval.

3.1.3.13 Typical Aircraft Sampling Sequence

3.1.3.13.1 Preflight preparations

On a typical test-day, the aircraft and crew departed its operations base at Provo, Utah, Municipal Airport at approximately 0600. After a 30-min flight, the aircraft landed at MAAF for presampling preparations, which included a thorough cleaning of probe and transport tube interior surfaces, filter holders, and gaskets with isopropanol-soaked cotton swabs. Clean preweighed filters were then installed in the holders and placed in position in the filter sampling manifold. Gas instrument warmup and checkout was also completed during this time interval. While the aircraft was on the ground, the gas instruments were continually operated from auxiliary ground power in order to achieve thermal and electronics stability.

3.1.3.13.2 Background Sampling Flight

After takeoff, the aircraft flew at an altitude of 305 m (1,000 ft) above ground level (AGL) in the vicinity of the test grid and began background sampling. Background aerosol sampling involved sampling of about 150 m^3 of background air by continuous operation of the filter sampling system for about 20 min. During this interval, initial zero and span calibrations were also completed on the NO_y, CO, and CO_2 instruments. Gas instrument calibration was followed by a sampling period directly from the transport tube to measure ambient gas concentrations. A 6-L grab sample of background air was also collected into a canister directly from the transport tube at this time. The 80-L bag was flushed with ambient air two times and filled a third time. The gas instruments were then switched to sample from the bag for a period of about 5 min or until instrument readings had stabilized on the bag gas concentrations, whichever occurred first. The aircraft was then flown back to MAAF, during which time a final zero and span calibration was completed with the gas

instruments. Following landing at MAAF, the filter holders were removed and taken inside B-48 (the SNL mobile laboratory) and carefully disassembled. The filters were removed and immediately placed in dry-ice storage. The filter holders were reloaded with clean filters and installed again on the aircraft. The aircraft crew then waited for a ready signal from the ground test director to begin the test sampling flight.

3.1.3.13.3 Test Sampling Flight

a. At the ready signal, the aircraft again departed for the test grid area. On arrival at the test grid, air-to-ground radio communication was established with the test officer. The aircraft then began flying an approximate 4- by 6-km (2.5- by 3.8-mi) racetrack pattern over the test site at its typical sampling speed of 50 m/s (90 knots). During this time initial zero and span checks were completed on the gas instruments. During Phase A and B tests, aircraft position was coordinated with the test officer's countdown, so that the detonation site was approximately 2 km (1.2 mi) directly off the left wing with the aircraft at 305 m (1,000 ft) AGL at detonation time. At detonation time, the aircraft continued flying away from the cloud for about 30 s and then turned 180 degrees to the left, which brought it onto a flight track headed directly at the cloud. Elapsed time from detonation to the first aircraft interception of the cloud was typically in the range of 45 to 60 s. This time lag allowed the buoyant cloud to rise up to the altitude of the aircraft and provided an adequate margin of safety for large debris fallout from the cloud prior to aircraft fly-through. During the Phase C tests, the aircraft was flown at a heading pointing directly at the detonation point and was kept at a minimum distance of 2 km (1.2 mi) at detonation time. This flight path was selected in order to allow a videotape record of the detonation to be made with a nose-mounted "forward-looking" video camera on the aircraft. Prior to the first pass through the cloud, the filter blowers were started with the transport tube flow in the bypass mode. On interception with the cloud, the transport tube flow was diverted through the filters for the duration of the cloud transect. The valve to the 80-L bag was opened at the same time so that the bag was filled with a fraction of the total transport tube flow. A diaphragm valve on an evacuated 6-L canister, installed on a sampling port projecting directly into the transport tube, was manually opened when the aircraft intercepted the cloud on the first sampling pass. The valve was left open, allowing the evacuated cylinder to fill to near atmospheric pressure while the aircraft was in the

cloud, after which it was closed. Typically, the aircraft was in the cloud during this first pass for about 3 to 5 s. As the aircraft exited the cloud, both filter and gas sampling bag valves were switched to the bypass position. The aircraft then was put into a short radius in preparation for another cloud penetration.

b. Second, third, and sometimes fourth penetrations were conducted in precisely the same manner as described for the first, except that no 6-L canister samples were collected. Following the third or fourth pass, the aircraft was flown in level flight in the standard racetrack pattern over the detonation site. At this time, the gas instruments were switched to sample from the bag and a canister sample was also taken from the bag, which now contained cloud gases from all three passes. Sampling was continued from the bag for 5 minutes to adequately measure the bag gas contents. The 80-L bag was then flushed two times with ambient air and completely evacuated in preparation for the next detonation.

c. Continuous recording was carried out with the nephelometer and the two wing-mounted aerosol spectrometers while the multiple cloud penetrations were flown. Range changes were made by instrument operators to optimize instrument sensitivity as the cloud became increasingly dispersed with time

d. In a multiple detonation series, the aircraft returned to the preestablished racetrack pattern over the site, while waiting for the next event. At this time, the 80-L bag was flushed two times with ambient air and completely evacuated in preparation for the next test. Following detonation, an identical sampling sequence was followed as described above for each detonation in the test.

3.1.3.13.4 Posttest Activities

a. For phases A and B, at the completion of sampling from the final detonation cloud, the aircraft was flown back to MAAF. During the return flight, a final zero and span check was completed with the continuous gas analyzers. On landing at MAAF, the filter holders were once again disconnected from the sampling manifold and taken to the equipment trailer. The filters were removed and immediately placed in dry-ice storage. Data files were backed up and sample collection forms completed. Following these activities, the aircraft and crew then departed for the

Provo airport, carrying the ice chest containing the exposed filters with them. Upon landing at Provo, the filters were immediately delivered to Alpine West Laboratories (AWL), where they were placed in cold storage prior to weighing, extraction, and analysis.

b. For phase C, the filters were weighed and put in the freezer at DPG.

3.1.3.13.5 Propellant Test Sampling Differences

Flight activities for the propellant burns were carried out in an identical manner as described for the detonations, with the exception that a shorter elapsed time between burn initiation and aircraft penetration of the cloud was chosen. Usually, the very buoyant propellant clouds were rapidly dispersed. Typically only two aircraft sampling fly-throughs were completed for each burn.

3.1.4 Soil and Fallout Sampling

The specific sampling points for soil and fallout from the detonations and burns are shown on the grid maps in paragraph 3.1.2 and the following paragraphs. The Technical Steering Committee (TSC) considered the assay of every sample and the compositing of samples. One of these considerations was the high expense of analyzing each individual sample from the test area, of more importance was the TSC's unanimous belief that composite sampling would provide the basis for accurately characterizing ejecta and fallout material, and that compositing would be sufficient in developing the methodology required to identify and quantify emittant products from propellant, explosive, and pyrotechnic (PEP) material.

3.2 Explosive and Propellant Material

3.2.1 TNT

TNT was used in the BB and all three field tests for both surface and suspended detonations. While its physical form varied, either flake or block (the product of washout demilitarization operations), for the field tests, the TNT used in the BB tests was virtually pure trinitrotoluene, as

shown by chemical analysis. No individual detonation exceeded 907 kg (2,000 lb). MIL-T-24BC (Reference 5) contains the military specification for TNT.

3.2.1.1 BangBox

BB testing preceded field testing by several months. Less than 23 kg (50 lb) of TNT were consumed during the entire test series. All was received as 227-grams (0.5-lb) demolition blocks, which had to be stripped of protective cardboard wrappings and metal parts before use. Each trial involved one or more single detonations, each having the block suspended approximately 1 m above the surface by a monofilament nylon cord strung from an aluminum rod bracket assembly. The BB trials were conducted as summarized in Table 2.1.

3.2.1.2 Field Test Phase A

3.2.1.2.1 Description

a. Block. The TNT blocks used during Phase A testing were made from reclaimed TNT which had been cast into 32-kg (70-lb) blocks. Most blocks were packaged in cloth/plastic bags inside a metal container. The bags adhered to the sides of the containers and could not be removed. A lesser amount of TNT blocks came in vapor-barrier bags. These blocks were left in their bags because they were friable and would have spilled on the ground if removed.

b. Flaked. Flaked TNT, also made from reclaimed TNT, was packaged in fiber containers, each holding 60 lb.

3.2.1.2.2 Application

a. Block. The metal boxes containing block TNT were stacked 1.0-m (40-in) deep x 0.7-m (26-in) wide x 1.1-m (44-in) high for detonation. Four 454-g (1-lb) blocks of TNT, used as initiators for the stacked TNT, were each double primed with electric blasting caps and placed on top corners of the stack. The block TNT in vapor-barrier bags was also stacked and initiated by double-primed 454-g (1-lb) TNT blocks.

b. Flaked. The flaked TNT was poured into mild-steel cylindrical buckets, approximately 907 kg (2000 lb) of TNT per bucket. Each bucket was approximately 1.2-m (48-in) high x 1.1-m (45-in) diameter and open at both ends, thus resulting in direct contact between the TNT and the soil. The cylinders were each recessed into the ground approximately 15 cm (6 in) and initiated by one 454-g (1-lb) TNT detonation block double-primed with electric blasting caps and placed on top of the flaked material.

c. All trials were conducted as summarized in Table 2.2.

3.2.1.3 Field Test Phase B

A combination of individual surface, sequential surface, and suspended detonations were conducted, again using reclaimed TNT.

3.2.1.3.1 Description

a. Block. The TNT blocks used during Phase B testing were 32-kg (70-lb) blocks cast from reclaimed TNT. All were wet, varied in strength from being fairly solid to being friable, and had an average 18-percent void space between blocks when placed in the cylinders. Their dark color indicated contamination by munitions components such as asphaltum and gums during the reclamation process. The vapor-barrier bags which could not be removed easily remained on the blocks in some instances.

b. Flaked. The flaked TNT, also the product of reclaimed TNT, was dry when received but, like the block TNT, appeared to have been contaminated during the reclamation process.

3.2.1.3.2 Application

a. Block. The blocks were loaded into cylinders similar to those used during Phase A testing, except that leak-proof bottoms had been added to prevent direct contact of TNT with the soil. Flaked TNT was used to fill voids between blocks. The cylinders were initiated by four 454-g (1-lb) TNT blocks placed inside the cylinder, approximately 20-cm (8-in) from the bottom. The detonating

blocks were wrapped with pentaerythritol tetranitrate (PETN) detonating cord which was run through holes drilled in the sides of the cylinders 15 m (50 ft) to a firing point, where it was initiated by a radio-actuated electric blasting cap. The cylinders were set directly on the ground for surface detonations; for suspended detonations, they were hung approximately 12 m (40 ft) above the ground from a wire cable stretched between two telephone poles.

b. Flaked. The flaked TNT was used to fill voids between blocks in the cylinders. No cylinders were loaded with flaked TNT exclusively.

c. All trials were conducted as summarized in Table 2.3.

3.2.1.4 Field Test Phase C

3.2.1.4.1 Description

Again, TNT used during Phase C was reclaimed explosive which had been reprocessed into flakes and blocks. However, this time the blocks were slightly smaller and weighed 28 kg (62 lb).

3.2.1.4.2 Application

Procedures used in setting up testing events were identical to those used during Phase B, with the exceptions that the cylinder diameter had been reduced to 1.0 m (38 in), and that the cylinders for the ORI was filled with flaked TNT. Plastic sheets were spread on the ground to prevent accidental TNT spills from contaminating the soil. All trials were conducted as summarized in Table 2.4.

3.2.2 Composition B

3.2.2.1 Description

Composition B, manufactured from TNT and RDX, is commonly referred to as "comp B". This explosive was used for six surface detonations during Field Test Phase C. The nominal composition of composition B is given in Table 3.1.

Table 3.1

Ingredient[a]	Weight (%)	Carbon Content (%)
RDX	59.5	16.2
TNT	39.5	37.0
Composition D-2 Wax	1.0	85.2

[a]Weights are approximate. RDX and TNT are ±2.0 and wax is ±0.03 percent.

Application

Received in flakedform, the composition B was loaded into steel cylinders for test detonations, each cylinder containing a maximum of 916 kg (2020 lb). Each cylinder was 96-cm (38-in) high x 122-cm (48-in) diameter, with a 20-cm (8-in) ring at the top to increase its loading capacity. All trials were conducted as summarized in Table 2.4.

3.2.3 Explosive D

3.2.3.1 Description

Explosive D was used for an ORI and six surface detonations in Field Test Phase C. Commonly referred to as "yellow D" because of its yellow color, explosive D is also known by its chemical name, ammonium picrate. It has a propensity to stain, and can cause toxic reactions, thus mandating personal protection for technicians working with it. Because of its low sensitivity, large initiators were used to ensure complete detonation and avoid spreading undetonated explosive throughout the test site. The nominal composition of explosive D is given in Table 3.2.

Table 3.2 Nominal Composition of Explosive D.

Ingredient	Weight (%)	Carbon Content (%)
Ammonium picrate	99.9	29.3
Sulfates	0.1	
Chloroform insoluble impurities	0.1	
Ash (maximum)	0.1	
Water-insoluble material (maximum)	0.1	

3.2.3.2 Application

Received in granular form, explosive D was loaded into steel cylinders for test detonations, each cylinder containing a maximum of 917 kg (2020 lb). Plastic explosive C4 was used to initiate each cylinder. Plastic sheets were placed on the ground to prevent any spillage from contaminating the soil. Explosive D trials are summarized in Table 2.4.

3.2.4 RDX

3.2.4.1 Description

RDX (hexamethylenetrinitroamine) is not present in ordnance items as a pure explosive. RDX used during Phase C was PBXN-6, a mixture of RDX and Viton A™ (hereafter referred to as RDX). The nominal composition of this explosive is given in table 3.3.

Table 3.3 Nominal Composition of PBXN-6.

Ingredient	Weight (%)	Carbon Content (%)
RDX	95.0	16.2
Viton A™	5.0	28.1

3.2.4.2 Application

Granular RDX was delivered in 60-lb (27-kg) pasteboard boxes. It was loaded into steel cylinders 1.2-meters (48-in) high x 1.0-meters (38-in) diameter. Four 0.6-kg (1.25-lb) blocks of C4 explosive were used to initiate each cylinder. RDX trials are summarized in Table 2.4 on page 2-10.

3.2.5 Single-Base Propellant

3.2.5.1 M1 Propellant - Field Test Phase C

3.2.5.1.1 Description

M1 propellant is a single-base propellant normally used with field artillery, howitzers, and guns. This propellant, consisting almost entirely of nitrocellulose, was received in bulk containers in the form of small multiperforated pellets, each approximately 1 cm long, with a diameter of about 0.4 cm. The nominal composition of the M1 propellant used in phase C is shown in Table 3.4.

Table 3.4 Nominal Composition of M1 Propellant.

Component	Weight Fraction %	Carbon Fraction %
Nitrocellulose (13.15 % N)	85.00	25.7
Dinitrotoluene	10.00	46.2
Dibutylphthalate	5.00	69.0
Diphenylamine (added)	1.00	85.2
Potassium sulfate (added)	1.00	0.0
Volatile solvents	1.26	52.1
Residual water (moisture)	0.60	0.0

3.2.5.1.2 Application

The propellant was spread in the three burn pans to a depth not exceeding 8 cm (3 in) and ignited at both ends of the pans. M1 propellant trials are summarized in Table 2.4 on page 2-11.

3.2.5.2 M6 Propellant - Field Test Phase C

3.2.5.2.1 Description

M6 propellant, as delivered to the test site in 27-kg (60-lb) fiber drums, was a single-base propellant manufactured as a multiperforated grain, 1.7 cm long and 0.8 cm in diameter, consisting almost entirely of nitrocellulose. The nominal composition of this propellant is given in Table 3.5. A carbon fraction of 0.293 was calculated from the mass composition and the molecular formulas of the propellant constituents.

Table 3.5 Nominal Composition of M6 Propellant.

Component	Weight Fraction %	Carbon Fraction %
Nitrocellulose	87.7	25.7
Dinitrotoluene	9.7	46.2
Dibutylphthalate	2.5	69.0
Diphenylamine (added)	0.86	85.2
Potassium sulfate (added)	0.74	0.0
Volatile solvents	1.8	52.1
Residual water	<0.32	0.0

3.2.5.2.2 Application

The propellant was spread in the three burn pans to a depth not exceeding 8 cm (3 in) and ignited at both ends. Propellant ignition was accomplished by black-powder trains, which were ignited by electric squibs. M6 propellant trials are summarized in Table 2.4 on pages 2-10 and 2-11.

3.2.6 Double Base Rocket Propellant

3.2.6.1 BangBox

A single burn trial of 454 grams (1 lb) of NOSIH-AA-2, with 26.6 grams (1 oz) of ethylcellulose added, was conducted in the BB. A description of the propellant is given in Table 3.6. A carbon fraction of 0.266 was calculated from the mass composition and the molecular formulas of the propellant constituents. An additional 5.9 percent by weight of ethylcellulose was added to the mixture, with a carbon fraction of 0.585, to simulate actual field practice in OB of this propellant residue.

Table 3.6 Composition of NOSIH-AA-2 Propellant.

Ingredient	Weight (%)	Carbon Fraction (%)
Nitrocellulose	51.0	27.0
Nitroglycerin	38.6	15.9
Triacetin	2.7	49.5
Di-normal-propyl-adipate	1.6	62.6
2-Nitrodiphenlyamine	2.0	67.3
Lead salicylate	1.5	34.9
Lead β resorcylate	0.5	32.8
Monobasic copper salicylate	2.0	49.8
Candelilla wax	0.1	85.2
Ethylcellulose (added)	5.9	58.5

3.2.7 Triple-Base Propellant - Field Test Phase A

3.2.7.1 Description

A triple-base gun propellant, M30, was tested during Phase A. A complete description of the propellant is given in Table 3.7. A carbon fraction of 0.178 was calculated from the mass composition and the molecular formulas of the propellant constituents.

Table 3.7 M30 Triple-Base Gun Propellant[a] Composition.

Component	Weight Fraction (%)	Carbon Fraction (%)
Nitrocellulose (12.6 % N)	28.0	26.5
Nitroglycerin	22.5	15.9
Nitroguanidine	47.7	11.5
Ethyl Centralite	1.5	76.1
Graphite	0.2	100.0
Total Volatiles	0.1	62.0
Total	100.0	17.8

[a]Radford Army Ammunition Plant Lot No. RAD-65385.

3.2.7.2 Application

The propellant material was placed in a steel burn pan that measured 1.2 m (4 ft) by 11.0 m (36 ft). Approximately 907 kg (2000 lb) was burned in each of two separate burns for the ORI tests. The full test involved the burning of about 3175 kg (7000 lb) of material in each of two separate burns. M30 propellant testing is summarized in Table 2.2 on page 2-5.

3.2.8 Composite Propellant - BangBox

3.2.8.1 Description

A composite rocket propellant, NOSIH-EC, was tested in the BB test. A complete description of the propellant is given in Table 3.8.

Table 3.8 NOSIH-EC Propellant Composition.

Component	Weight Fraction %	Carbon Fraction %
Hydroxyl-terminated polybutadiene (R45M)	8.015	88.8
2,2-Methylene bis(4-methyl)-6-t butyl phenol (AO 2246)	0.200	81.1
Dioctyl sebacate (DOS)	4.500	73.2
Phenyl di-isodecyl phosphite	0.200	71.2
5-Ethyl-1,3-diglycidyl-5-methyl hydantoin diepoxide (XU-238)	0.300	56.7
Aluminum oxide	1.000	0
Carbon black	0.100	100.0
Ferric acetylacetonate (FeAA)	0.005	51.0
Ammonium perchlorate	85.000	0
Diethylene triamine (DETA)	0.080	46.6
Isophorone di-isocyanate	0.600	64.4

3.2.9 Manufacturing Residue

3.2.9.1 Field Test Phase B

3.2.9.1.1 Description

A variety of propellant types was used during the Phase B test burns. The purpose of mingling propellant and inhibitor materials was to accurately represent procedures used at manufacturing facilities which thermally treat residue as it is generated. The mixtures are defined in Table 3.9. A complete description of the propellants is given in Tables 3.6, 3.8, and 3.10 to 3.13. Carbon fractions of 0.214, 0.213, and 0.212 were calculated from the mass composition and the molecular formulas of the propellants for the ORI burn and the two burns on trial 1, respectively.

Table 3.9 Manufacturing Residues Burned in Field Test Phase B.

Propellant Type	Weight per Trial[a] (lb)		
	ORI P1	Trial I P1	Trial I P2
NOSIH-EC	1528	1599	1584
NOSIH - AA2	1100	1100	1155
NOSIH-AA6 (chunk)	605	495	495
NOSIH-AA6 (sheet)	2574	2574	2574
"Propellant A"	799	784	760
"Ignition propellant"	10	10	10
Cellulose Acetate Inhibitor	36	36	36
TOTAL	6652	6598	6614

[a]Trial dates (all 1990): ORI - 19 Oct; Trial 1.

Table 3.10 NOSIH-AA6 Propellant Composition.

Component	Weight Fraction %	Carbon Fraction %
Nitrocellulose (12.2% N)	24.50	27.0
Nitrocellulose (12.6% N)	24.50	26.5
Nitroglycerin	38.80	15.9
Triacetin	3.25	49.5
Di-normal propyl adipate	2.00	62.6
2-Nitrodiphenylamine	2.00	67.3
LC-12-15	3.30	
Copper salicylate 1.60 %		49.8
Lead β-resorcylate 1.70 %		32.8
Candelilla wax	0.10	85.2
Carbon black	0.05	100.0
Aluminum	1.50	0

Table 3.11 "Propellant A" Composition.

Component	Weight Fraction %	Carbon Fraction %
Nitrocellulose (12.6% N)	49.89	26.5
Nitroglycerine	33.59	15.9
Triacetin	7.62	49.5
2-Nitrodiphenylamine	1.45	67.3
Aluminum	3.79	0
Lead salicylate	1.83	34.9
Lead resorcylate	1.44	32.8
Lead 2-ethyl hexoate	0.39	38.9
Graphite (added glaze)	0.03	100.0

Table 3.12 "Ignition Propellant" Composition.

Component	Weight Fraction %	Carbon Fraction %
Nitrocellulose (12.6% N)	68.44	26.5
Nitroglycerine	16.48	15.9
2-nitrodiphenylamine	1.91	67.3
Aluminum	7.30	0
Lead resorcylate	2.78	32.8
Lead salicylate	2.78	34.9
Carbon black	0.31	100.0
Graphite (added glaze)	0.04	100.0

Table 3.13 Cellulose Acetate Inhibitor Composition.

Component	Weight Fraction (%)	Carbon Fraction (%)
Cellulose acetate	75.0	50.0
Diethyl phthalate	16.7	64.9
Triphenyl phosphate	8.3	66.3

3.2.9.1.2 Application

The burn pans, used in phase A, were cleaned by test personnel prior to setup. The composite propellant, placed in the center of the three-pan array, could not be removed from cardboard shipping containers for the 19 October burn. Double-base propellants were placed in the two outer pans. Propellant manufacturing residue trials are summarized in Table 2.3 on page 2-7.

3.2.9.2 Field Test Phase C

3.2.9.2.1 Description

Manufacturing Residue propellants were used in the Phase-C test burns. They were NOSIH-AA2 and N-5. The propellant was in the form of rolls 10 cm (4 in) wide x 38 cm (15 in) diameter x 0.2 cm (0.08 in) thick, which would have been subjected to extrusion if its manufacturing process had

been continued. The mixtures for Phase C are defined in Table 3.14. The nominal composition of these propellants is given in Tables 3.6 and 3.15.

Table 3.14 Manufacturing Residues Burned in Field Test Phase C.

Propellant Type	Weight per Trial (lb)			
	Trial 1 P1	Trial 1 P2	Trial 2 P1	Trial 2 P2
NOSIH - AA2	1092	1014	1014	1014
N-5	3876	3800	3876	3876
TOTAL	4968	4814	4890	4890

Table 3.15 Composition of N5 Propellant.

Ingredient	Weight %	Carbon Fraction %
Nitrocellulose (12.6 % N)	50.0	26.5
Nitroglycerin	34.9	15.9
Nitrodiphenylamine	1.9	67.3
Diethyliphthalate	10.5	64.8
Lead ethylhexoate	1.8	38.9
Lead salicylate	0.8	34.9
Candelilla wax	0.2	85.2

3.2.9.2.2 Application

These propellant rolls were laid in the burn pans and ignited at both ends of the pans with a powder train. Propellant manufacturing residue trials are summarized in Table 2.4 on page 2-9 and 2-10.

3.3 Analyte List - Detection Levels

The analyte list and detection levels for the field test are shown in Table 3.16.

Table 3.16 Analyte List and Limits of Detection for Phases A, B, and C Tests.

Chemical Analyte	Analyte List			Limit of Detection in Acetonitrile ng/mL[a]	Limit of Detection in 400g of DPG Test Site Soils.[b]	
	Phase A	Phase B	Phase C		ppbW	ng/mL
2,4-Dinitrotoluene	TNT, M30	TNT, MR	TNT, Comp-B, RDX, Exp-D, M6, M1, MR	0.07	1	400
2,6-Dinitrotoluene				0.05	1	400
2,4,6-Trinitrotoluene				0.06	1	400
2-Nitronaphthalene				0.03	1	400
N-Nitrosodiphenylamine				0.12	10	4000
1,3,5-Trinitrobenzene		TNT		0.12	10	4000
2-Nitrodiphenylamine		MR		0.10	10	4000
1-Nitropyrene		TNT		1.30	10	4000
Naphthalene		TNT, MR		0.62	50	20000
Benz[a]anthracene				0.73	1	400
Benzo[a]pyrene				2.30	1	400
Pyrene		MR		0.83	1	400
Phenol[c]		TNT, MR		0.23	1000	400000
Dibenzofuran				0.31	1	400
Diphenylamine				0.21	1	400
4-Nitrophenol				0.30		
Biphenyl				1.15		
Phenanthrene				1.20		
1-Methylnaphthalene				0.62		
2-Methylnaphthalene				0.62		
Ethyl centralite[d]	M30					
Nitroglycerin		MR	MR	0.21	10	4000
Nitroguanidine[e]						
4-Nitrodiphenylamine		MR				
1,3,5-Trinitrophenol			Exp-D	0.35	20	8000
RDX, Cyclonite[f]			Comp-B, RDX	0.20	1	400
HMX, Octogen[g]						

[a]Detection limit for SFC/MS under chemical ionization/selected ion monitoring (signal/noise = 3).
[b]Based on an acetonitrile extraction of 400 g of soil and then evaporation of the extract to a 1 mL sample for assay. Based on signal to noise ratio of 3 with respect to the soil background.
[c]Analyzed with GC/MS on Phase A.
[d]Chemical name: N,N'-diethyl-N,N'-diphenylurea.
[e]Analysed as its methyl derivative.
[f]1,3,5-Trinitrohexahydro-1,3,5-triazine.
[g]1,3,5,7-Tetranitrooctahydro-1,3,5,7-tetrazocine.

3.3.1 Discussion of Detection and Quantification Limits.

The following paragraphs pertain to the 3 to 4 orders of magnitude differences between the "limits of detection" of the analytes in acetonitrile solution and the "limits of quantification" of these analytes when extracted from 400 grams of DPG soil samples. This large difference is normal when extracting and analyzing for analytes in soil samples for the following reasons:

a. Matrix effects and stability of composition, particularly during analytical conditions, must always be considered while assessing the level at which analytes may be reliably measured in a field sample if the analytes are associated with relatively large amounts of "foreign" material.

b. When the analytes are associated with relatively large amounts of foreign material, two matrix effects interact. The first is interference from a relatively large "chemical" background (as distinguished from electronic "noise") in the mass spectra resulting from the complex and somewhat variable mixture of natural soil components, such as humic substances. The second is the difficulty of recovering the analytes from the matrix. Soils, especially fine clay soils such as those at DPG, have a large specific surface with high adsorption isotherms. These conditions make the complete recovery of analytes increasingly difficult as the concentration level of the analyte falls. The background and recovery effects combine to reduce the detection and quantification reliability levels of quantification analysis.

3.4 Sampling/Analysis

3.4.1 Volatile Organics

Both direct and indirect whole air grab samples were collected in passivated 6-L evacuated SS canisters during aircraft penetrations of the plume. Direct samples were collected in canisters that were connected to a 6-mm (1/4-in) SS probe that projected directly into the transport tube as schematically shown in Figure 3.14 on page 3-24. On aircraft contact with the plume, the canister valve was manually opened and the canister filled to ambient pressure. During the Phase B and C tests, indirect whole air grab samples were also collected from the Teflon™ bag into which multiple plume samples were composited. Following completion of the plume sampling and a 10-s

purge to clear the line of ambient gas, a gas sample was drawn from the bag through a length of Teflon™ tubing into the evacuated canister. The 6-L canisters were immediately shipped to the Oregon Graduate Institute of Science & Technology for gas transfer and chromatographic analysis for CO, CO_2 and C_1 through C_{10} hydrocarbons.

3.4.1.1 Measurement of CO_2, CO, and CH_4 was done by a GC-FID-M (FID - Flame Ionization Detector) method using a Carle Instrument Model 211-M. The CO_2 and CO are methanated over a hot nickel catalyst at 400°. The conversion of the CO_2 and CO is 100% to CH_4. However, the absolute calibration is done against National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) standards for each compound. The method is very sensitive, and precision is excellent since the method is used for long-term global monitoring of the ambient atmosphere where high precision is necessary. The precision of analysis is; CH_4 @ 1700 ppbv ±0.2%, CO @ 100 ppbv ±3%, and CO_2 @ 345 ppmv ±0.3%.

3.4.1.2 The C_2 - C_{10} volatiles were measured by a different GC (using EPA's TO-14 compendium method) with no conversion to methane, but rather direct detection of each of the eluting compounds by flame ionization. A complete list of volatiles is available for every analysis (Appendix E); however, for the sake of brevity, "target" toxic species such as benzene and toluene were selected to show overall trends in volatile emissions from the various test conducted.

3.4.2 Semivolatile Organic Sampling and Analysis

3.4.2.1 Filter Description

Semivolatile organics were collected on the three 20-cm by 25-cm filters positioned at the termination of the aircraft transport tube. A complete description of the transport tube, valve, and flow measurement system is given in section 3.1.3. Quartz-fiber filters (Pallflex Corp, type QAOT) were used during the Phase A and B tests. These filters were prefired at 500 °C for at least 1 hour to remove organic material prior to preweighing and sample collection. In order to provide a weight-constant filter medium with which to measure particulate matter loading on the filter, Teflon™-coated glass fiber filters (Pallflex, Type T60A20) were used for sample collection during the phase C tests. Solvent extraction and SFC-MS analysis of blank Teflon™-coated glass fiber filters

showed no appreciable background organic material, so filters were used as received from the supplier and were not solvent-extracted prior to sample collection.

3.4.2.2 Sampling Methods

Almost all explosive tests conducted during field testing included three 907-kg (2000-lb) detonations. The cloud from each detonation was sampled for semivolatile organics during three aircraft passages through the cloud, with an approximate 5-second duration for each pass. The total sampling time in the cloud from all three detonations was about 45 s. To achieve maximum filter loading, the filters were not changed until all three detonation-produced clouds had been sampled. A typical sampling volume for a three-detonation test sequence was usually in the range of 8 to 10 m^3 of air for the Teflon™-coated glass fiber filters used in phase C. Sample volumes for the quartz-fiber filters used in the Phase A and B tests were in the range of 6 to 8 m^3. The lower sampling volumes for the quartz filters results from the increased airflow resistance through the quartz-fiber filters used during these tests.

3.4.2.3 Postsampling Filter Handling

During the phase A and B tests, the sample filters were removed from the filter holders when the aircraft landed, stored in either aluminum foil pouches or Teflon™ sheets to minimize filter contact with other contaminated surfaces, and placed in dry ice. During the Phase C tests, the filters were removed from the holders and weighed at DPG prior to being placed in dry ice storage. (See section 3.4.4 for additional information on filter weighing procedures.) All filter samples were preserved with dry ice during transport from the field location to AWL.

3.4.3 Real-Time Gases

3.4.3.1 Gas Analyzer Descriptions

Continuous gas analyzers installed on the aircraft and their measurement principle and detection limits are listed in Table 3.17. Gas filter correlation instruments were used for the measurement of CO_2 (Thermo Electron Corporation, model 41H) and CO (Thermo Electron Corporation, model 48). NO_x was measured with a chemiluminescent instrument. For phases A and B, a Columbia Scientific Instruments, model 1600 NO_x analyzer, was used and for Phase C, a Thermo Electron Corporation, model 42 was used. Ozone was measured during the phase B and C tests, using a UV absorption instrument (Thermo Electron Corporation, model 49). The CO and NO_x instruments are both certified as EPA equivalent methods, under 40 CFR 53. In-line cellulose filters were used in the air inlets of the CO and CO_2 instruments. An in-line Teflon™ filter was installed in the inlet of the NO_x instrument. The input plumbing pathway to these instruments is schematically shown in Figure 3.14 on page 3-24. The input flow to the gas instruments was manually selectable by an air-driven ball valve, so that air samples could be drawn directly from the transport tube or from the 80-L bag. Valve position was continuously recorded by the data acquisition system.

Table 3.17 OB/OD Real-Time Continuous Monitors Installed on the Aircraft.

Species	Instrument	Measurement Principle	Detection Level[a]
Carbon Dioxide	TECO Model 41H	Gas Filter Correlation	1.2 ppmv
Carbon Monoxide	TECO Model 48		0.1 ppmv
Ozone	TECO Model 49	UV[b] Absorption	5 ppbv
Oxides of Nitrogen	CSI Model 1600	Chemiuluminescence	6 ppbv

[a]Detection level defined as two times the standard deviation of the instrument noise.
[b]Ultraviolet

3.4.3.2 Gas Analyzer Calibration Procedures

Zero and span gas readings of each instrument were taken prior to and following each test measurement. Zero gas for the CO_2 instrument was produced by passing ambient air through a soda lime scrubber. A zero CO gas stream was produced by passing ambient air through a heated catalytic oxidation unit which converted all ambient CO to CO_2. A zero NO_x stream was produced by pumping ambient air through a scrubbing column containing a mixture of silica gel, activated charcoal, and Purafil™. Working-level span gases were also carried on the aircraft so that pretest and posttest zero and span gas checks could be conducted in flight. The CO and CO_2 span gases

were referenced to NIST standard gases in the possession of the Oregon Graduate Institute of Science & Technology. The NO span gas was measured with the NO_x instrument immediately following a multipoint calibration against a certified NO bottle standard. The NO level in the span cylinder measured by the calibrated instrument then became the assigned span value for the duration of the test series.

3.4.3.3 Gas Data Calculations

Multipoint calibrations with certified gas standards were completed on the CO_2, CO, and NO_x instruments prior to the onset of the test period in order to document instrument linearity over their working ranges. Daily instrument response factors were calculated from the pretest and posttest zero and span checks by the following formula.

3.1 Gas Data Calculation.

$$M = \frac{S}{\left(\frac{V_{si} + V_{sf}}{2}\right) - \left(\frac{V_{zi} + V_{zf}}{2}\right)}$$

where:

M = instrument response factor (ppm volt^{-1})
S = span gas value (ppm)
V_{si} = initial span reading (volt)
V_{sf} = final span reading (volt)
V_{zi} = initial zero reading (volt)
V_{zf} = final zero reading (volt)

Daily instrument response factors were calculated and used in favor of a single-response factor over the duration of the experiment. Past experiences have shown that, although the linearity of the instrument remains constant, daily electronics drift with varying temperature inside the aircraft can yield less accurate measurements when a single response factor is used. The use of a daily response factor that is derived from a daily two-point calibration (zero and span) takes daily instrument drift into account and yields a more accurate measurement of the particular gas. Gas concentrations in the bag were determined by calculating at least a 2-minute average instrument voltage reading while

the instrument was sampling from the 80-L bag. The starting point of the average was after the instrument had stabilized on the bag reading. The average voltage was then multiplied by the instrument response-factor. The same calculation was performed on the ambient air sample collected in the bag during the background flight. The ambient air gas concentration level was then subtracted from the cloud sample level to derive a background corrected cloud concentration level for each particular gas. Complete details of these calculations are given for a representative test case in Appendix C.

3.4.4 Airborne Particulate Matter

3.4.4.1 Gravimetric Analysis

Efforts were made to quantify the amount of particulate matter collected on the filters used for semivolatile organic analysis in each of the test series. Only crude estimates of particulate matter weight gain were available from the filter samples collected during the Phase A and B tests; because of the inherent weight instability of quartz filter media. Quartz fibers are susceptible to ambient moisture pickup and loss and thus are not well suited for gravimetric analysis. Teflon™-coated glass fiber filters were selected during the Phase C study in an effort to provide a more precise estimate of particulate loading because they are far less susceptible to environmental changes in humidity and temperature.

3.4.4.2 Weight Change

Filters were weighed prior to and after sample collection and the resultant weight change used as an estimate of particulate matter loading on the filters. A rigorous filter-weighing quality control program was initiated during Phase C to provide estimates of weight uncertainty during the initial and final weighing procedures. All filters were weighed on a precision microbalance (Mettler, model AE-20) with an approximate weighing precision of 100 μg. Overall weight uncertainty for the combined difference between an initial and final filter weight was about 1.5 mg.

3.4.4.3 Particulate Carbon Analysis

During the Phase A and B tests, a measure of particulate carbon content of the combustion or detonation clouds was determined by combustion analysis of a section of the quartz filter at Sunset Laboratories. This particulate carbon analysis incorporates a two-step volatilization and combustion process in which particulate carbon is burned, evolved as CO_2, catalytically reduced to methane, and detected with a flame-ionization detector. Differentiation between organic carbon, elemental carbon (soot), and inorganic or carbonate carbon is possible by using a multistep analysis procedure in which the combustion temperature and the carrier gas mix is varied (Johnson et al. 1981, Reference 6).

3.4.5 Aircraft-Based Video

Video recordings of all phase C test events were made with a forward-looking video camera mounted on the nose of the instrumented aircraft. A high speed, variable focal length lens (f1.0 to 2.2, 16 to 160 mm) was used to record the detonation while the aircraft was on a heading toward the detonation point and during subsequent sampling passes through the cloud. An on-screen elapsed timer was also used to mark the detonation and each passage of the aircraft through the plume. Originals of all VHS format videotapes made during the Phase C tests are archived at SNL. Selected video recordings were also made during the Phase A and B testing; however, many of these were made with a hand-held camera and are of less desirable quality than those made during the Phase C testing.

3.4.6 Meteorology

3.4.6.1 Synoptic weather for the test site was briefed each test day at 0700 hours to the test team prior to traveling to the test site by the Atmospheric Science Laboratory detachment at DPG. The briefing covered the wind speed and direction, cloud cover, and temperature gradient from the surface to the aircraft sampling height. The time window for the acceptable conditions for OB/OD testing was provided. The OB/OD test officer maintained radio contact with the weather detachment from the test control point throughout the field testing to avoid any unacceptable test conditions.

3.4.6.2 Standard meteorological surface observations of wind speed and direction, temperature, humidity, barometric pressures, and cloud cover were taken every 15 minutes at the test site. Tethersondes were also taken into the field to measure wind speed and direction, and temperature from the surface to 2000 meters above the ground.

SECTION 4 DATA COLLECTION, ANALYSIS, AND RESULTS

4.1 General Methods

This section covers the development of innovative methodology for the efficient and effective characterization of emissions from OB/OD, thermal treatment operations (carbon balance and supercritical fluid chromatography-mass spectrometry (SFC-MS)), existing methodology (gas chromatography-mass spectrometry (GC-MS)) and conversion factors for soil and air pollutant concentrations.

4.1.1 Carbon-Balance Method

4.1.1.1 *The emission factor (EF) is defined as the mass release of a particular species per unit mass of original explosive or propellant consumed.* The carbon-balance method of calculating EFs, is based on two premises: (1) the mass of carbon available in the explosive or propellant can be accounted for in the masses of the various carbon-containing product species, and (2) the proportional distribution among carbon-containing products within individual microregions of the cloud remains relatively constant, even though the actual values for individual concentrations may be different within different macroregions of the cloud.

4.1.1.2 Based on these two premises, the total volume of the cloud becomes irrelevant in making EF calculations, and the EF of any individual product, i, can be estimated by the equation:

Equation 4.1 Calculation of Emission Factor.

$$EF_i = (f_c)\,\frac{[D_{ij}]}{[C_j]}$$

where, f_c = mass fraction of carbon in the fuel;

$[D_{ij}]$ = average concentration of product, i, in any specific volume element, j, of the cloud; and

$[C_j]$ = concentration of all forms of carbon in the sample, from volume element, j.

For example, the maximum EF value calculated for 2,4-dinitrotoluene from Phase B *surface* detonation samples was 8.4×10^{-6} weight units of 2,4-dinitrotoluene (e.g., kg) per weight unit of TNT detonated (kg) . (Values used were $f_c = 0.37$, $[D_i] = 797 \times 10^{-6}$mg/m^3 of 2,4-dinitrotoluene, $[C_i]$ = 34.95mg/m^3 of carbon. The product of an EF for a given species and the total amount of material consumed gives the total atmospheric release of the species.

The carbon-balance method has great potential for calculating OB/OD combustion product EFs in large-scale outdoor tests because *total volumes of clouds and total concentrations of products over that whole "volume" need not be known;* only "grab samples" need to be taken within the cloud by aircraft sampling. Since CO_2 is by far the major product of combustion, only the net (background corrected) CO_2 and the target analytes of interest need to be measured above background in order to successfully use the carbon-balance method.

4.1.2 Analytical Methods for Semivolatile Organics

Filters, soils, and the contents of fallout collection pans were analyzed either by supercritical fluid chromatography-mass spectrometry (SFC-MS) or gas chromatography-mass spectrometry (GC-MS) to expedite the work and allow comparison between the two methods. Phase C tests that incorporated the thermally labile RDX and explosive D (picric acid) explosives required the use of SFC-MS.

4.1.2.1 Gas Chromatography-Mass Spectrometry

Microbore capillary gas chromatography interfaced with mass spectrometry at its present mature stage of development is currently the most sensitive and broadly applicable general method for the analysis of volatile and semivolatile organic compounds, and it is presently the accepted standard. It suffers, however, from two major deficiencies: (1) inadequate volatility of some compounds of interest, even after modification by derivitization, and (2) analyte thermal decomposition under the required conditions of operation.

4.1.2.2 Supercritical Fluid Chromatography-Mass Spectrometry

Supercritical fluid chromatography-mass spectrometry is a rapidly emerging alternative to GC-MS. SFC-MS largely overcomes the two major disadvantages of GC-MS mentioned earlier by taking advantage of the additional parameters of solvation of the analytes in the supercritical carrier fluid modulated by variations in the pressure (fluid density), and by the addition of chemical modifiers. Furthermore, SFC closely approaches GC in resolving power. SFC suffers a disadvantage in that the much larger volumes of gas produced by expansion of the carrier fluid at the MS interface are more difficult to handle, but that problem is being rapidly overcome with improved technology.

4.1.3 Soil and Fallout Samples

4.1.3.1 Conversion Factors for Soil and Particulate Samples

Soil samples include the pretest (background), ejecta, and fallout samples from the explosive detonations. The particulate samples include the sputter, fallout, and burn pan residue samples from the propellant burns. Analytical results are expressed as mass of analyte per mass of soil or particulate collected. Some useful conversions are as follows:

μg/g or mg/kg = ppm (one part per million by mass or weight)
ng/g or μg/kg = ppb (one part per billion by mass or weight)
pg/g or ng/kg = ppt (one part per trillion by mass or weight).

4.1.3.2 Statistical Treatment of the Data.

All field-test phases provided several estimates of soil concentration for each analyte and for each sample source (background, ejecta, and 50- and 100-meter fallout soil). All data were examined and descriptive statistics calculated. The variance for each of the analyte/sample sources were more nearly equal with a logarithmic transformation; thus, geometric means were used to express averages. Using the transformed data, the analysis of variance (ANOVA) was performed for each analyte to determine if concentration means from the four sample sources were different. Duncan's multiple-range test was used to determine which concentration means were different. When the

analyte concentration values were below the detection limit, they were used as missing values in the statistical analyses. The calculation of the geometric means from only the values above the detection limits provides a positively biased mean, which, for health effect risks considerations are conservative.

4.1.3.3 Ejecta.

Ejecta soil is the soil displaced at the point of a *surface* detonation and redeposited in the crater, in the berm around the crater, and within a few meters of the crater. The volume of the displaced soil was estimated, using an equation developed in the Tooele Army Depot OB/OD Study. The equation is given in Equation 4.2.

Equation 4.2 Volume of Crater

$$V = \frac{\pi}{24} (3 D^2 L + 4 L^3)$$

where V = volume of crater
D = crater width
L = crater depth

4.1.3.4 Observations Applicable to all Detonations

The careful observer will note the anomaly of several of the semivolatile organic analytes occurring at concentration levels higher than background in soil fallout pans (which always contain only a few grams of very fine, dry soil particulates or dust) at radial distances in the 150 to 200 m range. The contamination is apparently greater at distances more remote from the detonation rather than the reverse which would seem more logical (of course in absolute terms the amounts are very small by any standard). Moreover, analytes such as TNT and the DNTs occur in levels above background levels in fallout pans from RDX detonations where they are not explainable at all in terms of direct contamination from the primary explosive itself. A possible explanation of these anomalies may lie in the nature of the surface of the dry desert soil at DPG which consists primarily of a very light, fluffy powder when it is dry, i.e. very fine soil particulate. A natural consequence of its fineness is that the particulate has a high specific surface (surface area per unit mass) which increases inversely

with particle size; consequently its adsorptive capacity for foreign matter likewise increases. This fine powdery particulate is easily disturbed and hence transported readily by winds and blast waves, yet its very fineness precludes rapid settling out, so that the very material most easily suspended and slowest to settle, by virtue of its higher specific surface, may carry relatively higher proportions of adsorbed foreign matter. Even the casual observer will note, that whenever a surface detonation occurred, that a component of the blast wave is propagated parallel to the ground surface stirring up a cloud of dust projecting a few meters up into the atmosphere and extending radially out from the blast center several hundred meters. This cloud is the major source of the fallout pan samples at distances beyond the periphery of significant subsurface soil ejection. Furthermore this material has been subject to cross-contamination from previous operations elsewhere in the vicinity at DPG. The factors indicate that fallout pan samples located on the surface, containing these fine particles are primarily samples of the existing surface contamination at DPG rather than representative samples of the contamination from the detonation. Soil fallout samples are probably a composite of (1) soil particles that are in direct contact with the fireball of detonation products, and (2) soil particles from the desert soil that are transported by the blast wave.

4.1.4 Emission Factors

Emission factors are also expressed as a ratio of the mass (weight) of a particular pollutant released to the mass (weight) of explosive or propellant consumed. Since the EF is a ratio, it is a dimensionless value; i.e., the EF for an analyte multiplied by pounds of explosive yields the total pounds of analyte released.

4.2 Explosives

The explosives chosen for study in these OB/OD tests were selected on the basis of the materials in the current demilitarization inventory. Bulk TNT was included in all phases as a baseline for comparison of reproducibility of results from phase to phase. It was originally selected for study because it is the most oxygen deficient of the explosives and thus most dependent on environmental oxygen for combustion; i.e., it represents a worst case for the potential of incomplete combustion and thus the greatest potential for air and soil contamination with detonation products.

4.2.1 TNT Tests - Phases A, B, and C

4.2.1.1 Airborne Release

4.2.1.1.1 Gases

a. Gaseous species measured during the large-scale *surface* and suspended TNT detonations conducted during Phases A, B, and C included carbon dioxide (CO_2), carbon monoxide (CO), and oxides of nitrogen (NO_x). During the Phase B and C tests, cloud ozone (O_3) concentrations were also measured. Summary EF data for *surface* TNT detonations are given in Table 4.2.1 and those for the suspended TNT tests in Table 4.2.2. For the *surface* TNT tests, the data in Table 4.2.1 are a compilation of 18 total, separate measurements, taken during three test phases. The data in Table 4.2.2 represents a statistical summary of 10 measurements accomplished in Phase B and C. Details of the methods used to calculate the gas EFs are given in detail in Appendix C. The minimum, maximum and average EF are given in the tables for each species measured. These EF's are dimensionless, so the reader can calculate values in the units of choice. For example, Table 4.2.1 shows that an average of 0.0036 kg of NO_2 were produced for each kg of TNT detonated in Phase A. To calculate the total release of a particular species, multiply the EF by the original weight of explosive or propellant.

Table 4.2.1 Gas Emission Factors for Surface TNT Detonations.

Gas Species	Emission Factors (g/g)		
	Phase A	Phase B	Phase C
CO_2 - min	1.19	1.27	1.25
CO_2 - max	1.28	1.33	1.30
CO_2 - avg	1.26	1.29	1.28
CO - min	0.037[a]	0.016	0.036
CO - max	0.10	0.054	0.066
CO - avg	0.061	0.042	0.049
NO - min	0.00020	0.00098	0.00087
NO - max	0.0010	0.0016	0.0017
NO - avg	0.00070	0.0014	0.0014
NO_2 - min	0.00091	0.00079	0.0011
NO_2 - max	0.0070	0.0016	0.0017
NO_2 - avg	0.0036	0.0011	0.0014

[a]Phase A CO data are taken from 6-L canister data.

Table 4.2.2 Gas Emission Factors for Suspended TNT Detonations[a].

Gas Species	Emission Factor (g/g)	
	Phase B	Phase C
CO_2 - min	1.33	1.34
CO_2 - max	1.36	1.34
CO_2 - avg	1.35	1.35
CO - min	0.0029	0.0052
CO - max	0.016	0.0078
CO - avg	0.0073	0.0069
NO - min	0.0016	0.0021
NO - max	0.0039	0.0024
NO - avg	0.0025	0.0023
NO_2 - min	0.0012	0.0011
NO_2 - max	0.0031	0.0013
NO_2 - avg	0.0021	0.0012

[a]No suspended TNT detonations were done during the Phase A tests.

b. Carbon dioxide EF for the *surface* TNT detonations ranged from 1.19 to 1.33 for all *surface* tests conducted with an overall average of 1.28. This compares to a theoretical CO_2 EF of 1.36, assuming that all the carbon in the TNT is converted to CO_2. A ratio of the actual to theoretical CO_2 EF gives an estimate of the overall efficiency of the detonation. For all *surface* tests, the average detonation efficiency is 0.94, indicating that all but 6 percent of the carbon in the TNT is converted to CO_2. Most of the remaining carbon is in the CO category, as discussed further below. Notably, the TNT molecule carries enough oxygen within it to oxidize only about 37 percent of the TNT carbon to CO_2. A secondary combustion mechanism is responsible for the high carbon conversion efficiencies observed in the tests. This occurs by way of entrainment of oxygen in ambient air into the detonation fireball, where further combustion of TNT carbon occurs.

c. The average CO_2 EF from all suspended TNT detonations was 1.35. The corresponding ratio of actual to theoretical CO_2 yield is 0.99, which reveals an even higher conversion efficiency of TNT carbon to CO_2 than observed for the *surface* TNT tests. A likely explanation for this observed effect is increased air entrainment into the detonation fireball in the suspended tests as compared to the *surface* tests. In the *surface* tests, the fireball has extensive contact with the adjacent soil, which depresses fireball temperatures, entrains soil, and restricts the incorporation of ambient oxygen into the fireball.

d. For the *surface* TNT tests, CO EFs varied between 0.016 and 0.10, with an overall average of 0.049. Inter-test comparisons of average CO EFs from each test phase are quite good and range from a low of 0.042 (Phase B) to a high of 0.061 (Phase C) with a relative standard deviation (RSD) between the three tests of 16 percent. For the *surface* TNT tests, about 2 to 3 percent of the TNT carbon is converted to CO, with about 94 percent converted to CO_2. The balance of carbon is in the other categories such as VOC and particles, as discussed below.

e. Carbon monoxide EF for the suspended TNT Tests are lower than those observed for the *surface* TNT tests. The overall average CO EF from the Phase B and C suspended tests was 0.007. These observations are consistent with the higher detonation efficiencies noted above for the suspended TNT tests. About 0.3 percent of the TNT carbon is converted to CO, with 99 percent converted to CO_2 for the suspended-detonation configuration.

f. Nitric oxide (NO) EFs for the *surface* TNT detonations reveal that averages for each of the three test phases varied by a factor of approximately two. Nitric oxide ranged from a low of 0.2 x 10^{-3} in the Phase A test to a high of 1.7 x 10^{-3} in the Phase C test. The overall NO EF average was 1.2 x 10^{-3}, or about 0.1 percent. Nitrogen dioxide (NO_2) EF results were in the same range as those encountered for NO, with an overall average of 1.9 x 10^{-3}. A conservative estimate of an NO_2 EF was determined to be (0.0038), or about 0.4 percent, by assuming that all NO released in the detonation is eventually converted to NO_2 by normal atmospheric processes. All calculations on gas EFs assume 100-percent recovery from the 80-L Teflon® sampling bag in the aircraft.

g. A slightly higher EF for NO was observed in the suspended TNT trials as compared to the *surface* trials. The average EF for NO_2 remained the same for the *surface* and suspended detonations, although the *surface* detonation EFs were associated with a larger variability. The larger variability is expected because the NO and NO_2 formed from the fixation of N_2 and O_2 is dependent upon the temperature of the fireball and the availability of O_2. The quantity of soil entrained varied from detonation to detonation and this would also result in variation in fireball temperature from detonation to detonation. In contrast, very little soil was entrained in the suspended tests and the NO and NO_2 EF were quite constant. For the suspended TNT tests, a conservative estimate of total NO_2 release, assuming that all NO is converted to NO_2, is about 0.6 percent.

h. Although measurements of ozone (O_3) were made of both background and plume air collected in the bag, the results were inconclusive and suggest that O_3 is rapidly lost to the bag surfaces. Average ozone (O_3) recovery from the bag is about 41 percent, based on collection and measurement of ambient (40 ppb) O_3 levels. It is likely that O_3 readily reacts with bag surfaces and cloud constituents such as NO and particles; however, the relative importance of these two reaction sinks cannot be ascertained from this data. Here, it is reasonable to assume that the detonation results in a net loss of ozone, since much of the NO produced will ultimately be converted to NO_2 by a reaction pathway that consumes O_3.

4.2.1.1.2 Particulate Matter

a. Results from the filter gravimetric analyses for all phases of TNT testing are given in Table 4.2.3. Data are reported as average particle mass concentrations per unit volume of air sampled in the cloud for both *surface* and suspended detonations. The reported data normally represent an average of three cloud passes per detonation for multiple detonations. Particle mass concentration in the cloud was measured by the aircraft in multiple passes through the cloud starting at about detonation time plus 1 minute (T_0+1) to T_0+4 minutes. Results for *surface* TNT detonations are highly variable and range from an average of 45 mg/m^3 in Phase A to 258 mg/m^3 in Phase C. It is likely that the marked differences in cloud particle concentrations between the Phase A, B, and C tests are largely influenced by the degree of soil moisture and compaction at the detonation site. Ground crews noted very different soil conditions during the various testing phases. Those sites with loosely packed soil are much more likely to loft soil during the detonation. The suspended TNT detonations clearly loft less soil debris than the *surface* detonations, as evidenced by average cloud particulate loadings of 11 and 37 mg/m^3 for the Phase B and C tests, respectively.

Table 4.2.3 Summary of Total Particulate Mass Concentrations for Surface and Suspended TNT Detonations.

Test	Particulate Mass Concentration (mg/m^3)			
	Minimum	Maximum	Average	No. of Filter Samples
Phase A - surface	24	65	45	2
Phase B - surface	35	85	62	3
Phase C - surface	248	268	258	2
Phase B - Suspended	8	16	11	3
Phase C - Suspended	37	37	37	1

4.2.1.1.3 Volatile Organic Compounds

a. A statistical summary of VOC EFs measured during all *surface* TNT detonations in all testing phases is given in Table 4.2.4. A similar summary for all suspended TNT tests is given in Table 4.2.5. Only representative species including methane, total nonmethane hydrocarbons (TNMHC--the sum of the C_2 to C_{10} compounds detected), and benzene were selected to show the general

trends in VOC emissions from TNT tests. A representative example of all VOC species detected with a calculation of VOC species EFs is given in Appendix E.

Table 4.2.4 Volatile Organic Compound Emission Factors for Surface TNT Detonations[a].

Species	Emission Factor (g/g)		
	Phase A	Phase B	Phase C
CH_4 - min	930×10^{-6}	360×10^{-6}	610×10^{-6}
CH_4 - max	1600×10^{-6}	5200×10^{-6}	2200×10^{-6}
CH_4 - avg	1500×10^{-6}	1200×10^{-6}	1500×10^{-6}
Number of observations	5	19	6
TNMHC - min	750×10^{-6}	500×10^{-6}	BD[b]
TNMHC - max	1600×10^{-6}	11000×10^{-6}	5000×10^{-6}
TNMHC - avg	1400×10^{-6}	1900×10^{-6}	2100×10^{-6}
Number of observations	5	19	11
Benzene - min	58×10^{-6}	32×10^{-6}	0.27×10^{-6}
Benzene - max	120×10^{-6}	400×10^{-6}	130×10^{-6}
Benzene - avg	94×10^{-6}	93×10^{-6}	100×10^{-6}
Number of observations	5	19	11

[a]Emission factors are expressed in terms of 10^{-6} for ease of comparison, e.g., 930×10^{-6} is equivalent to 0.00093.
[b]Below detection limit.

b. Average methane EFs for *surface* TNT tests are about 0.0015 in all three phases. Similar results were observed for the TNMHC category, with an average EF of slightly less than 0.002. For these tests, the TNMHC category was primarily composed of light hydrocarbons, such as ethane, propane, acetylene, etc., with little or no contribution from toxic VOC species, such as benzene and toluene. The methane and TNMHC categories reveal information concerning the degree of detonation efficiency in much the same manner as the carbon dioxide EF. High conversion efficiency of the carbon in the parent explosive compound to CO_2 is accompanied by low production rates of methane and TNMHC. Benzene EFs for the *surface* TNT tests are about a factor of 10 lower than EFs for methane and TNMHC. The average benzene EF from all tests is very near 0.0001 in all three phases.

Table 4.2.5 Volatile Organic Compound Emission Factors for Suspended TNT Detonations[a].

Species	Emission Factor (g/g)	
	Phase B	Phase C
CH_4 - min	BD[b]	610×10^{-6}
CH_4 - max	220×10^{-6}	2200×10^{-6}
CH_4 - avg	61×10^{-6}	1500×10^{-6}
Number of observations	13	6
TNMHC - min	BD	BD
TNMHC - max	4800×10^{-6}	5800×10^{-6}
TNMHC - avg	210×10^{-6}	5000×10^{-6}
Number of observations	16	6
Benzene - min	BD	8.8×10^{-6}
Benzene - max	11×10^{-6}	130×10^{-6}
Benzene - avg	3.2×10^{-6}	62×10^{-6}
Number of observations	13	6

[a]Emission factors are expressed in terms of 10^{-6} for ease of comparison, e.g., 220×10^{-6} is equivalent to 0.000220.
[b]Below detection limit.

c. Similar data for the suspended TNT tests reveals generally lower average EFs for all detected VOC compounds. Methane EFs are quite variable, with a near 50-fold difference between the Phase B and C tests. Much larger differences also exist for the TNMHC category between Phase B and C suspended tests. Benzene EFs for the suspended TNT tests, at about 0.000003, are lower than those measured for the *surface* tests by about a factor of 30. Benzene is included here as representative of the potentially toxic VOC categories for bulk explosive detonations.

d. In general, the VOC EFs for suspended TNT tests are lower than for the *surface* TNT tests. This is consistent with the so called "detonation efficiency" determined for these two test configurations as discussed earlier. Interaction of the *surface* detonated TNT fireballs with soil materials very likely serves to reduce the duration of elevated temperatures within the fireball, as well as entrainment of ambient air into the fireball. The net result for the *surface* detonations is reduced conversion of carbon in the explosive to carbon dioxide with higher fractions of carbon monoxide and light hydrocarbon formation by incomplete combustion mechanisms.

4.2.1.1.4 Semivolatile Organics

a. EFs for the semivolatile organic target compounds are given in Table 4.2.6 for the *surface* TNT test and Table 4.2.7 for the suspended TNT test. As a conservative estimate, only the maximum value encountered in each test type is given in the table for each test series. In general, for both surface and suspended detonations, the majority of the compounds on the target analyte list were not detected on the filter samples.

Table 4.2.6 Maximum Semivolatile Organic Emission Factors Measured for Surface TNT Detonations[a].

Species[b]	Emission Factor (g/g)		
	Phase A	Phase B	Phase C
2,4-Dinitrotoluene	150 x 10^{-9}	8400 x 10^{-9}	BD[c]
2,6-Dinitrotoluene	19 x 10^{-9}	7100 x 10^{-9}	BD
2,4,6-Trinitrotoluene	220 x 10^{-9}	150 x 10^{-9}	60 x 10^{-9}
2-Nitronaphthalene	80 x 10^{-9}	270 x 10^{-9}	BD
N-Nitrosodiphenylamine	BD	4.4 x 10^{-9}	BD
1,3,5-Trinitrobenzene	BD	BD	BD
2-Nitrodiphenylamine	BD	N/A[d]	BD
1-Nitropyrene	BD	39 x 10^{-9}	BD
Naphthalene	BD	3700 x 10^{-9}	2600 x 10^{-9}
Benz[a]anthracene	2.2 x 10^{-9}	160 x 10^{-9}	100 x 10^{-9}
Benzo[a]pyrene	BD	240 x 10^{-9}	BD
Pyrene	BD	N/A	220 x 10^{-9}
Phenol	BD	5200 x 10^{-9}	BD
Dibenzofuran	BD	85 x 10^{-9}	180 x 10^{-9}
Diphenylamine	N/A	7.7 x 10^{-9}	170 x10^{-9}
4-Nitrophenol	BD	N/A	N/A
Biphenyl	BD	N/A	N/A
Phenanthrene	BD	N/A	N/A
1-Methylnaphthalene	BD	N/A	N/A
2-Methylnaphthalene	BD	N/A	N/A

[a]Emission factors are expressed in terms of 10^{-9} for ease of comparison, e.g., 150 x 10^{-9} is equivalent to 0.000000150.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels.
[c]Below detection limit.
[d]Not included on analyte list for analysis.

Table 4.2.7 **Maximum** Semivolatile Organic Emission Factors Measured for Suspended TNT **Detonations**[a].

Species[b]	Emission Factor (g/g)	
	Phase B	Phase C
2,4-Dinitrotoluene	200×10^{-9}	BD[c]
2,6-Dinitrotoluene	300×10^{-9}	BD
2,4,6-Trinitrotoluene	46×10^{-9}	140×10^{-9}
2-Nitronaphthalene	15×10^{-9}	BD
N-Nitrosodiphenylamine	29×10^{-9}	BD
1,3,5-Trinitrobenzene	BD	BD
2-Nitrodiphenylamine	N/A[d]	BD
1-Nitropyrene	59×10^{-9}	BD
Naphthalene	12×10^{-9}	1800×10^{-9}
Benz[a]anthracene	66×10^{-9}	320×10^{-9}
Benzo[a]pyrene	310×10^{-9}	BD
Pyrene	N/A	19×10^{-9}
Phenol	12000×10^{-9}	BD
Dibenzofuran	60×10^{-9}	190×10^{-9}
Diphenylamine	25×10^{-9}	BD

[a]Emission factors are expressed in terms of 10^{-9} for ease of comparison, e.g., 200×10^{-9} is equivalent to 0.000000200.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection limits.
[c]Below detection limit.
[d]Not included on analyte list for analysis.

b. In most cases semivolatile compounds detected during these tests include the parent compound, 2,4,6-TNT, as well as the 2,4- and 2,6-dinitrotoluene compounds. The compounds occurring in the highest concentrations are typically phenol and naphthalene, with EFs about 0.000001. Most of the other detected compounds are observed at levels 10-fold to 1000-fold lower than those for phenol and naphthalene.

c. An examination of semivolatile results for the suspended tests reveals that the emission levels do not change appreciably from those measured in the *surface* tests. This is an important observation and stands in contrast to the lower EFs for such species as CO and VOC seen in the

suspended TNT tests. Above-ground elevation of the bulk explosive prior to detonation does not appear to have a significant effect on the production of semivolatile organic compounds.

4.2.1.2 Soil

4.2.1.2.1 Ejecta.

Ejecta soil is the soil displaced at the point of a *surface* detonation and redeposited in the crater, in the berm around the crater, and within a few meters of the crater. The volume of the displaced soil was estimated using Equation 4.2, paragraph 4.1.3.3. The calculated crater volume for TNT tests are shown in Table 4.2.8. The volume of the displaced soil varied from 12 to 42 m^3. The calculated weight of the soil, based on a density of 2.5 g/cc, varied from 29 to 105 metric tons, with a mean of 56 metric tons. This loose soil was sampled, and the semivolatile organics remaining after the detonation were identified and quantified. Background soil samples of the sites were taken prior to the detonations to provide a baseline concentration level of semivolatile organics in the local soil.

Table 4.2.8 OB/OD Detonation Crater Dimension, Volume, and Weight of Displaced Soil.

Location	Rim Opening (m)	Depth (m)	Volume (m^3)	Weight of Soil (kg)	Average Weight (kg)
TNT Surface Detonations-Phase B					
1	5.6	2.1	30.71	76777	
2	4.9	1.7	18.60	46503	
3	5.3	1.3	15.49	38726	
4	5.0	1.8	20.73	51813	
5	6.5	2.2	42.08	105192	
6	ND[a]	1.9	ND	ND	
7	ND	1.4	ND	ND	
TNT Surface Detonations-Phase C					
C1	4.3	1.4	11.60	29005	
C2	4.6	1.6	15.44	38600	
C3	6.7	1.8	34.78	86961	
C4	4.5	1.7	16.09	40228	
C5	ND	ND	ND	ND	
C6	4.3	1.7	14.92	37290	
C0	5.3	2.0	26.25	65627	56066

[a]ND - no data.

a. Phase A. Soil sampling was accomplished to develop and refine field soil collection methods and the chemical extraction/assay procedures. The data are summarized in Table 4.2.9.

Table 4.2.9 Summary of Phase A Pretest and Ejecta Soil Samples for Semivolatile Organics.

Source of Sample	Compounds Found[a]	Concentration Range (ng/kg)[b]
Pretest 12-ft core	None	BD[c]
Pretest 15-cm core	2,4-Dinitrotoluene	0.58 to 1.2
	2,6-Dinitrotoluene	BD to 2.7
	2-Nitronaphthalene	2.3 to 2.9
Ejecta	2,4-Dinitrotoluene	68 to 170
	2,6-Dinitrotoluene	23 to 35
	2,4,6-Trinitrotoluene	300 to 4400
	2-Nitronaphthalene	1.1 to 4.9
	1,3,5-Trinitrobenzene	BD to 160
	Naphthalene	BD to 1200
Posttest 15-cm core	2,4-Dinitrotoluene	30
	2,6-Dinitrotoluene	BD
	2,4,6-Trinitrotoluene	1500
	2-Nitronaphthalene	1.1
	1,3,5-Trinitrobenzene	11
	Naphthalene	BD
Pan-composite	2,4-Dinitrotoluene	160
	2,6-Dinitrotoluene	140
	2,4,6-Trinitrotoluene	190
	2-Nitronaphthalene	2.7
	1,3,5-Trinitrobenzene	240
	Naphthalene	2300

[a]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[b]Represents ng of analyte per kg of soil.
[c]Below detection limit.

b. Phases B and C.

(1) Background samples were taken at all detonation sites. Although sampling procedures differed somewhat between phases B and C, (depth of cores, number of cores, and the compositing of samples), all samples were from an area at DPG considered uncontaminated from previous explosive detonations. The ejecta sampling at each site on Phases B and C were similar, although

compositing of samples differed between the two phases. The summary data are shown in Table 4.2.10. The analytes which showed increased concentrations (above concentration levels in the pretest soil) in the ejecta soil after detonation were 2,4,6-trinitrotoluene, 1,3,5-trinitrobenzene, benz[a]anthracene, pyrene, and phenol.

Table 4.2.10 Summary of Semivolatile Organic Concentrations from Phases B and C Pretest and Ejecta Soil Samples, Based on the Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Concentration Range (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
Pretest	10	7	2,4-Dinitrotoluene	BD[e] to 1.6	0.87
	10	5	2,6-Dinitrotoluene	BD to 9.3	5.0
	10	9	2,4,6-Trinitrotoluene	BD to 24	1.0
	10	8	2-Nitronaphthalene	BD to 1.6	0.33
	10	2	N-Nitrosodiphenylamine	BD to 0.19	0.020
	10	10	Naphthalene	0.016 to 4.8	0.89
	10	9	Benz[a]anthracene	BD to 0.39	0.21
	10	10	Pyrene	0.026 to 2.2	0.10
	10	10	Dibenzofuran	0.007 to 1.6	0.21
	10	2	Diphenylamine	BD to 0.55	0.40
Ejecta	13	9	2,4-Dinitrotoluene	BD to 8.0	1.3
	13	10	2,6-Dinitrotoluene	BD to 2.3	0.70
	13	13	2,4,6-Trinitrotoluene	1.7 to 360	23
	13	8	2-Nitronaphthalene	BD to 1.8	0.27
	13	6	N-Nitrosodiphenylamine	BD to 1.1	0.18
	13	8	1,3,5-Trinitrobenzene	BD to 39	0.97
	13	1	1-Nitropyrene	BD to 1.2	1.2
	13	13	Naphthalene	0.028 to 210	7.0
	13	10	Benz[a]anthracene	BD to 11	1.3
	13	12	Pyrene	BD to 53	2.4
	13	1	Phenol	BD to 69	69
	13	10	Dibenzofuran	BD to 18	0.59
	13	2	Diphenylamine	BD to 0.79	0.67

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per kg of soil.
[d]Geometric means were computed only from the values above the detection limit.
[e]Below detection limit.

4.2.1.2.2 Fallout

Fallout for these OB/OD tests is defined as the particulate material deposited beyond the ejecta area. On the Phase A trials, samples were collected to verify and refine the methodologies of sample placement, sample type, sample handling, and laboratory extraction and assay. The Phase B and C tests were designed to characterize the resulting soil fallout pattern and the amount of species deposited on the soil. The background and ejecta data were included along with the fallout data prior to performing the ANOVA; this permitted the comparison of background, ejecta, 50-meter fallout, and 100-meter fallout soil data.

a. Surface TNT Detonations, Phase A.

Fallout was sampled with both a 1-m^2 pan and a 15-cm depth core sampler at each sampling point. The data were valuable for identifying analytes present in the soil before and after detonation and for refining sampling technology; however, the close proximity of the detonations permitted overlap of fallout and thus rendered the data useless for characterizing a single detonation. A summary of the semivolatile organics detected, and the concentration for the two types of samples are shown in Table 4.2.11.

Table 4.2.11 Summary of Semivolatile Analyte Concentrations Detected in Soil Samples in Phase A TNT Detonations.

Analyte	Concentration (ng/kg)[a]	
	Soil Core	Fallout Pan
2,4-Dinitrotoluene	32	170
2,6-Dinitrotoluene	BD[b]	140
2,4,6-Trinitrotoluene	1600	190
2-Nitronaphthalene	1.2	2.6
1,3,5-Trinitrobenzene	12	240
Naphthalene	BD	2400

[a]Represents ng of analyte per kg of soil.
[b]Below detection limit.

(1) The results indicate the following:

(a) Chemical extraction and analysis of semivolatile analyte compounds is possible.

(b) The pan samples are more representative of the fallout soil than the 15-cm cores, which are almost entirely samples of undisturbed soil. The pan samples represent a deposition area of 1 m^2, whereas the 5-cm diameter core represents an area of 0.002 m^2.

(c) The pans must be located at least 50 meters from detonation points to avoid damage by the blast wave.

b. Surface TNT Detonations, Phases B and C.

Fallout sampling for a *surface* detonation was done with 1-m^2 pans on all trials. On the Phase B ORI and all Phase C trials, pans were placed on the 50-, 100-, 150-, and 200-meter circles. On other *surface* detonations, sampling was only on the 50-, and 100-meter circles.

(1) The analyte concentration data from the 50- and 100-meter sampling circles for the *surface* detonations are summarized in Table 4.2.12a. The analyte concentration data for the 150- and 200-meter sampling circles are summarized in Table 4.2.12b. The weight of sample available for assay after combining the fallout pan samples (six 1-m^2 samples) varied from 3.6 to 35 grams at 150 meters and 1 to 4.9 grams at 200 meters from the detonation. The analytes 2,4-dinitrotoluene, 2,4,6-trinitrotoluene, 1,3,5-trinitrobenzene, benz[a]anthracene, and pyrene were detected above background levels on the 50-meter circle. The analytes 2,4-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronaphthalene, 1,3,5-trinitrobenzene, naphthalene, benz[a]anthracene, pyrene, and dibenzofuran were detected above background levels on the 100-meter circle. The analytes identified on the 150-meter and 200-meter circles were the same analytes identified by soil samples from the ejecta, and fallout at 50 and 100 meters.

Table 4.2.12a Summary of Semivolatile Organic Concentrations from Phases B and C Fallout Soil Samples, Based on Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Concentration Range ($\mu g/kg$)[c]	Geometric Mean[d] ($\mu g/kg$)
	Total	AD[a]			
50-m circle	7	4	2,4-Dinitrotoluene	BD[e] to 32	4.0
	7	5	2,6-Dinitrotoluene	BD to 7.8	0.77
	7	7	2,4,6-Trinitrotoluene	6.8 to 45	13
	7	4	2-Nitronaphthalene	BD to 2.6	0.43
	7	3	1,3,5-Trinitrobenzene	BD to 0.89	0.28
	7	1	N-Nitrosodiphenylamine	BD to 0.069	0.069
	7	7	Naphthalene	0.50 to 74	6.0
	7	5	Benz[a]anthracene	BD to 6.4	1.3
	7	6	Pyrene	BD to 36	1.7
	7	5	Dibenzofuran	BD to 2.3	0.73
100-m circle	7	4	2,4-Dinitrotoluene	BD to 35	9.2
	7	4	2,6-Dinitrotoluene	BD to 21	3.0
	7	7	2,4,6-Trinitrotoluene	11 to 310	75
	7	2	2-Nitronaphthalene	BD to 47	8.7
	7	3	1,3,5-Trinitrobenzene	BD to 19	5.2
	7	7	Naphthalene	0.30 to 220	21
	7	6	Benz[a]anthracene	BD to 51	5.6
	7	2	Benzo[a]pyrene	BD to 8.5	6.4
	7	6	Pyrene	BD to 21	4.7
	7	4	Dibenzofuran	BD to 29	5.2
	7	1	Diphenylamine	BD to 5.4	5.4

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per kg of soil.
[d]Geometric means were computed from the values above the detection limit.
[e]Below detection limit.

Table 4.2.12b Summary of Semivolatile Organic Concentrations from Phases B and C Fallout Soil Samples, Based on Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Concentration Range (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
150-m circle	3	1	2,6-Dinitrotoluene	BD[e] to 2.1	2.1
	3	2	2,4,6-Trinitrotoluene	BD to 35	26
	3	2	Naphthalene	BD to 19	11
	3	1	Benz[a]anthracene	BD to 1.9	1.9
	3	2	Benzo[a]pyrene	BD to 9.1	7.8
	3	1	Pyrene	BD to 10	10
	3	2	Diphenylamine	BD to 97	33
200-m circle	3	2	2,4,6-Trinitrotoluene	BD to 680	110
	3	1	Naphthalene	BD to 510	510
	3	1	Benz[a]anthracene	BD to 87	87
	3	1	Pyrene	BD to 88	88
	3	3	Diphenylamine	5.7 to 97	24

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per kg of soil.
[d]Geometric means were computed from the values above the detection limit.
[e]Below detection limit.

(2) The Duncan's multiple-range test comparing the ejecta sample results with the fallout sample results for the semivolatile organics shows the following:

(a) The ejecta analyte concentration means were not different from the 50-meter concentration means.

(b) The 100-meter concentration means for 2,4-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronaphthalene, and dibenzofuran were larger than the ejecta concentration means.

(3) This increase in concentration of the semivolatile analytes on the fallout soil at greater distance from the detonation may be a function of particle size. The increased surface area per volume of particle that results with the smaller particles provides more surface area for absorption of the analyte. The results of these tests show that analytes in the 200-, 150-, and 100-meter fallout

samples were more concentrated than in the 50-meter fallout samples. The results did not show the 50-meter analyte concentrations to be greater than the ejecta concentration means. A probable explanation of this is that soil chunks are propelled as far as 50-meters and the sample is a composite of a wide range of particle sizes, including the larger chunks whose interior volume is not exposed to detonation products. This is in contrast to the fallout samples at greater distances, which consist of smaller particles.

(4) Relationship of Mass of Analyte to Fallout Area. The mass of analyte collected was compared to the total sampling area of the fallout pans making up the sample. The data are summarized in Tables 4.2.13a and 4.2.13b. These data are useful in estimating the amount of an analyte that is deposited on the terrain as a function of distance from the source.

Table 4.2.13a Summary of Semivolatile Organic Concentrations from Phases B and C Fallout Soil Samples, Based on Area Sampled.

Source of Sample	Number of Observations		Analyte[b]	Concentration Range ($\mu g/m^2$)[c]	Geometric Mean[d] ($\mu g/m^2$)
	Total	AD[a]			
50-m circle	7	4	2,4-Dinitrotoluene	BD[e] to 3.8	0.47
	7	5	2,6-Dinitrotoluene	BD to 0.48	0.080
	7	7	2,4,6-Trinitrotoluene	0.48 to 5.3	1.2
	7	4	2-Nitronaphthalene	BD to 0.25	0.045
	7	1	N-Nitrosodiphenylamine	BD to 0.008	0.008
	7	3	1,3,5-Trinitrobenzene	BD to 0.063	0.026
	7	7	Naphthalene	0.047 to 8.7	0.59
	7	5	Benz[a]anthracene	BD to 0.75	0.14
	7	6	Pyrene	BD to 4.2	0.18
	7	5	Dibenzofuran	BD to 0.24	0.081
100-m circle	7	4	2,4-Dinitrotoluene	BD to 0.29	0.15
	7	4	2,6-Dinitrotoluene	BD to 0.18	0.047
	7	7	2,4,6-Trinitrotoluene	0.045 to 2.7	0.88
	7	2	2-Nitronaphthalene	BD to 0.38	0.14
	7	3	1,3,5-Trinitrobenzene	BD to 0.16	0.052
	7	7	Naphthalene	0.090 to 2.1	0.24
	7	6	Benz[a]anthracene	BD to 0.48	0.064
	7	2	Benzo[a]pyrene	BD to 0.072	0.69
	7	6	Pyrene	BD to 0.60	0.054
	7	4	Dibenzofuran	BD to 0.30	0.086
	7	1	Diphenylamine	BD to 0.021	0.021

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per m^2 of terrain.
[d]Geometric means were computed from the values above detection limit.
[e]Below detection limit.

Table 4.2.13b Summary of Semivolatile Organic Concentrations from Phases B and C Fallout Soil Samples, Based on Area Sampled.

Source of Sample	Number of Observations		Analyte[b]	Concentration Range ($\mu g/m^2$)[c]	Geometric Mean[d] ($\mu g/m^2$)
	Total	AD[a]			
150-m circle	3	1	2,6-Dinitrotoluene	BD[e] to 0.012	0.012
	3	2	2,4,6-Trinitrotoluene	BD to 0.20	0.060
	3	2	Naphthalene	BD to 0.11	0.025
	3	1	Benz[a]anthracene	BD to 0.011	0.011
	3	2	Benzo[a]pyrene	BD to 0.038	0.018
	3	1	Pyrene	BD to 0.058	0.058
	3	2	Diphenylamine	BD to 0.029	0.017
200-m circle	3	2	2,4,6-Trinitrotoluene	BD to 0.11	0.041
	3	1	Naphthalene	BD to 0.420	0.420
	3	1	Benz[a]anthracene	BD to 0.071	0.071
	3	1	Pyrene	BD to 0.072	0.072
	3	3	Diphenylamine	0.0047 to 0.016	0.0083

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per m^2 of terrain.
[d]Geometric means were computed from the values above detection limit.
[e]Below detection limit.

c. Suspended TNT Detonations, Phase B.

The Phase B suspended detonation sampling was accomplished by taking a 15-cm diameter core to a depth of 2.5 cm on the 1-, 2-, 4-, 8-, and 16-meter sampling circles. The soil was sampled prior to the suspended detonation to establish background concentration levels for the semivolatiles. These samples were taken horizontally out to 16 meters from a point on the ground directly under the suspended TNT. The same fallout sampling points and procedures were used for the post detonation samples. An ANOVA comparing the means from each analyte for the background, 1-, 2-, 4-, 8-, and 16-meter samples detected no significant differences in the level of analyte. The data from the post detonation, 1-, 2-, 4-, 8-, and 16-meter samples, were combined for the summary in Table 4.2.14.

Table 4.2.14 Summary of Semivolatile Organic Concentrations from Phase B TNT Suspended Detonation Soil Samples.

Source of Sample	Number of Observations		Analyte[b]	Concentration Range (µg/kg)[c]	Geometric Mean[d] (µg/kg)
	Total	AD[a]			
Pretest	7	7	2,4-Dinitrotoluene	0.16 to 9.5	0.62
	7	7	2,6-Dinitrotoluene	0.012 to 1.3	0.08
	7	7	2,4,6-Trinitrotoluene	1.9 to 1200	33
	7	2	2-Nitronaphthalene	BD[e] to 0.10	0.04
	7	2	N-Nitrosodiphenylamine	BD to 0.30	0.27
	7	6	1,3,5-Trinitrobenzene	BD to 78	0.41
	7	7	Naphthalene	1.5 to 27	8.8
	7	7	Benz[a]anthracene	0.016 to 1.9	0.29
	7	7	Pyrene	.0.090 to 2.1	1.1
	7	7	Dibenzofuran	.034 to 0.51	0.22
	7	4	Diphenylamine	BD to 0.10	0.023
Posttest	20	20	2,4-Dinitrotoluene	0.02 to 13	0.93
	20	18	2,6-Dinitrotoluene	BD to 3.1	0.65
	20	20	2,4,6-Trinitrotoluene	3.3 to 1300	25
	20	13	2-Nitronaphthalene	BD to 1.1	0.12
	20	7	N-Nitrosodiphenylamine	BD to 2.8	0.41
	20	15	1,3,5-Trinitrobenzene	BD to 17	0.63
	20	20	Naphthalene	1.4 to 86	13
	20	16	Benz[a]anthracene	BD to 4.0	0.43
	20	19	Pyrene	BD to 7.7	1.7
	20	2	Phenol	BD to 1.8	55
	20	19	Dibenzofuran	BD to 31	0.55
	20	12	Diphenylamine	BD to 0.14	0.057

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents µg of analyte per kg of soil.
[d]Geometric means were computed only from the values above detection limit.
[e]Below detection limit.

4.2.1.2.3 Estimates of Total Deposition.

The methodologies developed and refined for collection of samples and analyses of data during the OB/OD testing are useful in arriving at estimates of soil deposition of emissions from munitions to be disposed of in the demilitarization inventory. The results from the detonation of approximately 1 metric ton of bulk TNT and the resulting deposition of 2,4-dinitrotoluene are used here as an example. Table 4.2.15 lists the maximum values for 2,4-dinitrotoluene concentration from the OB/OD TNT detonations that would be of use in an assessment of environmental impact.

Table 4.2.15 Summary of Fallout and 2,4-Dinitrotoluene Concentration by Weight and Area

Concentration	Back-ground	Ejecta	50-m Circle	100-m Circle	150-m Circle	200-m Circle
Fallout (grams of soil/m^2 of terrain)	NA[a]	NA	80	8.9	2.4	0.42
Geometric mean (μg of analyte/kg of soil)	0.87	1.3	4	9.2	BD[b]	BD
Maximum (μg/kg)	1.6	8.0	32	35	BD	BD
Geometric mean (μg of analyte/m^2 of terrain)	NA	NA	0.47	0.15	BD	BD
Maximum (μg/m^2)	NA	NA	3.8	0.29	BD	BD

[a]Not applicable.
[b]Below detection limit.

a. For example, the data above can be used to determine the maximum mass of residual 2,4-dinitrotoluene that would be expected from a 1-metric-ton detonation of TNT. Using the maximum crater soil weight given in Table 4.2.8 (105 metric tons) and the maximum concentration for 2,4-dinitrotoluene at the 100-meter circle given in Table 4.2.15 (35μg/kg), the calculated total 2,4-dinitrotoluene soil deposition from a 1-metric-ton TNT detonation is 3.7 grams. This is a conservative estimate, because all the ejecta soil is considered as contaminated at this level, whereas if the ejecta concentration value is used, it would be concluded that no 2,4-dinitrotoluene resulted from the detonation. The mean ejecta 2,4-dinitrotoluene concentration (1.3 μg/kg) does not significantly differ from the mean background concentration level at that test site (0.87 μg/kg).

b. A second example may be used to estimate the 2,4-dinitrotoluene fallout from a 1-metric-ton TNT detonation. This can be approximated by using the deposition concentration (μg of analyte per m^2 of terrain) multiplied by an assigned deposition area at each sampled distance. This is shown in Table 4.2.16 with the total amount of 2,4-dinitrotoluene fallout estimated at 76 mg. A similar calculation using the measured analyte concentration expressed in μg of analyte per kg of soil, multiplied by the mass of fallout soil in the deposition area, yields a total amount of 2,4-dinitrotoluene of 55 mg. This means that about 2.0 percent of the 3.7 gram total 2,4-dinitrotoluene soil deposition was recovered as fallout within 225 meters of the detonation site. In other words, about 98 percent of the total 2,4-dinitrotoluene residues are in the immediate vicinity of the crater in the soil ejecta.

Table 4.2.16 Concentration and Deposition Area Used to Determine Fallout Amount for 2,4-Dinitrotoluene.

Distance Interval (m)	Deposition Area (m^2)	Concentration ($\mu g/m^2$)	Fallout Amount (mg)
0 to 75	17,671	3.8	67
75 to 125	31,416	0.29	9
125 to 175	47,124	BD[a]	0
175 to 225	62,832	BD	0
		Total =	76

[a]Below detection limit.

c. The results reveal some important implications for future characterization of OB/OD demilitarization of explosive munitions. First, crater mass and fallout mass at various distances should be well documented. Along with these weight measurements, a concentration of analytes in the fallout soil is required. It is suggested that this can be accomplished with chemical analysis of soil at 100 meters; this distance is suggested because it provided sufficient sample size for extraction and it was also free of clods. The analyte concentration at 100 meters would be used to characterize the ejecta soil and fallout soil at all sampling points based on the mass of soil collected. If implemented, these changes would result in less chemical analyses, thus reducing the cost of testing.

4.2.2 Composition B Test - Phase C

4.2.2.1 Air Emissions

4.2.2.1.1 Gases

a. Gas EFs measured during the six 907-kg composition B detonations are statistically summarized in Table 4.2.17. Carbon dioxide EFs range from 0.86 to 0.87. An average value of 0.87 compares with a theoretical CO_2 EF of 0.92, assuming 100-percent conversion of explosive carbon to CO_2. This corresponds to a detonation efficiency of about 0.95. Although the oxygen balance of composition B at -53 percent is higher than that of TNT, the detonation efficiency for a *surface* detonation is about the same. From this observation it appears that the oxygen balance of the explosive molecule does not appear to play a significant role in the observed carbon conversion efficiency in the detonation process. The entrainment of ambient air into the fireball provides additional oxygen to provide the high carbon-conversion efficiencies observed.

Table 4.2.17 Gas Emission Factors for Composition-B Surface Detonations.

Species	Emission Factor (g/g)
CO_2 - min	0.86
CO_2 - max	0.87
CO_2 - avg	0.87
CO - min	0.026
CO - max	0.037
CO - avg	0.031
NO - min	BD
NO - max	1.8×10^{-3}
NO - avg	0.8×10^{-3}
NO_2 - min	0.009×10^{-3}
NO_2 - max	2.3×10^{-3}
NO_2 - avg	1.0×10^{-3}

b. Carbon monoxide EFs are correspondingly low, ranging from 0.026 to 0.037, with an average of 0.031. Emission factors measured for NO and NO_2 are in the vicinity of 1×10^{-3}. In both cases, the measured levels are comparable to those measured for TNT.

4.2.2.1.2 Particulates

Particulate mass concentrations measured during multiple aircraft passes through the detonation clouds from the composition B tests are summarized in Table 4.2.18. Cloud particle concentrations from the two three-detonation trials were about 200 mg/m^3. The carbon content of the particulate samples was not measured in this test series; however, on the basis of earlier phase B TNT tests, virtually all the collected particulates are suspended soil.

Table 4.2.18 Average Particulate Matter Concentrations Measured During Multiple Aircraft Sampling Passes of Composition-B Detonation Clouds.

Test Event	**Particulate Matter Concentration (mg/m^3)**
Composition-B - first 3-detonation series	218
Composition-B - second 3-detonation series	191

4.2.2.1.3 Volatile Organic Compounds

VOC EFs for the composition B *surface* detonations as sampled with 6-L canisters and followed by gas chromatographic analysis are summarized in Table 4.2.19. The results are very similar to those observed from the TNT tests, with relatively low methane and TNMHC releases. The toxic VOC category as represented by benzene is similarly low, with an average EF of about 0.000062.

Table 4.2.19 Volatile Organic Compound Emission Factors Measured for the Composition-B Detonation Tests.

Species	Emission Factor (g/g)
CH_4 - min	0.4×10^{-3}
CH_4 - max	0.8×10^{-3}
CH_4 - avg	0.6×10^{-3}
TNMHC - min	0.5×10^{-3}
TNMHC - max	2.3×10^{-3}
TNMHC - avg	1.2×10^{-3}
Benzene - min	29×10^{-6}
Benzene - max	86×10^{-6}
Benzene - avg	62×10^{-6}

4.2.2.1.4 Semivolatile Organics (Exotics)

Emission factors for the semivolatile organic target compounds are given in Table 4.2.20 for the Phase C surface detonation of composition B, which is a mixture of TNT and RDX. The values shown in the table are the maximum values obtained from two separate trials each consisting of three detonations in series. Analyses for the semivolatile target analytes were done by SFC-MS which allows the determination of thermally labile compounds such as the parent explosive RDX, which would otherwise decompose during separation by conventional gas chromatography. The EFs for the target analytes are all observed at less than the part per million (10^{-6}) level. The highest EFs observed were for 2,4-dinitrotoluene and naphthalene at levels of about 4×10^{-7}. Next highest EFs were 2,4,6-trinitrotoluene, and pyrene at a level of about 2×10^{-7}. In this test series the parent compound RDX was not seen although it accounts for about 40 percent of the mass of the composition B explosive. The remainder of the target analytes were either not detected or observed at lower levels. To place these EFs into perspective, consider that about 1 gram of TNT parent compound (accounts for about 60 percent of the composition B mass), would be released into the detonation cloud following the detonation of a metric ton of composition B, assuming that the TNT EF is 1×10^{-6}. If a stable detonation cloud volume of 10^6 cubic meters is assumed, the elevated

cloud concentration of TNT would be 1 μg per cubic meter. A further dilution of about 4 or 5 orders of magnitude would typically result following downwind movement of the cloud prior to its ground contact. Downwind ground-level concentrations of TNT would then be in the tens or hundreds of pg (10^{-12} g) per cubic meter of air.

Table 4.2.20 Maximum Semivolatile Organic Emission Factors Measured for Surface Composition B Detonations[a].

Species[b]	Emission Factor (g/g)
2,4-Dinitrotoluene	450 x 10^{-9}
2,6-Dinitrotoluene	24 x 10^{-9}
2,4,6-Trinitrotoluene	250 x 10^{-9}
2-Nitronaphthalene	86 x10^{-9}
N-Nitrosodiphenylamine	36 x 10^{-9}
1,3,5-Trinitrobenzene	59 x 10^{-9}
2-Nitrodiphenylamine	72 x 10^{-9}
1-Nitropyrene	56 x 10^{-9}
RDX	BD[c]
Naphthalene	420 x 10^{-9}
Benz[a]anthracene	7.4 x 10^{-9}
Benzo[a]pyrene	14 x 10^{-9}
Pyrene	210 x 10^{-9}
Phenol	—[d]
Dibenzofuran	BD
Diphenylamine	66 x 10^{-9}

[a]Emission factors are expressed in terms of 10^{-9} for ease of comparison, e.g., 450 x 10^{-9} is equivalent to 0.000000450.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels.
[c]Below detection limit.
[d]—Phenol was lost in the extraction of the semivolatiles.

4.2.2.2 Soil

4.2.2.2.1 Ejecta

a. Ejecta soil is the soil displaced at the point of a *surface* detonation and redeposited in the crater, in the berm around the crater, and within a few meters of the crater. The volume of the

displaced soil was estimated, using Equation 4.2, paragraph 4.1.3.3. The calculated results are given in Table 4.2.21. The volume of the displaced soil varied from 22 to 28 m^3. The calculated weight of this soil, based on a density of 2.5 g/cc, varied from 55 to 70 metric tons, with a mean of 64 metric tons. This loose soil was sampled, and the semivolatile organics remaining after the detonation were identified and quantified.

Table 4.2.21 OB/OD Detonation Crater Dimension, Volume, and Weight of Displaced Soil for Composition B.

Location	Rim Opening (m)	Depth (m)	Volume (m^3)	Weight of Soil (kg)	Average Weight (kg)
Composition B					
B0	5.0	2.0	23.82	59559	
B1	ND[a]	ND	ND	ND	
B2	5.0	1.9	22.24	55611	
B3	5.5	2.0	27.95	69868	
B4	5.0	2.0	23.82	59559	
B5	ND	ND	ND	ND	
B6	5.5	2.0	27.95	69868	
D0	5.5	2.0	27.95	69868	64056

[a]ND - no data.

b. Background samples were taken at all detonation sites. All detonation sites were located in an area at DPG considered uncontaminated from previous explosive detonations. The pretest (background) and ejecta summary data are given in Table 4.2.22. The analyte which showed increased concentration (above concentration levels detected in the pretest soil) in the ejecta soil after detonation was 2,4,6-trinitrotoluene.

Table 4.2.22 Composition B, Summary of Semivolatile Organic Concentrations from Phase C Pretest and Ejecta Soil Samples, Based on the Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
Pretest	3	3	2,4-Dinitrotoluene	1.3 to 6.4	3.7
	3	3	2,6-Dinitrotoluene	0.13 to 0.24	0.19
	3	3	2,4,6-Trinitrotoluene	0.58 to 2.3	1.2
	3	3	2-Nitronaphthalene	0.075 to 0.24	0.16
		2	N-Nitrosodiphenylamine	BD[e] to 1.3	0.68
	3	2	1,3,5-Trinitrobenzene	BD to 0.87	0.25
	3	2	2-Nitrodiphenylamine	BD to 0.21	0.14
	3	1	Naphthalene	BD to 0.16	0.16
	3	2	Benz[a]anthracene	BD to 1.2	0.93
	3	3	Pyrene	0.14 to 1.2	0.40
	3	3	Diphenylamine	0.11 to 0.36	0.22
Ejecta	3	3	2,4-Dinitrotoluene	10 to 17	14
	3	3	2,6-Dinitrotoluene	0.57 to 1.0	0.79
	3	3	2,4,6-Trinitrotoluene	12 to 14	13
	3	3	2-Nitronaphthalene	0.078 to 0.39	0.16
	3	1	N-Nitrosodiphenylamine	BD to 0.39	0.39
	3	3	1,3,5-Trinitrobenzene	0.14 to 0.39	0.22
	3	2	2-Nitrodiphenylamine	BD to 0.60	0.24
	3	1	1-Nitropyrene	BD to 0.14	0.14
	3	3	Naphthalene	3.4 to 13	6.9
	3	2	Benz[a]anthracene	BD to 1.9	1.5
	3	1	Benzo[a]pyrene	BD to 0.55	0.55
	3	3	Pyrene	1.4 to 4.5	2.7
	3	2	Dibenzofuran	BD to 1.6	1.4
	3	2	Diphenylamine	BD to 1.6	1.4

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per kg of soil.
[d]Geometric means were computed only from the values above the detection limit.
[e]Below detection limit.

4.2.2.2.2 Fallout

a. Fallout for the OB/OD thermal treatment testing is defined as the particulate material deposited beyond the ejecta area. The Phase C testing was conducted partly to characterize the resulting soil fallout pattern and amount of species deposited on the soil. The background and ejecta data were included along with the fallout data, prior to performing the ANOVA.

b. Phase C . Fallout for a *surface* detonation was sampled with 1-m^2 pans placed on the 50-, 100-, 150-, and 200-meter circles.

(1) The analyte concentration data from the 50- and 100-meter sampling circles for the *surface* detonations are summarized in Table 4.2.23a. The analyte concentration data for the 150- and 200-meter sampling circles are presented in Table 4.2.23b. The analytes detected above background levels on the 50-meter circle were 2,4-dinitrotoluene, and 2,4,6-trinitrotoluene. The analytes above background levels on the 100-meter circle were 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronaphthalene, pyrene, and diphenylamine. The analytes detected above background levels on the 150-meter circle were 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronaphthalene, 2-nitrodiphenylamine, pyrene, and diphenylamine. The analytes detected above background levels on the 200-meter circle were 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronapthalene, 1,3,5-trinitrobenzene, 2-nitrodiphenylamine, naphthalene, benz[a]anthracene, pyrene, and diphenylamine. Dibenzofuran was not found in the background sample but was found in some of the ejecta and fallout pan samples.

Table 4.2.23a Composition B, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
50-m circle	3	3	2,4-Dinitrotoluene	12 to 150	52
	3	1	2,6-Dinitrotoluene	BD[e] to 0.67	0.67
	3	3	2,4,6-Trinitrotoluene	11 to 220	39
	3	2	2-Nitronaphthalene	BD to 0.47	0.25
	3	3	1,3,5-Trinitrobenzene	0.26 to 1.6	0.50
	3	1	1-Nitropyrene	BD to 1.1	1.1
	3	3	Naphthalene	0.58 to 1.5	0.47
	3	2	Pyrene	BD to 1.4	0.76
	3	3	Dibenzofuran	0.36 to 3.1	1.0
100-m circle	3	3	2,4-Dinitrotoluene	640 to 1800	1230
	3	3	2,6-Dinitrotoluene	2.5 to 27	7.5
	3	3	2,4,6-Trinitrotoluene	47 to 92	69
	3	3	2-Nitronaphthalene	1.9 to 7.5	3.1
	3	3	1,3,5-Trinitrobenzene	0.062 to 9.8	0.96
	3	1	2-Nitrodiphenylamine	BD to 1.1	1.1
	3	1	1-Nitropyrene	BD to 1.0	1.0
	3	1	Naphthalene	BD to 8.7	8.7
	3	2	Benz[a]anthracene	BD to 8.6	6.5
	3	3	Pyrene	2.3 to 9.8	6.0
	3	1	Dibenzofuran	BD to 6.2	6.2
	3	3	Diphenylamine	1.3 to 6.6	3.4

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per kg of soil.
[d]Geometric means were computed from the values above the detection limit.
[e]Below detection limit.

Table 4.2.23b Composition B, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
150-m circle	3	3	2,4-Dinitrotoluene	360 to 5600	1200
	3	3	2,6-Dinitrotoluene	5.1 to 49	18
	3	3	2,4,6-Trinitrotoluene	13 to 330	81
	3	3	2-Nitronaphthalene	0.77 to 21	4.1
	3	2	1,3,5-Trinitrobenzene	BD[e] to 4.9	2.3
	3	3	2-Nitrodiphenylamine	1.3 to 17	5.9
	3	1	1-Nitropyrene	BD to 15	15
	3	2	Naphthalene	BD to 37	8.4
	3	3	Benz[a]anthracene	0.59 to 33	5.9
	3	3	Pyrene	1.4 to 64	9.8
	3	1	Dibenzofuran	BD to 35	35
	3	3	Diphenylamine	1.0 to 33	6.9
200-m circle	3	3	2,4-Dinitrotoluene	2100 to 8900	4400
	3	3	2,6-Dinitrotoluene	79 to 330	130
	3	3	2,4,6-Trinitrotoluene	130 to 970	450
	3	3	2-Nitronaphthalene	26 to 33	29
	3	3	1,3,5-Trinitrobenzene	9.0 to 21	15
	3	3	2-Nitrodiphenylamine	8.8 to 84	29
	3	1	1-Nitropyrene	BD to 37	37
	3	3	Naphthalene	8.9 to 140	34
	3	2	Benz[a]anthracene	26 to 76	51
	3	1	Benzo[a]pyrene	BD to 32	32
	3	1	Pyrene	30 to 170	73
	3	3	Dibenzofuran	4.6 to 57	20
	3	2	Diphenylamine	BD to 130	76

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per kg of soil.
[d]Geometric means were computed from the values above the detection limit.
[e]Below detection limit.

(2) The Duncan's multiple-range test comparing the ejecta sample results with the fallout sample results for the semivolatile organics shows the following:

(a) The ejecta analyte concentration means were not different from the 50-meter concentration means.

(b) The 100-meter concentration means for 2,4-dinitrotoluene, 2,6-dinitrotoluene, and 2-nitronaphthalene were larger than the ejecta concentration means for these same compounds.

(c) The 150-meter concentration means for 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-nitronaphthalene, and 2-nitrodiphenylamine were larger than the ejecta concentration means for these same compounds.

(d) The 200 meter concentration means for 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronaphthalene, 1,3,5-trinitrobenzene, 2 nitrodiphenylamine, benz[a]anthracene, pyrene, and diphenylamine were larger than the ejecta concentration means for these same compounds.

(3) This increase in concentration of the semivolatile analytes on the fallout soil at greater distance from the detonation may be a function of particle size. The increased surface area per volume of particle that results with the smaller particles provides more surface area for absorption of the analyte. The results of the OB/OD test show that analytes in the 200-, 150-, and 100-meter fallout samples were more concentrated than in the 50-meter fallout samples. The results did not show the 50-meter analyte concentrations to be greater than the ejecta concentration means. A probable explanation of this is that soil chunks are still being propelled as far as 50 meter and the sample is a composite of a wide range of particle sizes including the larger chunks whose interior volume is not exposed to detonation products. This is in contrast to the fallout samples at greater distances which consist of smaller particles.

(4) Relationship of Mass of Analyte to Fallout Area. The mass of analyte collected was compared to the total sampling area of the fallout pans making up the sample. The data is

summarized in Tables 4.2.24a and 4.2.24b. These data are useful in estimating the amount of an analyte that is deposited on the terrain as a function of distance from the source.

Table 4.2.24a Composition B, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Area Sampled.

Source of Sample	Number of Observations		Analyte[b]	Range Response (ng/m^2)[c]	Geometric Mean[d] (ng/m^2)
	Total	AD[a]			
50-m circle	3	3	2,4-Dinitrotoluene	630 to 9200	3100
	3	1	2,6-Dinitrotoluene	BD[e] to 47	47
	3	3	2,4,6-Trinitrotoluene	680 to 15000	2300
	3	3	2-Nitronaphthalene	BD to 25	14
	3	3	1,3,5-Trinitrobenzene	14 to 110	30
	3	1	1-Nitropyrene	BD to 66	66
	3	3	Naphthalene	4.0 to 90	28
	3	2	Pyrene	BD to 95	49
	3	3	Dibenzofuran	25 to 170	62
100-m circle	3	3	2,4-Dinitrotoluene	6800 to 9700	8500
	3	3	2,6-Dinitrotoluene	27 to 160	52
	3	3	2,4,6-Trinitrotoluene	250 to 820	480
	3	3	2-Nitronaphthalene	10 to 43	21
	3	3	1,3,5-Trinitrobenzene	0.33 to 57	6.7
	3	1	2-Nitrodiphenylamine	BD to 6.0	6.0
	3	1	1-Nitropyrene	BD to 6.0	6.0
	3	1	Naphthalene	BD to 47	47
	3	2	Benz[a]anthracene	BD to 50	37
	3	3	Pyrene	25 to 57	41
	3	1	Dibenzofuran	BD to 33	33
	3	3	Diphenylamine	14 to 38	24

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents ng of analyte per m^2 of terrain.
[d]Geometric means were computed from the values above detection limit.
[e]Below detection limit.

Table 4.2.24b Composition B, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Area Sampled.

Source of Sample	Number of Observations		Analyte[b]	Range Response (ng/m^2)[c]	Geometric Mean[d] (ng/m^2)
	Total	AD[a]			
150-m circle	3	3	2,4-Dinitrotoluene	1800 to 6800	3200
	3	3	2,6-Dinitrotoluene	22 to 98	49
	3	3	2,4,6-Trinitrotoluene	150 to 270	210
	3	3	2-Nitronaphthalene	9.2 to 15	11
	3	2	1,3,5-Trinitrobenzene	BD[e] to 20	15
	3	3	2-Nitrodiphenylamine	7.7 to 25	16
	3	1	1-Nitropyrene	BD to 6.7	6.7
	3	2	Naphthalene	BD to 82	55
	3	3	Benz[a]anthracene	11 to 23	16
	3	3	Pyrene	23 to 28	26
	3	1	Dibenzofuran	BD to 16	16
	3	3	Diphenylamine	15 to 22	19
200-m circle	3	3	2,4-Dinitrotoluene	1500 to 5300	2500
	3	3	2,6-Dinitrotoluene	57 to 92	71
	3	3	2,4,6-Trinitrotoluene	145 to 630	250
	3	3	2-Nitronaphthalene	5.7 to 32	16
	3	3	1,3,5-Trinitrobenzene	3.7 to 22	8.6
	3	3	2-Nitrodiphenylamine	7.8 to 37	16
	3	1	1-Nitropyrene	BD to 42	42
	3	3	Naphthalene	10 to 28	19
	3	3	Benz[a]anthracene	11 to 85	28
	3	3	Pyrene	27 to 90	41
	3	3	Dibenzofuran	5.2 to 28	11
	3	2	Diphenylamine	BD to 150	76

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents ng of analyte per m^2 of terrain.
[d]Geometric means were computed from the values above detection limit.
[e]Below detection limit.

4.2.3 Explosive D Test - Phase C

4.2.3.1 Air Emissions

4.2.3.1.1 Gases

a. Gas EFs for the six *surface* explosive D detonations are summarized in Table 4.2.25. The CO_2 EF average ranges from 0.97 to 1.00, with an average of 0.99. The theoretical EF is 1.07, assuming complete conversion of explosive carbon to CO_2. The ratio of observed carbon conversion to theoretical, or the detonation efficiency, is 0.93 and very nearly the same as all other *surface*-detonated explosives evaluated in this test series.Although the oxygen balance of explosive D at -52 percent is greater than TNT and about the same as composition B, the detonation efficiency for a *surface* detonation is about the same.

Table 4.2.25 Gas Emission Factors for Explosive-D Surface Detonations.

Species	Emission Factor (g/g)
CO_2 - min	0.97
CO_2 - max	1.00
CO_2 - avg	0.99
CO - min	0.046
CO - max	0.064
CO - avg	0.053
NO - min	0.4×10^{-3}
NO - max	1.5×10^{-3}
NO - avg	0.9×10^{-3}
NO_2 - min	0.4×10^{-3}
NO_2 - max	1.6×10^{-3}
NO_2 - avg	1.1×10^{-3}

b. Carbon-monoxide EFs for explosive D range from a low of 0.046 to a high of 0.064, with an average of 0.053. Nitric oxide and NO_2 EFs are in the vicinity of 0.001 and comparable to those

observed for the other explosives. The ratio of NO to NO_2 EFs for this explosive is also very nearly one.

4.2.3.1.2 Particulates

a. The particulate mass concentration in the explosive D detonation clouds as measured during multiple aircraft passes is summarized in Table 4.2.26. Cloud particle concentrations from the two trials of three-detonations each show more variability than encountered for the other explosive types, with a high concentration of about 300 and a low of 180 mg/m^3. Differences in soil compaction at the various detonation sites may account for the variability noted.

Table 4.2.26 Average Particulate Matter Concentrations Measured During Multiple Aircraft Sampling Passes of Explosive-D Detonation Clouds.

Test Event	Particulate Matter Concentration (mg/m^3)
Explosive-D - First 3-detonation series	184
Explosive-D - Second 3-detonation series	315

4.2.3.1.3 Volatile Organic Compounds

Volatile organic compound EFs from the explosive D tests are given in Table 4.2.27. Average methane EFs are higher than those for composition B, by nearly a factor of ten. Emission factors for the TNMHC and benzene categories are also higher, but only by a factor of about two.

Table 4.2.27 Volatile Organic Compound Emission Factors Measured for the Explosive-D Detonation Tests.

Species	Emission Factor (g/g)
CH_4 - min	0.7×10^{-3}
CH_4 - max	7.7×10^{-3}
CH_4 - avg	2.4×10^{-3}
TNMHC - min	1.2×10^{-3}
TNMHC - max	2.7×10^{-3}
TNMHC - avg	2.0×10^{-3}
Benzene - min	69×10^{-6}
Benzene - max	160×10^{-6}
Benzene - avg	110×10^{-6}

4.2.3.1.4 Semivolatile Organics (Exotics)

a. Emission factors for the semivolatile organic target compounds are given in Table 4.2.28 for the Phase C surface detonation of explosive D. The values shown in the table are the maximum values obtained from two separate tests each consisting of three detonations in series. Analysis for the semivolatile target analytes was done by SFC-MS which allows the determination of thermally unstable compounds which would otherwise decompose during separation by conventional gas chromatography. The emission factors for the target analytes are all observed at less than the part per million (10^{-6}) level. The highest emission factors observed were for 2,4-dinitrotoluene and naphthalene at levels of about 5×10^{-7}. Next highest were pyrene and dibenzofuran at a level slightly in excess of 1×10^{-7}. In this test series the parent compound picric acid is seen at a relatively low level of 5×10^{-8}. The remainder of the target elements were either not detected or observed at lower levels. To place these emission factors into perspective, consider that about 0.1 gram of picric acid would be released into the detonation cloud following the detonation of a metric ton of explosive D, if one conservatively assumes that the picric acid emission factor is 1×10^{-7}. If a stable cloud volume of 10^6 cubic meters is assumed, the elevated cloud concentration of picric acid would be about 0.1 μg per cubic meter. A further dilution of about 4 or 5 orders of magnitude would typically result following downwind movement of the cloud prior to its ground contact.

Downwind ground-level concentrations of TNT would then be in the tens or hundreds of pg (10^{-12} grams) per cubic meter of air, a vanishingly low level.

Table 4.2.28 Maximum Semivolatile Organic Emission Factors Measured for Surface Explosive D Detonations[a].

Species[b]	Emission Factor (g/g)
2,4-Dinitrotoluene	590×10^{-9}
2,6-Dinitrotoluene	80×10^{-9}
2,4,6-Trinitrotoluene	44×10^{-9}
2-Nitronaphthalene	43×10^{-9}
N-Nitrosodiphenylamine	58×10^{-9}
1,3,5-Trinitrobenzene	18×10^{-9}
2-Nitrodiphenylamine	58×10^{-9}
1-Nitropyrene	11×10^{-9}
Picric acid	50×10^{-9}
Naphthalene	630×10^{-9}
Benz[a]anthracene	19×10^{-9}
Benzo[a]pyrene	38×10^{-9}
Pyrene	180×10^{-9}
Phenol	---[d]
Dibenzofuran	110×10^{-9}
Diphenylamine	19×10^{-9}

[a]Emission factors are expressed in terms of 10^{-9} for ease of comparison, e.g., 590×10^{-9} is equivalent to 0.000000590.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels.
[c]Below detection limit.
[d]---Phenol was lost in the extraction of the semivolatiles.

4.2.3.2 Soil

4.2.3.2.1 Ejecta

a. Ejecta soil is the soil displaced at the point of a *surface* detonation and redeposited in the crater, in the berm around the crater, and within a few meters of the crater. The volume of the displaced soil was estimated using Equation 4.2, paragraph 4.1.3.3. The calculated results are given in Table 4.2.29. The volume of the displaced soil varied from 37 to 53 m^3. The calculated weight of this soil, based on a density of 2.5 g/cc, varied from 93 to 132 metric tons, with a mean of 114 metric tons. This loose soil was sampled, and the semivolatile organics remaining after the detonation were identified and quantified.

Table 4.2.29 OB/OD Detonation Crater Dimension, Volume, and Weight of Displaced Soil for Explosive D.

Location	Rim Opening (m)	Depth (m)	Volume (m^3)	Weight of Soil (kg)	Average Weight (kg)
Explosive D					
A1	7.5	2.0	48.37	120919	
A2	7.4	2.2	52.88	132211	
A3	6.7	2.1	41.87	104671	
A4	6.9	2.3	49.37	123431	
A5	6.5	2.0	37.37	93430	
A6	7.0	2.0	42.67	106683	113557

b. Background samples were taken at all detonation sites. All detonation sites were located in an area considered uncontaminated from previous explosive detonations. The pretest (background) and ejecta summary data are given in Table 4.2.30. The analyte which showed increased concentrations (above concentration levels in the pretest soil) in the ejecta soil after detonation was pyrene. The parent compound picric acid was found in the pretest soil sample; however it was below detection in the ejecta sample. N-nitrosodiphenylamine was found in 1 of 3 samples in the ejecta soil.

Table 4.2.30 Explosive D: Summary of Semivolatile Organic Concentrations from Phase C Pretest and Ejecta Soil Samples, Based on the Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (µg/kg)[c]	Geometric Mean[d] (µg/kg)
	Total	AD[a]			
Pretest	2	2	2,4-Dinitrotoluene	0.84 to 1.2	1.0
	2	2	2,6-Dinitrotoluene	0.074 to 0.15	0.11
	2	2	2,4,6-Trinitrotoluene	0.12 to 0.45	0.23
	2	2	2-Nitronaphthalene	0.026 to 0.24	0.080
	2	1	1,3,5-Trinitrobenzene	BD to 0.53	0.53
	2	1	2-Nitrodiphenylamine	BD to 0.29	0.29
	2	1	1-Nitropyrene	BD to 0.069	0.069
	2	1	Picric acid	BD to 0.37	0.37
	2	2	Naphthalene	1.0 to 2.6	1.6
	2	1	Benz[a]anthracene	BD to 0.98	0.98
	2	2	Pyrene	0.048 to 0.29	0.12
	2	2	Dibenzofuran	0.16 to 1.8	0.54
	2	2	Diphenylamine	0.24 to 0.32	0.28
Ejecta	3	3	2,4-Dinitrotoluene	0.48 to 1.3	0.92
	3	3	2,6-Dinitrotoluene	0.010 to 0.14	0.054
	3	3	2,4,6-Trinitrotoluene	0.52 to 7.4	1.3
	3	3	2-Nitronaphthalene	0.014 to 0.11	0.049
	3	1	N-Nitrosodiphenylamine	BD to 0.090	0.090
	3	3	1,3,5-Trinitrobenzene	0.022 to 0.14	0.043
	3	3	2-Nitrodiphenylamine	0.082 to 0.24	0.12
	3	3	1-Nitropyrene	0.0020 to 0.12	0.025
	3	3	Naphthalene	1.4 to 11	3.3
	3	2	Benz[a]anthracene	BD to 5.4	2.2
	3	1	Benzo[a]pyrene	BD to 0.67	0.67
	3	3	Pyrene	1.5 to 5.2	3.2
	3	3	Dibenzofuran	0.24 to 1.0	0.56
	3	3	Diphenylamine	0.058 to 0.26	0.15

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents µg of analyte per kg of soil.
[d]Geometric means were computed only from the values above the detection limit.
[e]Below detection limit.

4.2.3.2.2 **Fallout**

a. Fallout for the OB/OD thermal treatment testing is defined as the particulate material deposited beyond the ejecta area. The Phase C testing was to characterize the resulting soil fallout pattern and the amount of species deposited on the soil. The background and ejecta data were included along with the fallout data prior to performing the ANOVA.

b. Phase C . Fallout from a *surface* detonation was sampled with 1-m^2 pans placed on the 50-, 100-, 150-, and 200-meter circles.

(1) The analyte concentration data from the 50- and 100-meter sampling circles for the *surface* detonations are summarized in Table 4.2.31a. The analyte concentration data for the 150- and 200-meter sampling circles are presented in Table 4.2.31b. The analytes detected above background levels on the 50-meter circle were 2,4,6-trinitrotoluene, and pyrene. The analytes found above background levels on the 100-meter circle were 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 1,3,5-trinitrobenzene, picric acid, and pyrene. The analytes detected above background levels on the 150-meter circle were 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronapthalene, 1,3,5-trinitrobenzene, 2-nitrodiphenylamine, picric acid, pyrene, and diphenylamine. The analytes detected above background levels on the 200-meter circle were 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronapthalene, 1,3,5-trinitrobenzene, 2-nitrodiphenylamine, 1-nitropyrene, picric acid, naphthalene, benz[a]anthracene, pyrene, dibenzofuran and diphenylamine.

Table 4.2.31a Explosive D, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
50-m circle	3	3	2,4-Dinitrotoluene	0.48 to 0.56	0.51
	3	3	2,6-Dinitrotoluene	0.059 to 0.25	0.15
	3	3	2,4,6-Trinitrotoluene	0.73 to 38	5.3
	3	1	2-Nitronaphthalene	BD[e] to 0.085	0.085
	3	3	1,3,5-Trinitrobenzene	0.041 to 0.15	0.082
	3	1	2-Nitrodiphenylamine	BD to 0.61	0.61
	3	1	1-Nitropyrene	BD to 0.081	0.081
	3	2	Picric acid	BD to 1.9	1.2
	3	3	Naphthalene	0.97 to 6.5	2.2
	3	2	Benz[a]anthracene	BD to 0.97	0.89
	3	1	Pyrene	BD to 5.9	5.9
	3	1	Diphenylamine	BD to 1.7	1.7
100-m circle	3	3	2,4-Dinitrotoluene	10 to 15	12
	3	3	2,6-Dinitrotoluene	0.60 to 1.8	1.0
	3	3	2,4,6-Trinitrotoluene	4.5 to 34	12
	3	3	2-Nitronaphthalene	0.37 to 2.9	1.1
	3	2	N-Nitrosodiphenylamine	BD to 0.96	0.83
	3	3	1,3,5-Trinitrobenzene	0.69 to 2.2	1.3
	3	2	2-Nitrodiphenylamine	BD to 1.3	0.97
	3	2	1-Nitropyrene	BD to 0.18	0.14
	3	1	Picric acid	BD to 7.1	7.1
	3	3	Naphthalene	2.7 to 9.5	6.1
	3	2	Benz[a]anthracene	BD to 0.41	0.29
	3	3	Pyrene	7.6 to 12	10
	3	1	Dibenzofuran	BD to 2.4	2.4
	3	1	Diphenylamine	BD to 1.1	1.1

[a]Above detection limit.
[b]See Table 3.16 for list containing the semivolatile organics and the detection levels in soil.
[c]μg of analyte per kg of soil.
[d]Geometric means were computed from the values above the detection limit.
[e]Below detection limit.

Table 4.2.31b **Explosive** D, Summary of Semivolatile Organic Concentrations from Phase C **Fallout** Soil Samples, Based on Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (µg/kg)[c]	Geometric Mean[d] (µg/kg)
	Total	AD[a]			
150-m circle	3	3	2,4-Dinitrotoluene	34 to 410	82
	3	3	2,6-Dinitrotoluene	4.5 to 24	10
	3	3	2,4,6-Trinitrotoluene	11 to 73	20
	3	3	2-Nitronaphthalene	2.5 to 14	7.0
	3	3	N-Nitrosodiphenylamine	2.8 to 20	9.1
	3	3	1,3,5-Trinitrobenzene	3.5 to 17	7.1
	3	3	2-Nitrodiphenylamine	3.1 to 35	11
	3	3	1-Nitropyrene	3.2 to 16	7.8
	3	1	Picric acid	BD[e] to 18	18
	3	2	Naphthalene	BD to 29	11
	3	2	Benz[a]anthracene	BD to 5.1	3.2
	3	1	Benzo[a]pyrene	BD to 1.7	1.7
	3	2	Pyrene	BD to 65	24
	3	3	Dibenzofuran	9.2 to 130	24
	3	3	Diphenylamine	9.7 to 23	15
200-m circle	3	3	2,4-Dinitrotoluene	65 to 1300	210
	3	3	2,6-Dinitrotoluene	11 to 140	37
	3	3	2,4,6-Trinitrotoluene	15 to 460	120
	3	3	2-Nitronaphthalene	12 to 150	41
	3	3	1,3,5-Trinitrobenzene	8.1 to 100	31
	3	3	2-Nitrodiphenylamine	7.5 to 180	39
	3	3	1-Nitropyrene	4.6 to 38	18
	3	2	Picric acid	BD to 36	36
	3	3	Naphthalene	36 to 720	120
	3	1	Benz[a]anthracene	BD to 20	20
	3	1	Benzo[a]pyrene	BD to 53	53
	3	3	Pyrene	5.8 to 260	11
	3	3	Dibenzofuran	13 to 540	19
	3	2	Diphenylamine	BD to 140	10

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents µg of analyte per kg of soil.
[d]Geometric means were computed from the values above the detection limit.
[e]Below detection limit.

(2) The Duncan's multiple-range test comparing the ejecta sample results with the fallout sample results for the semivolatile organics shows the following:

(a) The only semivolatile analyte found at 50-meter in higher concentration than in the ejecta soil was diphenylamine. Picric acid was not recovered in the ejecta soil, although it was found in the background soil from the detonation sites.

(b) The measured 100-meter concentration means for 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-nitronaphthalene, 1,3,5-trinitrobenzene, and diphenylamine were larger than the ejecta concentration means.

(c) The 150-meter concentration means for 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-nitronaphthalene, N-nitrosodiphenylamine, 1,3,5-trinitrobenzene, 2-nitrodiphenylamine, 1-nitropyrene, and diphenylamine were larger than the ejecta concentration means for these same compounds.

(d) The measured 200-meter concentration means for 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronaphthalene, 1,3,5-trinitrobenzene, 2-nitrodiphenylamine, 1-nitropyrene, naphthalene, dibenzofuran, and diphenylamine were larger than the ejecta concentration means for these same compounds.

(3) This increase in concentration of the semivolatile analytes on the fallout soil at greater distance from the detonation may be a function of particle size (the increased surface area per volume of particle that results with the smaller particles provides more surface area for absorption of the analyte.) The results of OB/OD test show that analytes in the 200-, 150, and 100-meter fallout samples were more concentrated than in the 50-meter fallout samples. The results did not show the 50-meter analyte concentrations to be greater than the ejecta concentration means except for diphenylamine. A probable explanation of the increased concentration of analytes with distance is that soil chunks are still being propelled as far as 50 meter and the sample is a composite of a wide range of particle sizes including the larger chunks whose interior volume is not exposed to detonation products. This is in contrast to the fallout samples at greater distances, which consist of smaller particles.

(4) Relationship of Mass of Analyte to Fallout Area. The mass of analyte collected was compared to the total sampling area of the fallout pans making up the sample. The summary of this data is shown in Tables 4.2.32a and 4.2.32b. This data are useful in estimating the amount of an analyte that is deposited on the terrain as a function of distance from the source.

Table 4.2.32a Explosive D, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Area Sampled.

Source of Sample	Number of Observations		Analyte[b]	Range Response (ng/m²)[c]	Geometric Mean[d] (ng/m²)
	Total	AD[a]			
50-m circle	3	3	2,4-Dinitrotoluene	23 to 46	35
	3	3	2,6-Dinitrotoluene	4.9 to 20	10
	3	3	2,4,6-Trinitrotoluene	30 to 3600	360
	3	1	2-Nitronaphthalene	BD[e] to 3.5	3.5
	3	3	1,3,5-Trinitrobenzene	3.4 to 8.8	5.6
	3	1	2-Nitrodiphenylamine	BD to 25	25
	3	1	1-Nitropyrene	BD to 6.7	6.7
	3	2	Picric acid	BD to 180	76
	3	3	Naphthalene	81 to 270	150
	3	2	Benz[a]anthracene	BD to 91	78
	3	1	Pyrene	BD to 550	550
	3	1	Diphenylamine	BD to 160	160
100-m circle	3	3	2,4-Dinitrotoluene	67 to 110	84
	3	3	2,6-Dinitrotoluene	4.3 to 14	7.5
	3	3	2,4,6-Trinitrotoluene	37 to 220	87
	3	3	2-Nitronaphthalene	2.7 to 18	7.7
	3	2	N-Nitrosodiphenylamine	BD to 7.8	6.4
	3	3	1,3,5-Trinitrobenzene	5.0 to 14	9.6
	3	2	2-Nitrodiphenylamine	BD to 11	7.4
	3	2	1-Nitropyrene	BD to 1.3	1.1
	3	1	Picric acid	BD to 45	45
	3	3	Naphthalene	20 to 72	44
	3	2	Benz[a]anthracene	BD to 3.3	2.1
	3	3	Pyrene	48 to 100	72
	3	1	Dibenzofuran	BD to 16	16
	3	1	Diphenylamine	BD to 6.7	6.7

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents ng of analyte per m² of terrain.
[d]Geometric means were computed from the values above detection limit.
[e]Below detection limit.

Table 4.2.32b **Explosive** D, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Area Sampled.

Source of Sample	Number of Observations		Analyte[b]	Range Response (ng/m^2)[c]	Geometric Mean[d] (ng/m^2)
	Total	AD[a]			
150-m circle	3	3	2,4-Dinitrotoluene	58 to 100	80
	3	3	2,6-Dinitrotoluene	6 to 17	10
	3	3	2,4,6-Trinitrotoluene	2.7 to 130	20
	3	3	2-Nitronaphthalene	3.5 to 16	6.8
	3	3	N-Nitrosodiphenylamine	4.8 to 43	8.9
	3	3	1,3,5-Trinitrobenzene	1.5 to 28	6.9
	3	3	2-Nitrodiphenylamine	6.8 to 22	10.9
	3	3	1-Nitropyrene	2.3 to 27	7.6
	3	1	Picric acid	BD[e] to 32	32
	3	2	Naphthalene	BD to 50	22
	3	2	Benz[a]anthracene	BD to 11	2.4
	3	1	Benzo[a]pyrene	BD to 3.0	3.0
	3	2	Pyrene	BD to 16	16
	3	3	Dibenzofuran	16 to 32	23
	3	3	Diphenylamine	4.2 to 50	15
200-m circle	3	3	2,4-Dinitrotoluene	20 to 85	48
	3	3	2,6-Dinitrotoluene	6.2 to 11	8.6
	3	3	2,4,6-Trinitrotoluene	15 to 85	28
	3	3	2-Nitronaphthalene	6.7 to 13	9.4
	3	3	1,3,5-Trinitrobenzene	6.5 to 8.2	7.1
	3	3	2-Nitrodiphenylamine	7.5 to 12	9.0
	3	3	1-Nitropyrene	2.5 to 6.3	4.2
	3	2	Picric acid	BD to 37	9.2
	3	3	Naphthalene	12.2 to 47	28
	3	1	Benz[a]anthracene	BD to 3.7	3.7
	3	1	Benzo[a]pyrene	BD to 9.8	9.8
	3	3	Pyrene	5.8 to 25	13
	3	3	Dibenzofuran	8.8 to 35	16
	3	3	Diphenylamine	BD to 27	13

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents ng of analyte per m^2 of terrain.
[d]Geometric means were computed from the values above detection limit.
[e]Below detection limit.

4.2.4 RDX Test - Phase C

4.2.4.1 Air Emissions

4.2.4.1.1 Gases

a. The gas EFs for the six *surface* RDX detonations are statistically summarized in Table 4.2.33. The CO_2 EF average was 0.57 for these approximate 907 kg RDX *surface* detonations. Assuming that all carbon in the explosive is converted to CO_2, the resulting theoretical EF is 0.59. The detonation efficiency, (the ratio of the measured CO_2 EF to the theoretical value) for this explosive is about 0.97. The detonation efficiency for RDX is higher (indicating a greater percentage of carbon converted to CO_2) than the detonation efficiency measured for *surface* detonated TNT, composition B, and explosive D. The fact that the RDX molecule has a higher oxygen content (-21.6 % oxygen balance) compared to TNT (-73.9 % oxygen balance),composition B (-53.0% oxygen balance), explosive D (-52.0 % oxygen balance) could be a contributing factor to the increased detonation efficiency.. From this observation, it appears that the oxygen content of the explosive molecule may have an impact on the observed detonation efficiency. The relatively high and invariant carbon to CO_2 conversion efficiencies observed for these *surface* detonations also indicate the presence of a so-called "secondary combustion" mechanism, whereby ambient oxygen is entrained into the detonation fireball providing oxidant for further combustion of such incomplete detonation products as CO to CO_2.

Table 4.2.33 **Gas Emission Factors for RDX Surface Detonations.**

Species	Emission Factor (g/g)
CO_2 - min	0.55
CO_2 - max	0.58
CO_2 - avg	0.57
CO - min	0.026
CO - max	0.039
CO - avg	0.031
NO - min	0.5×10^{-3}
NO - max	1.6×10^{-3}
NO - avg	0.9×10^{-3}
NO_2 - min	0.4×10^{-3}
NO_2 - max	0.9×10^{-3}
NO_2 - avg	0.6×10^{-3}

b. The CO EFs for RDX ranged from 0.026 to 0.039, with an average of 0.031. Nitric oxide and NO_2 EFs for RDX are in the 10^{-3} range, with a ratio of about one. These values for both CO and NO_x species are comparable to those measured for surface detonated TNT.

4.2.4.1.2 Particulate Emissions

Particulate mass concentration as measured in multiple passes through the clouds from surface detonated RDX is summarized in Table 4.2.34. Cloud particle concentrations for the two three-shot tests are in the vicinity of 200 mg/m^3 and are similar to those measured in the *surface* TNT, composition B, and explosive D tests. The collected particulate samples for organic and elemental carbon content were not analyzed since the Teflon®-coated glass fiber filters employed during the Phase C testing phase are not well suited for this analysis procedure.

Table 4.2.34 Average Particulate Concentrations Measured During Multiple Aircraft Sampling Passes of RDX Detonation Clouds.

Test Event	Particulate Matter Concentration (mg/m^3)
RDX - first 3-detonation series	242
RDX - second 3-detonation series	179

4.2.4.1.3 VOC Emissions

Volatile organic compound EFs for the RDX *surface* detonations as measured with the 6-L grab canisters and gas chromatographic analysis are summarized in Table 4.2.35. Methane emissions are low and in the range observed for the other propellants and explosives tested. Total non-methane hydrocarbon concentrations are similarly low, with an average EF of 0.0013. The toxic sub-category of TNMHC as represented by benzene is also low with an average benzene EF of 0.000069. Although detonation efficiencies less than unity are observed for this explosive, these data reveal that only a very small amount of the original carbon ends up in the VOC category of emissions.

Table 4.2.35 Volatile Organic Compound Emission Factors Measured for the RDX Detonation Tests.

Species	Emission Factor (g/g) RDX
CH_4 - min	BD[a]
CH_4 - max	0.4×10^{-3}
CH_4 - avg	0.2×10^{-3}
TNMHC - min	0.7×10^{-3}
TNMHC - max	2.9×10^{-3}
TNMHC - avg	1.3×10^{-3}
Benzene - min	2.3×10^{-6}
Benzene - max	140×10^{-6}
Benzene - avg	69×10^{-6}

[a]Below detection limit.

4.2.4.1.4 Semivolatile Organics (Exotics)

a. Emission factors for the semivolatile organic target compounds are given in Table 4.2.36 for the Phase C RDX surface detonations. The values shown in the table are the maximum values obtained from two separate trials each consisting of three detonations in series. Analyses for the semivolatile target analytes were done by SFC-MS which allows the determination of thermally labile compounds such as the parent explosive RDX which would otherwise decompose during separation by conventional gas chromatography. The EFs for the target analytes are all observed at the part per million (10^{-6}) level or less. The highest EFs observed were for the RDX and dibenzofuran at about 2×10^{-6}. Next highest were 2,4-dinitrotoluene, naphthalene, pyrene, and diphenylamine at about 2×10^{-7}. It is not clear from these data whether the measured 2,4-dinitrotoluene and diphenylamine are derived from rearrangement of some small fraction of the RDX molecule during the detonation or whether they arise from previous contamination of the soils in the area of the surface RDX shots. One detonation of the three RDX detonations was primed with 1.8 kg of TNT (Table 2.4b) which could have been a contributor to some of these unexpected compounds; however, this alone does not explain these compounds being found when TNT was not used as a primer. It is more reasonable to attribute these compounds to the contaminated soil at the detonation site. The remainder of the target analytes were either not detected or observed at lower levels. To place these EFs into perspective consider that 1 gram of RDX parent compound would be released into the detonation cloud following the detonation of a metric ton of RDX, assuming that RDX EF is 1×10^{-6}. If a stable detonation cloud volume of 10^6 cubic meters is assumed, the elevated cloud concentration of RDX would be 1 μg per cubic meter. A further dilution of about 4 or 5 orders of magnitude would typically result following downwind movement of the cloud prior to its ground contact. Downwind ground-level concentrations of RDX would then be in the tens or hundreds of pg (10^{-12} g) per cubic meter of air.

Table 4.2.36 Maximum Semivolatile Organic Emission Factors Measured for Surface RDX Detonations[a].

Species[b]	Emission Factor (g/g)
2,4-Dinitrotoluene	210×10^{-9}
2,6-Dinitrotoluene	41×10^{-9}
2,4,6-Trinitrotoluene	98×10^{-9}
2-Nitronaphthalene	49×10^{-9}
N-Nitrosodiphenylamine	BD[c]
1,3,5-Trinitrobenzene	44×10^{-9}
2-Nitrodiphenylamine	34×10^{-9}
1-Nitropyrene	50×10^{-9}
RDX	2100×10^{-9}
Naphthalene	200×10^{-9}
Benz[a]anthracene	93×10^{-9}
Benzo[a]pyrene	140×10^{-9}
Pyrene	220×10^{-9}
Phenol	---[d]
Dibenzofuran	2000×10^{-9}
Diphenylamine	310×10^{-9}

[a]Emission factors are expressed in terms of 10^{-9} for ease of comparison, e.g., 210×10^{-9} is equivalent to 0.000000210.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels.
[c]Below detection limit.
[d]---Phenol was lost in the extraction of the semivolatiles.

4.2.4.2 Soil

4.2.4.2.1 Ejecta

a. Ejecta soil is the soil displaced at the point of a *surface* detonation and redeposited in the crater, in the berm around the crater, and within a few meters of the crater. The volume of the displaced soil was estimated using Equation 4.2 paragraph, 4.1.3.3. The calculated results are given in Table 4.2.37. The volume of the displaced soil varied from 21 to 37 m^3. The calculated weight of this soil, based on a density of 2.5 g/cc, varied from 52 to 94 metric tons with a mean of 67 metric tons. This loose soil was sampled, and the semivolatile organics remaining after the detonation were identified and quantified.

Table 4.2.37 OB/OD Detonation Crater Dimension, Volume, and Weight of Displaced Soil for RDX.

Location	Rim Opening (m)	Depth (m)	Volume (m^3)	Weight of Soil (kg)	Average Weight (kg)
RDX Explosive					
D1	6.5	1.5	26.65	66636	
D2	6.5	1.2	20.81	52037	
D3	6.0	1.5	22.97	57432	
D4	6.5	1.5	26.65	66636	
D5	6.5	2.0	37.37	93430	
D6	6.5	1.5	26.65	66636	67135

b. Background samples were taken at all detonation sites. All detonation sites were located in an area considered uncontaminated from previous explosive detonations. The pretest (background) and ejecta summary data are presented in Table 4.2.38. The analytes which showed increased concentrations (above concentration levels in the pretest soil) in the ejecta soil after detonation were naphthalene, pyrene, and dibenzofuran. N-nitrosodiphenylamine was found in all of the ejecta samples but not found in the soil background samples.

Table 4.2.38 RDX. Summary of Semivolatile Organic Concentrations from Phase C Pretest and Ejecta Soil Samples, Based on the Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
Pretest	3	3	2,4-Dinitrotoluene	0.56 to 0.73	0.62
	3	3	2,6-Dinitrotoluene	0.056 to 0.32	0.15
	3	3	2,4,6-Trinitrotoluene	0.16 to 0.64	0.39
	3	3	2-Nitronaphthalene	0.18 to 0.51	0.31
	3	3	1,3,5-Trinitrobenzene	0.14 to 0.30	0.20
	3	3	2-Nitrodiphenylamine	0.12 to 0.30	0.19
	3	3	1-Nitropyrene	0.20 to 0.80	0.42
	3	3	RDX	1.1 to 3.8	2.3
	3	3	Naphthalene	0.11 to 0.46	0.25
	3	3	Benz[a]anthracene	0.17 to 0.18	0.18
	3	3	Benzo[a]pyrene	0.14 to 0.16	0.15
	3	3	Pyrene	0.0027 to 0.062	0.018
	3	2	Dibenzofuran	BD[e] to 0.080	0.062
	3	3	Diphenylamine	0.24 to 0.25	0.25
Ejecta	3	3	2,4-Dinitrotoluene	0.34 to 2.0	0.86
	3	3	2,6-Dinitrotoluene	0.080 to 0.90	0.27
	3	3	2,4,6-Trinitrotoluene	0.28 to 0.67	0.37
	3	3	2-Nitronaphthalene	0.13 to 0.90	0.33
	3	3	N-Nitrosodiphenylamine	0.60 to 1.7	1.2
	3	3	1,3,5-Trinitrobenzene	0.13 to 0.77	0.27
	3	3	2-Nitrodiphenylamine	0.14 to 0.19	0.17
	3	2	1-Nitropyrene	BD to 0.23	0.10
	3	3	RDX	4.9 to 15	9.6
	3	3	Naphthalene	3.1 to 5.3	4.4
	3	3	Benz[a]anthracene	1.8 to 2.4	2.1
	3	2	Benzo[a]pyrene	BD to 0.41	0.33
	3	3	Pyrene	0.53 to 5.3	2.1
	3	3	Dibenzofuran	0.69 to 0.95	0.83
	3	2	Diphenylamine	BD to 0.48	0.46

[a]Above detection limit.
[b]See Table 3.16 for list containing the semivolatile organics and the detection levels in soil.
[c]μg of analyte per kg of soil.
[d]Geometric means were computed only from the values above the detection limit.
[e]Below detection limit.

4.2.4.2.2 Fallout

a. Fallout for the OB/OD thermal treatment testing is defined as the particulate material deposited beyond the ejecta area. The Phase C testing was to characterize the resulting soil fallout pattern and the amount of species deposited on the soil. The background and ejecta data were included along with the fallout data, prior to performing the ANOVA.

b. In Phase C, fallout sampling for a *surface* detonation was done with 1-m^2 pans placed on the 50-, 100-, 150-, and 200-meter circles.

(1) The analyte concentration data from the 50- and 100-meter sampling circles for the *surface* detonations are summarized in Table 4.2.39a. The analyte concentration data for the 150- and 200-meter sampling circles are given in Table 4.2.39b. The analytes detected above background concentration levels at the 50-meter distance from detonation were RDX, benz[a]anthracene, pyrene, and diphenylamine. At the 100-meter distance RDX, dibenzofuran, and diphenylamine were detected above background concentration levels. The analytes detected above background levels at the 150-meter distance were 2,4-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronapthalene, 2-nitrodiphenylamine, 1-nitropyrene, RDX, naphthalene, benz[a]anthracene, benzo[a]pyrene, pyrene, dibenzofuran, and diphenylamine. The analytes detected above background levels at the 200-meter distance were 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronapthalene, 1,3,5-trinitrobenzene, 2-nitrodiphenylamine, 1-nitropyrene, RDX, naphthalene, benz[a]anthracene, benzo[a]pyrene, pyrene, dibenzofuran, and diphenylamine. N-nitrosodiphenylamine was not found in the background soil samples; however, it was found in the ejecta and fallout pan samples.

Table 4.2.39a RDX, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
50-m circle	3	3	2,4-Dinitrotoluene	0.30 to 2.0	0.81
	3	3	2,6-Dinitrotoluene	0.081 to 0.84	0.26
	3	3	2,4,6-Trinitrotoluene	0.95 to 5.0	1.9
	3	3	2-Nitronaphthalene	0.36 to 1.6	0.68
	3	2	N-Nitrosodiphenylamine	BD[e] to 3.8	2.0
	3	3	1,3,5-Trinitrobenzene	0.093 to 0.92	0.23
	3	3	2-Nitrodiphenylamine	0.56 to 0.70	0.63
	3	3	1-Nitropyrene	0.045 to 1.0	0.17
	3	3	RDX	11 to 45	25
	3	3	Naphthalene	1.1 to 1.4	1.2
	3	3	Benz[a]anthracene	1.8 to 12	6.0
	3	2	Benzo[a]pyrene	BD to 2.9	2.4
	3	3	Pyrene	2.7 to 5.3	3.9
	3	1	Dibenzofuran	BD to 0.35	0.35
	3	1	Diphenylamine	BD to 0.67	0.67
100-m circle	3	3	2,4-Dinitrotoluene	0.16 to 0.79	0.39
	3	3	2,6-Dinitrotoluene	0.015 to 0.68	0.16
	3	3	2,4,6-Trinitrotoluene	0.48 to 4.8	2.1
	3	3	2-Nitronaphthalene	0.33 to 1.1	0.63
	3	2	N-Nitrosodiphenylamine	BD to 4.2	0.38
	3	3	1,3,5-Trinitrobenzene	0.0075 to 0.28	0.081
	3	3	2-Nitrodiphenylamine	0.051 to 1.2	0.75
	3	2	1-Nitropyrene	BD to 1.5	0.70
	3	3	RDX	8.6 to 130	32
	3	3	Naphthalene	0.82 to 1.8	1.1
	3	2	Benz[a]anthracene	BD to 8.8	1.3
	3	3	Benzo[a]pyrene	0.022 to 0.98	0.22
	3	3	Pyrene	0.0038 to 5.7	0.38
	3	1	Dibenzofuran	BD to 3.1	3.1

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per kg of soil.
[d]Geometric means were computed from the values above the detection limit.
[e]Below detection limit.

Table 4.2.39b RDX, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Weight of Sample.

Source of Sample	Number of Observations		Analyte[b]	Range Response (μg/kg)[c]	Geometric Mean[d] (μg/kg)
	Total	AD[a]			
150-m circle	3	3	2,4-Dinitrotoluene	2.2 to 110	21
	3	3	2,6-Dinitrotoluene	0.82 to 130	5.5
	3	3	2,4,6-Trinitrotoluene	12 to 150	62
	3	2	2-Nitronaphthalene	BD[e] to 120	21
	3	3	N-Nitrosodiphenylamine	6.6 to 210	30
	3	3	1,3,5-Trinitrobenzene	0.79 to 200	5.5
	3	2	2-Nitrodiphenylamine	BD to 78	20
	3	2	1-Nitropyrene	BD to 120	26
	3	2	RDX	BD to 1400	1000
	3	3	Naphthalene	15 to 210	47
	3	2	Benz[a]anthracene	BD to 220	19
	3	3	Benzo[a]pyrene	2.5 to 160	11
	3	3	Pyrene	9.0 to 250	30
	3	2	Dibenzofuran	BD to 93	32
	3	1	Diphenylamine	BD to 86	86
200-m circle	3	3	2,4-Dinitrotoluene	16 to 260	73
	3	2	2,6-Dinitrotoluene	BD to 66	16
	3	3	2,4,6-Trinitrotoluene	6.5 to 150	27
	3	3	2-Nitronaphthalene	6.5 to 150	27
	3	3	N-Nitrosodiphenylamine	15 to 170	40
	3	3	1,3,5-Trinitrobenzene	5.9 to 95	16
	3	3	2-Nitrodiphenylamine	4.9 to 35	17
	3	3	1-Nitropyrene	7.8 to 71	18
	3	3	RDX	290 to 1100	680
	3	3	Naphthalene	9.5 to 740	66
	3	3	Benz[a]anthracene	30 to 60	40
	3	1	Benzo[a]pyrene	BD to 79	79
	3	3	Pyrene	35 to 230	69
	3	2	Dibenzofuran	BD to 46	40
	3	3	Diphenylamine	18 to 46	28

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents μg of analyte per kg of soil.
[d]Geometric means were computed from the values above the detection limit.
[e]Below detection limit.

(2) The Duncan's multiple-range test comparing the ejecta sample results with the fallout sample results for the semivolatile organics shows the following:

(a) The 50-meter concentration means were not different than the ejecta concentration means.

(b) The 100-meter analyte concentration means were not different from the ejecta centration means.

(c) The analytes detected above ejecta concentration levels at the 150-meter distance were 2,4-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronapthalene, 2-nitrodiphenylamine, 1-nitropyrene, RDX, naphthalene, dibenzofuran, and diphenylamine.

(d) The analytes detected above ejecta concentration levels at the 200-meter distance were 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2,4,6-trinitrotoluene, 2-nitronapthalene, 1,3,5-trinitrobenzene, 2-nitrodiphenylamine, 1-nitropyrene, RDX, naphthalene, benz[a]pyrene, dibenzofuran, and diphenylamine.

(3) This increase in concentration of the semivolatile analytes on the fallout soil at greater distance from the detonation may be a function of particle size (the increased surface area per volume of particle that results with the smaller particles provides more surface area for absorption of the analyte.) The results of OB/OD test show that analytes in the 200-, 150, and 100-meter fallout samples were more concentrated than in the 50-meter fallout samples. The results did not show the 50-meter analyte concentrations to be greater than the ejecta concentration means. A probable explanation of the increased concentration of analytes with distance is that soil chunks are still being propelled as far as 50 meter and the sample is a composite of a wide range of particle sizes including the larger chunks whose interior volume is not exposed to detonation products. This is in contrast to the fallout samples at greater distances, which consist of smaller particles.

(4) The mass of analyte collected was compared to the total sampling area of the fallout pans comprising the sample. Those data are summarized in Tables 4.2.40a and 4.2.40b. These data are useful in estimating the amount of an analyte that is deposited on the terrain as a function of distance from the source.

Table 4.2.40a RDX, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples, Based on Area Sampled.

Source of Sample	Number of Observations		Analyte[b]	Range Response (ng/m^2)[c]	Geometric Mean[d] (ng/m^2)
	Total	AD[a]			
50-m circle	3	3	2,4-Dinitrotoluene	27 to 170	69
	3	3	2,6-Dinitrotoluene	6.6 to 69	22
	3	3	2,4,6-Trinitrotoluene	78 to 450	160
	3	3	2-Nitronaphthalene	30 to 130	58
	3	2	N-Nitrosodiphenylamine	BD[e] to 310	160
	3	3	1,3,5-Trinitrobenzene	7.5 to 76	20
	3	3	2-Nitrodiphenylamine	50 to 57	53
	3	3	1-Nitropyrene	3.7 to 83	14
	3	3	RDX	890 to 4100	2100
	3	3	Naphthalene	95 to 120	110
	3	3	Benz[a]anthracene	150 to 960	500
	3	2	Benzo[a]pyrene	BD to 260	200
	3	3	Pyrene	220 to 430	330
	3	1	Dibenzofuran	BD to 29	29
	3	1	Diphenylamine	BD to 55	55
100-m circle	3	3	2,4-Dinitrotoluene	7.2 to 18	12
	3	3	2,6-Dinitrotoluene	0.67 to 15	4.8
	3	3	2,4,6-Trinitrotoluene	22 to 170	67
	3	3	2-Nitronaphthalene	13 to 28	19
	3	2	N-Nitrosodiphenylamine	BD to 72	10
	3	3	1,3,5-Trinitrobenzene	0.33 to 11	2.5
	3	3	2-Nitrodiphenylamine	3.2 to 20	11
	3	2	1-Nitropyrene	BD to 25	18
	3	3	RDX	380 to 2200	980
	3	3	Naphthalene	30 to 37	34
	3	2	Benz[a]anthracene	BD to 150	35
	3	3	Benzo[a]pyrene	1.0 to 20	6.9
	3	3	Pyrene	0.17 to 100	12
	3	1	Dibenzofuran	BD to 53	53

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents ng of analyte per m^2 of terrain.
[d]Geometric means were computed from the values above detection limit.
[e]Below detection limit.

Table 4.2.40b **RDX, Summary of Semivolatile Organic Concentrations from Phase C Fallout Soil Samples. Based on Area Sampled.**

Source of Sample	Number of Observations		Analyte[b]	Range Response (ng/m^2)[c]	Geometric Mean[d] (ng/m^2)
	Total	AD[a]			
150-m circle	3	3	2,4-Dinitrotoluene	8.2 to 83	32
	3	3	2,6-Dinitrotoluene	1.8 to 57	8.4
	3	3	2,4,6-Trinitrotoluene	47 to 280	95
	3	2	2-Nitronaphthalene	BD[e] to 50	27
	3	3	N-Nitrosodiphenylamine	15 to 92	46
	3	3	1,3,5-Trinitrobenzene	2.3 to 85	8.4
	3	2	2-Nitrodiphenylamine	BD to 33	26
	3	2	1-Nitropyrene	BD to 52	33
	3	2	RDX	BD to 2700	1300
	3	3	Naphthalene	33 to 120	72
	3	2	Benz[a]anthracene	BD to 93	24
	3	3	Benzo[a]pyrene	5.7 to 70	17
	3	3	Pyrene	20 to 110	46
	3	2	Dibenzofuran	BD to 40	32
	3	1	Diphenylamine	BD to 37	37
200-m circle	3	3	2,4-Dinitrotoluene	38 to 68	49
	3	2	2,6-Dinitrotoluene	BD to 27	21
	3	3	2,4,6-Trinitrotoluene	3.3 to 38	15
	3	3	2-Nitronaphthalene	3.7 to 58	18
	3	3	N-Nitrosodiphenylamine	5.8 to 120	27
	3	3	1,3,5-Trinitrobenzene	1.0 to 38	11
	3	3	2-Nitrodiphenylamine	4.8 to 22	11
	3	3	1-Nitropyrene	1.3 to 50	12
	3	3	RDX	120 to 4800	450
	3	3	Naphthalene	17 to 130	44
	3	3	Benz[a]anthracene	10 to 130	27
	3	1	Benzo[a]pyrene	BD to 32	32
	3	3	Pyrene	17 to 150	46
	3	2	Dibenzofuran	BD to 18	10
	3	3	Diphenylamine	4.3 to 80	19

[a]Above detection limit.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels in soil.
[c]Represents ng of analyte per m^2 of terrain.
[d]Geometric means were computed from the values above detection limit.
[e]Below detection limit.

4.3 Propellants

4.3.1 Single Base Tests - Phase C

4.3.1.1 M-1 Propellant

4.3.1.1.1 Air Emissions

a. Gases

(1) Gas EFs for the M-1 single base propellant burns during the Phase C test series are given in Table 4.3.1. Measured CO_2 EFs for M-1 were the same for all test burns at a value of 1.11. Assuming that all the carbon in the original propellant is converted to CO_2, the resulting theoretical EF is also 1.11 when calculated to two decimal places. The equivalence of the measured and theoretical EFs (to two decimal places) reveals that greater than 99-percent conversion of propellant carbon to CO_2 is occurring in these large-scale burns.

Table 4.3.1 **Gas and VOC Emission Factors for M-1 Single Base Propellant.**

Species	Emission Factor (g/g)
CO_2 - min	1.11
CO_2 - max	1.11
CO_2 - avg	1.11
Number of observations	6
CO - min	5.4×10^{-6}
CO - max	900×10^{-6}
CO - avg	250×10^{-6}
Number of observations	4
NO - min	760×10^{-6}
NO - max	1600×10^{-6}
NO - avg	1200×10^{-6}
Number of observations	6
NO_2 - min	410×10^{-6}
NO_2 - max	510×10^{-6}
NO_2 - avg	470×10^{-6}
Number of observations	6
CH_4 - min	BD[a]
CH_4 - max	49000×10^{-6}
CH_4 - avg	8000×10^{-6}
Number of observations	8
TNMHC - min	BD
TNMHC - max	2000×10^{-6}
TNMHC - avg	460×10^{-6}
Number of observations	8
Benzene - min	BD
Benzene - max	35×10^{-6}
Benzene - avg	4.8×10^{-6}
Number of observations	8

[a]Below detection limit.

(2) Carbon monoxide EFs for M-1 are very low and in the 10^{-4} to 10^{-5} range. This is not surprising, considering the high CO_2 EFs encountered. Nitric oxide EFs for M-1 are in the range of 1×10^{-3} and are similar to those encountered for the *surface* TNT tests. Nitrogen dioxide levels are about a factor of ten lower, although as noted in an earlier section on total NO_x emission from TNT tests, it can be conservatively estimated that all NO produced in the burn will eventually be converted to NO_2. Correcting this assumption for the mass difference between the NO and the NO_2 molecule results in an average NO_2 EF for M-1 of 0.0023.

b. Particulate Matter

(1) Mass concentrations within the cloud during the Phase C September 5 and 6 M-1 tests were in the range of 1.3 to 2.6 mg m^{-3} as averaged over three passes in a time interval of about 4 minutes following propellant ignition. If the assumption is made that all particulate in the cloud is derived from the propellant and none is entrained soil, these measured cloud concentrations translate to a range of total particulate EFs between 4.5×10^{-3} and 9.2×10^{-3}, or between 0.5 and 1 percent of the propellant. Data from the wing-mounted aerosol probes reveals that the sizes of particles encountered in the cloud are all within the range that can be efficiently sampled by the aircraft inlet probe and transport tube. As a result the collected particulate mass can be reasonably interpreted as a total particulate mass.

c. Volatile Organic Compounds

(1) Emission factors for representative VOC's for the M-1 are given in Table 4.3.1. Considering the high carbon conversion efficiencies noted for both of these propellant types, it is not surprising that EFs for methane, TNMHC, and benzene appear at low levels. Methane shows the most variability with EFs ranging from the 10^{-2} level down to a non-detectable level. TNMHC levels range from the 10^{-4} level to non-detectable levels and are similar to those measured in TNT tests. Consistent with observations in the TNT tests, the TNMHC category is principally composed of non-toxic light weight gases such as ethane, propane, acetylene, etc. Benzene is observed at low concentration levels of about 5 μg/g of the M-1 propellant burned.

d. Semivolatile Organics

(1) Emission factors for the semivolatile organic category for the M-1 tests are given in Table 4.3.2. As a conservative estimate, only the maximum value determined in two discrete measurements is given in the table. As was noted for the TNT tests, most of the target analytes were below the detection level of the analytical instrument. Species observed above the detection level for the M-1 propellant include 2,4-DNT, phenol, naphthalene, and diphenylamine. Of all target analytes, naphthalene was detected at the highest concentration. This level corresponds to an EF of about 2×10^{-4}, which is still quite low in the context of air emissions.

Table 4.3.2 Semivolatile Organic Emission Factors for M-1 Single Base Propellant.

Species	Emission Factor (g/g)
2,4-Dinitrotoluene	1.2×10^{-9}
2,6-Dinitrotoluene	BD[a]
2,4,6-Trinitrotoluene	BD
2-Nitronaphthalene	BD
N-Nitrosodiphenylamine	BD
1,3,5-Trinitrobenzene	BD
1-Nitropyrene	BD
Naphthalene	19×10^{-9}
Benz[a]anthracene	BD
Benzo[a]pyrene	BD
Pyrene	BD
Phenol	3.4×10^{-9}
Dibenzofuran	BD
Diphenylamine	0.11×10^{-9}

[a]Below detection limit, which is less than 10×10^{-9} for most of the target analytes.

4.3.1.1.2 Soil Deposition

a. Sputter

Ten sputter pan samples were placed 1 meter from the burn pans to collect propellant granules ejected from the burn pans during the burn. All M-1 propellant residue landing in the powdery soil or collected in the 1-m^2 pans visually appeared to be charred residue. This observation was substantiated by the low level of the analytes recovered. The mass of ash collected in the sputter

pans averaged 8.76 g/m^2 on trial 1 and 5.61 g/m^2 on trial 2. The concentration of each analyte expressed as ng/g and ng/m^2 of soil surface are given in Table 4.3.3.

Table 4.3.3 Summary of Semivolatile Organic Concentrations from M-1 Propellant Burn, Sputter Pan Sampling.

Analyte	Number of Observations		Concentration Range	
	Total	AD[a]	(ng/g)[b]	(ng/m^2)[c]
2,4-Dinitrotoluene	2	2	81 to 160	440 to 850
2,6-Dinitrotoluene	2	2	1.4 to 4.1	7.8 to 22
2,4,6-Trinitrotoluene	2	1	BD[d] to 0.11	BD to 0.57
2-Nitronaphthalene	2	1	BD to 0.14	BD to 0.73
2-Nitrodiphenylamine	2	2	0.22 to 0.29	1.2 to 1.5
Naphthalene	2	2	1.4 to 5.5	7.3 to 30
Benz[a]anthracene	2	1	BD to 0.15	BD to 0.81
Diphenylamine	2	2	3.7 to 6.9	20 to 37

[a]Above detection limit.
[b]Represents ng of analyte per gram of fallout.
[c]Represents ng of analyte per m^2 of terrain.
[d]Below detection limit.

b. Fallout

Fallout pan samplers were placed in concentric circles 6 and 12 meters from the center of the burn pan array. The mass of ash collected in the pans at 6 meters was 7.5 and 2.2 g/m^2 on trial 1 and trial 2, respectively. The mass of ash collected in the pans at 12 meters was 0.88 and 0.61 g/m^2 for trial 1 and trial 2, respectively. No sampling was done beyond 12 meters on the M-1 burns; however, sampling beyond this distance on previous burns resulted in insufficient fallout for quantification of any of the analytes of interest. The analyte concentration data from the 6- and 12-meter fallout pans are summarized in Table 4.3.4. Using the maximum measured 2,4-dinitrotoluene concentration of 2800 ng/m^2 as representative of the terrain deposition out to 18 meters, results in a total deposition of 2.87 mg of 2,4-DNT spread over the 1000 m^2 or 0.25 acre.

Table 4.3.4 **Summary of Semi-volatile Analyte Concentrations from M-1 Propellant Burn, Fallout Pan Sampling.**

Analyte	Sample Distance (m)	Number of Observations		Concentration Range	
		Total	AD[a]	(ng/g)[b]	(ng/m²)[c]
2,4-Dinitrotoluene	6	2	2	310 to 510	970 to 1800
	12	2	2	530 to 900	1100 to 2800
2,6-Dinitrotoluene	6	2	2	12 to 12	36 to 37
	12	2	2	8.9 to 36	19 to 110
2,4,6-Trinitrotoluene	6	2	2	0.12 to 0.22	0.38 to 0.69
	12	2	1	BD[d] to 0.38	BD to 0.79
2-Nitronaphthalene	6	2	2	0.094 to 0.14	0.29 to 0.44
	12	2	0	BD	BD
2-Nitrodiphenylamine	6	2	1	BD to 0.14	BD to 0.44
	12	2	0	BD	BD
Naphthalene	6	2	1	BD to 0.017	BD to 0.052
	12	2	1	BD to 2.6	BD to 8.2
Benz[a]anthracene	6	2	2	0.13 to 0.16	0.40 to 0.51
	12	2	1	BD to 0.51	BD to 1.1
Diphenylamine	6	2	2	0.51 to 0.79	1.6 to 2.5
	12	2	2	0.49 to 2.2	1.5 to 4.6

[a]Above detection limit.
[b]Represents ng of analyte per gram of fallout.
[c]Represents ng of analyte per m^2 of terrain.
[d]Below detection limit.

c. Burn Pan Residue

Burn pan residue for each 3160 kg of M-1 propellant burned varied from 3.4 kg to 4.6 kg over the six burns. The average residual was 4.0 kg or about 0.1 percent of the initial weight of propellant. Burn pan residue samples for semivolatile organic analyses were taken on each burn. A composite sample for each of the two M-1 burn trials was analyzed. The semivolatile organic analytes detected and the concentrations are given in Table 4.3.5. The residue consisted primarily of elemental and inorganic carbon. Approximately 27 μg of semivolatile organic compounds were recovered from each gram of burn pan residue. The mass fraction of 2,4-DNT in the original propellant is 0.10. After burning, the mass fraction of 2,4-DNT in the residue is 0.000025. The marked reduction of

2,4-DNT in the propellant residue is consistent with the observation that the bulk of the residue is char or elemental carbon.

Table 4.3.5 Summary of Semivolatile Analyte Concentrations from M-1 Propellant Burn, Burn Pan Residue.

Analyte	Number of Observations		Concentration Range (ng/g)[b]
	Total	AD[a]	
2,4-Dinitrotoluene	2	2	13000 to 25000
2,6-Dinitrotoluene	2	2	610 to 1200
2,4,6-Trinitrotoluene	2	2	3.7 to 15
2-Nitronaphthalene	2	2	6.1 to 6.9
N-Nitrosodiphenylamine	2	2	16 to 110
2-Nitrodiphenylamine	2	1	BD[c] to 23
Naphthalene	2	2	5.2 to 16
Benz[a]anthracene	2	2	0.63 to 4.0
Diphenylamine	2	2	56 to 180

[a]Above detection limit.
[b]Represents ng of analyte per gram of pan residue.
[c]Below detection limit.

4.3.1.1.3 Total Release of 2,4-Dinitrotoluene

Based on the analysis results for M-1, estimates of total release of a typical target analyte such as 2,4-DNT can be estimated as follows. The original weight fraction of 2,4-DNT in the M-1 parent compound is about 0.10 (see Table 3.4). Based on fallout pan analysis, total release to the soil surrounding the burn pan is about 3 mg. Based on residue analysis, an estimate of the total amount of 2,4-DNT in the burn residue is about 100 mg. Based on the measured emission air factor, the total release of 2,4-DNT to the air is also about 3 mg. The total release of DNT to all receptors is therefore in the order of 100 mg. The amount of 2,4-DNT in the original weight of M-1 prior to ignition is about 300 kg. Using these estimates, the mass fraction of 2,4 DNT not consumed in the burn is about 0.0000003. In other words, all but about 0.3 ppm of the original 2,4-DNT is consumed in the combustion process and oxidized to CO_2.

4.3.1.2 M-6 Propellant

4.3.1.2.1 Air Emissions

a. Gases

(1) Gas EFs for the M-6 single base propellant burns during the Phase C test series are given in Table 4.3.6. Measured CO_2 EFs for M-6 were the same for all test burns at a value of 1.06. Assuming that all the carbon in the parent material is converted to CO_2, the resulting theoretical EF is also 1.06 when calculated to two decimal places. The equivalence of the measured and theoretical EFs (to two decimal places) reveals that greater than 99-percent conversion of propellant carbon to CO_2 is occurring in these large-scale burns.

Table 4.3.6 Gas and VOC Emission Factors for the M-6 Single Base Propellant.

Species	Emission Factor (g/g)
CO_2 - min	1.06
CO_2 - max	1.06
CO_2 - avg	1.06
Number of observations	6
CO - min	BD[a]
CO - max	470×10^{-6}
CO - avg	95×10^{-6}
Number of observations	9
NO - min	2300×10^{-6}
NO - max	2600×10^{-6}
NO - avg	2400×10^{-6}
Number of observations	6
NO_2 - min	470×10^{-6}
NO_2 - max	580×10^{-6}
NO_2 - avg	520×10^{-6}
Number of observations	6
CH_4 - min	1.3×10^{-6}
CH_4 - max	390×10^{-6}
CH_4 - avg	46×10^{-6}
Number of observations	9
TNMHC - min	BD
TNMHC - max	69×10^{-6}
TNMHC - avg	13×10^{-6}
Number of observations	9
Benzene - min	BD
Benzene - max	7.3×10^{-6}
Benzene - avg	1.7×10^{-6}
Number of observations	9

[a]Below detection limit.

(2) Carbon monoxide EFs for M-6 are very low and in the range 10^{-4} to below detection level. This is not surprising considering the very high CO_2 EFs encountered. Nitric oxide EFs for M-6 are in the range of 0.002 and are similar to those encountered for the *surface* TNT tests. Nitrogen dioxide levels are about a factor of 10 lower, although as noted in an earlier section on total NO_x emission from TNT tests, it can be conservatively estimated that all NO produced in the burn will eventually be converted to NO_2. With this assumption and correcting for the mass difference between the NO and the NO_2 molecule, the average NO_2 EF for M-6 would be 0.0042.

b. Particulate Matter

(1) Mass concentrations within the cloud during the Phase C August 29 and 30 M-6 tests reveal cloud concentrations in the range of 2.7 to 2.8 mg/m^3 as averaged over three passes in a time interval of about 4 minutes following propellant ignition. Assuming that all particulate in the cloud is derived from the propellant and none is entrained soil, these measured cloud concentrations translate to a range of total particulate EFs between 9.0×10^{-3} to 1.2×10^{-2}, or very near 1 percent of the propellant. Data from the wing-mounted aerosol probes reveals that the sizes of particles encountered in the cloud are all within the range that can be efficiently sampled by the aircraft inlet probe and transport tube. As a result the collected particulate mass can be reasonably interpreted as a "total" particulate mass.

c. Volatile Organic Compounds

(1) Emission factors for representative VOC's for the M-6 are given in Table 4.3.6. Considering the high carbon conversion efficiencies noted for M-6 propellant, it is no surprise that EFs for methane, TNMHC and benzene appear at low levels. The average EFs for methane, TNMHC, and benzene are 0.000046, 0.000013, and 0.0000017, respectively. Like the TNT results , the TNMHC category is principally composed of non-toxic light weight gases, such as ethane, propane, acetylene, etc.

d. Semivolatile Organics

(1) Emission factors for the semivolatile organic category from the M-6 tests are given in Table 4.3.7. As a conservative estimate, only the maximum value determined in two discrete measurements for each propellant is given in the table. As was noted for the TNT tests, most of the target analytes were below the detection level of the analytical instrument. Species observed above the detection level for the M-6 propellant include 2,4-DNT, 2,6-DNT, N-nitrosodiphenylamine, phenol, naphthalene, and diphenylamine. Of all target analytes, naphthalene was detected at the highest concentration. This level corresponds to an EF of about 75 x 10^{-9}.

Table 4.3.7 Semivolatile Organic Emission Factors for M-6 Single Base Propellants.

Species	Emission Factor (g/g)
2.4 Dinitrotoluene	1.0 x 10^{-9}
2.6 Dinitrotoluene	0.077 x 10^{-9}
2,4.6 Trinitrotoluene	BD[a]
2-Nitronaphthalene	BD
N-Nitrosodiphenylamine	0.14 x 10^{-9}
1.3,5-Trinitrobenzene	BD
1-Nitropyrene	BD
Naphthalene	75 x 10^{-9}
Benz[a]anthracene	BD
Benzo[a]pyrene	BD
Pyrene	BD
Phenol	1.5 x 10^{-9}
Dibenzofuran	BD
Diphenylamine	0.026 x 10^{-9}

[a]Below detection limit, which is less than 10 x 10^{-9} for most target analytes.

4.3.1.2.2 Soil Deposition

a. Sputter

Ten sputter pan samples were placed 1 meter from the burn pans to collect propellant granules ejected from the burn pans during the burn. All M-6 propellant residue landing in the powdery soil or collected in the 1-m^2 pans visually appeared to be charred residue. This observation was substantiated by the low level of the analytes recovered. The mass of ash collected in the sputter

pans averaged 24.2 g/m². The concentration of each analyte expressed as ng/g and ng/m² of terrain surface are given in Table 4.3.8.

Table 4.3.8 Summary of Semivolatile Analyte Concentrations from M-6 Burn, Sputter Pan Sampling.

Analyte	Number of Observations		Concentration Range	
	Total	AD[a]	(ng/g)[b]	(ng/m²)[c]
2,4-Dinitrotoluene	3	3	8.1 to 12	44 to 66
2,4,6-Trinitrotoluene	3	1	BD[d] to 0.004	BD to 0.022
2-Nitronaphthalene	3	2	BD to 0.010	BD to 0.056
1,3,5-Trinitrobenzene	3	1	BD to 0.009	BD to 0.048
1-Nitropyrene	3	1	BD to 0.009	BD to 0.049
Naphthalene	3	3	0.34 to 1.00	1.9 to 5.4
Benz[a]anthracene	3	1	BD to 0.51	BD to 2.7
Benzo[a]pyrene	3	2	BD to 0.34	BD to 1.9
Pyrene	3	1	BD to 0.30	BD to 1.6
Phenol	3	1	BD to 0.14	BD to 0.78
Dibenzofuran	3	2	BD to 1.4	BD to 7.7
Diphenylamine	3	3	0.16 to 4.0	0.88 to 22

[a]Above detection limit.
[b]Represents ng of analyte per gram of fallout.
[c]Represents ng of analyte per m² of terrain.
[d]Below detection limit.

b. Fallout

Fallout pan samplers were placed in concentric circles 6 and 12 meters from the center of the burn pan array. The mass of ash collected in the pans at 6 meters was 8.6 g/m². The mass of ash collected in the pans at 12 meters was 2.8 g/m². No sampling was done beyond 12 meters on the M-6 burns; however, sampling beyond this distance on other propellant burns resulted in insufficient fallout for quantification of any of the analytes of interest. The analyte concentration data from the 6- and 12-meter fallout pans are summarized in Table 4.3.9. Using the maximum measured 2,4-dinitrotoluene concentration of 1300 ng/m² as representative of the terrain deposition out to 18 meter, results in a total deposition of 1.32 mg of 2,4-DNT spread over 1000 m² or 0.25 acre.

Table 4.3.9 Summary of Semivolatile Analyte Concentrations from M-6 Burn, Fallout Pan Sampling.

Analyte	Sample Distance (m)	Number of Observations		Concentration Range	
		Total	AD[a]	(ng/g)[b]	(ng/m²)[c]
2,4-Dinitrotoluene	6	3	3	45 to 410	140 to 1300
	12	3	3	37 to 230	110 to 480
2,4,6-Trinitrotoluene	6	3	1	BD[d] to 0.786	BD to 2.5
	12	3	3	0.088 to 1.0	0.28 to 3.1
2-Nitronaphthalene	6	3	2	BD to 0.11	BD to 0.34
	12	3	3	0.007 to 0.18	0.21 to 0.55
N-Nitrosodiphenylamine	6	3	1	BD to 20	BD to 63
	12	3	1	BD to 4.0	BD to 13
2-Nitrodiphenylamine	6	3	1	BD to 1.1	BD to 3.5
	12	3	1	BD to 0.16	BD to 0.49
Naphthalene	6	3	2	BD to 0.84	BD to 2.6
	12	3	2	BD to 9.6	BD to 30
Benz[a]anthracene	6	3	3	0.12 to 2.2	0.38 to 6.8
	12	3	1	BD to 0.062	BD to 0.13
Benzo[a]pyrene	6	3	3	0.18 to 1.1	0.57 to 3.5
	12	3	0	BD	BD
Pyrene	6	3	2	BD to 0.36	BD to 1.1
	12	3	0	BD	BD
Phenol	6	3	1	BD to 0.15	BD to 0.46
	12	3	0	BD	BD
Dibenzofuran	6	3	3	2.0 to 53	6.1 to 170
	12	3	2	BD to 2.8	BD to 8.9
Diphenylamine	6	3	3	0.44 to 26	1.4 to 83
	12	3	3	0.28 to 5.6	0.58 to 18

[a]Above detection limit.
[b]represents ng of analyte per gram of fallout.
[c]Represents ng of analyte per m^2 of terrain.
[d]Below detection limit.

c. Burn Pan Residue

Burn pan residue for each 3200 kg of M-6 propellant burned varied from 2.3 to 3.2 kg, the average residue was 2.6 kg or about 0.1 percent of the original propellant mass. Burn pan residue samples for semivolatile analyses were taken on each burn trial, with a composite sample for each of the four M-6 burn trials analyzed. The semivolatile analytes detected and their concentrations are given in Table 4.3.10. The residue consisted primarily of elemental and inorganic carbon. Approximately 200 μg of semivolatile organic compounds were recovered from each gram of residue. The mass fraction of 2,4-DNT in the M-6 propellant was 0.10. After burning, the mass fraction of 2,4-DNT in the residue was 0.00013. Based on these results, the semivolatile organic fraction in the propellant residue is very low, corresponding to about 0.000000103 of the original propellant weight prior to burning. The marked reduction of 2,4-DNT in the propellant residue is consistent with the observation that the bulk of the residue is char or elemental carbon.

Table 4.3.10 Summary of Semivolatile Analyte Concentrations From M-6 Burn, Burn Pan Residue.

Analyte	Number of Observations		Concentration Range (ng/g)[b]
	Total	AD[a]	
2,4-Dinitrotoluene	6	6	10000 to 130000
2,4,6-Trinitrotoluene	6	6	3.7 to 280
2-Nitronaphthalene	6	6	8.2 to 160
2-Nitrodiphenylamine	6	6	14 to 320
Naphthalene	6	2	BD[c] to 860
Benz[a]anthracene	6	5	BD to 680
Pyrene	6	4	BD to 280
Dibenzofuran	6	6	150 to 72000
Diphenylamine	6	6	62 to 2000

[a]Above detection limit.
[b]Represents ng of analyte per gram of pan residue.
[c]Below detection limit.

4.3.1.2.3 Total Release of 2,4-Dinitrotoluene

Based on the analysis results for M-6, estimates of total release of a typical target analyte such as 2,4-DNT can be estimated as follows. The original weight fraction of 2,4-DNT in the M-6 parent compound is about 0.10 (see Table 3.5). Based on fallout pan analysis, total release to the soil surrounding the burn pan is about 1.3 mg. Based on residue analysis, an estimate of the total amount of 2,4-DNT in the burn residue is about 400 mg. Based on the measured emission air factor, the total release of 2,4-DNT to the air is also about 3 mg. The total release of DNT to all receptors is therefore in the order of 400 mg. The amount of 2,4-DNT in the original weight of M-6 prior to ignition is about 300 kg. Using these estimates, the mass fraction of 2,4 DNT not consumed in the burn is about 0.0000013. In other words, all but about 1.3 ppm of the original 2,4-DNT is consumed in the combustion process and oxidized to CO_2.

4.3.2 Triple Base Test - Phase A

4.3.2.1 Air Emissions

4.3.2.1.1 Gases

a. Gas EFs for the Triple Base Propellant burn carried out during the Phase A test series are statistically summarized in Table 4.3.11. Minimum and maximum EFs are given for important gaseous species. Sample size was limited to two samples for most species in this particular test event. The CO_2 EF was observed to be 0.66 in both samples collected. This compares with a theoretical CO_2 EF of 0.65 for this particular propellant, assuming that all propellant carbon is converted to CO_2. This observation is accompanied by very low ($\sim$0.00003) EFs for CO. This trend of high carbon conversion to CO_2 is consistent with observations made on the M-1 and M-6 single- base propellants. A single measurement of NO and NO_2 which was completed on this particular test reveals an EF in the 10^{-3} range and similar to those encountered with the M-1 and M-6 propellants. Assuming total conversion of emitted NO to NO_2, the total NO_2 EF is very near 1 percent for this propellant.

Table 4.3.11 **Gas Emission Factors for Triple Base Propellants.**

Species	Emission Factor (g/g)
CO_2 - min	0.66
CO_2 - max	0.66
CO_2 - avg	0.66
Number of observations	2
CO - min	20×10^{-6}
CO - max	30×10^{-6}
CO - avg	25×10^{-6}
Number of observations	2
NO - min	5.2×10^{-3}
NO - max	5.2×10^{-3}
NO - avg	5.2×10^{-3}
Number of observations	1
NO_2 - min	2.1×10^{-3}
NO_2 - max	2.1×10^{-3}
NO_2 - avg	2.1×10^{-3}
Number of observations	1

4.3.2.1.2 Particulate Matter

a. Precision weighing was not carried out on the filter samples from the Phase A tests. As a result, only rough estimates of particulate mass concentrations in the cloud are available. Particulate concentrations in the cloud were determined to be about 4 mg/m^3 for the two-burn sequence. This cloud concentration corresponds to a particulate matter EF of about 2 percent. Some existing evidence suggests that some of the particles in the cloud were soil particles entrained in the smoke column from the burning propellant; however, further testing is required to establish this fact.

4.3.2.1.3 Volatile Organic Compounds

a. Emission factors for principal VOC compounds are given in Table 4.3.12. All species given in the table were below detection, with the exception of the TNMHC category. Levels at this

category were very low (10^{-6}). These observations are consistent with the low VOC emissions observed for the M-1 and M-6 propellant tests.

Table 4.3.12 Volatile Organic Compound Emission Factors for Triple-Base Propellant.

Species	Emission Factor (g/g)
CH_4 - min	BD[a]
CH_4 - max	BD
CH_4 - avg	BD
Number of observations	2
TNMHC - min	0.34×10^{-6}
TNMHC - max	2.6×10^{-6}
TNMHC - avg	1.5×10^{-6}
Number of observations	2
Benzene - min	BD
Benzene - max	BD
Benzene - avg	BD
Number of observations	2

[a]Below detection limit.

4.3.2.1.4 Semivolatile Organic Compounds

a. All target analytes were at or below the analytical detection limit for the triple-base propellant. The detection limit for most of these semivolatile organics corresponds to a range of about 10^{-8} to 10^{-9}. These results yield further evidence of the clean burning nature of many of these propellant types.

4.3.2.2 Soil Deposition

4.3.2.2.1 Sputter

No samples were collected in close proximity to the burn pans. A visual inspection of the area after the burn showed a number of small indentations in the powdery soil. Each indentation contained a charred skeleton of the M-30 propellant granule. These indentations extended out approximately

3 meters from the burn pan. A sample of these char residues was collected and assayed by both GC-MS and SFC-MS. None of the semivolatile compounds on the analyte list were detected.

4.3.2.2.2 Fallout

A composite sample composed of fallout from the 6- and 12-meter sampling circles was assayed. The compounds detected and the concentrations were phenol, 190 μg/g; ethyl centralite, 96 μg/g; nitroglycerin, 43 μg/g; and nitroguanidine, 55 μg/g. Fallout pan samples were also placed on a circle 30 meters from the burn pans; however, the amount of fallout material collected at this range was too small for a valid chemical assay.

4.3.2.2.3 Burn Pan Residue

The analytes and the concentrations detected in the burn pan residue were phenol, 0.12 μg/g; 2-nitrodiphenylamine, 0.51 μg/g; ethyl centralite, 2.8 μg/g; nitroglycerin, 0.73 μg/g; and, nitroguanidine, 0.79 μg/g.

4.3.3 Manufacturing Residue Tests - Phases B and C

4.3.3.1 Manufacturing Residue Test - Phase B

4.3.3.1.1 The composition of the propellants in the manufacturing residue was known to contain ammonium perchlorate and some metals which would release undesirable emittant products during combustion. These emissions need to be quantified prior to RCRA Sub-part X permitting.

4.3.3.1.2 During the BB study a special task force from Battelle Columbus Division drew samples during the BB study to identify/quantify the PCDD's and PCDF's (Reference BB Volume-2, Appendix B; also BB Volume-1, paragraphs 5.7.6 and 5.7.7, page 5-22, and BB Volume-2, paragraphs 7.3.2.10 and 7.3.2.11, page 7-19)

4.3.3.1.3 Sampling for HCL during the BB study was not conclusive due to the inability of sampling to account for a chlorine balance from the composite propellant (Reference BB Volume-1, paragraph 5.7.5, page 5-22, and BB Volume-2, paragraph 7.3.2.9, pages 7-18 and 7-19).

4.3.3.1.4 During the BB study, metals were sampled successfully on Teflon™ filter media (Reference BB Volume-1, paragraph 5.7.4, page 5-17, table 5.5c, page 5-20; and BB Volume-2, paragraph 7.3.2.6, page 7-18).

4.3.3.1.5 During the design of the field tests, the TSC recommended that sampling/analysis for HCL, PCDD's,PCDF's and metals not be done. This discussion was based on the lack of funding and time, and other needs of the project which necessitated Teflon™ coated glass fiber filters or quartz fiber filters. Metals could not be successfully assayed from these filters. Additionally the methodology and technology objectives of this study did not require the development of these data.

4.3.3.1.6 Accordingly the following sections do not address these issues.

4.3.3.1.7 Air Emissions

a. Gases

(1) Gas emissions for the mixed-manufacturing propellant waste burn carried out during the Phase B test series are given in Table 4.3.13. The measured CO_2 EF is 0.77 and, consistent with the other propellants examined in these tests, is within 1 percent of what one would expect to see if all the carbon in the propellant is converted to CO_2. The CO EFs are correspondingly low, and in the range of 10^{-3} to 10^{-4}. The manufacturing residue, like the other propellants tested in this study, shows remarkably clean burning characteristics when burned in bulk quantities. Nitric oxide and nitrogen dioxide emissions for this propellant material were similar to those measured for the single- and triple-base materials discussed earlier, with levels in the range of 10^{-4} and 10^{-3}.

b. Particulate Matter

Table 4.3.13 Gas Emission Factors for Phase B Manufacturing Residue Burns.

Species	Emission Factor (g/g)
CO_2 - min	0.77
CO_2 - max	0.77
CO_2 - avg	0.77
Number of observations	9
CO - min	69×10^{-6}
CO - max	1700×10^{-6}
CO - avg	490×10^{-6}
Number of observations	9
NO - min	1.9×10^{-3}
NO - max	3.8×10^{-3}
NO - avg	2.8×10^{-3}
Number of observations	2
NO_2 - min	0.34×10^{-3}
NO_2 - max	0.67×10^{-3}
NO_2 - avg	0.51×10^{-3}
Number of observations	2

(1) The average particulate matter concentration as measured in several passes of the aircraft through the cloud from the Phase B manufacturing residue burn was 4.7 mg/m^3. This concentration level is similar to those measured in the other propellant burn clouds. Assuming that all particles in the cloud are combustion products from the burn and that no soil is entrained into the smoke column during the burning process, the particulate matter EF corresponding to this cloud particle concentration level is about 1.6 percent. Thus, for every kilogram of propellant consumed, 16 grams of particulate material will be released to the atmosphere.

c. Volatile Organic Compounds

(1) Emission factors for VOC measured for the manufacturing residue are given in Table 4.3.14. Results are very similar to those determined for the M-30 triple-base material, in that only very low EFs (10^{-4}) for the general class of TNMHC are detected; however, specific species such as CH_4 and benzene are not detected. These results are consistent with the observed general pattern of highly

efficient combustion of nearly all single-, double-, and triple-base propellants examined in this test program.

Table 4.3.14 Volatile Organic Compound Emission Factors, Phase B, Manufacturing Residue Burns.

Species	Emission Factor (g/g)
CH_4 - min	BD[a]
CH_4 - max	BD
CH_4 - avg	BD
Number of observations	6
TNMHC - min	2.2×10^{-6}
TNMHC - max	230×10^{-6}
TNMHC - avg	45×10^{-6}
Number of observations	6
Benzene - min	BD
Benzene - max	BD
Benzene - avg	BD
Number of observations	6

[a]Below detection limit.

d. Semivolatile Organic Compounds

(1) Emission factors for the semivolatile organic category for the Phase B manufacturing residue burn are given in Table 4.3.15. Emission factors for most of the analytes on the target list are either nondetectable with a corresponding EF in the range of 10^{-8} to 10^{-9}, or are detected at a slightly higher level. The two analytes seen at the highest levels are naphthalene and phenol, with EFs in the 10^{-6} range. The pattern of semivolatile compound emissions from this propellant class is consistent with the emissions measured for the other single-, and triple-base propellants examined in this test series.

4.3.3.1.8 Soil Deposition

a. Sputter

Table 4.3.15 Semivolatile Organic Emission Factors, Phase B, Manufacturing Residue Burns.

Species	Emission Factor (g/g)
2,4-Dinitrotoluene	BD[a]
2,6-Dinitrotoluene	BD
2,4,6-Trinitrotoluene	BD
2-Nitronaphthalene	3.7×10^{-9}
N-Nitrosodiphenylamine	19×10^{-9}
Naphthalene	1500×10^{-9}
Benz[a]anthracene	38×10^{-9}
Benzo[a]pyrene	23×10^{-9}
Pyrene	71×10^{-9}
Phenol	8000×10^{-9}
Dibenzofuran	260×10^{-9}
Diphenylamine	20×10^{-9}

[a]Below detection limit which is less than 10×10^{-9} for most of the target analytes.

Ten sputter pan samples were placed 1 meter from the burn pans to collect propellant granules ejected from the burn pans during the burns. All propellant residue landing in the powdery soil or collected in the 1-m^2 pans visually appeared to be charred residue. This observation was substantiated by the low level of the analytes recovered. The mass of ash collected in the sputter pans averaged 2.8 g/m^2. The concentration of each analyte expressed as ng/g and ng/m^2 of terrain surface is given in Table 4.3.16.

Table 4.3.16 Summary of Semivolatile Analyte Concentrations, Phase B, Manufacturing Residue Burn, Sputter Pan Sampling.

Analyte	Number of Observations		Concentration Range	
	Total	AD[a]	(ng/g)[b]	(ng/m²)[c]
Naphthalene	2	2	39 to 54	240 to 290
Pyrene	2	2	42 to 58	260 to 310
Phenol	2	2	0.65 to 0.77	4.0 to 4.1
Dibenzofuran	2	2	2.4 to 2.8	13 to 17
Nitroglycerin	2	2	22 to 23	120 to 130

[a]Above detection limit.
[b]Represents ng of analyte per gram of fallout.
[c]Represents ng of analyte per m^2 of terrain.

b. Fallout

Fallout pan samplers were placed in concentric circles 6 and 12 meters from the center of the burn pan array. The mass of ash collected in the pans at 6 meters was 0.85 g/m^2. The mass of ash collected in the pans at 12 meters was 1.3 g/m^2. No sampling was conducted beyond 12 meters on the manufacturing residue burns; however, sampling beyond this distance on previous burns resulted in insufficient fallout for quantification of any of the analytes of interest. The analyte concentration data from the 6- and 12-meter fallout pans are summarized in Table 4.3.17. Using the maximum measured 2,4-dinitrotoluene concentration of 1300 ng/m^2 as representative of the terrain deposition out to 18 meters, results in a total deposition of 1.32 mg of 2,4-DNT, spread over 1000 m^2 or 0.25 acre.

Table 4.3.17 Summary of Semivolatile Analyte Concentrations, Phase B, Manufacturing Residue Burn, Fallout Pan Sampling.

Analyte	Sample Distance (m)	Number of Observations		Concentration Range	
		Total	AD[a]	(ng/g)[b]	(ng/m²)[c]
2,6-Dinitrotoluene	6	2	2	100 to 700	170 to 1300
	12	2	1	BD[d] to 210	BD to 540
N-Nitrosodiphenylamine	6	2	0	BD	BD
	12	2	2	1.7 to 6.7	11 to 18
2-Nitrodiphenylamine	6	2	1	BD to 2.5	BD to 4.1
	12	2	2	13 to 17	34 to 110
Naphthalene	6	2	2	73 to 300	130 to 490
	12	2	2	160 to 390	1000 to 1000
Pyrene	6	2	2	67 to 510	120 to 840
	12	2	2	54 to 410	340 to 1100
Phenol	6	2	2	0.62 to 6.9	1.1 to 11
	12	2	2	8.1 to 16	41 to 50
Dibenzofuran	6	2	2	14 to 29	25 to 47
	12	2	2	5.4 to 16	33 to 41
Diphenylamine	6	2	1	BD to 2.7	BD to 4.5
	12	2	2	0.81 to 1.3	3.4 to 5.0
Nitroglycerin	6	2	2	76 to 100	140 to 170
	12	2	2	110 to 310	670 to 810

[a]Above detection limit.
[b]Represents ng of analyte per gram of fallout.
[c]Represents ng of analyte per m^2 of terrain.
[d]Below detection limit.

c. Burn Pan Residue

The amount of propellant burned was about 3000 kg on each burn. The burn pan residue amount varied from 3.4 kg to 7.4 kg or about 0.1 to 0.2 percent of the initial weight of propellant. The burn pan residue was analyzed by Chemtech, using EPA method 8270 (acid/base/neutral compounds), with the only compounds detected being phenol at 0.054 mg/kg of residue and the phthalates (phthalate compounds are not included on the semivolatile analyte list).

4.3.3.2 Manufacturing Residue Burn Test - Phase C

4.3.3.2.1 Air Emissions

a. Gases

Gas EFs for the mix of Navy NOSIH-AA-2 and N-5 manufacturing residues burned during Phase C test series are statistically summarized in Table 4.3.18. Minimum and maximum EFs are given for all significant gaseous species. Sample size was limited to four Teflon® bag samples for the NO and NO_2 species and about eight samples for CO_2, CO, and the VOC compounds. The minimum, maximum, and average CO_2 EF was observed to be 1.00 in all samples collected. This compares with a theoretical CO_2 EF of 1.00 for this particular propellant, assuming that all propellant carbon is converted to CO_2. The high CO_2 EFs are accompanied by very low ($\sim$0.0008) EFs for CO. This trend of high carbon conversion to CO_2 in these burns is consistent with observations made on the M-1 and M-6 single-base propellants as well. Nearly all of these propellants have a positive or near positive oxygen balance, so that little or no excess ambient air is required in the combustion zone to achieve complete conversion of carbon to CO_2. Nitrogen oxide emissions are at about the 0.1 percent level with nearly all of the gases in the NO category. These levels are consistent with those determined for the M-1 and M-6 propellant types discussed earlier. Assuming that all NO is ultimately converted to NO_2, the resulting NO_2 EF following NO oxidation is about 0.004 for this manufacturing residue.

Table 4.3.18 **Gas Emission Factors for the Phase C Manufacturing Residue Burns.**

Species	Emission Factor (g/g)
CO_2 - min	1.00
CO_2 - max	1.00
CO_2 - avg	1.00
Number of observations	8
CO - min	0.005×10^{-3}
CO - max	3.0×10^{-3}
CO - avg	0.7×10^{-3}
Number of observations	8
NO - min	1.8×10^{-3}
NO - max	4.1×10^{-3}
NO - avg	2.6×10^{-3}
Number of observations	4
NO_2 - min	22×10^{-6}
NO_2 - max	600×10^{-6}
NO_2 - avg	150×10^{-6}
Number of observations	4

[a]Below detection limit.

b. Particulate Matter

Particulate matter concentrations were measured twice during multiple aircraft passes through the plume. Each measurement represents an average of three cloud passages from two successive burns, starting at about 45 seconds and extending out to about 2.5 minutes after the completion of the burn. Gravimetric analysis of the particulate material collected on the filter and information on the air volume drawn through the filter provide a means of calculating the average cloud particulate matter concentration. Average cloud concentrations measured for August 14 and August 15 burns were 3.3 and 3.2 mg/m^3, respectively. Concentration levels are consistent with low levels observed for other propellant types examined in these test series. These cloud concentrations correspond to a particulate matter EF of about 1 percent. Some existing evidence suggests that some of the particles in the cloud were soil particles entrained in the smoke column from the burning propellant; however, further testing is required to verify this theory.

c. Volatile Organic Compound

Emission factors for principal VOC compounds are given in Table 4.3.19 for the manufacturing residue test. Major species shown in the table include CH_4, TNMHC, and benzene. However all were detected at very low EF levels. Methane and TNMHC are both detected at slightly less than the 0.1 percent level and benzene is detected at the 0.01 percent level. These observations are similarly consistent with the low VOC emissions observed for the M-1 and M-6 propellant tests.

Table 4.3.19 Volatile Organic Compound Emission Factors for the Phase C Manufacturing Residue Burns.

Species	Emission Factor (g/g)
CH_4 - min	3.8×10^{-6}
CH_4 - max	3400×10^{-6}
CH_4 - avg	750×10^{-6}
Number of observations	5
TNMHC - min	130×10^{-6}
TNMHC - max	1200×10^{-6}
TNMHC - avg	560×10^{-6}
Number of observations	7
Benzene - min	2.9×10^{-6}
Benzene - max	34×10^{-6}
Benzene - avg	16×10^{-6}
Number of observations	7

d. Semivolatile Organics (Exotics)

Emission factors for the semivolatile organic target compounds are given in Table 4.3.20 for the phase C manufacturing residue propellant burns. The values shown in the table are the maximum values obtained from two separate tests each consisting of two burns in series. Analysis allows the determination of thermally unstable compounds such as nitroglycerin which would otherwise decompose during injection and separation by conventional gas chromatography. The emission factors for the target analytes are all observed at the part per million (10^{-6}) level or less. The highest emission factors observed were for naphthalene, pyrene, and diphenylamine. Efficient combustion of the nitrodiphenylamine, present in the parent propellant at a level of 2 percent of the weight, is evidenced by an emission factor for diphenylamine of 3×10^{-7}. It is not likely that the

measured 2,4-dinitrotoluene, 2,6-dinitrotoluene, and 2,4,6-trinitrotoluene are derived from the chemical rearrangement of propellant constituents during the burn. It is noteworthy that nitroglycerin, one of the major propellant constituents, is not detected in the air samples collected. Similarly, the remainder of the target analytes were either not detected or observed at low (10^{-8} or 10^{-9}) levels.

Table 4.3.20 **Maximum Semivolatile Organic Emission Factors Measured for the Phase C Manufacturing Residue Burns[a].**

Species[b]	Emission Factor (g/g)
2,4 Dinitrotoluene	160×10^{-9}
2,6 Dinitrotoluene	140×10^{-9}
2,4,6 Trinitrotoluene	64×10^{-9}
2-Nitronaphthalene	83×10^{-9}
N-Nitrosodiphenylamine	27×10^{-9}
1,3,5-Trinitrobenzene	5.3×10^{-9}
2-Nitrodiphenylamine	13×10^{-9}
1-Nitropyrene	BD[c]
Nitroglycerin	BD
Naphthalene	540×10^{-9}
Benz[a]anthracene	140×10^{-9}
Benzo[a]pyrene	81×10^{-9}
Pyrene	320×10^{-9}
Phenol	---[d]
Dibenzofuran	120×10^{-9}
Diphenylamine	310×10^{-9}

[a]Emission factors are expressed in terms of 10^{-9} for ease of comparison, e.g., 160×10^{-9} is equivalent to 0.000000160.
[b]See Table 3.16 for a list containing the semivolatile organics and the detection levels.
[c]Below detection limit.
[d]---Phenol was lost in the extraction of the semivolatiles.

4.3.3.2.2 Soil Deposition

a. Sputter

Ten sputter pan samples were placed 1 meter from the burn pans to collect propellant granules ejected from the burn pans during the burn. All manufacturing residue landing in the powdery soil or collected in the 1-m^2 pans visually appeared to be charred residue. This observation was substantiated by the low level of the analytes recovered. The mass of ash collected in the sputter pans averaged 3.2 g/m^2 on trial 1 and 1.8 g/m^2 on trial 2. The concentration of each analyte expressed as ng/g and ng/m^2 of soil surface is given in Table 4.3.21.

Table 4.3.21 Manufacturing Residue Burn: Summary of Semivolatile Organic Concentrations, Sputter Pan Sampling, Phase C.

Analyte	Number of Observations		Concentration Range	
	Total	AD[a]	(ng/g)[b]	(ng/m^2)[c]
2,4-Dinitrotoluene	2	2	5.5 to 21	15 to 58
2,6-Dinitrotoluene	2	2	1.8 to 8.1	4.9 to 22
2,4,6-Trinitrotoluene	2	1	BD[d] to 7.1	BD to 19
2-Nitronaphthalene	2	1	BD to 3.2	BD to 8.6
Naphthalene	2	1	BD to 13	BD to 34
Benz[a]anthracene	2	1	BD to 35	BD to 94
Benzo[a]pyrene	2	1	BD to 3.1	BD to 8.4
Pyrene	2	1	BD to 6.2	BD to 17
Dibenzofuran	2	1	BD to 30	BD to 80

[a]Above detection limit.
[b]Represents ng of analyte per gram of fallout.
[c]Represents ng of analyte per m^2 of terrain.
[d]Below detection limit.

b. Fallout

Fallout pan samplers were placed in concentric circles 6 and 12 meters from the center of the burn pan array. The mass of ash collected in the pans at 6 meters was 3.1 and 3.6 g/m^2 on trial 1 and trial 2, respectively. The mass of ash collected in the pans at 12 meters was 9.8 and 1.4 g/m^2 for trial 1 and trial 2, respectively. No sampling was conducted beyond 12 meters on the phase C manufacturing residue burns; however, sampling beyond this distance on previous burns resulted in insufficient fallout for quantification of any of the analytes of interest. The analyte concentration data from the 6- and 12-meter fallout pans are given in Table 4.3.22. Using the maximum measured

2,4-dinitrotoluene concentration of 24 ng/m^2 as representative of the terrain deposition out to 18 meters, results in a total deposition of 0.024 mg of 2,4-DNT spread over the 1000 m^2 or 0.25 acre.

Table 4.3.22 **Manufacturing Residue Burn: Summary of Semivolatile Analyte Concentrations, Fallout Pan Sampling, Phase C.**

Analyte	Sample Distance (m)	Number of Observations		Concentration Range	
		Total	AD[a]	(ng/g)[b]	(ng/m^2)[c]
2,4-Dinitrotoluene	6	2	2	7.3 to 7.5	11.4 to 11.8
	12	2	2	3.7 to 23	3.9 to 24
2,6-Dinitrotoluene	6	2	2	4.3 to 5.0	6.8 to 7.9
	12	2	2	0.62 to 4.8	0.65 to 5.1
2,4,6-Trinitrotoluene	6	2	0	BD[d]	BD
	12	2	2	0.62 to 120	0.64 to 120
2-Nitronaphthalene	6	2	2	2.3 to 5.0	3.7 to 7.9
	12	2	2	0.42 to 8.4	0.44 to 8.8
1,3,5-trinitrobenzene	6	2	0	BD	BD
	12	2	1	BD to 5.4	BD to 5.7
Naphthalene	6	2	1	BD to 11	BD to 18
	12	2	1	BD to 23	BD to 24
Benz[a]anthracene	6	2	1	BD to 7.8	BD to 12
	12	2	1	BD to 29	BD to 30
Benzo[a]pyrene	6	2	1	BD to 1.7	BD to 2.7
	12	2	1	BD to 0.079	BD to 0.083
Pyrene	6	2	1	BD to 3.0	BD to 4.6
	12	2	1	BD to 15	BD to 16
Dibenzofuran	6	2	0	BD	BD
	12	2	1	BD to 48	BD to 50
Diphenylamine	6	2	0	BD	BD
	12	2	1	BD to 21	BD to 21

[a]Above detection limit.
[b]Represents ng of analyte per gram of fallout.
[c]Represents ng of analyte per m^2 of terrain.
[d]Below detection limit.

c. Burn Pan Residue

Burn pan residue for each 2200 kg of manufacturing residue burned varied from 0.37 kg to 1.1 kg over the four burns. The average residual was 0.61 kg, or about 0.03 percent of the initial weight

of propellant. Burn pan residue samples for semivolatile organic analyses were taken on each burn. A composite sample for each of the burn trials was analyzed. The semivolatile organic analytes detected and the concentrations are given in Table 4.3.23.

Table 4.3.23 Manufacturing Residue Burn: Summary of Semivolatile Analyte Concentrations, Burn Pan Residue, Phase C.

Analyte	Number of Observations		Concentration Range (ng/g)[b]
	Total	AD[a]	
2,4-Dinitrotoluene	2	2	1.8 to 6.0
2,6-Dinitrotoluene	2	2	3.5 to 5.0
2-Nitronaphthalene	2	2	0.13 to 3.6
Benzo[a]pyrene	2	2	11 to 11
Pyrene	2	2	3.2 to 5.2
Dibenzofuran	2	2	18 to 22
Diphenylamine	2	1	BD[c] to 1.9

[a]Above detection limit.
[b]Represents ng of analyte per gram of pan residue.
[c]Below detection limit.

4.4 Comparison of BangBox and Field TNT Detonations

EFs from the BangBox, open-air *surface*, and open-air suspended TNT detonations are summarized in Table 4.4.1. This table gives values for CO_2, CO, NO, NO_2, volatile organics, (methane, TNMHC, and benzene), and the selected list of semivolatiles.

Table 4.4.1 **Average** Emission Factors for the Volatile and Maximum Emission Factors for the **Semivolatile** Analytes from the BangBox and Open-Air Detonation with TNT.

Analyte	BangBox	Phase A	Phase B		Phase C	
		Surface	Surface	Suspended	Surface	Suspended
CO_2	1.32	1.26	1.29	1.35	1.28	1.35
CO	4.9×10^{-3}	61×10^{-3}	42×10^{-3}	7.3×10^{-3}	49×10^{-3}	6.9×10^{-3}
NO	11×10^{-3}	0.70×10^{-3}	1.4×10^{-3}	2.5×10^{-3}	1.4×10^{-3}	2.3×10^{-3}
NO_2	0.56×10^{-3}	3.6×10^{-3}	1.1×10^{-3}	$2.1 \times ^{-3}$	1.4×10^{-3}	1.2×10^{-3}
Methane	0.025×10^{-3}	1.5×10^{-3}	1.2×10^{-3}	0.061×10^{-3}	1.5×10^{-3}	1.5×10^{-3}
TNMHC	0.057×10^{-3}	1.4×10^{-3}	1.9×10^{-3}	0.21×10^{-3}	2.1×10^{-3}	5.0×10^{-3}
Benzene	2.4×10^{-6}	94×10^{-6}	93×10^{-6}	3.2×10^{-6}	100×10^{-6}	62×10^{-6}
2,4-DNT	170×10^{-9}	150×10^{-9}	8400×10^{-9}	200×10^{-9}	BD[a]	BD
2,6-DNT	140×10^{-9}	19×10^{-9}	7100×10^{-9}	300×10^{-9}	BD	BD
2,4,6-TNT	620×10^{-9}	220×10^{-9}	150×10^{-9}	46×10^{-9}	60×10^{-9}	140×10^{-9}
2-NN	160×10^{-9}	80×10^{-9}	270×10^{-9}	15×10^{-9}	ED	BD
N-NSDPA	200×10^{-9}	BD	4.4×10^{-9}	29×10^{-9}	BD	BD
1,3,5-TNB	0.45×10^{-9}	BD	BD	BD	BD	BD
2-NDPA	N/A[b]	N/A	N/A	N/A	BD	BD
1-NP	1/13[c]	BD	39×10^{-9}	59×10^{-9}	BD	BD
Naph	28×10^{-6}	BD	3.7×10^{-6}	0.012×10^{-6}	2.6×10^{-6}	1.8×10^{-6}
B[a]A	BD	2.2×10^{-9}	160×10^{-9}	66×10^{-9}	100×10^{-9}	320×10^{-9}
B[a]P	360×10^{-9}	BD	240×10^{-9}	310×10^{-9}	BD	BD
Pyrene	32×10^{-9}	BD	NA	N/A	220×10^{-9}	19×10^{-9}
Phenol	9.9×10^{-6}	BD	5.2×10^{-6}	12000×10^{-6}	BD	BD
DBF	150×10^{-9}	BD	85×10^{-9}	60×10^{-9}	180×10^{-9}	190×10^{-9}
DPA	BD	N/A	7.7×10^{-9}	25×10^{-9}	170×10^{-9}	BD

[a]Below detection limit.
[b]N/A - Not on the analyte list.
[c]Detected on one of 13 assays, at very low level.

4.4.1 Emission Factor Comparison.

Changes in the EF for any particular species would not be expected if the explosive configuration (suspended or *surface*) or the size of the detonation has no effect on the amount of the pollutant produced, since the EF is the amount of pollutant released, normalized to the original mass of

material. The EF for several of the gases reveals that either scale or configuration effects are operative. For example, the CO_2 EF is higher for the BangBox and suspended outdoor tests when compared to those from the outdoor *surface* detonations. Since the small-scale BangBox and large-scale suspended EF for CO_2 are similar, it can be surmised that the suspended configuration of the explosive is an important parameter in the CO_2 formation process. As discussed earlier, the presence of entrained soil debris in the detonation fireball during the *surface* tests is believed to depress the fireball temperature, as well as limit the degree of entrainment of ambient air into the fireball. Similar EF discontinuities can be noted for CO, CH_4, and TNMHC species when the BangBox and suspended tests are compared to the *surface* tests. Differences in the semivolatile target analyte EFs from BangBox, suspended, and *surface* TNT tests are less pronounced when compared to those of the gaseous products. The semivolatile category of emission products appears to be least influenced by explosive configuration or scale. These results suggest that small-scale, low cost experiments may be useful in the determination of pollutant releases, if the EF scale effects for some of the less-toxic gaseous species can be appropriately considered at the smaller scales.

4.4.2 Comparison of Carbon Distribution.

The fate of TNT carbon for all TNT test categories is summarized in Table 4.4.2. Here, an average of the mass fraction of carbon released as CO_2, CO, CH_4, TNMHC, particulate organic carbon (OC), and particulate elemental carbon (EC) is shown for the BangBox, *surface*, and suspended TNT detonations. As noted in the results section for each test configuration, the majority of the carbon goes to CO_2. In all cases, the CO_2 category receives in excess of 92 percent of the original TNT carbon. Allotments to the CO_2 category are highest for detonations carried out in the absence of soil and are lowest for those done in close contact with soil. With a few exceptions, each of the other two emission categories (EC and OC) receive about 1 percent of the original carbon. A notable exception is the CO category in the *surface* tests, which receives about 5 percent of the original carbon mass. The particulate organic carbon category for the open air-tests is a worst-case estimate as it appears in this table, since measurements of local Dugway soil reveal a significant particulate organic carbon component in the soil. Distinguishing between soil-derived and TNT-derived particulate OC is not attempted here. However, soil analysis results suggest that nearly all the carbon in the OC category may originate from soil entrained in the cloud. This is not the case with particulate EC, category since soil analysis shows nondetectable levels of EC.

Table 4.4.2 Distribution of Carbon Emissions by Pollutant Category for BangBox and Open-Air Surface and Suspended TNT Detonations.

Species[a]	Mass Fraction of Carbon Released					
	BangBox	Phase A Surface	Phase B Surface	Phase C Surface	Phase B Suspended	Phase C Suspended
CO_2 (gas)	0.977	0.950	0.920	0.936	0.983	0.974
CO (gas)	0.006	0.013	0.053	0.056	0.008	0.008
CH_4 (gas)	BD[b]	0.014	0.002	0.003	BD	0.005
TNMHC (gas)	BD	0.009	0.004	0.005	BD	0.013
OC[c] (particles)	0.0001	0.007	0.014	N/M[d]	0.0001	N/M
EC[e] (particles)	0.017	0.008	0.007	N/M	0.017	N/M

[a]In all cases, the carbon mass fraction release to the compounds included in the semivolatile organic target analyte list is less than 5×10^{-5}.
[b]Below detection limit.
[c]An analysis of Dugway soil suggests that nearly all the particulate organic carbon (OC) detected in the cloud may be attributable to suspended soil. Here, it is conservatively assumed that all detected OC is an emission product from the TNT detonation and is not corrected for soil contributions.
[d]N/M - Measurement for the species of carbon not made.
[e]Elemental carbon.

4.5 Dispersion Model Sreening Analysis

4.5.1 Dispersion modeling has been extensively used to estimate downwind pollutant concentrations that would arise from either a continuous or instantaneous release of pollutants from a point source. An analysis was carried out using the DPG volume source dispersion model RTVSM (Reference 7) and a range of EFs measured for surface TNT detonations during the OB/OD tests. This particular model uses simple Gaussian dispersion calculations to estimate maximum and timed average ground level concentrations. The stable cloud radius was derived using Briggs plume rise techniques (References 8 and 9) which specify that the cloud radius expands linearly at a factor of 0.64 of the cloud height for an instantaneous source. Results can be used to assess potential exposure hazards that personnel in the region of cloud impact with the ground might encounter. Three release scenarios were selected for dispersion analysis that reflect downwind concentrations of three general classes of pollutants. These include (1) criteria gases such as CO; (2) VOC species such as benzene; and, (3) semivolatile organic compounds such as benzo[a]pyrene. Input assumptions for each of the three cases are given in Table 4.5.1. An initial

explosive mass of 1 metric ton (1,000 kg) was used in all model cases along with a stabilized cloud height estimate of 330 m. The cloud height estimate represents a conservative estimate in good agreement with *minimum* stabilized cloud heights actually observed during aircraft sampling of detonation clouds during the various testing phases. This cloud height estimate represents a worst case analysis from the perspective of predicting ground level concentrations since the lower (minimum) cloud height will yield higher ground level concentrations.

Results from the three cases selected are shown Table 4.5.1 with Figure 4.1 showing an output plot of the RTVSM model for CO. Maximum peak instantaneous and maximum 15-minute average ground level concentrations for each of the three cases examined are at low levels. For example, surface detonation of 1 metric ton of TNT would result in peak ground level CO concentrations of 210 $\mu g/m^3$ or about 0.18 ppm. These levels are insignificant in light of the fact that rural "clean air" background CO levels are typically in the vicinity of 0.1 ppm. A similar result occurs for benzene. Where the model predicts downwind peak instantaneous benzene concentrations of 0.43 $\mu g/m^3$, actual background levels in "clean air" are in the range of 0.5 to 1.5 $\mu g/m^3$. The background benzene concentration level is thus nearly the same as that arising from a TNT detonation as predicted by this dispersion model. The semivolatile case reveals even lower peak instantaneous ground concentration levels in the vicinity of 0.43 ng/m^3. Typical polynuclear aromatic hydrocarbon concentrations such as benzo[a]pyrene are encountered in "clean air" at concentration levels ranging from 0.01 to 0.40 ng/m^3 (Reference 10). Here again, benzo[a]pyrene pollutant contributions at downwind ground level locations are in the same range as clean air ambient background concentrations and would not be distinguishable from clean air background levels. Of particular note is the fact that 15 minute average downwind concentrations as "seen" by a ground level receptor at a fixed point during passage of a single diluted puff are lower than the peak instantaneous values by about a factor of ten. Since most personnel exposure criteria are based on exposure intervals of 15 minutes or longer, these levels are more representative of potential downwind exposure levels that may be encountered. These dispersion model results strongly suggest that air emissions from these large scale detonations pose no health threat to personnel downwind of the cloud.

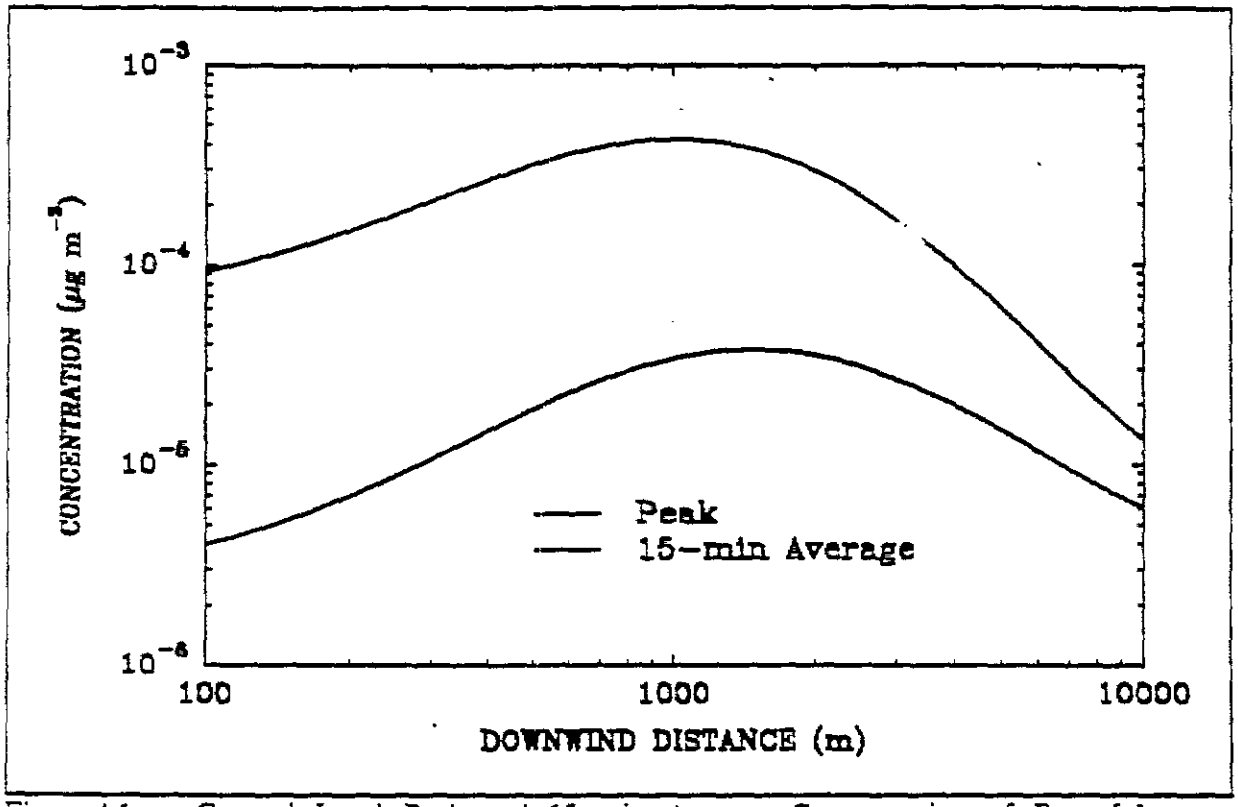


Figure 4.1 Ground Level Peak and 15 min Average Concentration of Benzo[a]pyrene Downwind of a 1000-kg Surface Detonation of TNT.

Table 4.5.1 Input Data and Downwind Ground Level Pollutant Concentrations for Selected Cases Using the DPG Volume Source Dispersion Model.

Input/Output Parameter	**Case 1 Gas (CO)**	**Case 2 VOC (Benzene)**	**Case 3 Semi-volatile (Benzo[a]Pyrene)[a]**
EF	5×10^{-2}	1×10^{-4}	0.1×10^{-6}
Total Release (kg)[b]	50	0.1	0.0001
Stable Cloud Height (m)	330	330	330
Stable Cloud Radius (m)	211	211	211
Wind Speed (m/s^1)	5	5	5
Stability Class	Unstable	Unstable	Unstable
Max Downwind Inst. Conc[c] ($\mu g/m^3$)	210	0.43	0.00043
Max 15 min Avg Conc[d] ($\mu g/m^3$)	19	0.038	0.000038
Downwind range for peak conc (km)	1	1	1
Downwind range for avg conc (km)	1.5	1.5	1.5

[a]Benzo[a]pyrene was only found on the TNT detonations during Phase B test.
[b]Total pollutant release is based on a 1000 kg surface detonation of bulk TNT and an assumption that all of the compound becomes an air emission. This is essentially true for Case 1 and Case 2 but is approximately a 2 order of magnitude over estimate for Case 3 (semi-volatile).
[c]Maximum downwind instantaneous concentration at ground level.
[d]Maximum downwind 15 minute average concentration at ground level.

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SECTION 5. SUMMARY OF QA ACTIVITIES FOR OB/OD PROGRAM

5.1. Overview

5.1.1. The OB/OD program was conducted in four phases, a controlled chamber test (BangBox), and three field tests (Phases A, B, and C).

5.1.2. The purposes of the BangBox tests were (1) to characterize the emission products resulting from OB/OD operations, (2) to evaluate candidate sampling and analysis methods for measuring these emission products, and (3) to develop the QA and QC procedures necessary to ensure that the program met its data quality objectives.

5.1.3. Field Test Phase A was a pilot test to evaluate the candidate sampling and analysis techniques selected from the results of the BangBox tests. Field Test Phases B and C were full-scale field tests to assess the impact of OB/OD activities on the environment and to determine if BangBox-type tests adequately simulate the emission products from real world OB/OD operations.

5.1.4. All organizations making measurements in the OB/OD project were expected to have either standard operating procedures (SOP's) or letters of instruction (LOI's) for each phase of the program. Two organizations, SSL and OGC, did not have approved LOI's in place until after the BangBox tests were completed. However, these organizations are very small and one principal analyst handles all the samples. In the view of all auditors, the lack of an approved LOI did not affect the quality of the analyses provided by these two organizations. The SOP's and LOI's were revised as the program progressed and the measurement methods were improved or revised.

5.1.5. A quality assurance project plan (QAPP) containing the SOP's and LOI's was developed for each phase of the program. The QAPP described the quality control (QC) activities that would be followed by the organizations making measurements in that phase of the program. Sample QC activities used in the OB/OD program were (1) matrix spikes, (2) method of standard additions, (3) replicates, (4) split samples, (5) sample chain-of custody, (6) up to date and readable laboratory logbooks, and (7) preventive maintenance on the equipment.

5.1.6. Two organizations were responsible for the external QA, ELI (Provo, Utah) and U.S. Environmental Protection Agency Atmospheric Research and Exposure Assessment Laboratory (USEPA/AREAL) Quality Assurance Division (Research Triangle Park, NC).

5.1.6.1. ELI, the contract QA organization for AMCCOM conducted quality systems audits (QSA) on all organizations making measurements to provide a qualitative assessment of the conformance of the organization to their QC procedures and to it's LOI's/SOP's. The ELI QSA's addressed the following: (1) LOI status, (2) field/laboratory sampling, (3) field/laboratory analysis, (4) instrument/method calibration, (5) preventive/corrective maintenance, (6) internal QC procedures, (7) sample preparation and storage, (8) preparation and use of spiked samples, (9) instrument/equipment selection and use, (10) determination of detection limits/limits of quantification, (11) sample handling and transportation, (12) data reduction and analysis, (13) logbooks, (14) personnel working with samples, (15) building diagrams, (16) research journals, (17) tracking system for samples, and (18) overall assessment/recommendations and comments.

5.1.7. The USEPA audit team conducted QSA's and quality performance audits (QPA's) on the organizations making measurements. QPA's provide a quantitative assessment of an organization's performance by challenging their measurement system with accurately prepared samples which have levels or values that are unknown to the organization being audited. These EPA QPA's included checks on the following: (1) Sample flow-rate accuracy, (2) Carbon monoxide, carbon dioxide, nitrogen oxide, nitrogen dioxide, ozone, and sulfur dioxide air monitor accuracy, (3) percent recovery of semivolatile organic compounds (SVOC's) from soil, particulate, and canister samples, and (4) percent recovery of VOCs from canisters.

5.1.8. Appendix J provides an "in-depth" description of the procedures used for the QSA's and QPA's, the findings of the QSA's, QPA's, and corrective actions taken by the audited organization, and the auditors' assessment of the impact of the findings on the data quality. Tables 5.1 and 5.2 reveal when and by whom QSA's and QPA's were conducted.

5.1.9. A summary of the findings by measurement type and, where appropriate, an assessment of the findings on the data quality of the OB/OD thermal treatment program is provided below.

5.2. Inorganic Gases (Carbon Monoxide, Carbon Dioxide, Nitrogen Oxide, Nitrogen Dioxide, Sulfur Dioxide, Ozone) Measured by Continuous Monitors

5.2.1. All monitors (including the associated data collection system) were operating within an accuracy of ±10 percent (the data quality goal for the program), with the exception of the carbon dioxide monitor in phase A. This later monitor was reading high by 14 percent, because the zero had shifted. However, this shift did not affect the use of the measurement, because the carbon dioxide measured before the plane entered the plume was subtracted from the carbon dioxide measured in the plume. Since the baseline shift affected both measurements equally, the amount of carbon dioxide formed from the detonation was accurately measured. SNL recalibrates the monitor as soon as the shift in baseline is detected. The logbooks were kept current and SRMs (standard reference materials from the National Institute for Standards and Technology (NIST) were used to calibrate the carbon monoxide, carbon dioxide, nitrogen oxide, and sulfur dioxide instruments. Since there are not SRM's for nitrogen dioxide or ozone, these instruments were calibrated with transfer standards traceable to the NIST.

5.2.2. Two problems occurred throughout the OB/OD program. The auditors continually found that SNL did not have spare parts for the monitors on the aircraft, and SNL failed to check out the monitors before the aircraft left Albuquerque. While these problems did not affect the quality of the data, they did cause extensive delays during the field tests. Sometimes a full day's testing was canceled because one or more of the monitors was not operating and the required spare part was not available on site.

5.3. Flow Rate of Particulate and VOST Samplers

5.3.1. Particulate Sampler

The flow-rate through the aircraft's sampling probe was checked at the probe inlet during the three field tests and determined to be within the ±5 percent of the reference flow. This was within the ±10 percent data quality objective for the OB/OD project.

5.3.2. VOST Sampler

The sampler was used only in the BangBox tests. All samplers had flow-rates within 7 percent of the reference standard.

5.4. Volatile Organic Samplers

5.4.1. During all four phases of the program 6-L canisters provided to EPA by OGC were spiked with known quantities of VOCs by EPA at 1 to 5 ppb. The canisters were then returned to OGC. The percent recoveries achieved by OGC for the OB/OD target compounds were consistently excellent and well within the 75- to 125-percent target range. Precision was also excellent, generally less than 5-percent RSD.

5.4.2. QSA's were completed on the VOC sampler in the BangBox test, the three field tests, and also in the OGC laboratory. No deficiencies that would affect data quality were found. During Phase A and once in Phase C, the inlet valve to the canister's sampling manifold failed to open. In these cases the samples were voided.

5.5. Semivolatile Organic Samplers

5.5.1. 32-L Tanks with Filters on Inlet

This sampler was used in the BangBox test in an attempt to simultaneously collect large VOC and semivolatile organic compounds (SVOCs) samples. The SVOC's were expected to be collected on the filter and also in the tanks. EPA placed known quantities of seven SVOC's in the tanks and sent them to BCD and to AWL for extraction, and subsequent analysis for SVOC's. Recoveries of all seven compounds were less than 50 percent, the OB/OD program's lower limit for SVOC analysis. The audit results showed that this was not a viable sampler for the program and it was dropped from the program before the field tests were begun.

5.5.1.1. QSA's by EPA and ELI showed that both laboratories followed the LOI for the method and that the sampler was leak-free prior to use in the BangBox tests.

5.5.2. Semivolatile Organic Sampling Train Sampler

5.5.2.1. This sampler, which used a filter followed by XAD-2® cartridges to collect SVOC's, was used in the BangBox tests in an attempt to collect large quantities of SVOC. EPA placed known quantities of seven SVOC's on XAD-2® sampling cartridges and sent them to BCD and AWL for extraction and analysis. A solution containing the same seven SVOC's accompanied the cartridges to serve as a benchmark measure on the analytical portion of the method. BCD achieved recoveries between 70 and 135 percent for the solution, but recovered less than 50 percent for three of the seven compounds placed on the XAD-2®. AWL achieved less than 50-percent recovery for all seven compounds. It was subsequently determined that the XAD-2® had been heated too long during cleanup prior to use, and all samples were then voided. The VOST sampler was dropped from the program before field tests were begun, because the BangBox tests and the open literature indicated that a high-volume filter would be adequate for collecting SVOC's. The QSA's determined that BCD and AWL followed the LOI for the extraction and analysis of the samples.

5.6. SVOCs Particulate from Sampler (Aircraft) and Fallout Pans

5.6.1. The material collected on the filter and in the fallout pans from detonations was expected to be mostly soil particles containing some SVOC's. EPA placed known quantities of SVOC's on background soil samples from DPG, and these were then extracted and analyzed by AWL. The first spiked soil samples (BangBox Test) contained 5 to 36 μg of seven SVOC's. AWL achieved quantitative recovery for all seven SVOC's using both SFC-MS and GC-MS. For Phase A, no spiked soil samples were used because the objective was to check out the sample collection procedures developed from the BangBox tests. Spiked soil samples were used in Phases B and C, however, where ancillary tests were also done to evaluate the spiking and analytical methods being used in the OB/OD project.

5.6.1.1. Nanogram rather than μg quantities of analytes were used for Phases B and C because the BangBox test results showed that only ng quantities of analytes would likely be encountered in the soil samples from the field test. The analytes spiked on the soil samples in Phases B and C were somewhat different from those used in the BangBox spiked soil samples, i.e., 1-nitropyrene, dibenzofuran, pyrene, 1,3,5-trinitrobenzene, 2,6-dinitrotoluene, 2,4-dinitrotoluene and naphthalene were added and N-nitrosodiphenylamine and the two nitrophenols were deleted from the original list.

5.6.1.2. Low recoveries (less than 50%) were found for all analytes for the Phase B soil sample spikes; these low recoveries were subsequently determined to have resulted from reduced sensitivity of the SFC-MS used to analyze the extracts. The reduced sensitivity resulted from the chromatographic coating being striped from the SFC's column by the acetonitrile carrier and being carried to the MS' quadrapole area where it deposited. The SFC-MS unit was repaired for the Phase C samples and acceptable recoveries were achieved for the analytes except phenol, 1,3,5-trinitrobenzene, 2,6-dinitrotoluene and naphthalene. The samples used for Phase C were spiked using two established methods, the slurry/rotary evaporator technique and the aluminum (foil) roll technique to see if the spiking technique affected the recovery of the analytes from the soil. In the slurry technique the solvent (100 - 200 ml per 400 grams of soil) is removed at elevated temperatures (45-80°C) using a rotary evaporator. There was concern that some of the more labile analytes would be lost. In contrast, the aluminum roll technique lets the solvent (1 ml) air-evaporate. Five soil samples were spiked by the slurry technique and five were spiked by the aluminum roll techniques. The samples were spiked with the same quantities of analytes. All extracts were analyzed by GC-MS and SFC-MS to also determine if the GC-MS and SFC-MS gave equivalent results.

5.6.2. The results of these tests (based on the percent of the analyte recovered from the soils) were:

5.6.2.1. There was no difference in soils spiked by the aluminum roll and those spiked by the slurry/rotary evaporator technique.

5.6.2.2. Phenol was not recovered from any sample. Therefore, phenol should not be used as a target analyte at least if a Soxhlet extraction procedure is used. Whether phenol would be recovered if a sonification technique is used for extraction is unknown.

5.6.2.3. Consistently low recoveries were obtained for diphenylamine. This is expected because amines are tightly bound to soils. Low recoveries were also found in many samples for 1,3,5-trinitrobenzene, 2,6-dinitrotoluene and naphthalene.

5.6.2.4. Samples that were not spiked showed small quantities of 1,3,5-trinitrobenzene and 2,4-dinitrotoluene. This indicated either previous contamination of the soil sample before it was received for spiking or the presence of an interfering ion.

5.6.2.5. The results showed that the analytes can be quantitatively transferred to dichloromethane from the acetonitrile used to extract the analytes from the soil. This is encouraging because it provides a means to remove the acetonitrile solvent before the sample is placed in the SFC-MS system. (Acetonitrile was found to dissolve the gas chromatographic column's stationary phase which caused the column material to enter the MS unit.)

5.6.3. At this time, there are no reference soil samples that contain accurately known recoverable quantities of SVOC's, so the overall accuracy of the extraction and analysis of the DPG soil samples for SVOC's is uncertain. However, AWL obtained the precision normally expected for soil analyses when they extracted and analyzed duplicate field samples and when they reanalyzed extracts from soil samples months after the original analyses.

5.6.4. Quality system audits on AWL when they were extracting and analyzing soil and filter (particulate) samples showed that they were properly calibrating the SFC-MS unit and using the extraction technique in the LOI. Record keeping was a continual problem but in each instance the problems were corrected and it is felt that no samples were misidentified. AWL is a small research laboratory with one principle analyst and it is not accustomed to employing the labor-intensive sample tracking system normally used by laboratories that provide routine analytical services.

5.7. Metals by XRF

5.7.1. Only QSA's were performed, since LBL uses NIST certified calibration standards. Metals analyses (19 metals) were done on samples from the BangBox and from Phase C. The QSA's determined that the laboratory consistently achieved precision of ± 6 percent or better on its QC samples, well within their ± 10 percent QC goals. If the ± 10 percent QC target goal was exceeded, the analysis was voided and the sample was reanalyzed after the instrument was recalibrated. LBL is essentially a three-man operation with one principal analyst. They employ an EPA-approved analytical method.

5.8. Elemental and Volatilizable Carbon

Only QSA's were conducted on the carbon measurement system, because SSL was employing a comprehensive QC program. Sucrose samples placed on filters and rods containing accurately known quantities of carbon containing compounds were used for calibration and for QC checks. The QSA's revealed no deficiencies or deviations from the LOI.

5.9. Real Time Particle Measurements (Aircraft)

Only QSA's were conducted on the two particle counters employed on the aircraft, because there are no field-proven calibration/auditing systems. Both instruments were calibrated against NIST standards less than one year before the field tests, which met the date quality goal. These instruments were used primarily to detect entry into and exit from the plume, and no particle concentration calculations were attempted.

5.10. HCN, NH_3, HCL Samplers

These samplers, which employed impingers, were used in the BangBox tests. Measurable quantities of the three compounds were not detected in the BangBox, and the use of the sampler was discontinued. The QSA showed that the published reference method was followed for sampling and analysis and that certified calibration standards were used to calibrate the colorimeter.

5.11. Fallout and Burn Pan Sampler Placement and Recovery

Extensive QSA's were performed by EPA and ELI during all three field tests. No major deficiencies or deviations from the LOI's were found that would impact on the quality of the data. The Lockheed Engineering and Sciences Company (LESC) personnel were observed to be well-trained, conscientious, and very proficient in executing their duties. No cases of sample misidentification were detected, and all samples were taken in accordance with the LOIs.

5.12. Particulate Weight Determination

5.12.1. The particulate sample filters from the BangBox and phases A and B were transported to AWL for conditioning and particulate weight determination. The filters from Phase C were conditioned and weighed at DPG by SNL. The decision was made to weigh the Phase C filters at DPG to reduce the chance that particulate would be lost from the filters during transport and to provide improved facilities for filter conditioning.

5.12.2. QSA's did not detect any instances where samples were misidentified, or the particulate contaminated or lost after collection. However, AWL's record-keeping system was cumbersome to follow, because the logbook was organized by date and not by sample number. Since the filters were weighed at periodic intervals over several days (until a constant weight was obtained) the auditor had to check numerous pages to determine how many times a specific filter was weighed and the change in weight between determinations.

Table 5.1 Schedule of Quality System Audits During OB/OD Program

Audited Organization	Test Phase	Auditing Organization	
		ELI	EPA
Battelle-Columbus	BangBox	28 Dec 88	NA[a]
Oregon Graduate Center	BangBox	24 Jan 89	NA
	Phase B	18 Jan 90	7 Nov 89
Sunset Laboratory	BangBox	23 Jan 89	NA
	Phase A	9 May 89	NA
	Phase B	17 Jan 90	NA
Lawrence Berkeley Laboratory	BangBox	31 Jan 89	NA
Brigham Young University (PIXE[b] Lab)	Phase B	14 Feb 90	21 Feb 90
Lockheed Engineering and Science Co.	Phase C	6-19 Aug 90	6-27 Aug 90
			20 Feb 90
Environmental Laboratories Inc.	Phase C	NA	6-27 Aug 90
Sandia National Laboratories	BangBox	16-17 Dec 88	30 Nov-2 Dec 88
			Feb 89
	Phase A	NA	Jun 89
	Phase B	13-19 Oct 89	13-27 Oct 89
	Phase C	NA	6 Aug- 19 Sep 90
Alpine West Laboratories	BangBox	18 Jan 89	NA
	Phase A	17 Jul 89	NA
	Phase B	9 Feb 90	19, 24 Oct 89
			5-6 Dec 89
			20-21 Feb 90
	Phase C	NA	16 Aug 90
			15 Nov 90

[a]Not applicable, QSA not conducted by ELI or EPA.
[b]Particle induced X-ray emission.

Table 5.2 Schedule of EPA Quality Performance Audits During OB/OD Program.

Audited Organization	Test Phase	Audit Dates	Measurement Parameters or Analyte Involved
Sandia National Laboratories	BangBox	6-8 Feb 89	Flow rate: particulate samplers, XAD cartridge sampler. Gas analyzers: CO, CO_2, O_3, SO_2, NO, NO_2.
	Phase A	Jun 89	Gas analyzers: CO, CO_2.
	Phase B	Oct 89	Flow rate: aircraft probe.
			Gas analyzers: CO, CO_2, O_3, SO_2.
	Phase C	6-10 Aug 90	Flow rates.
			Gas analyzers: CO, CO_2, O_3, NO, NO_2.
Alpine West Laboratories	BangBox	Dec 88	Spiked soil, spiked XAD-2 cartridges.
			Spiked 32-L tank.
	Phase B	Nov 89	Spiked soil.
	Phase C	Dec 90	Spiked soil.
Battelle-Columbus Division	BangBox	Dec 88	Spiked soil, spiked XAD-2 cartridges.
			Spiked 32-L tank.
Oregon Graduate Center	BangBox	Dec 88	Spiked 6-L canisters.
	Phase B	Nov 89	Spiked 6-L canisters.
	Phase C	Aug 90	Spiked 6-L canisters.

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SECTION 6. CONCLUSIONS

6.1. Background

6.1.1. BangBox

The BB conclusions are stated in the BB report, Volume 1.

6.1.2. Field Test Phase A

6.1.2.1. Purpose

Field Test Phase A was designed as a program ORI.

6.1.2.2. Objectives

6.1.2.2.1 Objective 1 - Evaluate the performance of the instrumented FWAC as a sampling platform during large-scale field OB/OD tests.

a. The FWAC proved to be a suitable sampling platform. The aircraft's design enabled the aircraft to enter and sample the plume within approximately 1 min after the detonation, and make repeated penetrations of the plume. The sampling passes made through the cloud permitted real-time analyses of some gases and captured sufficient quantities of gases and particulates for subsequent analyses.

b. Additionally the instruments and procedures used on the FWAC were judged suitable for subsequent testing.

6.1.2.2.2 Objective 2 - Determine if target species can be adequately sampled and measured above background levels.

a. Carbon dioxide and other target species were adequately sampled and measured above background levels using real-time instruments aboard the FWAC.

b. The VOC's were successfully measured above background levels with the 6-L canister sampler. Carbon dioxide and CO were also successfully measured above background with the 6-L canister.

c. The quartz fiber filters collected sufficient particulate for the detection and quantification. of SVOC's.

6.1.2.2.3 Objective 3 - Evaluate the utility of the carbon balance method in the field testing environment.

The utility of the carbon balance method was confirmed. The FWAC ability to enter the plume and measure CO_2 well above background supports the carbon balance method applicability to field testing.

6.1.2.2.4 Objective 4 - Evaluate soil sampling, handling, and assay procedures (e.g. SFC/MS) for field OB/OD tests.

Soil sampling, handling, and assay procedures were proven suitable for capturing and analyzing emittant products released into the soil during field testing.

6.1.3. Field Test Phase B

6.1.3.1. Purpose

Confirm suitability of instruments and procedures developed in Phase A, and determine if relationship exists between BB test data and field test data.

6.1.3.2. Objectives

6.1.3.2.1 Objective 1 - Sample and analyze the combustion products of large-scale OB/OD operations which were conducted in a manner representing treatment site practices.

The combustion products of large-scale OB/OD operations were successfully sampled and analyzed. However, the test could not accommodate evaluation of emission product accumulation at a single site resulting from repeated detonations.

6.1.3.2.2 Objective 2 - Sample and analyze the combustion products produced by large-scale OB/OD operations which were conducted from suspended detonations.

Large-scale OD suspended detonations were successfully conducted, and the resulting clouds sampled and analyzed. While emission products were essentially the same as for non-suspended surface detonations, a more efficient conversion of the explosive carbon into CO_2 and decreased levels of the other carbon compounds were detected.

6.1.3.2.3 Objective 3 - Determine if the field test detonation data can be related to the BB test detonation data.

The initial comparison between the BB and field test data reveals that a relationship between BB and field test data can be established. The pattern that emerges is: (1) small-scale detonations in the BB test produced a more efficient conversion of TNT carbon to CO_2 than did large-scale detonations in the field; (2) the VOC levels experienced during large-scale field testing were higher than those experienced during BB testing; and (3) the semivolatile organic compounds detected and quantified were very similar.

6.1.3.2.4 Objective 4 - Provide the foundation for establishing a database on TNT and selected propellant combustion products.

The initial combustion product database for bulk TNT and selected propellant manufacturing residues was established. A list of analytes and their concentration per mass for air emissions, soil, and residue has been established.

6.1.4. Field Test Phase C

6.1.4.1. Purpose

Supplement the basic TNT and propellant data, and expand the database to include additional explosives and propellants.

6.1.4.2. Objectives

6.1.4.2.1 Objective 1 - Conduct additional TNT detonations to facilitate relating BB test results to field test results.

The additional successful TNT OD conducted during phase C added to the database of air EF's from field test phases A and B. The conclusions are discussed in paragraph 6.1.4.2.3.

6.1.4.2.2 Objective 2 - Conduct additional TNT tests to establish the reproducibility (between test precision) of TNT OD emissions.

The surface TNT tests phases A, B, and C were very reproducible, e.g., EF's for CO_2 varied from 1.26 to 1.29, CO varied from 42×10^{-3} to 61×10^{-3}, and methane varied from 1.2×10^{-3} to 1.5×10^{-3}. Section 4 contains specific results for all the compounds targeted in the OB/OD testing.

6.1.4.2.3 Objectives 3-7 - Sample and analyze the explosive and burning decomposition products of composition B, explosive D, RDX, M1 and M6 propellants, and additional propellant manufacturing residues.

a. The explosives tested during phase C produced results (emissions and levels) very similar to those results obtained for TNT tested in phases A and B. The small-scale BB test showed more efficient conversion of TNT carbon to CO_2 than found during field testing; (2) the VOC levels increased in the large-scale field test, and the semivolatile organic compounds detected and quantified during all tests were very similar.

b. The soil data from phases B and C were very similar (overlapping ranges of the concentration values), therefore all the analysis were performed on the total data package of phases B and C. Phase A was not considered because it was an ORI.

c. The propellant data was very efficient in conversion of carbon to CO_2, however the residue in the pan after burning was tested and showed the presence of 2,4-DNT, which is one of the parent compounds in the M1 and M6 propellants.

d. This phase of the study did not include analysis for metals and non-metals (elementals).

6.2. General Overall Test Program

6.2.1. Purpose

Supply waste characterization data for OB/OD permit applications under RCRA subpart X.

6.2.2. Objectives and Responses

6.2.2.1. Objective 1 - Identify and validate sampling and analytical technology, instrumentation, and procedures needed to provide RCRA subpart X data characterization.

6.2.2.1.1 The results of this phase of the OB/OD thermal-treatment emission study authenticate the innovative technologies and methodologies selected for identifying and characterizing emission products.

6.2.2.1.2 The comparable TNT data from the BB and field tests indicates that the time and costs of characterizing emissions from specific PEP materials in the inventory can be significantly reduced by using properly designed BangBox-like chambers.

6.2.2.1.3 If the comparable results, established during this test remains consistent during further BB testing, the techniques and methods developed will assist in the identification of PEP materials for which OB/OD thermal treatment methods is not applicable and for which alternative

technologies must be developed. With this knowledge, the development of alternative technologies can be focused and more cost-effective.

6.2.2.2. Objective 2 - Identify and quantify emissions and residues produced by OB/OD thermal treatment methods.

6.2.2.2.1 Identification and quantification of emission products and residues produced by OB/OD methods was accomplished for those items tested and the amount of pollutants released into the atmosphere and soil were considered inconsequential. This data was used to authenticate methodology and technology used during this phase of the study.

6.2.2.2.2 This objective will be completed during the next phase of the overall program when item- and site-specific testing will be undertaken.

6.2.2.3. Objective 3 - Provide input for development and validation of an OB/OD dispersion model.

6.2.2.3.1 An OB/OD dispersion model was developed during this phase of the study. The model will require field validation before being made available.

6.2.2.3.2 A dispersion model acceptable to EPA is an essential adjunct to the BB emission characterization data in that it provides the mechanism to generate the downwind concentration receptor locations as inputs required for support of site-specific permit applications.

6.2.2.3.3 The data obtained from sample analysis, as applied to the DPG-RTVSM model, indicates exceptionally low downwind peak and average concentrations for all pollutant categories following downwind dispersion of the detonation cloud.

6.2.2.4. Objective 4 - Identify specific items that can be treated by OB/OD thermal treatment methods without adverse environmental impact.

6.2.2.4.1 The study suggests that the bulk explosives and propellants examined during field testing will produce and release acceptable levels of emittants to the environment by surface OB/OD methods. While these results are encouraging, site-specific testing is needed to provide data to support risk assessments. Only after these risk assessments are completed may a definitive statement be made concerning the effect (if any) OB/OD operations have on human health and the environment.

6.2.2.4.2 For many items, OB/OD thermal treatment operations may be an environmentally safe means of treatment, in addition to being cost-effective. If this proves true, OB/OD should be considered for use as an integral part of a balanced DoD total demilitarization/treatment program.

6.3. Air Emissions

6.3.1. Detonation/Combustion Efficiency

A high degree of carbon conversion to CO_2 occurred for all types of PEP materials examined in this test series.

6.3.1.1. Propellants

All tested propellants consistently showed carbon conversion efficiencies exceeding 99 percent.

This is primarily a result of two factors: (1) The oxygen balance of most of the propellant materials tested was relatively high, and the propellant molecule carried most of the oxygen required for complete combustion; (2) Propellant materials were in steel pans eliminating interaction with adjacent soil. The absence of soil in the flame zone resulted in high flame temperatures and facilitated complete combustion of carbon.

6.3.1.2. Explosives

Carbon conversion efficiencies for the bulk explosive materials tested were lower than those observed for propellants, but were still in excess of 92 percent for all explosive types and configurations tested.

6.3.1.2.1 This observation applies to TNT which has a very low (-73.9 percent) oxygen balance and represents a worst case explosive from the perspective of pollutant emissions.

6.3.1.2.2 The carbon conversion efficiencies in excess of 92 percent found for low oxygen-balance surface-detonated TNT reveals that a mechanism of secondary combustion is in effect during these detonations.

a. Entrainment of ambient oxygen into the fireball region following detonation of the explosive accounts for this secondary combustion of intermediate detonation products to CO_2.

b. Suspended detonations of TNT (for which soils is a relative unimportant consideration) produced higher carbon conversion efficiencies. This suggest the presence of soil in the immediate vicinity of the detonation (typical of surface detonations), restricts the flow of ambient air into the fireball region.

6.3.1.2.3 The carbon conversion efficiencies for other bulk-explosive types examined in this series (i.e., RDX, explosive D, composition B) show that carbon conversion efficiencies are approximately the same as for TNT, even though all of the explosives tested have higher oxygen balances than TNT.

6.3.1.2.4 The data indicates that while the oxygen balance of the explosive molecule is important, it is not the only parameter determining the degree of efficiency of the detonation.

6.3.1.2.5 All explosives have the capability to produce high-carbon-efficiency detonations if sufficient ambient oxygen is entrained following formation of the fireball.

6.3.1.2.6 The configuration of the detonation (surface vs. suspended) appears also to be an important parameter in determination of the carbon conversion efficiency.

6.3.2. Carbon Distribution

6.3.2.1. Carbon not converted to CO_2 is found in other species produced by the combustion such as carbon monoxide, methane, nonmethane hydrocarbons, organic carbon particulate and elemental carbon particulate.

6.3.2.2. In general, each of these categories, with the exception of CO_2 and CO, receives between 0.1 and 1 percent of the total original carbon.

6.3.2.3. The amount of CO formed ranged from 0.5 percent for suspended detonations to 5 percent for surface detonations.

6.3.2.4. Distribution of carbon within the nonmethane hydrocarbon category reveals a relatively high distribution of the carbon to the light, non toxic, nonmethane hydrocarbons, such as ethane, propane, acetylene, etc.

6.3.2.4.1 There is little experimental evidence to suggest that any significant portion of the source carbon goes to the heavier aromatic volatiles, such as benzene and toluene.

6.3.2.5. The elemental carbon (soot) and the organic particulate carbon categories each typically receive on the order of 0.1 to 1 percent of the carbon.

6.3.2.5.1 The amount of particulate organic carbon from soil debris in the cloud and that produced by the detonations could not be separated.

6.3.2.6. Analysis of the particulate organic material collected in these detonation and propellant cloud samples reveals that a considerable fraction is due to the environmentally ubiquitous phthalates, which were also found in the background samples.

6.3.3. Scaling Issues

6.3.3.1. The degree to which the size of the detonation affects relative distribution of pollutants released from the detonation is an important part of this study.

6.3.3.1.1 A comparison of emission factors for the various pollutant species examined in the BangBox and in the field tests shows that emission factors for potentially toxic emissions are relatively constant, despite a near 4,000-fold increase in the scale of the detonation.

6.3.3.1.2 Light gases such as CO and methane show the greatest variation in EF with changes in size of the detonation.

6.3.3.1.3 The other pollutant categories such as NO_x, VOC, and semivolatile categories show less pronounced changes in EF with changes in size of the detonation.

6.3.3.2. These results strongly indicate that BB-type testing can be successfully used to assess pollutant emissions from various explosive types and configurations.

6.3.3.3. Use of such testing will significantly reduce both the time and costs required for emission characterization of PEP materials in the DoD inventory.

6.3.4. Source Pollutant Dispersion Modeling

6.3.4.1. Results of the DPG real-time volume source dispersion model (RTVSM) for estimating ground-level concentrations of analytes from a 1-metric-ton (1000-kg) surface detonation show exceptionally low downwind peak and average concentrations for all pollutant categories following downwind dispersion of the detonation cloud.

6.3.4.2. Surface-detonation TNT events which were conducted to obtain typical EF such as CO (EF = 5×10^{-2}), benzene (EF = 1×10^{-4}) and benzo[a]pyrene (EF = 0.1×10^{-6}) reveal that ground level peak and 15-min average concentrations would be indistinguishable from background levels of these various pollutants.

6.4. Soil Deposition of OB/OD Emissions

6.4.1. OD Emissions

6.4.1.1. Total amounts of emission products for semivolatile organics can also be quantified from the mass of disturbed soil (estimated from the crater dimensions) and the concentration of analytes in the soil. For example, this method shows that 3.7 g of 2,4-dinitrotoluene will be produced and released to the soil following a 907-kg TNT detonation.

6.4.1.2. Emission products of semivolatile organics can be identified and quantified from the fallout soil at specific distances from the explosive source. This method shows that 76 mg (2 percent) of the total 3.7 g of 2,4-dinitrotoluene produced was recovered within 225 m of the detonation site.

6.4.1.3. The major portion of all the semivolatile organic particulate remains in the loose soil of the crater and ejecta area (the immediate vicinity of the crater). The loose soil is subjectively estimated to account for about 97 to 98 percent of all the semivolatiles produced.

6.4.2. OB Emissions

6.4.2.1. Open burning is very effective in volatilizing and burning the parent material. The small quantities of residue left are largely composed of char or elemental carbon.

6.4.2.2. The OB of M1 and M6 propellant resulted in a residue fraction of approximately 0.1 percent of the original mass of propellant. The 2,4-dinitrotoluene, which makes up 10 percent of the parent propellant, is reduced to 0.0025 and 0.013 percent of the residue for M1 and M6 respectively. An even greater reduction occurs in the fallout material, where the maximum 2,4-dinitrotoluene amount was 0.00009 and 0.0004 percent for M1 and M6 propellant respectively, indicating that carbon conversion is still occurring in the plume from the burning propellant.

6.4.2.3. Residue in the burn pan following the Phase C manufacturing residue burn was approximately 0.03 percent of the original mass. Using the maximum measured 2,4-dinitrotoluene

concentration of 24 ng/m^2 as representative of the terrain deposition from a 2-metric ton burn, results in a total deposition of 0.024 mg of 2,4-dinitrotoluene spread over 1000 m^2.

6.4.2.4. The OB of M30 triple base propellant burned during Phase A trials was composed of 28.0 percent nitrocellulose, 22.5 percent nitroglycerin, and 47.7 percent nitroguanidine, respectively, by weight of the parent propellant. After burning, nitroglycerin and nitroguanidine were detected and represents 0.00007 and 0.00008 percent of the residue respectively. These low residue fractions show near complete combustion of the propellant.

SECTION 7. RECOMMENDATIONS

7.1. Multiple Continuous Detonations

Conduct OD tests to determine the environmental impact to the crater area and surrounding fallout area resulting from continuous detonations at a single detonation point. This type detonation procedure is typical of those used during many treatment operations. Data on emission product accumulation in the soil is essential for evaluation of potential short- and long-term contamination. This includes subjecting the soils to Toxicity Characteristic Leaching Procedures (TCLP) to obtain critical data for the site specific characterization studies.

7.2. Buried Detonations

Conduct open detonations tests to determine the environmental impact to the air and terrain resulting from conducting buried OD. Because some treatment operations are conducted in areas which mandate that all detonations are to be buried detonations, this type of test data will be necessary to support permitting. Results of buried detonation tests will also be compared with those of surface detonation tests for an evaluation of these two methods of treatment.

7.3. Soil Extraction and Analysis

Evaluate other types of extraction and analysis programs (e.g. HPLC) in addition to refinement of GC/MS and SFC/MS, to permit rapid analysis of a large number of samples.

7.4. BangBox Design and Construction

7.4.1. Design and construct a BB to handle all typical explosive ordnance configurations (e.g. shells, mines, bombs), with a soil component using concepts and needs that have been established by the current phase of the OB/OD study. This facility will provide the means of developing a comprehensive database for selected families of PEP items.

7.4.2. Conduct OB and OD studies of those propellants and explosives used in field test phase C. The recommended testing will provide data for comparison to the large scale field tests and is necessary to establish that small scale tests will characterize emission products and confirm that large scale field tests are not necessary. The relationship between BB and field testing has been proven for TNT, but must also be established for other explosives before a generic statement can be made.

7.5. Models

7.5.1. Provide the empirical data from BB and field tests, to designated DoD personnel so that they may both verify and/or improve on existing thermodynamic equilibrium models and develop new models.

7.5.2. Complete the development and validation of the OB/OD Dispersion Model. This model is required to determine the downwind dose at receptor locations for use in risk analysis.

7.6. Technical Steering Committee

Retain the technical steering committee in its present composition to provide technical guidance on future testing. The aggregate knowledge of munitions testing (including sampling and analyses) and interpretation that is collectively possessed by the TSC, with its membership consisting of DoD, EPA, academia, USATHAMA, USAEHA, USAMC Environmental Office, and contractors, will continue to provide an invaluable interface between government agencies, academia, and industrial communities.

7.7. International Cooperation

Expand upon existing relationships between the OB/OD study program and friendly foreign government agencies investigating environmental consequences of OB/OD operations. The German Ministry of Defense has recommended that we continue these relationships, and has also requested a copy of the current OB/OD report. Contacts established with foreign agencies through

official channels offer considerable potential for expanding the U.S. database on PEP combustion products and enhancement of our technology.

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APPENDIX A - FILTER SYSTEM FLOW MEASUREMENTS

Accurate determination of particle concentration requires an accurate measurement of the volume of air sampled. Because of the varying air densities encountered during OB/OD tests, clearly defined standard reporting conditions must be established and the methods for converting from actual to standard conditions must be understood. All air volumes reported in this study are based on continuously measured flow rates and sampling durations.

The flow rate on the centerline of the transport tube was continuously monitored with a Pitot tube. As noted in the previous section, the flow in the tube is highly turbulent (Reynolds number greater than 50,000), and it is reasonable to assume that the average linear velocity down the tube and the centerline velocity are the same. The basic relationship between the velocity and the velocity pressure measured with the Pitot tube is given in equation A.1 below.

Equation A.1 Pitot Tube Velocity and Pressure.

$$V = 1096 \left(\frac{VP}{0.075 \cdot F} \right)^{0.5}$$

where V is the actual velocity in feet per minute and VP is the velocity pressure in inches of water. The 1096 term is a factor derived from the Bernoulli equation using the acceleration due to gravity, the relative densities of the manometer fluid (water) and air , and units of measurement conversions. The 0.075 term represents the density of air at standard conditions in pounds per cubic foot and F is a density correction factor to allow for differences between actual and standard conditions as given by equation A.2 below.

Equation A.2 Density Correction Factor.

$$F = \left(\frac{Press_{ambient}(mmHg)}{760} \right) \left(\frac{298}{273.1 - Temp_{ambient}(^{\circ}C)} \right)$$

Air velocity through the probe and transport tube is sufficiently fast enough that there is little change in air temperature at the Pitot tube from that measured outside the aircraft. Consequently, the externally measured ambient temperature is used for all density-correction calculations. Similarly, the static pressure regain in the transport tube is too small (a few cm of water) to significantly alter the ambient pressure from that measured by the pressure altitude sensor; therefore, the externally measured ambient pressure is used in the calculations as well. The tube velocity at ambient conditions, the density correction factor, and the tube cross-sectional area (71.26 cm^2) are multiplied together to obtain the volumetric flow rate at standard conditions. After combining all the factors and the conversion factors between different systems of units, the final equation is given by equation A.3 below.

Equation A.3 Volumetric Flow rate.

$$Q = 90.71\left(VP \cdot \frac{PRESS_{amb}\ (mmHg)}{273.1 + TEMP_{amb}(^{\circ}C)}\right)^{0.5}$$

where Q is the volumetric flow rate through all three filters in standard liters per second. Typical flow rates encountered with three quartz filters under normal (50 m s^{-1}) flight velocity is about 100 L s^{-1}. The factor 90.71 is a composite of the Bernoulli equation constant (1096), the cross-sectional area of the transport tube, and units of measurement conversions.

APPENDIX B - SOIL AND FALLOUT SEMIVOLATILE ORGANIC DATA

This appendix contains an example of the soil and fallout data that are on file for the OB/OD Phases A, B, and C tests. One page of the data are given in Table B.1, taken from the Phase B soil sampling and fallout data. The data sheet includes a brief description of the source of the sample, a QA custody number (which permits tracking of the sample), the sample size (in grams) on which the laboratory assay was based, and the actual laboratory results (ng/sample). These inputs were used to compute the concentrations in $\mu g/kg$ (equivalent to ppb) and ng/m^2. In computing the concentration per square meter (ng/m^2) the total weight of sample collected and the number of square meters sampled were used. The weights shown for background, ejecta, and core samples were corrected for moisture content.

All computations were accomplished in Lotus 123®, version 2.2. The complete set of data may be requested from AMCCOM.

Table B.1 OB/OD Phase B Soil Sample Data.

Sample Source	QA Custody Number	Sample Size (g)	Compound												
			2,4-DNT	2,6-DNT	2,4,6-TNT	2-NN	N-NSDPA	1,3,5-TNB	2-NDPA	1-NP	Naph	B[a]A	B[a]P	Pyrene	Phenol	DBF
TNT-Trial-1-Ejecta																
Site 2 Outside 1m	02873	402.1														
ng/sample			3200	BD*	39000	BD	27	6500	BD	BD	1200	BD	BD	150	BD	140
µg/kg			7.96	BD	97.0	BD	0.0671	16.2	BD	BD	2.98	BD	BD	0.373	BD	0.348
TNT-Trial-1-Ejecta																
Site 2 Outside 4m	02874	280.7														
ng/sample			BD	BD	3500	BD	BD	BD	BD	BD	58000	3000	BD	15000	BD	5100
µg/kg			BD	BD	12.47	BD	BD	BD	BD	BD	206.7	10.68	BD	53.4	BD	18.2
TNT-Trial-1-Ejecta																
Site 6	02945	897.5														
ng/sample			2000	70	320000	18	1000	35000	BD	BD	15000	500	BD	1100	BD	200
µg/kg			2.23	0.08	357	0.02	1.11	38.9	BD	BD	16.7	0.557	BD	1.23	BD	0.222
TNT-Trial-1-Fallout																
Site 2-50m Composite	02897	202														
ng/sample			6500	440	9100	BD	14	31	BD	BD	15000	1300	BD	7300	BD	120
µg/kg			32.2	2.18	45.1	BD	0.0694	0.154	BD	BD	74.4	6.44	BD	36.2	BD	0.595
ng/m^2			376	254	5259	BD	8.09	17.9	BD	BD	8669	751	BD	4219	BD	69.4
TNT-Trial-1-Fallout																
Sit 2-100m Composite	02898	14.1														
ng/sample			110	BD	2200	BD	BD	BD	BD	BD	3100	720	BD	41	BD	410
µg/kg			7.80	BD	156	BD	BD	BD	BD	BD	219	51.1	BD	2.91	BD	29.1
ng/m^2			72.8	BD	1455	BD	BD	BD	BD	BD	2050	476	BD	27.1	BD	271

*Below detection.

APPENDIX C - GAS SAMPLE DATA REDUCTION PROCEDURES

Introduction

The Twin Otter aircraft is used in conjunction with OB/OD tests to collect gas and particle samples from detonation or combustion clouds of various explosives and propellants. The gas sampling instruments are set up to collect and analyze gases from the aircraft air sampling tube by means of (1) direct air sampling from the tube and (2) an 80-L sampling bag that can be filled from the sampling tube during penetration of the smoke plume. Normally the gas bag is filled during several consecutive passes through the plume.

A data acquisition system (DAS) is used to acquire analog voltage signals from the gas sampling instrumentation in real-time. The gases sampled are Carbon Dioxide (TECO Model 41H); Carbon Monoxide (TECO Model 48); Oxides of Nitrogen (TECO Model 42); and Ozone (TECO Model 49). Carbon Dioxide voltages are measured at two outputs that yield an offset voltage reading (350 ppm/w background substraction) and a direct reading voltage. Measuring both voltages allows for a measurement range that covers the range of 0 to 800 ppm CO_2. The data is stored on a "hard" disk, allowing retrieval of the raw data files and further processing, using Lotus® spreadsheets.

Each test event includes a sampling flight, a background flight and periodic span and zero checks on all instruments. Prior to each flight, zero and span data are gathered on the ground to assure proper instrument operation.

In-flight gas measurements are made from the tube until a plume pass is begun, whereupon a valve is switched to fill the teflon bag. After three passes are completed, the gases are drawn from the bag and analyzed by the various gas instruments. During analysis of the bag sample, a voltage signal to the DAS is switched "on" to mark the beginning of the measurement period and "off" to mark the end of the period. As a result, a mark is recorded in the data file to show when the instruments were sampling from the bag. At the conclusion of the sampling flight, the zeros and spans are again measured to check and allow for correction of instrument drift.

Raw Data Files

The raw data file contains all voltage outputs from the gas instruments, along with sample time and the tube/bag valve position. Zero and span average and standard-deviation values are calculated for each gas from the appropriate sampling times as recorded in the operator's notebook. A data quality check on the raw data from each instrument is carried out by graphing the voltage data as a function of time. Examination of these plots reveals when a stable reading from the bag is obtained. The graphs typically show a plateau region indicating when each instrument has stabilized on the gas concentration in the bag. The average and standard deviation values for the bag are calculated from this region. An example of the raw voltage and time data, along with the associated average voltage from the plateau region is given for the September 6, 1990 M-1 propellant burn test in Table C-1. The zero and span data are handled in a similar file not shown here for brevity.

Background Correction

Background flights are conducted to determine background readings for each gas of interest in the ambient atmosphere. Background flights are flown in the same general vicinity as the sample flights and generally on the same day. Background flights are similar to sample flights, in that zero and span data are taken before and after each flight. However, during the flight, background gas data from both the tube and the bag are taken.

Raw Gas Data Summary File

The data from the raw data file (Table C-1) are collected into one file, showing zero, span, sample, and background voltages for each gas. An example of this file for the September 6, 1990 M-1 propellant burn test is shown in Table C-2.

Gas Concentration Data File

Voltages for each gas were collected into a final spreadsheet, where the bag gas concentrations is calculated using an instrument response factor, M, by the following formula:

Equation C.1 Bag Gas Concentration Calculation.

$$M = \frac{S}{\frac{V_{si} + V_{sf}}{2} - \frac{V_{zi} + V_{zf}}{2}}$$

where

M = instrument response factor (ppm/volt)

S = span gas value (ppmv)

V_{si} = initial span reading (volt)

V_{sf} = final span reading (volt)

V_{zi} = initial zero reading (volt)

V_{zf} = final zero reading (volt).

The final bag gas concentration is calculated from the measured sample and zero-voltage averages and the response factor, M, as given by the following expression:

Equation C.2 Final Bag Gas Concentration Calculation.

$$C = (V_{samp} - \frac{V_{zi} + V_{zf}}{2}) * M$$

where C is the bag concentration in ppm, V_{samp} is the average sample voltage from the bag, and V_{zi} and V_{zf} are as defined above.

The instrument response factor, M, is calculated on a daily basis for each instrument and was entered into a final spreadsheet file, which is used to convert the voltage signal from the instrument to engineering units of parts per million (ppmv). An example of this file is given in Table C-3 for the September 6, 1990 M-1 propellant burn. All daily calibration data, including the span gas cylinder values in ppmv (column 2), the bag sample voltage (column 3) the initial and final zero voltage for each gas, columns 4 and 5, and the initial and final span voltages (columns 6 and 7) are included in the file. The initial and final zero and span voltages are averaged (columns 8 and 9) and are used to calculate an instrument response factor M, (column 10). The response factor is

multiplied by the difference between the average sample voltage (column 3) and the average zero voltage (column 8) to yield the gas concentration in ppmv (column 11). An example of this file is given in Table C-3. The final column in this table shows the gas concentration in units of ppm for each sample collected.

Finally, the background-corrected gas concentration used in all emission factor calculations is determined by subtracting the sample value from the background value for each gas of interest.

Table C-1 Example of Voltage Data from Gas Instruments During Sampling from Bag Filled During M-1 Propellant Burn, Mon, 6 Sep 90.

Time HH:MM:SS	Valve Position 0 = Tube 2 = Bag	CO_2 Real volts	CO_2 Shift volts	CO volts	NO volts	NO_2 volts	NO_x volts	Ozone volts
12:31:50	2.000	4.990	2.661	0.347	1.025	1.792	1.470	-0.005
12:31:55	2.000	4.985	2.666	0.522	1.030	1.797	1.489	-0.005
12:32:00	2.000	4.990	2.729	0.527	1.846	-0.127	1.763	-0.005
12:32:05	2.000	4.985	2.710	0.542	1.831	-0.107	1.777	0.000
12:32:10	2.000	4.985	2.686	0.542	1.904	0.586	2.046	0.000
For brevity, the entire data collection period is not shown								
12:35:10	2.000	5.029	2.720	0.288	1.978	0.488	2.095	0.000
12:35:15	2.000	5.020	2.710	0.337	1.978	0.449	2.114	-0.010
12:35:20	2.000	4.990	2.700	0.044	1.973	0.439	2.085	-0.005
12:35:25	2.000	4.980	2.715	0.078	1.968	0.435	2.085	0.000
12:35:30	2.000	5.010	2.715	0.225	1.968	0.444	2.085	-0.010
	Average	4.995	2.712	0.087	1.974	0.450	2.093	-0.005
	Stand Dev	0.011	0.019	0.214	0.019	0.037	0.016	0.004

Table C-2a *Summary Instrument Voltage Data From All Calibrations, Test Flights, and Background Flights Conducted on 6 Sep 90.*

		CO_2 REAL volts	CO_2 SHIFT volts	CO volts	NO volts	NO_2 volts	NO_x volts	O_3 volts
September 06, 1990 Pre-test zero and span summary data								
ZERO	AVG	-0.005		0.006	-0.005	-0.003	-0.006	-0.006
	STD	0.002		0.017	0.002	0.004	0.003	
SPAN CO_2 Lo, NO_x	AVG	3.347	0.349	NA[a]	2.727	1.930	3.216	NA
	STD	0.015	0.015	NA	0.004	0.023	0.005	NA
SPAN CO_2 Hi, CO, O_3	AVG	4.400	1.402	3.971	NA	NA	NA	0.397
	STD	0.023	0.022	0.044	NA	NA	NA	0.004
September 06 M-1 PROPELLANT BURN #1 Bag Sample Summary Data								
12.303-12.336	AVG	4.989	2.274	0.118	1.441	0.454	1.560	-0.002
	STD	0.009	0.035	0.208	0.015	0.024	0.014	0.006
September 06 M-1 PROPELLANT BURN #2 Bag Sample Summary Data								
12.536-12.592	AVG	4.995	2.712	0.087	1.974	0.450	2.093	-0.005
	STD	0.011	0.019	0.214	0.019	0.037	0.016	0.004
September 06 M-1 PROPELLANT BURN #3 Bag Sample Summary Data								
12.742-12.821	AVG	4.963	2.121	0.071	1.377	0.445	1.488	-0.005
	STD	0.079	0.031	0.218	0.016	0.021	0.013	0.004

[a]NA - Only one level of span gas used in calibration for CO, NO_xs, and O_3.

Table C-26 Summary Instrument Voltage Data from All Calibrations, Test Flights, and Background Flights Conducted on 6 Sep 90.

		CO_2 REAL volts	CO_2 SHIFT volts	CO volts	NO volts	NO_2 volts	NO_x volts	O_3 volts
September 06, 1990 Post-test zero and span data								
ZERO	AVG	-0.020		0.019	-0.007	-0.013	-0.013	-0.006
	STD	0.007		0.016	0.011	0.007	0.009	0.005
SPAN CO_2Lo, NO_x	AVG	3.435	0.436	NA[a]	2.766	1.890	3.242	NA
	STD	0.019	0.021	NA	0.010	0.035	0.012	NA
SPAN CO_2Hi, CO, O_3	AVG	4.542	1.545	3.951	NA	NA	NA	0.399
	STD	0.019	0.018	0.034	NA	NA	NA	0.024
September 06, 1990 Background flight summary data4								
BKG. TUBE	AVG	3.395	0.397	0.198	-0.007	-0.005	-0.007	0.045
	STD	0.013	0.013	0.273	0.010	0.009	0.008	0.007
BKG. BAG	AVG	3.402	0.403	0.542	-0.004	0.001	-0.010	0.025
	STD	0.036	0.035	0.928	0.013	0.008	0.008	0.008
September 06, 1990 Post-background flight zero and span summary data								
ZERO	AVG	-0.020		0.048	-0.007	-0.019	-0.012	-0.006
	STD	0.007		0.019	0.009	0.011	0.009	0.005
SPAN CO_2Lo, NO_x	AVG	3.348	0.348	NA	2.782	1.845	3.241	NA
	STD	0.011	0.010	NA	0.011	0.013	0.013	NA
SPAN CO_2Hi, CO, O_3	AVG	4.390	1.389	3.956	NA	NA	NA	0.394
	STD	0.011	0.009	0.019	NA	NA	NA	0.006

[a]NA - Only one level of span gas used in calibration for CO, NO_xs, and O_3.

Table C-3a Summary Gas Instrument Data That Includes Zero, Span, and Sample Data For M-1 Propellant Burn on 6 Sep 90.

	GAS SPAN (ppm)	V_{sam}[a] (volts)	V_{zi}[b] (volts)	V_{zf}[c] (volts)	V_{si}[d] (volts)	V_{sf}[e] (volts)	V_{za}[f] (volts)	V_{sa}[g] (volts)	M	BAG CONC (ppm)
M-1 PROPELLANT BURN #1 9/6/90 THE CO2 SHIFTED VOLTAGE IS USED FOR THE CO2 VALUE BECAUSE THE ACTUAL VOLTAGE IS OFF-SCALE										
NO	1.098	1.441	-0.005	-0.007	2.727	2.766	-0.006	2.747	0.399	0.577
NO_x	1.383	1.560	-0.006	-0.013	3.216	3.242	-0.010	3.229	0.427	0.670
NO_2	0.280	0.454	-0.003	-0.013	1.930	1.890	-0.008	1.910	0.146	0.093
CO	7.900	0.118	0.006	0.019	3.971	3.951	0.013	3.961	2.001	0.211
CO_2 LOW	338.000	2.274	-0.005	-0.020	3.347	3.435	-0.013	3.391	103.704	546.933
CO_2 HIGH	450.000				4.400	4.542		4.471		
O_3	0.400	-0.002	-0.006	-0.006	0.397	0.399	-0.006	0.398	0.990	0.004
M-1 PROPELLANT BURN #2 9/6/90										
NO	1.098	1.974	-0.005	-0.007	2.727	2.766	-0.006	2.747	0.399	0.790
NO_x	1.383	2.093	-0.006	-0.013	3.216	3.242	-0.010	3.229	0.427	0.898
NO_2	0.280	0.450	-0.003	-0.013	1.930	1.890	-0.008	1.910	0.146	0.108
CO	7.900	0.087	0.006	0.019	3.971	3.951	0.013	3.961	2.001	0.149
CO_2 LOW	338.000	2.712	-0.005	-0.020	3.347	3.435	-0.013	3.391	103.704	592.356
CO_2 HIGH	450.000				4.400	4.542		4.471		
O_3	0.400	-0.005	-0.006	-0.006	0.397	0.399	-0.006	0.398	0.990	0.001

[a]Average sample voltage from the bag.
[b]Initial zero reading.
[c]Final zero reading.
[d]Initial span gas reading.
[e]Final span gas reading.
[f]Average of initial and final zero reading.
[g]Average of initial and final span gas reading.

Table C-3b Summary Gas Instrument Data That Includes Zero, Span, and Sample Data For M-1 Propellant Burn on 6 Sep 90.

	GAS SPAN (ppm)	V_{sam}[a] (volts)	V_{zi}[b] (volts)	V_{zf}[c] (volts)	V_{si}[d] (volts)	V_{sf}[e] (volts)	V_{za}[f] (volts)	V_{sa}[g] (volts)	M	BAG CONC (ppm)
M-1 PROPELLANT BURN #3 9/6/90										
NO	1.098	1.377	-0.005	-0.007	2.727	2.766	-0.006	2.747	0.399	0.552
NO_x	1.383	1.488	-0.006	-0.013	3.216	3.242	-0.010	3.229	0.427	0.640
NO_2	0.280	0.445	-0.003	-0.013	1.930	1.890	-0.008	1.910	0.146	0.088
CO	7.900	0.071	0.006	0.019	3.971	3.951	0.013	3.961	2.001	0.117
CO_2 LOW	338.000	2.121	-0.005	-0.020	3.347	3.435	-0.013	3.391	103.704	531.067
CO_2 HIGH	450.000				4.400	4.542		4.471		
O_3	0.400	-0.005	-0.006	-0.006	0.397	0.399	-0.006	0.398	0.990	0.001
BACKGROUND FLIGHT 9/6/90 BAG SAMPLE										
NO	1.098	-0.004	-0.007	-0.007	2.766	2.782	-0.007	2.774	0.395	0.001
NO_x	1.383	-0.010	-0.013	-0.012	3.242	3.241	-0.013	3.242	0.425	0.001
NO_2	0.280	0.001	-0.013	-0.019	1.890	1.845	-0.016	1.868	0.149	0.000
CO	7.900	0.542	0.019	0.048	3.951	3.956	0.034	3.954	2.015	1.025
CO_2 LOW	338.000	3.402	-0.020	-0.020	3.435	3.348	-0.020	3.392	104.235	354.606
CO_2 HIGH	450.000				4.542	4.390		4.466		
O_3	0.400	0.025	-0.006	-0.006	0.399	0.394	-0.006	0.397	0.994	0.031

[a]Average sample voltage from the bag.
[b]Initial zero reading.
[c]Final zero reading.
[d]Initial span gas reading.
[e]Final span gas reading.
[f]Average of initial and final zero reading.
[g]Average of initial and final span gas reading.

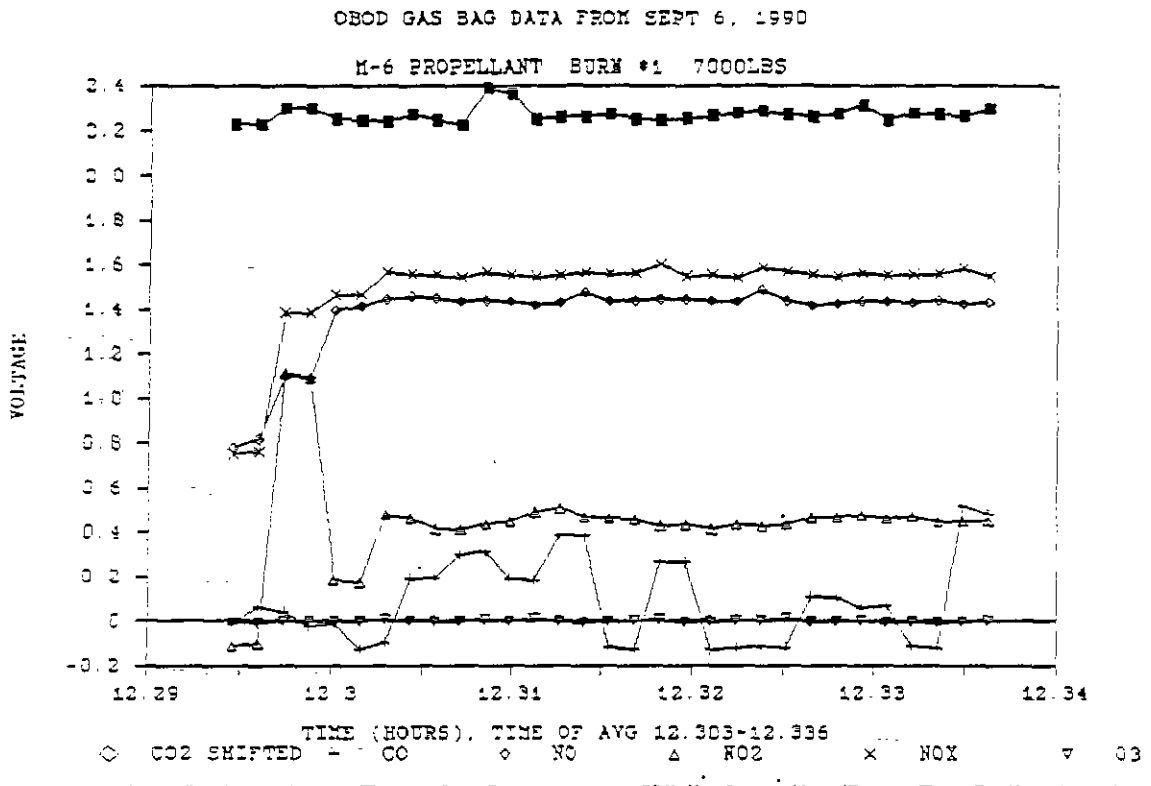


Figure C-1 Raw Voltage Data From Gas Instruments While Sampling From Bag Following The First M-1 Propellant Test.

▪ valve open position voltage

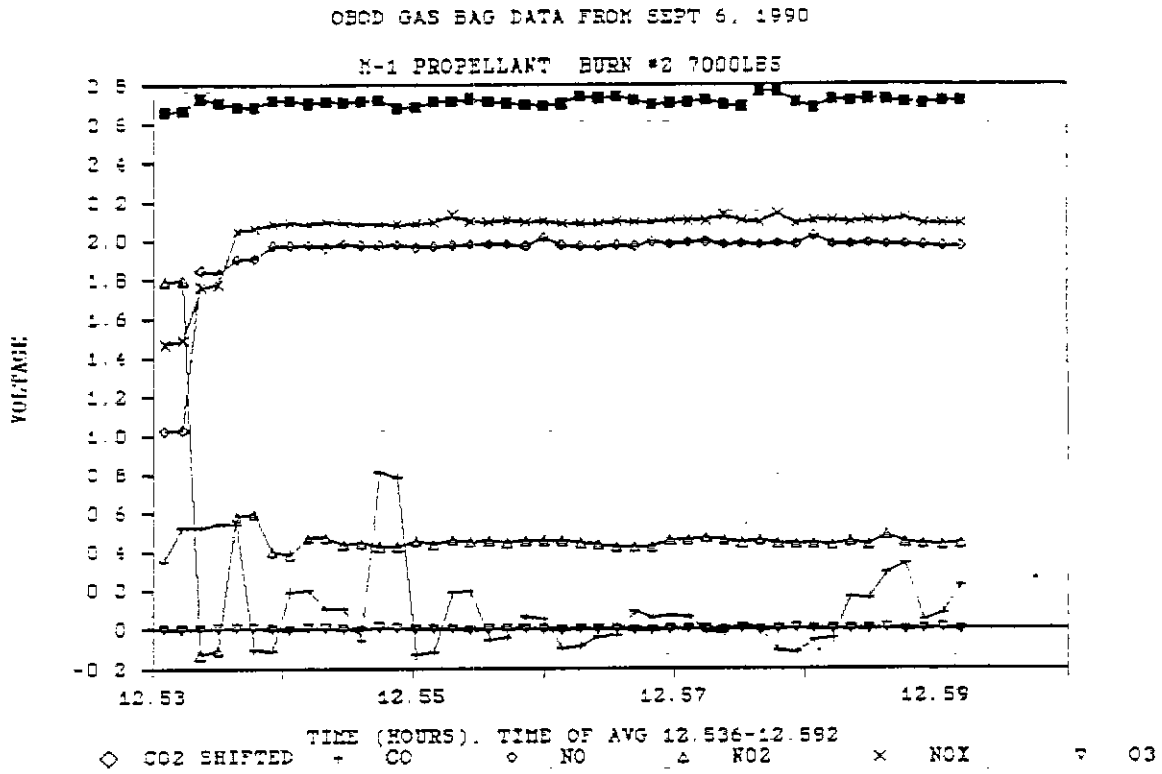


Figure C-2 Raw Voltage Data From Gas Instrument While Sampling From Bag Following Second M-1 Propellant Burn.

■ valve open position voltage

APPENDIX D - PARTICULATE MATTER DATA REDUCTION

Particulate matter data is handled in conjunction with other data to calculate average cloud particulate matter concentrations, and in the special case of propellant burns, a particulate matter emission factor. The calculation begins with the weight gain on each of the three filters used to collect the particulate sample. The weight gain is determined from a weighing of the filter prior to sampling and after sampling. Control filters are weighed along with sample filters to correct for differences in filter weight that are attributable to filter handling or storage conditions. For example, in the Phase C test, the data is contained in a worksheet named PHZCWGT.WK1 shown excerpted in Table D-1. Also included in this spreadsheet for each filter sample is a measure of the total volume of air sampled through the filter during all aircraft passes through the plume as measured by a pitot tube installed on the centerline of the transport tube. The total volume is determined by a continuous measure of the linear air velocity (as calculated from velocity pressure) through the tube whenever the filter sample port was open. An average velocity, calculated over the entire filter sampling interval and corrected for atmospheric pressure changes and temperature, is multiplied by the cross sectional area of the tube to yield the total sampled volume of air at standard conditions (25 °C and 1 atmosphere).

The average background corrected particle mass concentration, C, in the cloud as measured over multiple aircraft passes through the cloud is given by:

$$C = \frac{M_s}{V_s} - \frac{M_b}{V_b}$$

where M_s and M_b is the total particulate mass measured on the sample and background filters, and V_s and V_b is the total air volume drawn through the filter for the sample and background sample.

In the case of the propellant burns, the particle emissions are assumed to originate from the combustion process only (no entrained soil).

Table D-1 Filter Weight and Volume Data.

Date	Test Description	Adjusted Total Mass (mg)	Total Sample Volume (m^3)	Mass Conc (mg m^{-3})
August 29	Background	3.9	226.15	0.017
August 29	M-6 Propellant #3	27.2	10.07	2.7
August 30	Background	3.1	214.48	0.014
August 30	M-6 Propellant #4	30.5	10.78	2.8
September 05	Background	2.9	223.28	0.013
September 05	M-1 Propellant #1	15.8	11.90	1.3
September 06	M-1 Propellant #2	24.6	9.58	2.6
September 06	Background	3.0	182.79	0.016
September 18	Background	7.0	193.33	0.036
September 18	Comp B #1 (3x)	2190.8	10.05	218.0
September 18	Comp B #2 (3x)	1649.7	8.66	190.5

Under these circumstances, a total particulate matter emission factor can be calculated by the following:

$$EF_{part} = \frac{C_{part}}{C_{tot}} * f_c$$

where EF_{part} is the particulate matter emission factor, C_{part} is the average cloud particulate matter concentration, C_{tot} is the background corrected total carbon content in the sampled volume, (Table D-2) and c_f is the carbon mass fraction in the original propellant material.

Table D-2 Total Background Corrected Carbon Content in Air Samples.

Date	Test Description	Background Corrected Total Carbon (mg C m^{-3})
August 29	M-6 Propellant	176.14
August 30	M-6 Propellant	142.02
September 05	M-1 Propellant	180.05
September 06	M-1 Propellant	176.83

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APPENDIX E - VOLATILE ORGANIC COMPOUND DATA-REDUCTION

Emission factors (EF) are calculated for volatile organic compounds (VOC) using sample analysis data provided by the Oregon Graduate Institute for Science and Technology for each of the 6-L canister samples collected during aircraft sampling of detonation or combustion clouds. The emission factors are determined using the carbon balance technique that is also employed for calculation of gas and semivolatile organic EF's. The VOC analysis procedure provides concentration levels for carbon monoxide, carbon dioxide, methane as well as most hydrocarbons in the C_2 through C_{10} range. Data are provided in tabular format for both background and test samples as shown in Tables E-1, a, b and c; and E-2 a, b, and c for an M-1 propellant test conducted on September 06, 1990 (Note: Although not shown on this particular table, CO_2 concentrations for the tube background sample and tube test sample were 348 and 670 ppm respectively. The CO_2 data is provided in another analysis report not included here for the sake of brevity.)

The EF calculation is begun by subtracting the background level of the VOC species of interest from the level determined in the test sample. This value multiplied by the carbon fraction in the original material and is then divided by the total carbon in the sample as represented by the background corrected CO and CO_2 concentration levels. Here, as in other cases, CO and CO_2 are presumed to account for over 99 percent of the total carbon released in the burn. Consequently, the small carbon contributions from methane and total non-methane hydrocarbons as well as the carbon appearing as soot are neglected for the sake of computational simplicity. Their omission results in, at worst, an error in the EF of $\pm$ 5 percent. In most instances it will be less than one percent. Emission factors were calculated for only several categories of VOC in order to consolidate the vast amount of information contained in each one of these VOC analysis sheets. Normally calculations were carried out for methane (CH_4), total non-methane hydrocarbons (TNMHC) and benzene. Benzene (as probably the most toxic compound on the list) was selected in order to have some indicator of a "toxic" VOC compound used as a general marker or indicator of overall VOC toxicity in the sample.

The expression used to calculate the EF for a particular species appearing among the products of detonation or burning, is given by the equation E.1.

Equation E.1 Emission Factor Calculation.

$$EF_x = \frac{(X_t - X_b) f_c}{([CO]_t - [CO]_b)\ 0.429 + ([CO_2]_t - [CO_2]_b)\ 0.273}$$

where

EF_x = emission factor for the species of interest

$[X_t]$ = species concentration in the test sample

$[X_b]$ = species concentration in the background sample

f_c = fraction of carbon in the original test (PEP) material (0.303 for M-1)

$[CO_2]_t$ = CO_2 concentration in the test sample

$[CO_2]_b$ = CO_2 concentration in the background sample

$[CO]_t$ = CO concentration in the test sample

$[CO]_b$ = CO concentration in the background sample

The factor 0.429 and 0.273, are the fractions of the gases, CO and CO_2, respectively which are carbon.

Note: All concentrations must be expressed in self-consistent units of whatever kind. In this report concentrations are expressed both in parts per million by volume (ppmV) and in micrograms per cubic meter of dry air at 25°C and 1 atmosphere assuming ideal gas behavior (an excellent assumption at the relatively low pressures involved.

Table E-1a Volatile Organic Compound Background Data for M-1 Propellant

Date 09/06/90 Location: OBOD		Can # SDA168 Tube Sample # 168	
CO 78, ppm $CH_4$1778 ppm	**$\mu g/m^3$**	**ppbv-c**	**Percent**
Total Identified Hydrocarbons	54.2	90.5	44.7
Alkanes (Parafins)	43.0	71.8	35.3
Alkenes (Olefins)		0.0	0.0
Aromatics	11.2	18.7	9.2
Terpenes		0.0	0.0
Total Unidentified Hydrocarbons	67.0	111.9	55.3
Total Nonmethane Hydrocarbons	121.2	202.4	100.0
Compounds	**$\mu g/m^3$**	**ppbv-c**	**ID code**
Ethane	0.2	0.3	1
Ethylene			2
Acetylene			3
Propane	1.7	2.8	4
Propene			5
i-butane	0.5	0.8	6
i-butene			7
1-butene			8
1,3-butadiene			8a
n-butane	0.5	0.8	9
trans-2-butene			10
2,2-dimethylpropane			11
cis-2-butene			12
3-methyl-1-butene			13
i-pentane			14
1-pentene			15
2-methyl-1-butene			16
n-pentane			17
Isoprene			18
trans-2-pentene			19
cis-2-pentene			20
2-methyl-2-butene			21
2,2-dimethylbutane	0.5	0.8	22

Table E-1b Volatile Organic Compound Background Data for M-1 Propellant.

Date 09/06/90 Location: OBOD		Can # SDA168 Tube Sample # 168	
Compound	**µg/m³**	**ppbv-c**	**ID Code**
Cyclopentene			23
4-methyl-1-pentene			24
Cyclopentane	0.5	0.8	25
2,3-dimethylbutane	0.6	1.0	26
cis-4-methyl-2-pentene			26a
2-methylpentane	3.4	5.7	27
3-methylpentane	1.8	3.0	28
2-methyl-1-pentene			29
1-hexane			30
n-hexane	4.8	8.0	31
trans-2-hexene			32
2-methyl-2-pentene			33
cis-2-hexene			35
alpha-thujene			T1
Camphene			T2
Sabinene			T3
Mercene			T4
beta-iterpinene			T4a
Sesquiterpine			T11
beta-terpinene			T5
Methylcyclopentene	1.9	3.2	36
2,4-dimethylpentane	0.3	0.5	37
Benzene	1.8	3.0	38
Cyclohexane	3.0	5.0	39
2-methylhexane	1.5	2.5	39a
2,3-dimethylhexane	0.4	0.7	40
3-methylhexane	1.9	3.2	41
n-heptane	2.3	3.8	43
methylcyclohexane	3.2	5.3	44
2,4-dimethylhexane			45
2,3,4-trimethylpentane			46

Table E-1c Volatile Organic Compound Background Data for M-1 Propellant.

Date 09/06/90 Location: OBOD		Can # SDA1168 Tube Sample # 168	
Compound	**µg/m³**	**ppbv-c**	**ID Code**
Toluene	3.1	5.2	47
2,3-dimethylhexane			48
2-methylheptane	0.5	0.8	49
3-ethylhexane	0.4	0.7	50
n-octane	1.1	1.8	51
Ethylcyclohexane			52
Ethylbenzene	0.8	1.3	53
m-xylene & p-xylene	**2.4**	**4.0**	**54**
Styrene	1.1	1.8	56
o-xylene	0.5	0.8	57
n-nonane	1.2	2.0	58
alpha-pinene			59
i-propylbenzene			60
n-propylbenzene			61
p-ethyltoulene	0.3	0.5	62
m-ethyltoluene	0.4	0.7	63
1,3,5-trimethylbenzene			64
o-ethyltoluene			65
beta-pinene			66
Methylstyrene			67a
1,2,4-trimethylbenzene	0.8	1.3	68
n-decane	1.4	2.3	69
1,2,3-trimethylbenzene			69a
1,3-diethylbenzene			69b
1,4-diethylbenzene			69c
alpha-terpinene			T6
2-carene			T7
beta-phellandrene			T8
gamma-terpinene			T9
d-limonene			70
Terpinene			T10

Table E-2a Volatile Organic Compound Test Data for M-1 Propellant.

Date 09/06/90 Location: OBOD		Can # SDA184 Tube Sample # 184	
CO 78, ppm CH4 1778 ppm	µg/m³	ppbv-c	Percent
Total Identified Hydrocarbons	16.8	28.1	31.5
Alkanes (Paraffins)	10.8	18.0	20.2
Alkenes (Olefins)	2.1	3.5	3.9
Aromatics	3.9	6.5	7.3
Terpenes		0.0	0.0
Total Unidentified Hydrocarbons	36.7	61.3	68.6
Total Nonmethane Hydrocarbons	53.5	89.3	100.1
Compounds	**µg/m³**	**ppbv-c**	**ID code**
Ethane	1.3	2.2	1
Ethylene			2
Acetylene			3
Propane	0.8	1.3	4
Propene			5
i-butane			6
i-butene	1.2	2.0	7
1-butene			8
1,3-butadiene			8a
n-butane	0.6	1.0	9
trans-2-butene			10
2,2-dimethylpropane			11
cis-2-butene			12
3-methyl-1-butene			13
i-pentane			14
1-pentene			15
2-methyl-1-butene			16
n-pentane			17
Isoprene			18
trans-2-pentene			19
cis-2-pentene			20
2-methyl-2-butene			21
2,2-dimethylbutane	2.3	3.8	22

Table E-2b Volatile Organic Compound Test Data for M-1 Propellant.

Date 09/06/90 Location: OBOD		Can # SDA184 Tube Sample # 184	
Compound	**$\mu g/m^3$**	**ppbv-c**	**ID Code**
Cyclopentene	0.2	0.3	23
4-methyl-1-pentene	0.7		24
Cyclopentane	1.2		25
2,3-dimethylbutane			26
cis-4-methyl-2-pentene			26a
2-methylpentane			27
3-methylpentane			28
2-methyl-1-pentene			**29**
1-hexane			30
n-hexane	0.4	0.7	31
trans-2-hexene			32
2-methyl-2-pentene			33
cis-2-hexene			35
alpha-thujene			T1
Camphene			T2
Sabinene			T3
Mercene			T4
beta-iterpinene			T4a
Sesquiterpine			T11
beta-terpinene			T5
Methylcyclopentene	0.4	0.7	36
2,4-dimethylpentane			37
Benzene	0.3	0.5	38
Cyclohexane	0.2	0.3	39
2-methylhexane	0.5	0.8	39a
2,3-dimethylhexane			40
3-methylhexane	1.2	2.0	41
n-heptane	0.3	0.5	43
methylcyclohexane			44
2,4-dimethylhexane			45
2,3,4-trimethylpentane	0.5	0.8	46

Table E-2c Volatile Organic Compound Test Data for M-1 Propellant.

Date 09/06/90 Location: OBOD		Can # SDA184 Tube Sample # 184	
Compound	**µg/m³**	**ppbv-c**	**ID Code**
Toluene	0.4	0.7	47
2,3-dimethylhexane			48
2-methylheptane			49
3-ethylhexane			50
n-octane	0.2	0.3	51
Ethylcyclohexane			52
Ethylbenzene			53
m-xylene & p-xylene			**54**
Styrene			56
o-xylene	1.3	2.2	57
n-nonane			58
alpha-pinene			59
i-propylbenzene			60
n-propylbenzene			61
p-ethyltoluene			62
m-ethyltoluene	0.3	0.5	63
1,3,5-trimethylbenzene			64
o-ethyltoulene			65
beta-pinene			66
Methylstyrene			67a
1,2,4-trimethylbenzene	1.6	2.7	68
n-decane	2.1	3.5	69
1,2,3-trimethylbenzene			69a
1,3-diethylbenzene			69b
1,4-diethylbenzene			69c
alpha-terpinene			T6
2-carene			T7
beta-phellandrene			T8
gamma-terpinene			T9
d-limonene			70
Terpinene			T10

APPENDIX F - SEMIVOLATILE ORGANIC DATA REDUCTION

The principles used in the calculation of the emission factors for semivolatile organic compounds are the same as used for gas and VOC analysis. Data obtained from the laboratory are reported in nanograms of a particular target analyte per total sample received, whether filters, soil, or fallout pan. If all three of the exposed air filters from a given test were analyzed, the results from all three are simply summed to obtain the total amount of a given substance collected in the test. In selected cases where only two of the three filters were analyzed (the third being used for a different analysis) it was assumed that all three collected equal amounts of material and the total adjusted accordingly.

The total amount of a given analyte from each test sample is then divided by the volume of sample air drawn through all of the filters, reduced to standard cubic meters, as measured by a Pitot tube mounted in the center line of the aerosol transport tube on the aircraft to yield its concentration in nanograms per cubic meter. (See Appendix A for procedures to calculate tube air velocity and total sample volume). Similar calculations are carried out for the background samples collected the same date and location. Each target analyte air concentration value is then used along with the total net carbon concentration measured in the sample and the carbon fraction of the PEP material being tested to calculate its respective emission factor.

A complication in the calculation results from the fact the filter samples represent the summation from sampling the emission clouds from three distinct successive detonations or burns, (This is done to acquire an adequately sized sample). whereas the required accompanying CO and CO_2 assays are obtained from an 80-L Teflon® bag attached to the same aerosol transport tube as the filters. However, a separate CO_2 and CO sample is collected for every pass through the emission cloud. A weighted average of CO_2 and CO gas concentrations is calculated using the fraction of the total air volume for all of the tests of a given type represented by a given bag sample. Assuming well mixed conditions the composition of a bag sample in a given instance should be the same as that drawn simultaneously through the filters.

The expression used to calculate the EF for the semivolatile organic target analytes is then as follows:

Equation F-1 Emission Factor Calculation for Semivolatiles.

$$EF_x = \frac{\left(\frac{M_t}{V_t} - \frac{M_b}{V_b}\right) f_c}{C_{wc}}$$

where

EF_x = emission factor (EF)of a specified target analyte (x)

M_t = total test analyte mass on all test filters

V_t = total test air volume drawn through all test filters

M_b = total background analyte mass on all background filters

V_b = total background air volume drawn through all background filters

f_c = carbon fraction of the test material (0.303 for M-1 propellant)

C_{wc} = weighted average total carbon concentration in the sample

Note: All values must be expressed in consistent units.

The total weighted average carbon concentration, C_{tot} is given by the following:

Equation F-2 Calculation of Total Weighted Average Carbon Concentration.

$$C_{tot} = \sum \left(\frac{V_i}{V_{tot}} \left([\overline{CO_2}]_i + [\overline{CO}]_i \right) \ 0.491 \right)$$

where

C_{tot} = total carbon in sample (mg m^{-3})

V_i = total standard gas volume drawn through filters in i-th sample

V_{tot} = total standard gas volume drawn through all filters on all samples from a given test

$[CO_2]_i$ = average background corrected CO_2 concentration (ppmV) in the i-th bag sample

$[CO]_i$ = average background corrected CO concentration (ppmV) in the i-th bag sample

Notes: The factor, 0.491 converts the ppmV concentration of any gas containing only one atom of carbon per molecule behaving ideally to mg/m^3 carbon at standard conditions.

The summation is carried out for i = 1 to i = n, where n is the total number of bag samples collected during a given filter sampling.

Table F-1 Semivolatile Target Analyte Loadings on Background and Test Filters for 6 Sep 90 M-1 Propellant Test.

Analyte	Total Sample Loading (ng)					
	Filter 3427 Bkgnd	Filter 3428 Bkgnd	Filter 3429 Bkgnd	Filter 3423 Test	Filter 3424 Test	Filter 3425 Test
2,4 Dinitrotoluene	1.1	1.0	1.2	1.1	1.0	1.5
2,6 Dinitrotoluene						
2,4,6 Trinitrotoluene						
2-Nitronaphthalene						
N-Nitrosodiphenylamine						
1,3,5-Trinitrobenzene						
2-Nitrodiphenylamine						
1-Nitropyrene						
Naphthalene	33.2				30.5	23.0
Benzo[a]anthracene						
Benzo[a]pyrene						
Pyrene						
Phenol	4.9	4.8		0.9	2.7	2.5
Dibenzofuran						
Diphenylamine		0.1		0.1		

No data entry - indicates below detection level.

Table F-2 Air Volume and Gas Concentration Data or 6 Sep 90 M-1 Propellant Test.

Parameter	Background Sample	Test Sample
Total Sample Vol. (m^{-3})	182.79	9.58
Test 1 Sample Vol. (m^{-3})		2.88
Test 2 Sample Vol. (m^{-3})		3.84
Test 3 Sample Vol. (m^{-3})		2.86
Bkgnd-corr CO_2 / CO Bag 1 (ppm)		192 / ND
Bkgnd-corr CO_2 / CO Bag 2 (ppm)		138 / ND
Bkgnd-corr CO_2 / CO Bag 3 (ppm)		177 / ND

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APPENDIX G - SEMIVOLATILE ORGANIC ASSAY

The semivolatiles collected on soil particles and sampled by Teflon® coated glass fiber filters and soil ejecta and fallout were all assayed by SFC/MS and most samples were also assayed by GC/MS. The RDX semivolatile data is shown in this appendix as an example of the data available for each detonation or burn. RDX was chosen because two of the compounds, N-nitrosodiphenylamine and RDX are not identified and quantified with the GC/MS method of assay; however, they are identified and quantified with the SFC/MS method of assay. Table G.1 gives the QA custody number used to identify each sample from the initial field collection through the data analysis, the origin of the collected sample, and the weight of the soil that was extracted for the sample assay. Tables G.2a through G.2d show the concentration determined for each sample by the two methods of assay. Duplicate samples were collected for all the assays from sites D1, D3, and D5 (e.g. samples number 4065 and 4069 are independent background samples).

Table G.1 Sample Identification and Weight of Particles in Sample.

QA CUSTODY NUMBER	LOCATION	SAMPLE TYPE	SAMPLE SOURCE	WEIGHT OF SAMPLE (g)
3613	Aircraft	Filter	Air (Trial 1)	
3614	Aircraft	Filter	Air (Background)	
3615	Aircraft	Filter	Air (Trial 2)	
4065	Site D1, D3, D5	Background	Detonation site	372.8
4069	Site D1, D3, D5	Background	Detonation site	372.2
4067	Site D2, D4, D6	Background	Detonation site	377.8
4634	Site D1, D3, D5	Ejecta	Detonation crater	375.9
4640	Site D1, D3, D5	Ejecta	Detonation crater	359.1
4646	Site D2, D4, D6	Ejecta	Detonation crater	386.6
4622	Site D1, D3, D5	Fallout	50m from detonation	369.8
4623	Site D1, D3, D5	Fallout	50m from detonation	396.1
4624	Site D1, D3, D5	Fallout	100m from detonation	236.2
4625	Site D1, D3, D5	Fallout	100m from detonation	102.4
4626	Site D1, D3, D5	Fallout	150m from detonation	22.8
4627	Site D1, D3, D5	Fallout	150m from detonation	2.57
4628	Site D1, D3, D5	Fallout	200m from detonation	26.3
4629	Site D1, D3, D5	Fallout	200m from detonation	1.02
4648	Site D2, D4, D6	Fallout	50m from detonation	356.3
4649	Site D2, D4, D6	Fallout	100m from detonation	268.4
4650	Site D2, D4, D6	Fallout	150m from detonation	13.4
4651	Site D2, D4, D6	Fallout	200m from detonation	2.41

Table G.2a Data of the Supercritical-Fluid Chromatography/Mass Spectrometry and Gas Chromatography/Mass Spectrometry for the RDX Detonations.

SEMIVOLATILE COMPOUNDS	3613		3614		3615		4065		4069		4067	
	SFC/MS (ng/Ml)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)
2,4-Dinitrotoluene	410	230	220	210	240	330	220	500	270	920	210	410
2,6-Dinitrotoluene	33	18	160	33	70	20	120	69	75	41	21	28
2,4,6-Trinitrotoluene	61	18	260	BD[a]	160	BD	240	71	220	65	61	BD
2-Nitronaphthalene	85	BD	350	BD	91	BD	190	45	120	31	68	26
N-Nitrosodiphenylamine	BD	NA[b]	BD	NA	BD	NA	BD	NA	BD	NA	BD	NA
1,3,5-Trinitrobenzene	92	BD	190	BD	48	BD	110	1	51	2	71	35
2-Nitrodiphenylamine	60	BD	180	BD	60	BD	110	400	80	430	44	230
1-Nitropyrene	66	BD	150	BD	83	BD	300	BD	170	BD	74	BD
RDX	2200	NA	4600	NA	3400	NA	1400	NA	1100	NA	400	NA
Naphthalene	330	1600	210	970	310	1900	120	81	170	160	41	140
Benz[a]anthracene	96	190	91	BD	65	BD	66	91	68	BD	63	56
Benzo[a]pyrene	270	BD	76	BD	41	BD	53	BD	61	BD	55	BD
Pyrene	180	380	260	410	320	500	1	28	23	17	14	27
Phenol	---[c]	---	---	---	---	---	---	---	---	---	---	---
Dibenzofuran	150	140	110	53	3000	120	30	33	18	48	BD	51
Diphenylamine	45	64	250	43	150	38	91	7	92	12	95	11

[a]BD - below detection limit.
[b]NA - a target analyte not detected by GC/MS.
[c]Phenol was lost in the extraction of the semivolatile.

Table G.2b Data of the Supercritical-Fluid Chromatography/Mass Spectrometry and Gas Chromatography/Mass Spectrometry for the RDX Detonations.

SEMIVOLATILE COMPOUNDS	4634		4640		4646		4622		4623		4624	
	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)
2,4-Dinitrotoluene	740	660	340	440	130	220	320	110	120	170	110	18
2,6-Dinitrotoluene	340	100	93	35	31	1	310	7	100	BD[a]	87	BD
2,4,6-Trinitrotoluene	250	77	100	56	110	16	530	270	2000	1600	1000	42
2-Nitronaphthalene	340	71	110	35	50	7	580	49	220	BD	79	BD
N-Nitrosodiphenylamine	650	NA[b]	590	NA	230	NA	1400	NA	BD	NA	BD	NA
1,3,5-Trinitrobenzene	290	130	47	420	79	BD	340	BD	58	BD	66	BD
2-Nitrodiphenylamine	73	BD	49	BD	66	18	240	240	220	BD	120	BD
1-Nitropyrene	BD	BD	83	BD	18	52	370	BD	40	BD	80	BD
RDX	4600	NA	5300	NA	1900	NA	4000	NA	18000	NA	6800	NA
Naphthalene	2000	2600	1900	2000	1200	2000	530	210	420	260	210	87
Benz[a]anthracene	910	520	750	740	680	210	4300	1100	4000	1000	BD	130
Benzo[a]pyrene	BD	BD	97	BD	160	210	BD	BD	1160	BD	120	BD
Pyrene	200	120	1900	1700	1200	20	1000	700	1600	2100	600	190
Phenol	---[c]	---	---	---	---	---	---	---	---	---	---	---
Dibenzofuran	260	170	340	390	340	290	130	77	BD	180	BD	27
Diphenylamine	180	150	160	100	BD	2	BD	19	BD	63	BD	3

[a]BD - below detection limit.
[b]NA - a target analyte not detected by GC/MS.
[c]Phenol was lost in the extraction of the semivolatile.

Table G.2c Data of the Supercritical-Fluid Chromatography/Mass Spectrometry and Gas Chromatography/Mass Spectrometry for the RDX Detonations.

SEMIVOLATILE COMPOUNDS	4625		4626		4627		4628		4629		4648	
	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)
2,4-Dinitrotoluene	81	110	49	150	280	140	410	290	270	270	730	1300
2,6-Dinitrotoluene	70	BD[a]	34	BD	340	40	100	15	BD	19	29	170
2,4,6-Trinitrotoluene	490	77	280	BD	390	60	160	63	20	40	340	480
2-Nitronaphthalene	110	14	88	17	300	78	170	59	22	28	130	410
N-Nitrosodiphenylamine	430	NA[b]	440	NA	550	NA	690	NA	170	NA	370	NA
1,3,5-Trinitrobenzene	26	BD	18	BD	510	BD	210	41	6	11	33	BD
2-Nitrodiphenylamine	120	BD	120	BD	200	BD	130	BD	29	140	250	BD
1-Nitropyrene	150	BD	130	BD	310	BD	300	130	8	BD	16	BD
RDX	13000	NA	16000	NA	3700	NA	29000	NA	1000	NA	11000	NA
Naphthalene	180	82	740	BD	550	170	250	1800	750	220	450	2200
Benz[a]anthracene	900	180	37	37	560	BD	800	110	61	80	640	420
Benzo[a]pyrene	100	BD	74	90	420	BD	BD	BD	BD	BD	680	BD
Pyrene	580	320	280	110	640	BD	920	200	230	72	1900	2600
Phenol	---[c]	---	---	---	---	---	---	---	---	---	---	---
Dibenzofuran	320	250	BD	63	240	110	BD	200	35	31	BD	290
Diphenylamine	BD	12	BD	25	220	50	480	380	26	35	240	520

[a]BD - below detection limit.
[b]NA - a target analyte not detected by GC/MS.
[c]Phenol was lost in the extraction of the semivolatile.

Table G-2d Data of the Supercritical-Fluid Chromatography/Mass Spectrometry and Gas Chromatography/Mass Spectrometry for the RDX Detonations.

SEMIVOLATILE COMPOUNDS	4649		4650		4651	
	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)	SFC/MS (ng/mL)	GC/MS (ng/mL)
2,4-Dinitrotoluene	43	59	500	90	230	230
2,6-Dinitrotoluene	4	9	11	29	160	BD[a]
2,4,6-Trinitrotoluene	130	BD	1700	54	230	23
2-Nitronaphthalene	170	20	BD	50	350	8
N-Nitrosodiphenylamine	9	NA[b]	88	NA	35	NA
1,3,5-Trinitrobenzene	2	52	14	BD	230	BD
2-Nitrodiphenylamine	19	60	BD	42	84	33
1-Nitropyrene	BD	BD	BD	BD	170	BD
RDX	2300	NA	BD	NA	690	NA
Naphthalene	220	160	200	76	100	BD
Benz[a]anthracene	49	76	BD	BD	85	BD
Benzo[a]pyrene	6	BD	34	BD	190	BD
Pyrene	1	35	120	BD	100	43
Phenol	---[c]	---	---	---	---	—
Dibenzofuran	BD	99	150	140	110	64
Diphenylamine	BD	46	BD	140	110	10

[a]BD - below detection limit.
[b]NA - a target analyte not detected by GC/MS.
[c]Phenol was lost in the extraction of the semivolatile.

APPENDIX H - REFERENCES

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APPENDIX I - ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AEHA	U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland
AFB	Air Force Base
AMC	U.S. Army Materiel Command, Alexandria, Virginia
AMCCOM	U.S. Army Armament, Munitions and Chemical Command, Rock Island, Illinois
amino-PAH	aminopolycyclic aromatic hydrocarbons
ANOVA	analysis of variance
AP	ammonium perchlorate
APS	aerodynamic particle sizer
ASASP	active scattering aerosol spectrometer probe
AWL	Alpine West Laboratories, Provo, Utah
BB	BangBox
BCD	Battelle Columbus Division, Columbus, Ohio
BD	target analyte not found in concentrations above detection limits
BYU	Brigham Young University, Provo, Utah
CAA	Clean Air Act
CDD	chlorinated dibenzodioxin
CDF	chlorinated dibenzofuran
CI-SIM	chemical ionization, selective-ion monitoring
CSI	Columbia Scientific Instruments
C·V	concentration times cloud volume method
CWA	Clean Water Act
DMC	Data Management Center
DMPS	differential mobility particle sizer
DoD	Department of Defense
DPG	U.S. Army Dugway Proving Ground, Dugway, Utah
EC	electron capture *or* elemental carbon
ECD	electron capture detector
EDAX	energy-dispersive X-ray analysis
EER	Energy and Environmental Research Corporation, Irvine, California

EF	emission factor(s)
EI	electron impact
EI-MS	mass spectrometer used in the electron impact ionization mode
EI/MS	electron impact ionization/ mass spectrometry
EIS	environmental impact statement
ELI	Environmental Labs, Incorporated, Provo, Utah
EOD	explosive ordnance disposal
EPA	U.S. Environmental Protection Agency
EPO	Environmental Protection Office, U.S. Army Dugway Proving Ground, Dugway, Utah
ER	expansion ratio
FID	flame ionization detector
FSSP	forward scattering spectrometer probe
FTIR	Fourier Transform Infrared Spectrometry
FWAC	fixed-wing aircraft
GC	gas chromatograph(y)
GC-ECD	gas chromatography with an electron capture detector
GC-FID	gas chromatography with a flame ionization detector
GC/MS	gas chromatography-mass spectrometry
GLP	good laboratory practices
HE	high explosive
HMX	octamethylenehexanitramine
HNBB	hexanitrobibenzyl
HRGC/HRMS	combined capillary column gas chromatography/high resolution mass spectrometry
HS	high-speed
LASD	Los Angeles Sheriff Department
LBL	Lawrence Berkeley Laboratory, Berkeley, California
LC	liquid chromatography
LOD	limit of detection
LOI	letter(s) of instruction

MR	multiple range
MRI	Midwest Research Institute, Kansas City, Kansas
MS	mass spectrometry (or mass spectrometer)
MSA	Mine Safety and Appliance Company
NA	not targeted for analysis *or* not applicable
NASA	National Aeronautical and Space Administration
NATICH	National Air Toxics Information Clearinghouse
NBS-SRM	National Bureau of Standards (now NIST)- Standard Reference Material
ND	no data *or* detection limit not determined
NEPA	National Environmental Policy Act
NF	not found in the sample matrix *or* not determined
NIST	National Institute of Science and Technology
nitro-PAH	nitropolycyclic aromatic hydrocarbons
NIOSH	National Institute for Occupational Safety and Health
NOSIH	Naval Ordnance Station, Indian Head, Maryland
NO_x	nitrogen oxides
NS	not sampled
OB	open burning
OB/OD	open burning/open detonation
OC	organic carbon
OD	open detonation
OGC	Oregon Graduate Center, Beaverton, Oregon
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbons
PANH	polycyclic aromatic nitrogen heterocycles
PAOH	polycyclic aromatic oxygen heterocycles
PCDD	polychlorinated dibenzodioxins
PCDF	polychlorinated dibenzofurans
PETN	pentaerythritol tetranitrate
PEP	propellants, explosives, and pryotechnics
PIC	products of incomplete combustion
PICI/SIM	Positive ion chemical ionization/selective ion monitoring

PID	photoionization detector
PIP	product improvement program
PM	program manager
PMS	Particle Measuring Systems, Inc.
PUF	polyurethane foam
QA	quality assurance
QA/QC	quality assurance/quality control
QC	quality control
QAA	quality assurance agency
QAPP	quality assurance project plan
QAU	quality assurance unit
RCRA	Resource Conservation and Recovery Act
RDX	hexamethylenetrinitramine
RFD	Reno (Nevada) Fire Department
RIC	relative ion count
RSD	relative standard deviation
RTP	Research Triangle Park, North Carolina
SDPDA	Special Defense Property Disposal Account
SEM	scanning electron microscope/microscopy
SFC	supercritical fluid chromatography
SFC/MS	supercritical fluid chromatography/mass spectrometry
SF_6	sulfur hexafluoride
SIM	selected-ion monitoring (or selective-ion monitoring)
SNL	Sandia National Laboratories, Albuquerque, New Mexico
SOP	standing operating procedures
SS	stainless steel
SSC	stainless steel canister
SSL	Sunset Laboratory, Forest Grove, Oregon
STEL	short-term exposure limit
STP	standard temperature and pressure (25°C and 760 torr)
TCD	thermal conductivity detector
TDP	test design plan

TEAD	U.S. Army Tooele Army Depot, Tooele, Utah
TECO	Thermo Electron Instruments (Company)
TECOM	U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland
THC	total hydrocarbon
TLV	threshold limit values
TNT	2,4,6-trinitrotoluene
TSC	technical steering committee
TSP	total suspended particulate
TWA	time-weighted average
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland
UV	ultraviolet
VOC	volatile organic compounds
VOST	semivolatile organic sampling train
VSDM	Volume Source Diffusion Model
XRF	X-ray fluorescence *or* X-ray fluorescence spectrometer

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APPENDIX J - GLOSSARY

B-48 The Sandia National Laboratories (SNL) mobile laboratory on-site at the U.S. Army Michael Army Airfield, Dugway Proving Ground, Utah. This laboratory contained filter support equipment and test equipment and parts for repairing instrumentation and sample collectors aboard the sampling aircraft.

BangBox An inflatable 16-m diameter hemisphere used for conducting closed chamber tests involving detonation of small amounts of explosive and burning of small amounts of propellant.

burn pans Steel pans used to contain propellants during burning and prevent soil contamination by residues.

cloud volume method a procedure which uses carbon as a tracer for the products of a detonation or propellant burn in a cloud. Assumes that cloud of detonation or combustion products is homogeneous in relative composition. Volume of cloud is not required for computation of the mass of an analyte.

carbon balance method a procedure which uses carbon as a tracer for the products of a detonation or propellant burn in a cloud. Assumes that cloud of detonation or combustion products is homogeneous in relative composition. Volume of cloud is not required for computation.

composition B An explosive composed primarily of RDX and TNT in an approximately 60/40 ratio (by weight).

donor charge A small explosive charge used to initiate the detonation of a substantially larger explosive charge. Sometimes referred to as an "initiator", "initiating charge", or "primer".

double-base propellant	A propellant consisting primarily of nitrocellulose and nitroglycerine. Mix used during OB/OD field test was approximately 50 percent nitrocellulose and 35 percent nitroglycerin.
ejecta	Soil displaced from the point of a surface detonation and which is deposited near the detonation crater.
exotics	Volatile organic compounds which, if detected during laboratory assay, would most likely be found at trace levels.
explosive D	An explosive consisting primarily of picric acid. Frequently referred to as "yellow D" due to its characteristic yellow color. Relatively insensitive and requires a substantially larger initiating charge than other military explosives to ensure complete detonation.
field test	A series of open-air trials using techniques and material identical to those used in, or proposed for, actual operations.
FWAC	A fixed-wing aircraft outfitted to sample, analyze, and collect combustion emissions from the open detonation of explosive and open burning of propellants.
Interim Test	A series of open-air trials using end-item PEP material which were conducted at the Tooele Army Depot during 1986.
kickout	Pieces of propellant ejected from burn pans either by low-level shock waves or thermal-generated drafts.
M1 Propellant	A single-base propellant used to fire projectiles by field artillery howitzers, and guns.
M6 Propellant	See M1 Propellant

Operational readiness inspection	A trial, frequently referred to as an "ORI", designed to ensure methods, equipments, and personnel are prepared to undertake subsequent data-gathering trials.
PBXN-6	Mixture of RDX and Viton A® in a 95/5 ratio. Referred to as "RDX" within this report.
PETN	A military explosive (pentaerythritol tetranitrate) commonly used in detonating cord.
propellant manufacturing residue	Incompletely manufactured propellant. No scrap material included in residue used during OB/OD field testing.
RDX	A military explosive consisting primarily of hexamethylenetrinitroamine. See PBXN-6.
single-base propellant	A propellant consisting of approximately 85 percent nitrocelluiose.
sputter	Pieces of propellant ejected from burn pans by the energy of their burning.
sputter pan	A square metal pan designed and located so as to capture particles of propellants lofted out of burn pans during open burning testing.
supercritical fluid chromatography	SFC ia a chromatographic technique where a supercritical fluid is used as the mobile phase. SFC has efficiencies comparable to that of gas chromatography and a solvating mobile phase such as in liquid chromatography.

surface detonation	A detonation which was set up with explosives set on the ground, or placed in a container set on the ground.
transport tube	The tube used to transport outside air into the FWAC for instrument sampling.
triple base propellant	A propellant consisting primarily of nitrocellulose, nitroglycerine, and nitroguanadine. Triple-base propellent used during OB/OD field testing was approximately 28 percent nitrocellulose, 22 percent nitroglycerin, and 48 percent nitroguanidine.
suspended detonation	A method used in the OB/OD Phase B and C tests to suspend 907 kg of TNT in steel drums 40 feet off the ground for subsequent detonation.
TNT	An explosive consisting almost exclusively of trinitrotoluene.
washout explosive	Explosive reclaimed from munitions by a process of opening a munition and removing the explosive filler by flushing the casing/container with high-pressure hot water.
yellow D	See explosive D.

APPENDIX K - OB/OD PROGRAM SYNOPSIS

1. Original Study Purpose

The original OB/OD study was intended to provide munitions and propellent thermal treatment emissions data to satisfy increasingly stringent state and Federal permitting requirements.

2. Interim Test

The initial effort, now referred to as the Interim Test, was conducted at the Tooele Army Depot with the objective of directly obtaining this data. End-item munitions and propellants were tested, and a variety of samplers, real-time analyzers, and assay procedures used to characterize their combustion products. This test did not meet its objectives because the technology to detect and quantify emissions at desired levels had either not been developed, or was not made available to the project.

3. Program Reevaluation

Upon conclusion of the Interim Test and after consultation with certain EPA agencies, the decision was made that an orderly, scientific methodology was necessary to provide accurate and replicable test data which would satisfy current and anticipated requirements of state and Federal environmental regulatory agencies. This would necessarily involve use of state-of-the-art technologies and instruments capable of meeting anticipated regulatory agency requirements.

4. Current OB/OD Phase

4.1 Objectives

4.1.1 The recently-concluded phase of the OB/OD Thermal Treatment Emissions Study was designed and conducted as the first step of this premise, i.e., to find, test, and authenticate technologies and procedures which could then be used to obtain data to support OB/OD permitting. An ancillary objective was to ascertain if small-scale controlled testing could be related to large-scale

field testing and thus reduce the time and expense which typify large-scale testing.

4.1.2 The types of bulk explosives and propellants tested are components of a large percentage of demilitarization account end items. Munition-specific variables such as shell-casing components were not tested; however, with high-order detonation of complete munitions, the same combustion products are expected.

4.2 Results

4.2.1 The primary consequence of this testing was the assessment of instruments' and procedures' abilities to accurately capture and analyze combustion products, and the evaluation of scaling BB data to field data for detonations and burns. The secondary consequence was characterization of emission products imparted into the atmosphere and soil for the items tested.

4.2.2 The emission data along with meteorological diffusion models can generate expected downwind dosage values which can be compared with ambient air concentration limits set by states. The ejecta concentration data for the soil in the crater area can be used to estimate the total amount of the analyte that remains in the soil after a detonation. Fallout concentrations can be used to determine the analyte and the amount that is deposited on the undisturbed surface.

4.2.3 Results of the small-scale BangBox and large-scale field tests are highly encouraging. Both procedures and instruments were proved to be accurate and capable of meeting the requirements of the study. The amount of pollutants released into the atmosphere and soil were considered inconsequential.

4.2.4 The data indicates that, for those items tested, there is no serious impact to the environment; however, further studies must be done to determine the full environmental impact of OB/OD thermal treatment methods for the following reasons:

4.2.4.1 Bulk explosives constitute only a small fraction of the demilitarization inventory.

4.2.4.2 Their combustion products may not represent combustion products of encased munitions

4.2.4.3 Tests were site-specific only to a single locale.

4.2.4.4 The procedures used did not represent procedures customarily used at some treatment facilities, e.g. buried detonations.

4.3 Status

4.3.1 The current phase of the OB/OD study authenticated acceptable technology and methodology that can be used to obtain the munition- and site-specific emission characterization data. This data may then be used as part of the information needed to obtain permits for continued OB/OD operations. The data can be acquired by either constructing a single BangBox at a single site or constructing a BangBox at each specific site for emission characterization of site-specific munitions and soil.

4.3.2 An OB/OD dispersion model was also developed during the field trials of the study. A model acceptable to EPA is an essential adjunct to the BangBox emission characterization data in that it provides the mechanism to generate downwind concentrations at receptor locations, and input required for risk assessment to support site-specific permit applications. The model will require refinement and field validation before being made available to potential users.

4.3.3 As site- and munition-specific emissions data are collected and evaluated, they can provide part of the basis for risk assessment input which will evaluate which munitions, and explosive and propellants in the DoD inventory are applicable to OB/OD treatment, and which are not. For those not appropriate, the emissions characterization data can be used to more effectively focus efforts on the development and permitting of required alternative technologies.

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Exhibit 6

OPEN BURNING EMISSIONS STUDY

SCREEN2 AIR DISPERSION MODELING

June 29, 1994

D. A. Hulburt

Hercules Aerospace Company

Allegany Ballistics Laboratory

Rocket Center, WV 26726

GLOSSARY

ABL	Allegany Ballistics Laboratory
ACGIH	American Conference of Government Industrial Hygiensts.
DB	Double Base Propellant. See XLDB
GASGEN	Gas Generator Propellant. A propellant family containing small amounts of lead compounds that was used in the study to assess open burning emissions of lead.
HTPB	Hydroxyterminated Polybutadiene Propellant. A propellant family containing ammonium perchlorate oxidizer that was used in the study to assess open burning emissions of hydrogen chloride and chlorine.
NAAQS	National Ambient Air Quality Standard
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
POLU13	Computer code for predicting products of combustion from open burning of propellants and explosives.
SCREEN2	Computer code for predicting air dispersion of pollutants.
STEL	Short Term Exposure Limit
TWA	Time Weighted Average
XLDB	Cross–linked Double Base. A propellant family containing small amounts of lead compounds that was used in the study to assess open burning emissions of lead.

OPEN BURNING EMISSIONS STUDY

SCREEN2 AIR DISPERSION MODELING

A. SUMMARY

Conservative ground level average concentrations for lead, hydrogen chloride, and chlorine emissions from open burning operations at ABL have been calculated for receptors in the vicinity of the burning grounds. The results are summarized in Table I. The predicted lead concentration is at most 0.025 ug/m3, and for most receptors substantially less. Predicted lead concentrations are thus well below the 1.5 ug/m3 NAAQS. Even under the worst case assumption that all XLDB and GASGEN propellant would be burned simultaneously, the exposure concentration is at most about 2.3% of the NAAQS. Maximum predicted average HCl concentration is 1.5 ug/m3, and for Cl2 the maximum predicted average concentration is 0.82 ug/m3. There are no NAAQS for HCl or Cl2. Predicted average and peak concentrations are below corresponding ACGIH or OSHA limits in all cases. Based on these results, open burning at ABL does not present a threat to human health or the environment.

The open burning combustion code POLU13 was used to predict the products of combustion from open burning of six propellant/explosive (P/E) formulation families representing the materials produced at ABL and the P/E wastes generated and burned. The results of these studies were previously documented and reported (1). Output from the POLU13 studies (combustion products composition, temperature, and volume) were used as input to the SCREEN2 dispersion model.

Over 5000 quarter-hour observations of wind velocity and direction recorded at the ABL weather station were analyzed to develop the frequency distribution of wind speed and direction. These observations represent nearly one year of data during the 10 am to 4 pm time interval during which open burning operations may be conducted. These data were integrated with the dispersion model results and receptor data to calculate exposure concentrations at receptors in the vicinity of ABL.

The SCREEN2 dispersion model was run for various combinations of wind speed and atmospheric stability to develop raw concentration-distance data for four propellant/burning situations (the formulation with the highest lead content, the lead containing formulation with significant production, the formulation and condition yielding the highest hydrogen chloride emissions, and the formulation and condition yielding the highest chlorine emissions). The worst case concentration vs wind speed envelope for various downwind distances was derived from the raw data, and used in conjunction with the target receptor and weather data to arrive at exposure concentrations.

Receptors were selected based on residences and places of assembly in primary downwind locations from the burning ground. Average exposures were calculated for these receptors.

B. EMISSIONS FROM OPEN BURNING

Selection of P/E formulations for study, and the emissions data generated by the POLU13 computer code were documented and reported previously (1). Salient features and results of this work are repeated here as an aid in understanding the follow-on dispersion modeling studies. Evaluation of these results indicated that lead compounds, hydrogen chloride, and chlorine were the emissions of potential human health/environmental concern. Four cases from the twelve baseline cases (6 formulations at 2 combustion air ratios) were selected for inclusion in the air dispersion modeling. The first case selected (gas generator, or GASGEN propellant) has the highest lead content and therefore lead emissions. Since this propellant is a very minor production

TABLE I
OPEN BURNING EMISSIONS
CONSERVATIVE GROUND LEVEL CONCENTRATION ESTIMATES FROM SCREEN2 MODEL

ID	LOCATION DESCRIPTION	NOM RGE m	NOM AZ deg	XLDB – Pb R. F. = 140 GR ug/m3	XLDB – Pb R. F. = 140 NET ug/m3	GASGEN–Pb R. F. = 695 GR ug/m3	GASGEN–Pb R. F. = 695 NET ug/m3	HTPB – HCl R. F. = 140 GR ug/m3	HTPB – HCl R. F. = 140 NET ug/m3	HTPB – Cl2 R. F. = 140 GR ug/m3	HTPB – Cl2 R. F. = 140 NET ug/m3
1	Residence	980	216	0.52	0.0037	1.08	0.0016	24.1	0.172	17.7	0.127
2	Residence	500	238	1.00	0.0071	2.00	0.0029	57.9	0.414	31.9	0.228
3	Barn	425	255	3.49	0.0249	7.33	0.0106	209.3	1.495	115.3	0.824
4	Residence	400	225	0.82	0.0059	1.67	0.0024	48.9	0.349	26.8	0.191
5	Residence	350	185	0.32	0.0023	0.85	0.0012	25.6	0.183	13.9	0.099
6	Residence	550	160	0.53	0.0038	0.90	0.0013	21.5	0.153	14.6	0.104
7	Residence	650	150	0.57	0.0040	1.03	0.0015	25.4	0.181	13.2	0.094
BAS	Bel Air School	2250	130	0.28	0.0020	0.44	0.0006	12.1	0.087	7.1	0.051
300	Building 300	950	68	0.13	0.0009	0.26	0.0004	5.9	0.042	3.6	0.026
28	Route 28 E of OB Area	2800	270	1.31	0.0094	2.63	0.0038	67.5	0.482	44.5	0.318
28	Route 28 ESE of OB Area	2500	292	0.25	0.0018	0.50	0.0007	13.4	0.096	8.3	0.059
28	Route 28 SE of OB Area	2800	315	0.34	0.0024	0.73	0.0010	21.1	0.150	13.4	0.096
P/BA	Along Pinto Road @ 800 m	800	125	0.41	0.0030	0.88	0.0013	20.9	0.149	12.8	0.092
P/BA	Along Pinto Road @ 1200 m	1200	125	0.30	0.0021	0.79	0.0011	21.4	0.153	11.4	0.081
P/BA	Along Pinto Road @ 1600 m	1600	125	0.40	0.0028	0.89	0.0013	17.9	0.128	11.0	0.078
P/BA	Along Pinto Road @ 2000 m	2000	125	0.38	0.0027	0.74	0.0011	16.0	0.114	9.2	0.066

NOTES: 1 The "GR" value is the average concentration during actual OB operations
2 The "NET" value is the overall average concentration, considering the percentage of time actual OB operations are conducted
The NET value is the GR value, reduced by the stated Reduction Factor (R. F.)
3 Receptor locations are shown on Figure 12

(and waste) contributor, the other lead containing propellant (double base, or DB or XLDB) was also included, because it is a greater contributor to the overall average emission concentration. The formulation with the highest ammonium perchlorate level generates the highest hydrogen chloride or chlorine level. This propellant was the hydroxy-terminated polybutadiene binder propellant (HTPB). At the low end of the combustion air range, hydrogen chloride is preferentially formed, while at the high end of the combustion air range, chlorine is preferentially formed.

Output from the POLU13 code which was used as input to the SCREEN2 dispersion model included the amount of combustion product, temperature of combustion products, and total volume of combustion products.

C. WEATHER DATA

ABL has a weather station located at its test range, which is approximately 1100 meters southeast of the burning grounds. Weather data is recorded at fifteen minute intervals at this station. Weather data (wind speed and direction) between the hours of 10 am and 4 pm (bracketing time interval over which open burning is conducted) for nearly a one year period (May 3, 1993 thru April 4, 1994) was downloaded and analyzed to determine the bivariate wind speed/direction distribution. Over 5000 individual readings make up the database. The frequency distribution data are summarized in Table II and plotted in Figures 1 thru 11. These data were used to develop wind condition probabilities.

D. AIR DISPERSION MODELING STUDIES

1. General Approach and Wind Speed/Stability Class Combinations

The SCREEN2 model was used for calculating emission concentrations as a function of downwind distance for various combinations of wind speed and stability class. Since open burning is conducted during the day shift only, within the 10 am to 4 pm window, Stability Classes E and F were excluded from the study as they apply to nighttime conditions only. This also meant that the complex terrain option could not be used, since the SCREEN2 model defaults to Class F stability (E for urban) and a stack height wind speed of 2.5 m/s under this option. The weather data indicates a fastest wind of 9 mph (4 m/s). The Wind Speed and Stability Class Combinations of Table 2 of the SCREEN2 Model User's Guide were modified accordingly, so that the combinations for which the model was run were as follows:

Stability Class	10-m Wind Speed, m/s						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
A	*	*	*	*	*		
B	*	*	*	*	*	*	*
C	*	*	*	*	*	*	*
D	*	*	*	*	*	*	*

TABLE II
SUMMARY OF ABL WIND SPEED AND DIRECTION DATA

Wind Direction, degrees

mph	0.0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0	202.5	225.0	247.5	270.0	292.5	315.0	337.5	TOT	%
0	1399	8	11	18	13	15	54	47	33	55	46	59	58	54	83	89	2042	40.6
1	86	24	23	13	10	31	86	56	37	64	51	60	105	37	108	149	940	18.7
2	112	16	5	7	7	17	51	12	17	33	30	47	166	41	72	184	817	16.2
3	63	2	4	4	3	3	18	2	1	5	23	37	199	35	52	209	660	13.1
4	38	0	2	3	0	0	1	1	1	5	14	21	125	15	23	96	345	6.9
5	12	0	1	0	0	0	0	0	0	0	4	10	64	6	8	25	130	2.6
6	5	0	0	0	1	0	0	0	0	0	0	3	37	5	2	4	57	1.1
7	0	0	0	0	0	0	0	0	0	0	0	0	16	2	1	2	21	0.4
8	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	1	9	0.2
9	0	0	0	0	0	0	0	0	0	0	0	1	7	0	0	0	8	0.2
TOT	1715	50	46	45	34	66	210	118	89	162	168	238	785	195	349	759	5029	100.0
1-9	*316*	*42*	*35*	*27*	*21*	*51*	*156*	*71*	*56*	*107*	*122*	*179*	*727*	*141*	*266*	*670*	*2987*	
%	10.6	1.4	1.2	0.9	0.7	1.7	5.2	2.4	1.9	3.6	4.1	6.0	24.3	4.7	8.9	22.4	100.0	

Data are frequency of occurrence for quarter-hour readings between 10:00 am and 4:00 pm from May 3, 1993 to Apr 4, 1994

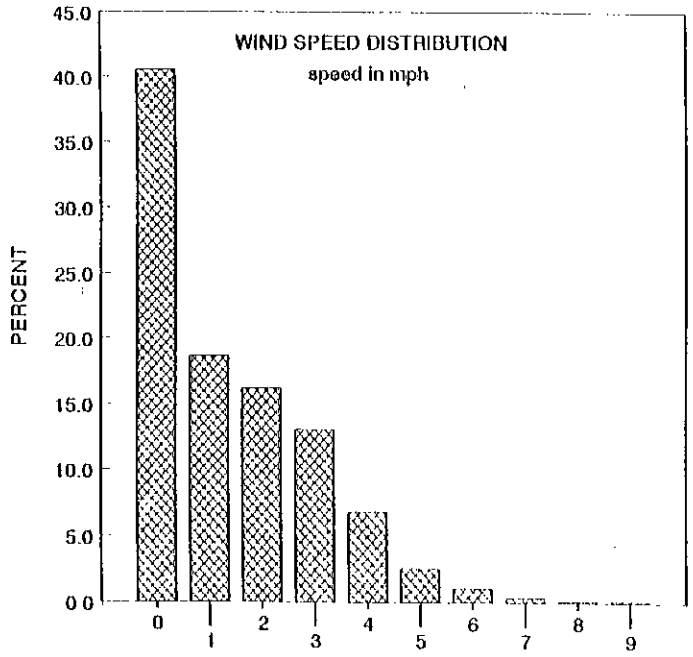


Figure 1

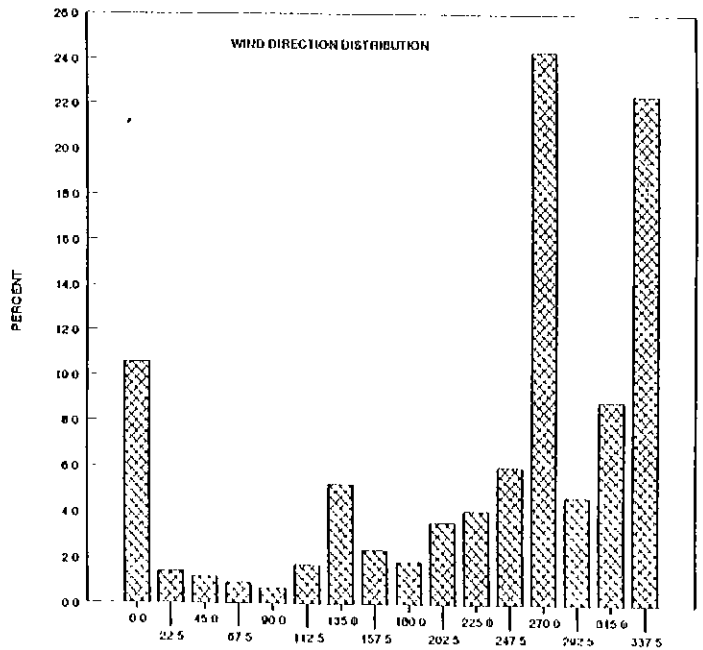
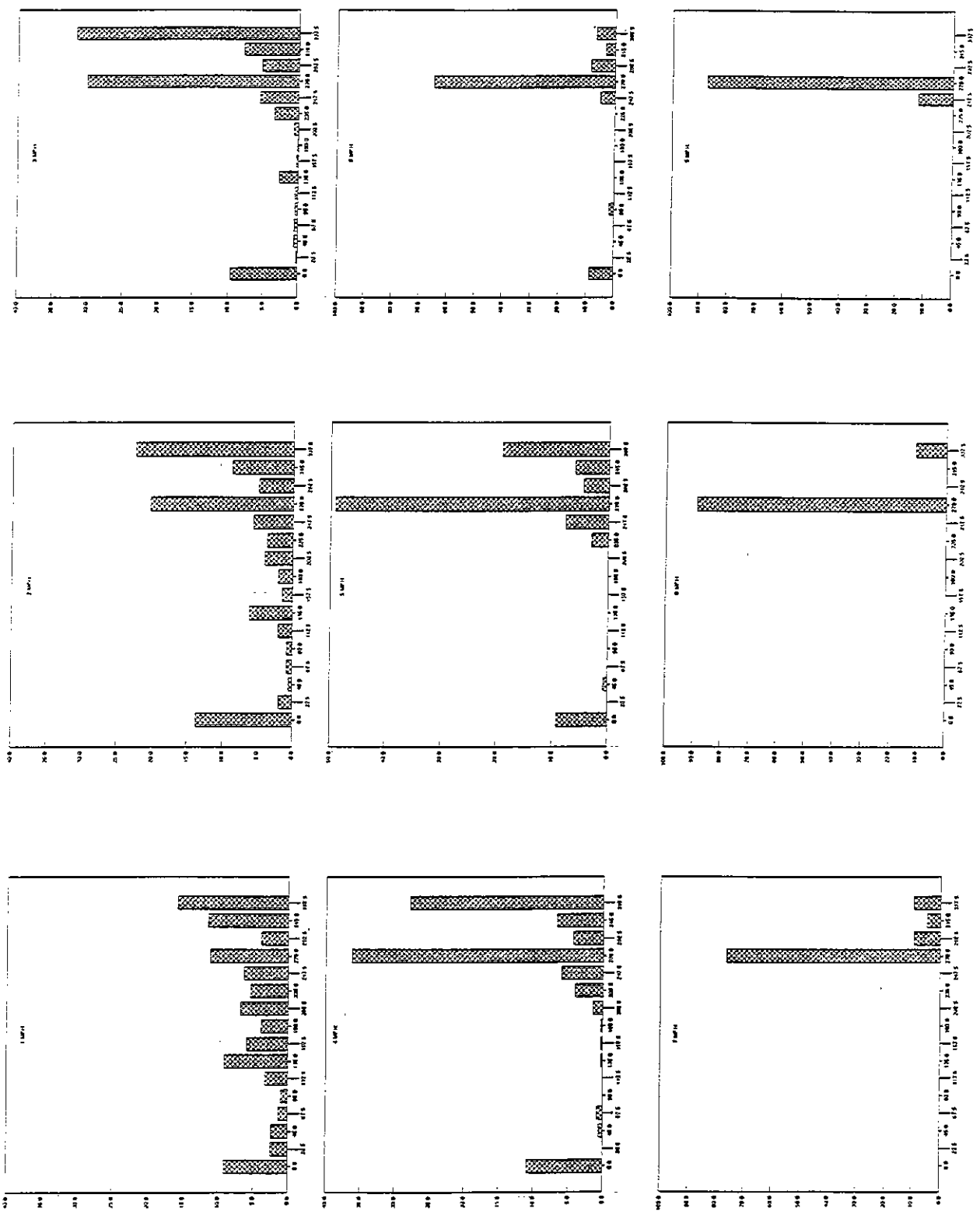


Figure 2



Figures 3–11. Wind Direction Distributions for Wind Speeds of 1 – 9 mph

2. Model Input Data

Source Type. All runs were made for a point source. The burning pans have an overall dimension of 6' x 16' with earthern liners with sloping edge surfaces for a net useable area for distributing waste P/E of about 4' x 14.' As these dimensions are negligible with respect to the downwind distances of concern, the assumption of a point source was considered valid.

Emission Rate. The emission rate of the species of interest was calculated from the POLU13 combustion products composition (gm/100 gm material burned) times the material burn rate of 200 gm/sec. The material burn rate was established from observations of burning time for known weights of P/E waste.

Stack Height. A stack height of 3 m was used. This accounts for the actual height of the burning pan above ground level plus an effective height of the flame, i.e. the "stack" exit is taken as approximated by the tip of the flame.

Stack Inside Diameter. A stack diameter of 2.57 m was used. This diameter gives a stack area equivalent to the 4' x 14' useable pan area, and is if anything conservative since it is the maximum useable area and therefore gives the lowest stack velocity.

Stack Gas Exit Velocity. The stack gas exit velocity was calculated from the POLU13 output of volume of gases produced corrected to stack temperature, and the stack area. It should be noted that the direct POLU13 output is total volume of gases in liters at Standard Temperature and Pressure (stp) for 100 gms of total emissions products. The output value therefore must be adjusted for temperature and for a material burn rate of 200 gm/sec before being divided by the stack area.

Stack Gas Temperature. The stack gas temperature is taken directly from the POLU13 output.

Ambient Temperature. An ambient temperature of 293 °K was used for all runs.

Receptor Height Above Ground. All runs assumed a ground level receptor.

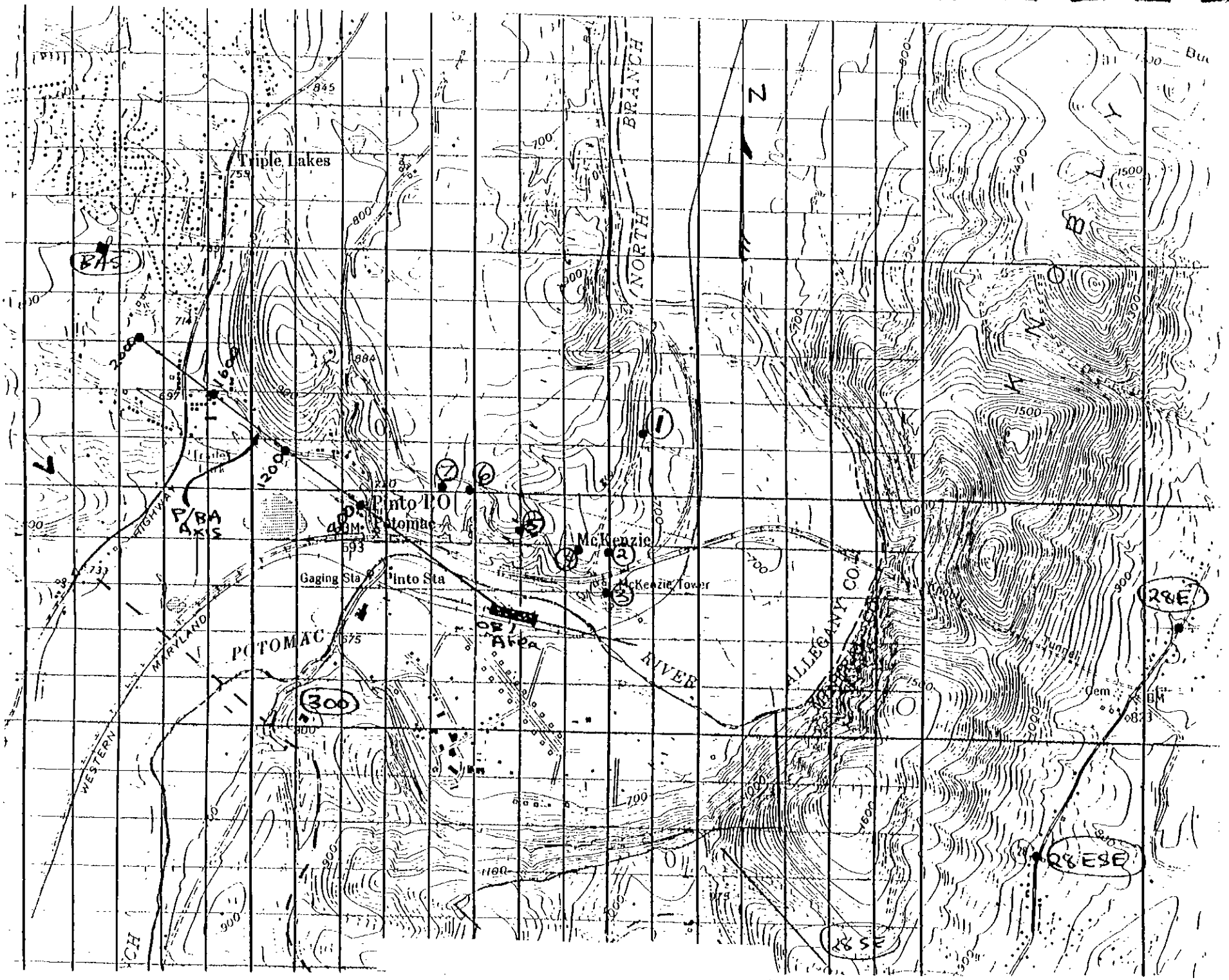
Other Options. Rural terrain was assumed. No building downwash options were exercised, and simple terrain was assumed for the reasons discussed above. The automated distance option was used over the 100 to 2000 meter range for all speed/stability combinations and over the 2000 to 4000 meter range for the worst case stability for each wind speed.

An example of input data and calculations is provided in Appendix A.

3. Emission Concentrations Methodology

For each of the four cases (GASGEN/Lead, XLDB/Lead, HTPB/Hydrogen Chloride, and HTPB/Chlorine), the SCREEN2 model was run for each of the wind speed/stability class combinations identified above (total of 26 runs each, or grand total of 104 runs). For each wind speed and distance, the maximum concentration among the several stability classes was selected. These concentrations were plotted versus wind speed with distance as a parameter to provide a "worst case" concentration estimate. That is, the analysis assumes the worst case stability for each downwind distance and wind speed.

Receptors were selected, based on a knowledge of residences and places of assemblage in the vicinity of the burning ground. Locations of the receptors are shown on Figure 12. The distance and wind direction azimuth for each of the receptors were determined from Figure 12.


Triple Lakes
NORTH BRANCH
POTOMAC RIVER
Pinto P.O.
Potomac
McKenzie
McKenzie Tower
Gaging Sta
Pinto Sta
P/BA AXIS
MARYLAND
WESTERN
ALLEGANY CO.
Gem
28SE
28SSE
28SE
BM
300

To account for slight differences in distance and azimuth from individual burning pads, and to allow for off-axis exposures from winds not directly aligned with the source to target axis, a forty-five degree wind fan was used in developing probabilities of wind blowing towards the receptor. The wind distribution table was entered to determine the probability of wind of given speed and "proper" direction for each receptor. Exposure concentrations were read from the concentration/speed/distance plots and multiplied by the probability of the given wind. All contributions were summed to yield the expected average exposure concentration during periods of actual burning. This value is reported as the GR (gross) value in Table I. The GR concentrations were multiplied by the factor which represents the percentage of overall time that open burning of the given waste maximally occurs. The result is the overall average expected exposure concentration (the NET value in Table I).

4. Lead Emissions from Gas Generator (GASGEN) Propellant

GASGEN propellant has the higher lead content of the two lead containing propellants among the six P/E families, and therefore has the greater instantaneous lead emission rate of the two. Production rate and waste generation of this type of propellant is very small (less than 5000 pounds burned in 1993) so that it is not necessarily the major contributor to the overall average concentration, upon which the NAAQS is based.

Working data, graphs, and tables from which the GASGEN lead data in Table I were derived are provided in Appendix B. Information provided includes a summary of the SCREEN2 output data, plots of the worst-case concentration vs wind speed vs distance data, and calculation tables for integrating the concentration data with wind probability data. For brevity, SCREEN2 output data for integer wind velocities only is shown in the summary table. The plots include the worst-case stability data for the 1.5, 2.5, and 3.5 mps wind speeds as well.

The reduction factor (695) for including the percentage of time that open burning occurs is based on the conservative assumption that 5000 pounds per year are burned at the 200 gm/sec rate all within a single calendar quarter.

5. Lead Emissions from Double Base (DB or XLDB) Propellant

This propellant has approximately one-half as much lead content than GASGEN propellant, but is a much more prevalent formulation in the production/waste stream. Supporting information similar to that for the GASGEN propellant is provided in Appendix C. As can be seen from Table I, while the gross exposure concentrations for XLDB are about half that of GASGEN, the net values are about twice as much, due to the difference in amount burned/time of emission.

6. Emissions from Composite (HTPB) Propellant

Composite propellants are based on ammonium perchlorate (AP) oxidizer. The chlorine in the AP ends up as hydrogen chloride and/or chlorine in the combustion products. Hydrogen chloride is preferentially formed at lower air uptake ratios, and chlorine at higher air uptake ratios. The HTPB composite formulation contains the highest AP level and therefore produces the most HCl/Cl2. SCREEN2 modeling was done for the 60% air uptake case for hydrogen chloride emissions, and the 80% air uptake case for chlorine emissions.

Supporting data for hydrogen chloride is provided in Appendix D, and for chlorine in Appendix E.

Neither hydrogen chloride nor chlorine have NAAQS established. In the absence of such criteria, the predicted concentrations were viewed in conjunction with ACGIH and OSHA exposure limit values. The pertinent limit values are as follows:

Limit Criterion	Chlorine mg/m3	Hydrogen Chloride mg/m3
ACGIH: TWA	1.5	---
ACGIH: STEL	2.9	---
ACGIH: CEILING	---	7.5
OSHA: PEL (ceiling)	3	7

Both OSHA and ACGIH have short term or ceiling limits for Cl2 and HCl. The more restrictive limits are the OSHA ceiling PELs. With these criteria, the average gross concentrations from Table I, or the absolute worst case wind/stability condition concentration from the workup sheets in the Appendices are a more relevant evaluation parameter than the overall average. From Table I, it is seen that target receptor 3 is again the "worst case." The gross concentration for Cl2 is 0.12 mg/m3 and for HCl is 0.21 mg/m3, which are well below the OSHA PELs of 3 and 7 mg/m3 respectively. A review of the individual data in the Appendices reveals that at most, a single case concentration reaches 40-50% of the ceiling value, but for most targets rarely exceeds 20% of the ceiling limit. Thus no known criteria are violated, even on an instantaneous basis.

E. FUTURE WORK

ABL has active discussions underway with Demilitarization and Technology Branch of the US Army Armament, Munitions and Chemical Command and with Sandia National Laboratories for future emission studies of open burning of P/E materials. The Material Test Directorate at the US Army Dugway Proving Ground has obtained funding to modify their "Bang Box" apparatus for pilot scale open burning to develop the capability of quantitatively determining HCl and Cl2 emissions from open burning of composite propellants. Hercules intends to support this effort by supplying propellant samples and technical support to the project technical steering committee. The capabilities of Sandia National Laboratories in the areas of air monitoring and plume tracking are being investigated, and we hope to engage Sandia to make air monitoring measurements during actual open burning operations at ABL. ABL will provide additional details under separate cover.

REFERENCES

(1) Open Burning Products of Combustion Study, Revision 1, transmitted in letter "Resolution of Open Burning Regulatory Issues," dated February 16, 1994

APPENDIX A

SAMPLE CALCULATIONS AND INPUT DATA

SAMPLE CALCULATIONS AND INPUT DATA

Lead emissions from open burning of double base propellant (XLDB) is used throughout as an illustrative example of the approach and calculations used to develop the emissions predictions.

PRODUCTS OF COMBUSTION

The printout of the POLU13 computer run for the subject case is attached to this Appendix. The top section contains the propellant ingredient, chemical formula, ingredient percentage, heat of formation, and density data, which are inputs used by the POLU13 code. Note that there are two columns of data in the subsequent sections of the printout. The left column is a baseline calculation assuming the propellant were burned in the absence of air. The right column is the column of interest, and is for the 60% air uptake basis. Output data of interest are the flame temperature, volume of gases, and grams of combustion product per 100 grams of propellant burned.

DISPERSION MODEL

The printout of the SCREEN2 dispersion model run for the subject case for a wind speed of 3 m/s and stability class C is also attached. The upper portion of the printout contains a printout of the input data used by the model. Input data for the model was discussed in general in the body of this report. Specific calculations for the illustrative example are provided below.

Emission Rate Total grams of lead compounds/100 grams burned x propellant burn rate

From the POLU13 output, the total grams of lead compounds is 0.771 (.655+.002+.001+.113)

Emission Rate = (0.771 grams/100 grams)x(200 grams/sec) = 1.542 grams/sec

Stack Exit Velocity

From the POLU13 output, the volume of gases is 189.5 liters/100 grams (material and air) @ STP
From the POLU13 output, the temperature of the gases is 1400 °K

$$\text{Volumetric gas rate} = 189.5 \frac{\text{Liters}}{100\ \text{gms}} \times \frac{1400\ ^\circ\text{K}}{273\ ^\circ\text{K}} \times \frac{100\ \text{gms total}}{40\ \text{gms matl}} \times 200 \frac{\text{gms}}{\text{sec}} \times 0.001 \frac{\text{m3}}{\text{L}} = 4.86 \frac{\text{m3}}{\text{sec}}$$

$$\text{Stack exit area} = 3.14159 \times \left(\frac{2.574}{2}\right)^2 = 5.20\ \text{m2}$$

Stack exit velocity = gas rate / exit area = 4.86/5.20 = 0.935 m/s

The dispersion model output is the data table at the bottom of the page, which provides the predicted ground level concentration as a function of downwind distance over the range 100 meters to 2000 meters for the illustrative case. The data in this table, along with that for other wind speeds and stability classes are compiled on summary data sheets in the Appendices for each of the propellant cases covered in the study. The data from the illustrative case appears in Appendix C, which is the appendix for XLDB propellant.

ENVELOPE CONCENTRATION CURVES

For each distance and wind speed, the data for the various stability classes were reviewed to determine the worst case stability (highest predicted concentration). These were then plotted as concentration versus wind speed with distance as a parameter on the graphs for each propellant case. The graphs were then used in conjunction with potential receptors and wind frequency data to compute predicted average concentrations at specific receptors. For example, for the illustrative case of 3 m/s and C stability, it represents the worst case over the distance range of 400-600 meters.

CALCULATION OF CONCENTRATION AT SPECIFIC RECEPTORS

As an example, the calculations for Receptor 1 for open burning of XLDB propellant will be worked through. The calculation table for this case is repeated from Appendix C below.

MPH	mps	n1 202.5	n2 225.0	nt	f	C	fC
1	0.45	64	51	115	0.0228	8	0.1829
2	0.89	33	30	63	0.0125	12	0.1503
3	1.34	5	23	28	0.0055	17	0.0946
4	1.79	5	14	19	0.0037	20	0.0755
5	2.24	0	4	4	0.0007	22	0.0174
6	2.68	0	0	0			
7	3.13	0	0	0			
8	3.58	0	0	0			
9	4.02	0	0	0			
							0.5209

Column 1 is the wind speed in miles per hour. Column 2 is the corresponding speed in meters per second. Receptor 1 is located at 930-1030 meters from the burn pads along a wind direction azimuth of 210-222 degrees. The two wind directions used to establish the 45 degree wind fan are 202.5 degrees and 225 degrees respectively. Columns 3 and 4 contain the wind frequency data for these directions and corresponding wind speeds, as taken from Table II. Column 5 is just the sum of Columns 3 and 4. Column 6 is the overall probability of a wind of the given velocity and directions, which is calculated by dividing the Column 5 value by 5029, the total number of wind data observations. Column 7 is the envelope concentration value at the receptor distance for the given wind speed as read from the graphs in Appendix C. Column 8 is the expected concentration contribution from the given wind speed, and is calculated by multiplying Column 6 by Column 7. The sum of the values in Column 8 is the expected average exposure concentration during periods of open burning. This value appears as the GR value in Table I.

The overall average concentration is the sum value of Column 8 multiplied by the factor representing the percentage of the time that open burning of the particular propellant occurs. For the XLDB propellant this factor is 1/140, so that dividing the 0.52 ug/m3 value by 140 results in an average predicted concentration of 0.0037 ug/m3, which appears as the NET value in Table I.

MATERIAL= XLDB/AIR 40/60

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---

	H	C	N	O	ZR	SN	PB	BI	%	Hf	DENSITY
DBTDA	0.024	0.012	0.000	0.004	0.000	0.001	0.000	0.000	0.0002	0.	0.0480
LEAD CITRATE	0.016	0.012	0.000	0.017	0.000	0.000	0.003	0.000	1.300	-689.	0.1300
BTTN	0.007	0.004	0.003	0.009	0.000	0.000	0.000	0.000	9.030	-386.	0.0549
CARBON (GRAPHITE)	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.	0.0816
NC(12.2)	0.008	0.006	0.002	0.010	0.000	0.000	0.000	0.000	0.460	-648.	0.0578
2-NITRODIPHENYLAMINE	0.010	0.012	0.002	0.002	0.000	0.000	0.000	0.000	0.490	83.	0.0494
NITROGLYCERIN - NG	0.005	0.003	0.003	0.009	0.000	0.000	0.000	0.000	16.770	-392.	0.0578
POLY GLYCOL-ADIPATE	0.016	0.010	0.000	0.005	0.000	0.000	0.000	0.000	5.750	-1134.	0.0430
RDX-(S)	0.006	0.003	0.006	0.006	0.000	0.000	0.000	0.000	62.000	72.	0.0656
MNA	0.008	0.007	0.002	0.002	0.000	0.000	0.000	0.000	1.000	-49.	0.0433
N-100	0.006	0.004	0.001	0.001	0.000	0.000	0.000	0.000	1.660	-280.	0.0470
ZIRCONIUM CARBIDE	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	1.000	-436.	0.2430
TRI-PHENYL BISMUTH	0.015	0.018	0.000	0.000	0.000	0.000	0.000	0.001	0.040	255.	0.0573
AIR-(G)	0.000	0.000	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0	0.0000

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

0 (H)	(C)	(N)	(O)	(ZR)	(SN)	(PB)	(BI)
2.959780	1.705117	2.050048	2.884376	0.009687	0.000001	0.003701	0.000091

WT. MATERIAL	100.000	40.000
WT. AIR	0.000	60.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2914.167	2832.770
FLAME TEMP. T(F)	4786.100	4639.585
ENTHALPY KCAL/GFW	-14.181	-5.672

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000 PSI TO 14.70 PSI-

FLAME TEMP. T(K)	1281.144	1400.458
FLAME TEMP. T(F)	1846.659	2061.424
ENTHALPY KCAL/GFW	-85.170	-65.384
T.VOL.GASES--LITERS (GASES AT STP)	94.770	189.499

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-03

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO	33.058	0.849
N2	28.716	146.990
CO2	23.099	73.703
H2O	11.441	26.440
H2	1.703	0.025
ZrO2S	1.192	1.189
Pb	0.763	0.655
Bi2	0.018	0.017
Pb3O4S	0.001	0.002
Bi2O3S	0.000	0.001
Pb2	0.000	0.001
PbO	0.000	0.113

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	N2	CO2	H2O	H2	ZrO2S	Pb	Bi2	Pb3O4S	PbH	Bi2O3S	NH3	Pb2	PbO	PbO2S
PbOS	PbOS	PbO*	PbO*	BiS	PbS	Pb*	Bi	ZrO2	ZrO2S	ZrO2*	N2O5	ZrO	ZrN	ZrNS
ZrN*	ZrCS	ZrC*	CH4	ZrH	N2O4	N2O4S	N2O4*	Zr	Zr	ZrS	Zr*	Zr*	ZrS	C4N2
N2O3	C3O2	NHO3	NO3	C5	C4H10	C4H8	C2N2	C4	O3	NHO2	NO2	C3H8	C2H4O	N2O
CNHO	C3H6	N3	CNO	CN2	CN2	C2O	C2N	C3	H2O2	HO2	N2H4	N2H4*	O2	NHO
C2H6	N2H2	CH2O	NO	NO	CHO	CHO	CNH	C2H4	SnOS	C2H2	CN	CN	C2H	C2
Sn	SnS	H3O	H2O*	H2O*	HO	HO	NH2	O	CH3	NH	CH2	N	CH	C
CS	CS	H	H											

06/22/94
16:37:00

*** SCREEN2 MODEL RUN ***
*** VERSION DATED 92245 ***

XLDB PROPELLANT FOR LEAD EMISSIONS, 60% AIR

SIMPLE TERRAIN INPUTS:

SOURCE TYPE	=	POINT
EMISSION RATE (G/S)	=	1.54200
STACK HEIGHT (M)	=	3.0000
STK INSIDE DIAM (M)	=	2.5700
STK EXIT VELOCITY (M/S)	=	.9350
STK GAS EXIT TEMP (K)	=	1400.0000
AMBIENT AIR TEMP (K)	=	293.0000
RECEPTOR HEIGHT (M)	=	.0000
URBAN/RURAL OPTION	=	RURAL
BUILDING HEIGHT (M)	=	.0000
MIN HORIZ BLDG DIM (M)	=	.0000
MAX HORIZ BLDG DIM (M)	=	.0000

BUOY. FLUX = 11.971 M**4/S**3; MOM. FLUX = .302 M**4/S**2.

*** STABILITY CLASS 3 ONLY ***
*** 10-METER WIND SPEED OF 3.00 M/S ONLY ***

****
*** SCREEN AUTOMATED DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES **

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
100.	.8374E-01	3	3.0	3.0	960.0	45.96	14.55	10.57	NO
200.	14.88	3	3.0	3.0	960.0	45.96	26.46	18.41	NO
300.	30.33	3	3.0	3.0	960.0	45.96	36.72	24.20	NO
400.	35.45	3	3.0	3.0	960.0	45.96	46.54	29.53	NO
500.	35.04	3	3.0	3.0	960.0	45.96	56.32	34.99	NO
600.	32.14	3	3.0	3.0	960.0	45.96	66.03	40.51	NO
700.	28.54	3	3.0	3.0	960.0	45.96	75.64	46.03	NO
800.	25.04	3	3.0	3.0	960.0	45.96	85.16	51.55	NO
900.	21.91	3	3.0	3.0	960.0	45.96	94.60	57.06	NO
1000.	19.21	3	3.0	3.0	960.0	45.96	103.95	62.54	NO
1100.	16.91	3	3.0	3.0	960.0	45.96	113.22	67.99	NO
1200.	14.96	3	3.0	3.0	960.0	45.96	122.42	73.42	NO
1300.	13.31	3	3.0	3.0	960.0	45.96	131.55	78.82	NO
1400.	11.90	3	3.0	3.0	960.0	45.96	140.62	84.20	NO
1500.	10.70	3	3.0	3.0	960.0	45.96	149.63	89.56	NO
1600.	9.669	3	3.0	3.0	960.0	45.96	158.59	94.89	NO
1700.	8.775	3	3.0	3.0	960.0	45.96	167.49	100.20	NO
1800.	7.999	3	3.0	3.0	960.0	45.96	176.34	105.49	NO
1900.	7.321	3	3.0	3.0	960.0	45.96	185.14	110.76	NO
2000.	6.725	3	3.0	3.0	960.0	45.96	193.89	116.00	NO
MAXIMUM 1-HR CONCENTRATION AT OR BEYOND 100. M:									
436.	35.76	3	3.0	3.0	960.0	45.96	50.17	31.54	NO

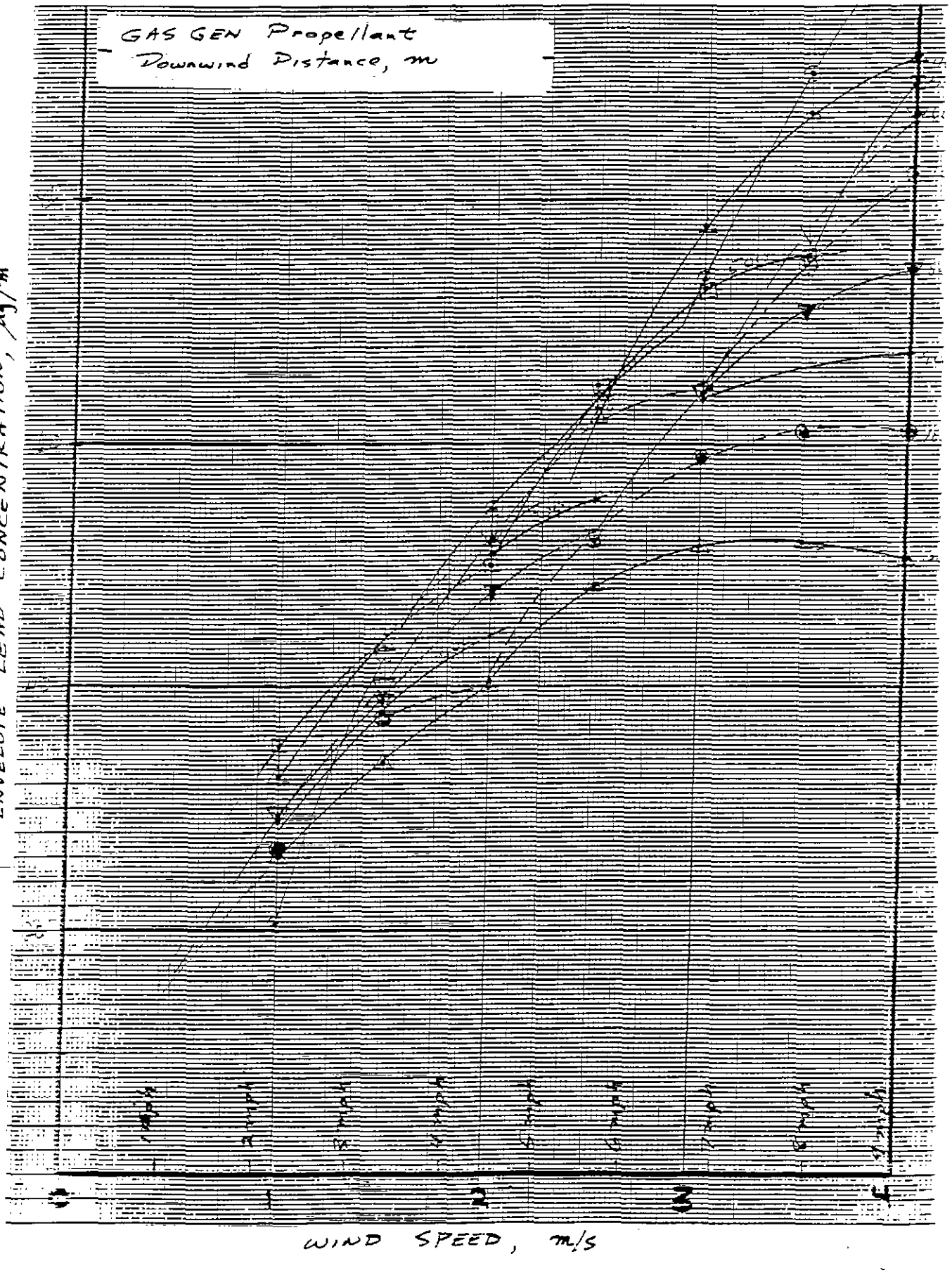
APPENDIX B

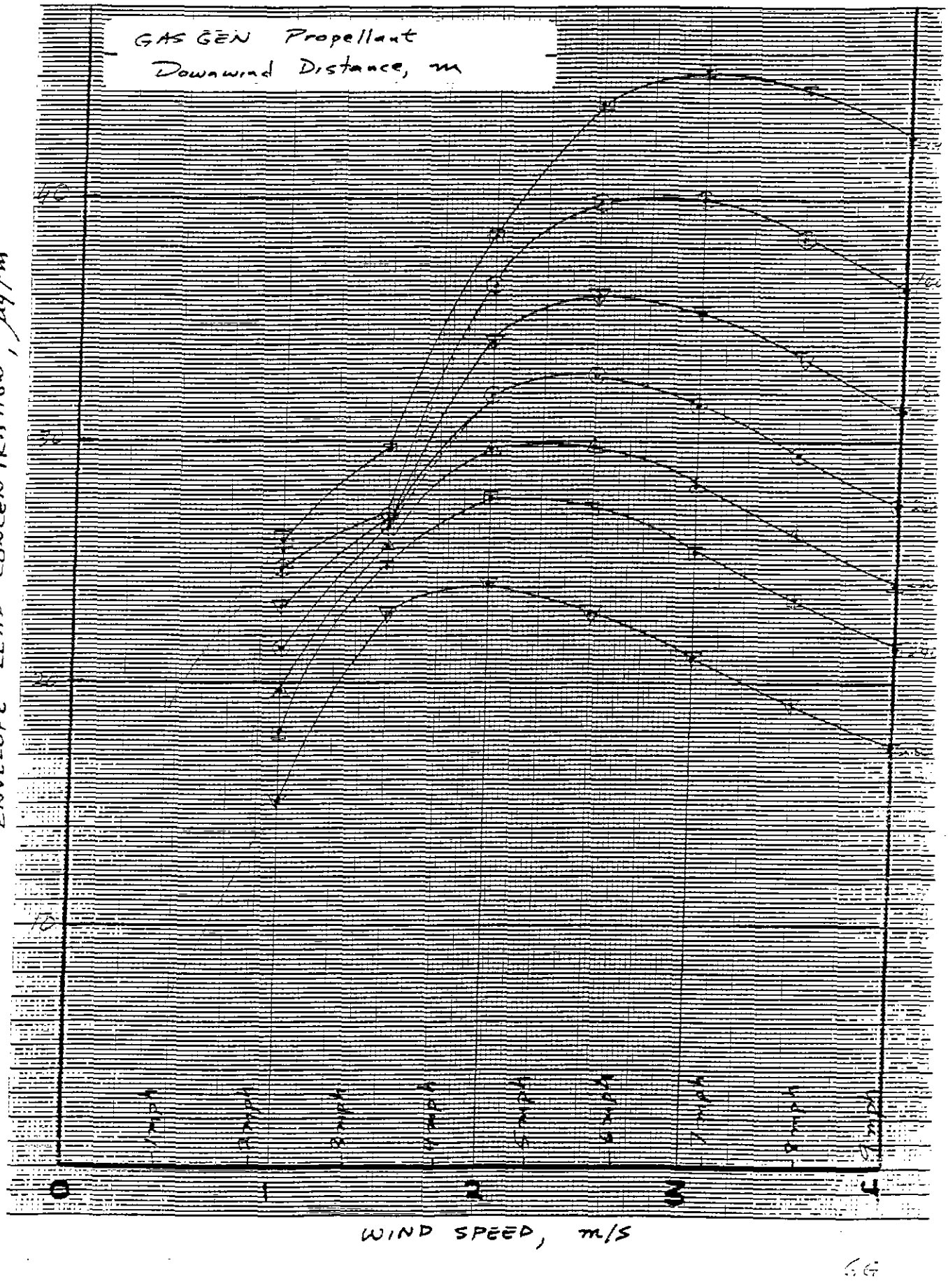
GASGEN PROPELLANT SUPPORTING DATA

LEAD EMISSIONS

PREDICTED LEAD CONCENTRATIONS VERSUS DISTANCE, STABILITY CLASS, & WIND SPEED FOR GASGEN PROPELLANT

CLS	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	MAXIMUM VALUES			
mps	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
200	7.3	45.7	75.5	3.4	26.7	67.6	98.1	2.0	13.4	45.0	89.0	1.3	5.1	15.6	37.5	7.3	45.7	75.5	98.1
300	20.6	54.6	56.6	8.5	46.8	73.7	79.7	4.3	29.8	72.5	103.8	2.3	10.9	34.0	70.6	20.6	54.6	73.7	103.8
400	32.6	43.6	36.1	14.5	51.9	61.5	57.9	6.8	42.8	78.0	91.8	2.8	16.2	48.0	85.7	32.6	51.9	78.0	91.8
500	35.2	29.9	22.2	21.3	49.0	48.1	41.7	10.0	50.0	72.8	75.6	3.4	22.0	57.9	89.6	35.2	50.0	72.8	89.6
600	29.4	19.1	13.4	26.3	42.5	37.2	30.9	13.5	52.1	64.2	61.5	4.2	27.6	63.2	87.0	29.4	52.1	64.2	87.0
700	23.1	12.6	8.6	28.7	35.9	29.2	23.6	17.0	50.8	55.4	50.3	5.1	32.4	64.9	81.2	28.7	50.8	64.9	81.2
800	19.5	8.6	5.8	29.1	30.1	23.4	18.5	20.0	47.8	47.7	41.7	6.1	36.1	64.1	74.4	29.1	47.8	64.1	74.4
900	17.4	6.1	4.1	28.2	25.3	19.0	14.9	22.4	44.2	41.1	34.9	4.1	38.7	61.8	67.6	28.2	44.2	61.8	67.6
1000	15.9	4.7	3.0	26.6	21.4	15.7	12.2	24.2	40.3	35.6	29.7	8.2	40.3	58.7	61.1	26.6	40.3	58.7	61.1
1100	14.7	3.9	2.3	24.6	18.3	13.2	10.2	25.4	36.7	31.1	25.5	9.0	40.3	55.1	55.5	25.4	40.3	55.1	55.5
1200	13.6	3.5	1.8	22.6	15.8	11.2	8.6	26.0	33.3	27.3	22.1	9.7	39.9	51.6	50.6	26.0	39.9	51.6	50.6
1300	12.7	3.2	1.5	20.7	13.7	9.6	7.4	26.1	30.3	24.2	19.4	10.4	39.2	48.3	46.3	26.1	39.2	48.3	46.3
1400	11.9	3.0	1.4	19.0	12.0	8.4	6.4	25.9	27.5	21.5	17.1	11.1	38.4	45.3	42.5	25.9	38.4	45.3	42.5
1500	11.2	2.8	1.3	17.4	10.6	7.3	5.6	25.5	25.1	19.3	15.2	11.7	37.4	42.4	39.2	25.5	37.4	42.4	39.2
1600	10.6	2.7	1.2	16.0	9.4	6.5	4.9	24.8	23.0	17.4	13.6	12.2	36.4	40.0	36.3	24.8	36.4	40.0	36.3
1700	10.1	2.5	1.1	14.9	8.4	5.8	4.4	24.1	21.0	15.7	12.3	12.7	35.3	37.5	33.7	24.1	35.3	37.5	33.7
1800	9.6	2.4	1.1	13.9	7.5	5.2	3.9	23.2	19.3	14.3	11.1	13.2	34.1	35.3	31.3	23.2	34.1	35.3	31.3
1900	9.1	2.3	1.0	13.0	6.8	4.7	3.5	22.4	17.8	13.1	10.1	13.6	33.0	33.3	29.3	22.4	33.0	33.3	29.3
2000	8.7	2.2	1.0	12.2	6.2	4.2	3.2	21.5	16.5	12.0	9.3	13.9	31.9	31.5	27.4	21.5	31.9	31.5	27.4
2100								20.6					30.8	29.8	25.7	20.6	30.8	29.8	25.7
2200								19.7					29.8	28.2	24.2	19.7	29.8	28.2	24.2
2300								18.9					28.7	26.8	22.8	18.9	28.7	26.8	22.8
2400								18.0					27.7	25.5	21.5	18.0	27.7	25.5	21.5
2500								17.3					26.8	24.2	20.4	17.3	26.8	24.2	20.4
2600								16.5					25.9	23.1	19.3	16.5	25.9	23.1	19.3
2700								15.8					25.0	22.0	18.3	15.8	25.0	22.0	18.3
2800								15.2					24.2	21.1	17.4	15.2	24.2	21.1	17.4
2900								14.6					23.4	20.1	16.6	14.6	23.4	20.1	16.6
3000								14.0					22.6	19.3	15.8	14.0	22.6	19.3	15.8
3500								11.6					19.3	15.8	12.8	11.6	19.3	15.8	12.8
4000								9.9					16.7	13.3	10.6	9.9	16.7	13.3	10.6


GAS GEN Propellant
Downwind Distance, m
ENVELOPE LEAD CONCENTRATION, µg/m³
WIND SPEED, m/s
1
2
3
4


GAS GEN Propellant
Downwind Distance, m
ENVELOPE LEAD CONCENTRATION, μg/m³
WIND SPEED, m/s
0
1
2
3
4

46 1512

GG

Receptor 1
Azimuth 210 - 222
Range 930 - 1030

MPH	mps	202.5 n1	225 n2	nt	f	C	fC
1	0.45	64	51	115	0.0228	16	0.3658
2	0.89	33	30	63	0.0125	26	0.3257
3	1.34	5	23	28	0.0055	35	0.1948
4	1.79	5	14	19	0.0037	41	0.1549
5	2.24	0	4	4	0.0007	48	0.0381
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							1.0795

Receptor 2
Azimuth 230 - 245
Range 450 - 550

MPH	mps	225 n1	247.5 n2	nt	f	C	fC
1	0.45	51	60	111	0.0220	21	0.4635
2	0.89	30	47	77	0.0153	32	0.4899
3	1.34	23	37	60	0.0119	41	0.4891
4	1.79	14	21	35	0.0069	49	0.3410
5	2.24	4	10	14	0.0027	58	0.1614
6	2.68	0	3	3	0.0005	67	0.0399
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	1	1	0.0001	90	0.0178
							2.0029

Receptor 3
Azimuth 250 - 260
Range 350 - 500

MPH	mps	247.5 n1	270 n2	nt	f	C	fC
1	0.45	60	105	165	0.0328	21	0.6890
2	0.89	47	166	213	0.0423	32	1.3553
3	1.34	37	199	236	0.0469	41	1.9240
4	1.79	21	125	146	0.0290	49	1.4225
5	2.24	10	64	74	0.0147	58	0.8534
6	2.68	3	37	40	0.0079	67	0.5329
7	3.13	0	16	16	0.0031	80	0.2545
8	3.58	0	8	8	0.0015	92	0.1463
9	4.02	1	7	8	0.0015	98	0.1558
							7.3340

Receptor 4
Azimuth 215 - 235
Range 350 - 450

MPH	mps	1/2S n1	225 n2	nt	f	C	fC
1	0.45	62	51	113	0.0224	21	0.4718
2	0.89	40	30	70	0.0139	32	0.4454
3	1.34	21	23	44	0.0087	41	0.3587
4	1.79	13	14	27	0.0053	49	0.2630
5	2.24	5	4	9	0.0017	58	0.1037
6	2.68	2	0	2	0.0002	67	0.0199
7	3.13	0	0	0	0	80	0
8	3.58	0	0	0	0	92	0
9	4.02	1	0	1	0.0000	98	0.0097
							1.6725

Receptor 5
Azimuth 170 - 200
Range 350

MPH	mps	180 n1	202.5 n2	nt	f	C	fC
1	0.45	37	64	101	0.0200	21	0.4217
2	0.89	17	33	50	0.0099	32	0.3181
3	1.34	1	5	6	0.0011	41	0.0489
4	1.79	1	5	6	0.0011	49	0.0584
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.8472

Receptor 6
Azimuth 150 - 170
Range 500 - 600

MPH	mps	1/2S n1	157.5 n2	nt	f	C	fC
1	0.45	62	56	118	0.0233	21	0.4906
2	0.89	34	12	46	0.0091	32	0.2927
3	1.34	10	2	12	0.0022	42	0.0960
4	1.79	1	1	2	0.0003	48	0.0190
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.8984

Receptor 7
Azimuth 145 – 155
Range 600 – 700

MPH	mps	135 n1	157.5 n2	nt	f	C	fC
1	0.45	86	56	142	0.0282	18	0.5082
2	0.89	51	12	63	0.0125	28	0.3507
3	1.34	18	2	20	0.0039	37	0.1471
4	1.79	1	1	2	0.0003	48	0.0190
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							1.0252

Receptor: Bel Air School
Azimuth 130
Range 2250

MPH	mps	n1	135 n2	nt	f	C	fC
1	0.45	0	86	86	0.0171	10	0.1624
2	0.89	0	51	51	0.0101	18	0.1825
3	1.34	0	18	18	0.0035	24	0.0859
4	1.79	0	1	1	0.0001	29	0.0056
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.4365

Receptor 300
Azimuth 67.5 – 200
Range 950

MPH	mps	67.5 n1	67.5 n2	nt	f	C	fC
1	0.45	13	13	26	0.0051	16	0.0827
2	0.89	7	7	14	0.0027	26	0.0723
3	1.34	4	4	8	0.0015	35	0.0556
4	1.79	3	3	6	0.0011	41	0.0489
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.2596

Receptor 28
Azimuth 270
Range 2800

MPH	mps	n1	270 n2	nt	f	C	fC
1	0.45	0	105	105	0.0208	7	0.1461
2	0.89	0	166	166	0.0330	14	0.4621
3	1.34	0	199	199	0.0395	21	0.8309
4	1.79	0	125	125	0.0248	24	0.5965
5	2.24	0	64	64	0.0127	24	0.3105
6	2.68	0	37	37	0.0073	23	0.1655
7	3.13	0	16	16	0.0031	21	0.0655
8	3.58	0	8	8	0.0015	19	0.0295
9	4.02	0	7	7	0.0013	18	0.0243
							2.6313

Receptor 28
Azimuth 292.
Range 2500

MPH	mps	n1	292.5 n2	nt	f	C	fC
1	0.45	0	37	37	0.0073	9	0.0662
2	0.89	0	41	41	0.0081	16	0.1304
3	1.34	0	35	35	0.0069	23	0.1600
4	1.79	0	15	15	0.0029	26	0.0775
5	2.24	0	6	6	0.0011	28	0.0334
6	2.68	0	5	5	0.0009	27	0.0268
7	3.13	0	2	2	0.0003	25	0.0099
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.5044

Receptor 28
Azimuth 315
Range 2800

MPH	mps	n1	315 n2	nt	f	C	fC
1	0.45	0	108	108	0.0214	7	0.1503
2	0.89	0	72	72	0.0143	14	0.2004
3	1.34	0	52	52	0.0103	21	0.2171
4	1.79	0	23	23	0.0045	24	0.1097
5	2.24	0	8	8	0.0015	24	0.0388
6	2.68	0	2	2	0.0003	23	0.0089
7	3.13	0	1	1	0.0001	21	0.0040
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.7295

Receptor: Pinto – Bel Air
Azimuth 120 – 130
Range 800

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	16	0.3722
2	0.89	17	51	68	0.0135	26	0.3515
3	1.34	3	18	21	0.0041	36	0.1503
4	1.79	0	1	1	0.0001	44	0.0087
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.8828

Receptor: Pinto – Bel Air
Azimuth 120 – 130
Range 1200

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	14	0.3257
2	0.89	17	51	68	0.0135	24	0.3245
3	1.34	3	18	21	0.0041	32	0.1336
4	1.79	0	1	1	0.0001	38	0.0075
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.7914

Receptor: Pinto – Bel Air
Azimuth 120 – 130
Range 1600

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	19	0.4420
2	0.89	17	51	68	0.0135	24	0.3245
3	1.34	3	18	21	0.0041	27	0.1127
4	1.79	0	1	1	0.0001	34	0.0067
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.8860

Receptor: Pinto – Bel Air
Azimuth 120 – 130
Range 2000

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	15	0.3489
2	0.89	17	51	68	0.0135	21	0.2839
3	1.34	3	18	21	0.0041	25	0.1043
4	1.79	0	1	1	0.0001	30	0.0059
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.7432

APPENDIX C

XLDB PROPELLANT SUPPORTING DATA

LEAD EMISSIONS

PREDICTED LEAD CONCENTRATIONS VERSUS DISTANCE, STABILITY CLASS, & WIND SPEED FOR XLDB PROPELLANT

CLS	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	MAXIMUM VALUES			
mps	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
200	2.0	17.9	35.0	0.8	8.6	26.9	44.2	0.5	3.7	14.9	34.1	0.3	1.2	4.1	11.2	2.0	17.9	35.0	44.2
300	7.9	26.1	29.4	3.2	19.5	34.8	40.3	1.7	11.3	30.3	47.5	1.0	4.1	12.7	27.7	7.9	26.1	34.8	47.5
400	14.2	22.7	19.7	5.4	23.6	31.0	30.7	2.5	17.1	35.4	45.0	1.1	6.0	18.6	35.9	14.2	23.6	35.4	45.0
500	17.1	16.3	12.4	8.4	23.8	25.3	22.7	3.7	21.3	35.0	38.7	1.4	8.3	23.5	39.8	17.1	23.8	35.0	39.8
600	15.4	10.7	7.6	11.0	21.6	20.1	17.1	5.0	23.4	32.1	32.4	1.6	10.6	26.9	40.3	15.4	23.4	32.1	40.3
700	12.7	7.1	4.9	12.7	18.8	16.0	13.1	6.5	23.8	28.5	27.0	1.9	12.7	28.7	39.0	12.7	23.8	28.7	39.0
800	11.0	4.9	3.3	13.5	16.1	12.9	10.4	7.9	23.1	25.0	22.6	2.3	14.6	29.3	36.7	13.5	23.1	29.3	36.7
900	9.9	3.5	2.3	13.5	13.7	10.6	8.4	9.1	21.9	21.9	19.1	2.7	16.1	29.0	34.0	13.5	21.9	29.0	34.0
1000	9.0	2.6	1.7	13.1	11.7	8.8	6.9	10.1	20.4	19.2	16.4	3.1	17.2	28.2	31.3	13.1	20.4	28.2	31.3
1100	8.3	2.2	1.3	12.4	10.1	7.4	5.8	10.9	18.9	16.9	14.1	3.4	17.5	26.9	28.7	12.4	18.9	26.9	28.7
1200	7.7	2.0	1.0	11.6	8.7	6.3	4.9	11.4	17.4	14.9	12.3	3.6	17.7	25.5	26.4	11.6	17.7	25.5	26.4
1300	7.2	1.8	0.9	10.8	7.6	5.4	4.2	11.8	16.0	13.3	10.8	3.9	17.6	24.2	24.4	11.8	17.6	24.2	24.4
1400	6.8	1.7	0.8	10.1	6.7	4.7	3.6	11.9	14.7	11.9	9.6	4.2	17.5	22.9	22.5	11.9	17.5	22.9	22.5
1500	6.4	1.6	0.7	9.3	5.9	4.2	3.2	11.9	13.5	10.7	8.5	4.5	17.3	21.6	20.9	11.9	17.3	21.6	20.9
1600	6.0	1.5	0.7	8.7	5.3	3.7	2.8	11.8	12.4	9.7	7.7	4.7	17.0	20.5	19.4	11.8	17.0	20.5	19.4
1700	5.7	1.4	0.6	8.1	4.7	3.3	2.5	11.6	11.4	8.8	6.9	4.9	16.7	19.4	18.1	11.6	16.7	19.4	18.1
1800	5.5	1.4	0.6	7.7	4.3	2.9	2.2	11.4	10.6	8.0	6.3	5.1	16.3	18.4	16.9	11.4	16.3	18.4	16.9
1900	5.2	1.3	0.6	7.2	3.8	2.6	2.0	11.1	9.8	7.3	5.7	5.3	15.9	17.4	15.9	11.1	15.9	17.4	15.9
2000	5.0	1.3	0.6	6.8	3.5	2.4	1.8	10.7	9.1	6.7	5.2	5.5	15.5	16.5	14.9	10.7	15.5	16.5	14.9
2100								10.4				5.7	15.1	15.7	14.0	10.4	15.1	15.7	14.0
2200								10.0				5.9	14.7	15.0	13.2	10.0	14.7	15.0	13.2
2300								9.7				6.0	14.3	14.3	12.5	9.7	14.3	14.3	12.5
2400								9.3				6.1	13.9	13.6	11.8	9.3	13.9	13.6	11.8
2500								9.0				6.2	13.5	13.0	11.2	9.0	13.5	13.0	11.2
2600								8.7				6.3	13.1	12.4	10.6	8.7	13.1	12.4	10.6
2700								8.3				6.4	12.7	11.9	10.1	8.3	12.7	11.9	10.1
2800								8.0				6.5	12.3	11.4	9.6	8.0	12.3	11.4	9.6
2900								7.8				6.5	12.0	10.9	9.2	7.8	12.0	10.9	9.2
3000								7.5				6.6	11.6	10.5	8.8	7.5	11.6	10.5	8.8
3500								6.3				6.7	10.1	8.7	7.1	6.7	10.1	8.7	7.1
4000								5.5				6.6	8.8	7.3	5.9	6.6	8.8	7.3	5.9

XLDB Propellant

Downwind Distance, m

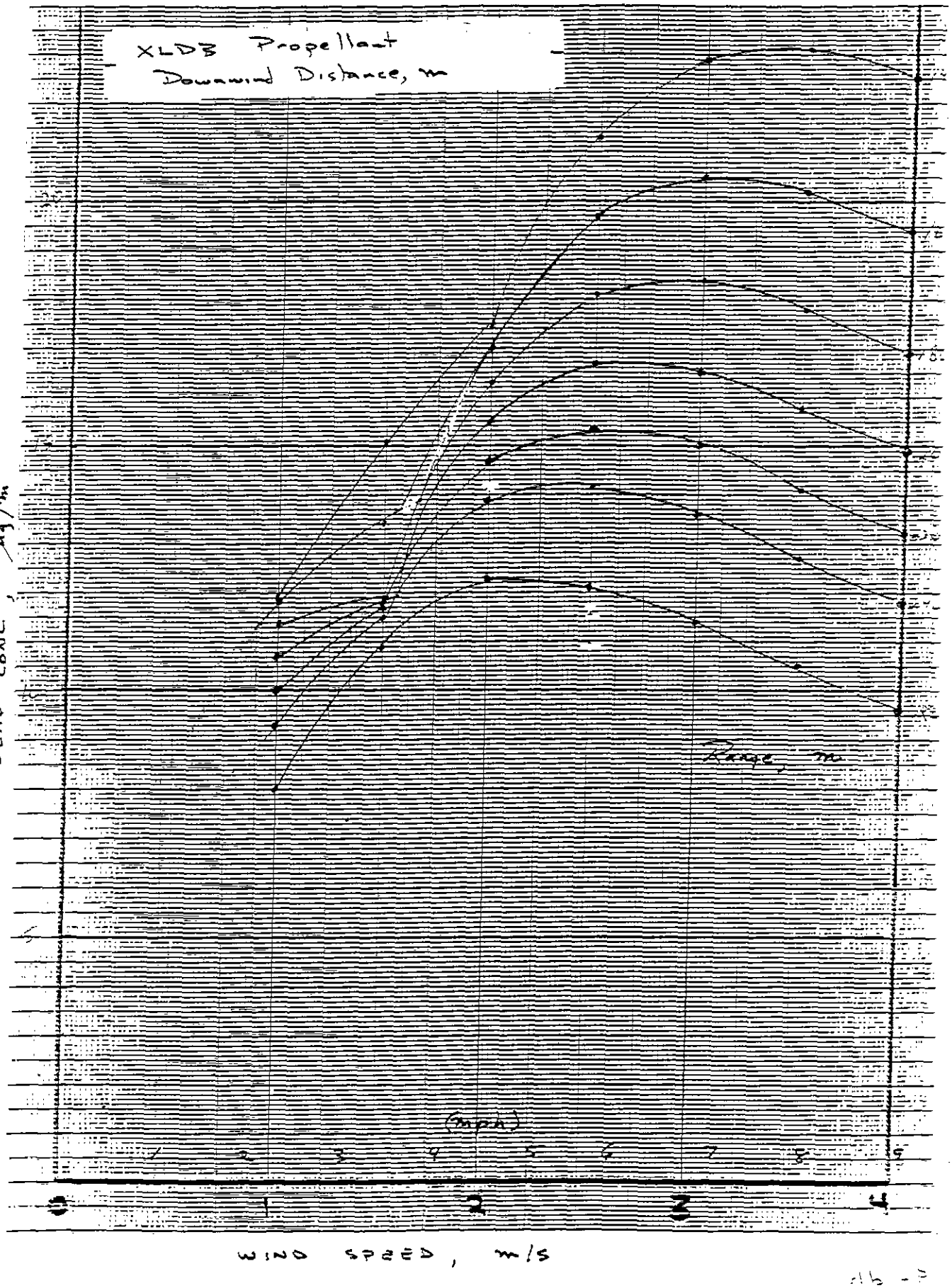
ENVELOPE LEAD CONC, $\mu g/m^3$

Range, m

(max)

WIND SPEED, m/s

46 1512


XLDB Propellant
Downwind Distance, m
ENVELOPE LEAD CONC, mg/m3
Range, m
(mph)
WIND SPEED, m/s

Receptor 1
Azimuth 210 - 222
Range 930 - 1030

MPH	mps	202.5 n1	225 n2	nt	f	C	fC
1	0.45	64	51	115	0.0228	8	0.1829
2	0.89	33	30	63	0.0125	12	0.1503
3	1.34	5	23	28	0.0055	17	0.0946
4	1.79	5	14	19	0.0037	20	0.0755
5	2.24	0	4	4	0.0007	22	0.0174
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.5209

Receptor 2
Azimuth 230 - 245
Range 450 - 550

MPH	mps	225 n1	247.5 n2	nt	f	C	fC
1	0.45	51	60	111	0.0220	12	0.2648
2	0.89	30	47	77	0.0153	17	0.2602
3	1.34	23	37	60	0.0119	18	0.2147
4	1.79	14	21	35	0.0069	22	0.1531
5	2.24	4	10	14	0.0027	27	0.0751
6	2.68	0	3	3	0.0005	31	0.0184
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	1	1	0.0001	43	0.0085
							0.9952

Receptor 3
Azimuth 250 - 260
Range 350 - 500

MPH	mps	247.5 n1	270 n2	nt	f	C	fC
1	0.45	60	105	165	0.0328	12	0.3937
2	0.89	47	166	213	0.0423	17	0.7200
3	1.34	37	199	236	0.0469	18	0.8447
4	1.79	21	125	146	0.0290	22	0.6386
5	2.24	10	64	74	0.0147	27	0.3972
6	2.68	3	37	40	0.0079	31	0.2465
7	3.13	0	16	16	0.0031	36	0.1145
8	3.58	0	8	8	0.0015	42	0.0668
9	4.02	1	7	8	0.0015	43	0.0684
							3.4907

Receptor 4
Azimuth 215 - 235
Range 350 - 450

MPH	mps	1/2S n1	225 n2	nt	f	C	fC
1	0.45	62	51	113	0.0224	12	0.2696
2	0.89	40	30	70	0.0139	15	0.2087
3	1.34	21	23	44	0.0087	19	0.1662
4	1.79	13	14	27	0.0053	22	0.1181
5	2.24	5	4	9	0.0017	27	0.0483
6	2.68	2	0	2	0.0002	31	0.0092
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	1	0	1	0.0000	43	0.0042
							0.8246

Receptor 5
Azimuth 170 - 200
Range 350

MPH	mps	180 n1	202.5 n2	nt	f	C	fC
1	0.45	37	64	101	0.0200	8	0.1606
2	0.89	17	33	50	0.0099	11	0.1093
3	1.34	1	5	6	0.0011	17	0.0202
4	1.79	1	5	6	0.0011	22	0.0262
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.3165

Receptor 6
Azimuth 150 - 170
Range 500 - 600

MPH	mps	1/2S n1	157.5 n2	nt	f	C	fC
1	0.45	62	56	118	0.0233	14	0.3271
2	0.89	34	12	46	0.0091	16	0.1463
3	1.34	10	2	12	0.0022	19	0.0434
4	1.79	1	1	2	0.0003	22	0.0087
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.5256

xldb

Receptor 7
Azimuth 145 – 155
Range 600 – 700

MPH	mps	135 n1	157.5 n2	nt	f	C	fC
1	0.45	86	56	142	0.0282	11	0.3105
2	0.89	51	12	63	0.0125	14	0.1753
3	1.34	18	2	20	0.0039	18	0.0715
4	1.79	1	1	2	0.0003	22	0.0087
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.5663

Receptor: Bel Air School
Azimuth 130
Range 2250

MPH	mps	n1	135 n2	nt	f	C	fC
1	0.45	0	86	86	0.0171	8	0.1368
2	0.89	0	51	51	0.0101	10	0.1014
3	1.34	0	18	18	0.0035	11	0.0393
4	1.79	0	1	1	0.0001	14	0.0027
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.2803

Receptor 300
Azimuth 67.5 – 200
Range 950

MPH	mps	67.5 n1	67.5 n2	nt	f	C	fC
1	0.45	13	13	26	0.0051	8	0.0413
2	0.89	7	7	14	0.0027	12	0.0334
3	1.34	4	4	8	0.0015	17	0.0270
4	1.79	3	3	6	0.0011	20	0.0238
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.1256

Receptor 28
Azimuth 270
Range 2800

MPH	mps	n1	270 n2	nt	f	C	fC
1	0.45	0	105	105	0.0208	4	0.0835
2	0.89	0	166	166	0.0330	7	0.2310
3	1.34	0	199	199	0.0395	10	0.3957
4	1.79	0	125	125	0.0248	12	0.2982
5	2.24	0	64	64	0.0127	12	0.1527
6	2.68	0	37	37	0.0073	12	0.0882
7	3.13	0	16	16	0.0031	11	0.0349
8	3.58	0	8	8	0.0015	11	0.0167
9	4.02	0	7	7	0.0013	10	0.0132
							1.3144

Receptor 28
Azimuth 292.
Range 2500

MPH	mps	n1	292.5 n2	nt	f	C	fC
1	0.45	0	37	37	0.0073	5	0.0367
2	0.89	0	41	41	0.0081	8	0.0652
3	1.34	0	35	35	0.0069	11	0.0765
4	1.79	0	15	15	0.0029	13	0.0387
5	2.24	0	6	6	0.0011	14	0.0167
6	2.68	0	5	5	0.0009	14	0.0139
7	3.13	0	2	2	0.0003	13	0.0053
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.2532

Receptor 28
Azimuth 315
Range 2800

MPH	mps	n1	315 n2	nt	f	C	fC
1	0.45	0	108	108	0.0214	2	0.0429
2	0.89	0	72	72	0.0143	7	0.1002
3	1.34	0	52	52	0.0103	11	0.1137
4	1.79	0	23	23	0.0045	12	0.0548
5	2.24	0	8	8	0.0015	12	0.0190
6	2.68	0	2	2	0.0003	12	0.0047
7	3.13	0	1	1	0.0001	11	0.0021
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.3378

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 800

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	7	0.1628
2	0.89	17	51	68	0.0135	13	0.1757
3	1.34	3	18	21	0.0041	17	0.0709
4	1.79	0	1	1	0.0001	22	0.0043
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.4139

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 1200

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	4	0.0930
2	0.89	17	51	68	0.0135	10	0.1352
3	1.34	3	18	21	0.0041	16	0.0668
4	1.79	0	1	1	0.0001	18	0.0035
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.2986

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 1600

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	8	0.1861
2	0.89	17	51	68	0.0135	12	0.1554
3	1.34	3	18	21	0.0041	13	0.0542
4	1.79	0	1	1	0.0001	16	0.0030
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.3989

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 2000

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	8	0.1861
2	0.89	17	51	68	0.0135	11	0.1419
3	1.34	3	18	21	0.0041	12	0.0480
4	1.79	0	1	1	0.0001	15	0.0028
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							0.3790

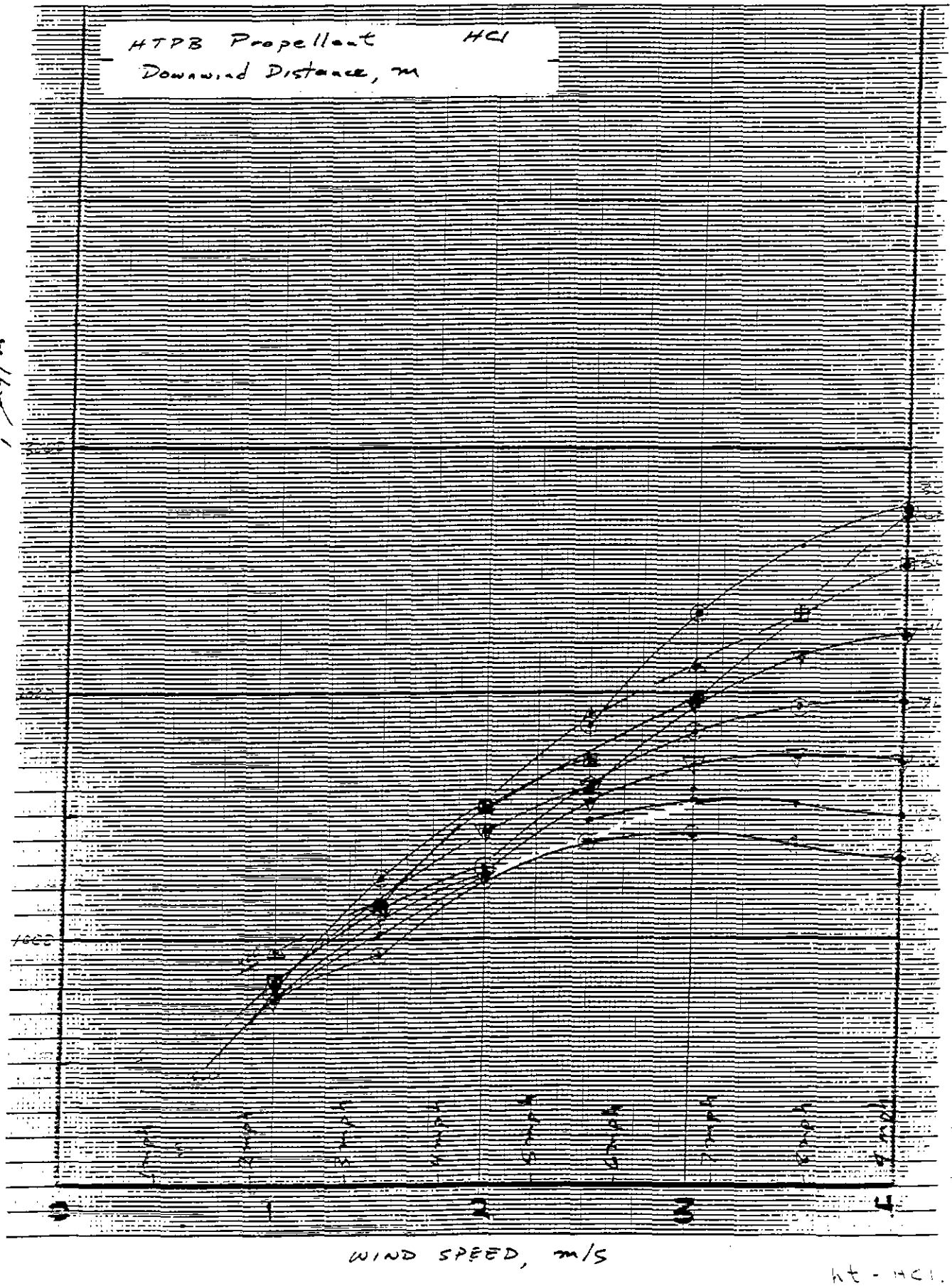
APPENDIX D

HTPB PROPELLANT SUPPORTING DATA

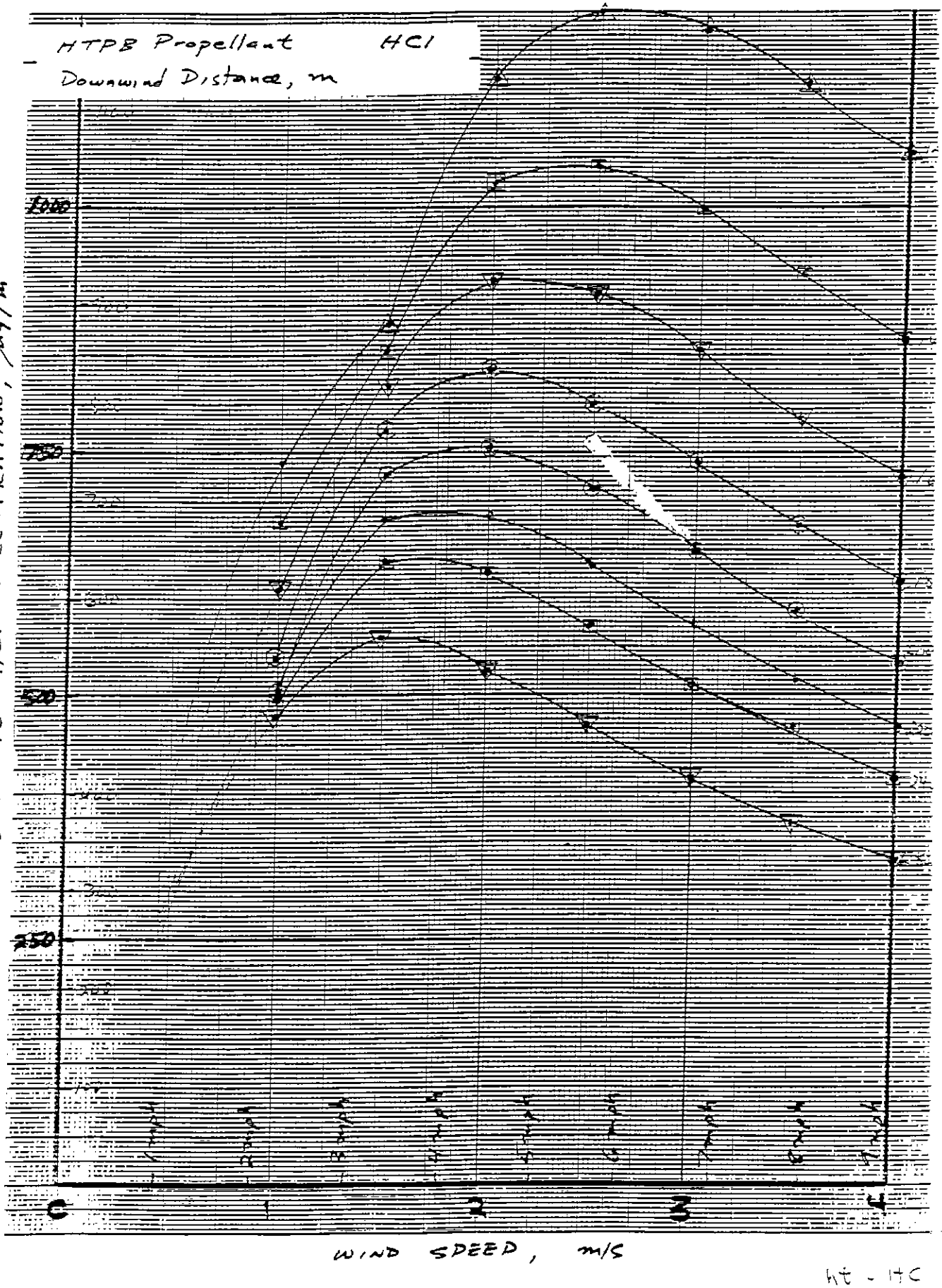
HYDROGEN CHLORIDE EMISSIONS

PREDICTED HCl CONCENTRATIONS VERSUS DISTANCE, STABILITY CLASS, & WIND SPEED FOR HTPB PROPELLANT

CLS	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	MAXIMUM VALUES			
mps	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
200	384	1530	1918	188	1183	2197	2612	107	718	1947	3079	64	275	850	1849	384	1530	2197	3079
300	788	1335	1185	399	1509	1842	1757	197	1250	2318	2753	86	506	1494	2641	788	1509	2318	2753
400	948	915	699	612	1388	1357	1177	322	1512	2099	2129	113	748	1857	2725	948	1512	2099	2725
500	829	581	414	774	1154	987	811	459	1532	1754	1626	148	960	1981	2525	829	1532	1981	2525
600	606	357	246	828	927	735	586	583	1431	1440	1263	189	1116	1952	2243	828	1431	1952	2243
700	441	231	157	809	744	563	441	677	1287	1185	1003	234	1210	1844	1963	809	1287	1844	1963
800	358	157	106	752	603	442	343	737	1140	985	813	281	1253	1704	1713	752	1253	1704	1713
900	316	111	74	682	496	356	274	767	1004	829	672	328	1257	1558	1499	767	1257	1558	1499
1000	288	84	54	610	413	292	224	773	885	705	564	374	1235	1418	1317	773	1235	1418	1317
1100	265	70	41	543	349	244	186	762	782	607	481	400	1185	1293	1174	762	1185	1293	1174
1200	246	62	33	483	298	206	157	740	694	527	414	424	1131	1182	1054	740	1131	1182	1054
1300	230	58	27	431	257	177	134	711	619	462	361	444	1077	1084	952	711	1077	1084	952
1400	215	54	24	386	224	153	116	678	555	409	318	460	1024	998	864	678	1024	998	864
1500	203	51	23	347	196	134	102	643	500	364	282	473	973	952	789	643	973	952	789
1600	192	48	21	315	174	118	89	609	452	326	251	484	924	854	724	609	924	854	724
1700	182	46	20	287	155	105	79	574	411	294	226	492	877	794	667	574	877	794	667
1800	173	43	19	264	139	94	71	542	375	266	204	497	834	740	617	542	834	740	617
1900	165	41	18	245	125	85	64	511	343	243	186	501	793	691	573	511	793	691	573
2000	158	40	18	228	113	76	58	481	316	222	170	503	754	648	533	503	754	648	533
2100												503	719	608	498	503	719	608	498
2200												502	685	573	467	502	685	573	467
2300												500	654	540	438	500	654	540	438
2400												497	625	511	413	497	625	511	413
2500												493	597	483	389	493	597	483	389
2600												488	572	459	368	488	572	459	368
2700												483	548	436	348	483	548	436	348
2800												477	525	415	331	477	525	415	331
2900												471	504	395	314	471	504	395	314
3000												465	484	377	299	465	484	377	299
3500												429	402	306	240	429	402	306	240
4000												394	341	254	198	394	341	254	198


HTPB Propellant HCl
Downwind Distance, m
ENVELOPE HCl CONCENTRATION, µg/m³
WIND SPEED, m/s
0
1
2
3
4

ht - HCl.


HTPB Propellant HCl
Downwind Distance, m
1000
750
500
250
0
1
2
3
4
ENVELOPE HCl CONCENTRATION, mg/m3
WIND SPEED, m/s

46 1512

ht - HC

Receptor 1
Azimuth 210 - 222
Range 930 - 1030

MPH	mps	202.5 n1	225 n2	nt	f	C	fC
1	0.45	64	51	115	0.0228	200	4.5734
2	0.89	33	30	63	0.0125	700	8.7691
3	1.34	5	23	28	0.0055	950	5.2893
4	1.79	5	14	19	0.0037	1160	4.3825
5	2.24	0	4	4	0.0007	1350	1.0737
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							24.088

Receptor 2
Azimuth 230 - 245
Range 450 - 550

MPH	mps	225 n1	247.5 n2	nt	f	C	fC
1	0.45	51	60	111	0.0220	680	15.008
2	0.89	30	47	77	0.0153	900	13.780
3	1.34	23	37	60	0.0119	1100	13.123
4	1.79	14	21	35	0.0069	1400	9.7434
5	2.24	4	10	14	0.0027	1650	4.5933
6	2.68	0	3	3	0.0005	1900	1.1334
7	3.13	0	0	0	0	2200	0
8	3.58	0	0	0	0	2400	0
9	4.02	0	1	1	0.0001	2700	0.5368
							57.920

Receptor 3
Azimuth 250 - 260
Range 350 - 500

MPH	mps	247.5 n1	270 n2	nt	f	C	fC
1	0.45	60	105	165	0.0328	680	22.310
2	0.89	47	166	213	0.0423	900	38.118
3	1.34	37	199	236	0.0469	1100	51.620
4	1.79	21	125	146	0.0290	1400	40.644
5	2.24	10	64	74	0.0147	1700	25.014
6	2.68	3	37	40	0.0079	2000	15.907
7	3.13	0	16	16	0.0031	2300	7.3175
8	3.58	0	8	8	0.0015	2500	3.9769
9	4.02	1	7	8	0.0015	2750	4.3746
							209.28

Receptor 4
Azimuth 215 - 235
Range 350 - 450

MPH	mps	1/2S n1	225 n2	nt	f	C	fC
1	0.45	62	51	113	0.0224	680	15.279
2	0.89	40	30	70	0.0139	900	12.527
3	1.34	21	23	44	0.0087	1100	9.6241
4	1.79	13	14	27	0.0053	1400	7.5164
5	2.24	5	4	9	0.0017	1700	3.0423
6	2.68	2	0	2	0.0002	2000	0.5965
7	3.13	0	0	0	0	2300	0
8	3.58	0	0	0	0	2500	0
9	4.02	1	0	1	0.0000	2750	0.2734
							48.859

Receptor 5
Azimuth 170 - 200
Range 350

MPH	mps	180 n1	202.5 n2	nt	f	C	fC
1	0.45	37	64	101	0.0200	680	13.656
2	0.89	17	33	50	0.0099	900	8.9481
3	1.34	1	5	6	0.0011	1100	1.3123
4	1.79	1	5	6	0.0011	1450	1.7299
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							25.647

Receptor 6
Azimuth 150 - 170
Range 500 - 600

MPH	mps	1/2S n1	157.5 n2	nt	f	C	fC
1	0.45	62	56	118	0.0233	500	11.682
2	0.89	34	12	46	0.0091	750	6.8602
3	1.34	10	2	12	0.0022	1050	2.4010
4	1.79	1	1	2	0.0003	1350	0.5368
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							21.480

ht hcl

Receptor 7
Azimuth 145 - 155
Range 600 - 700

MPH	mps	135 n1	157.5 n2	nt	f	C	fC
1	0.45	86	56	142	0.0282	400	11.294
2	0.89	51	12	63	0.0125	750	9.3955
3	1.34	18	2	20	0.0039	1050	4.1757
4	1.79	1	1	2	0.0003	1250	0.4971
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							25.362

Receptor: Bel Air School
Azimuth 130
Range 2250

MPH	mps	n1	135 n2	nt	f	C	fC
1	0.45	0	86	86	0.0171	280	4.7882
2	0.89	0	51	51	0.0101	480	4.8677
3	1.34	0	18	18	0.0035	650	2.3265
4	1.79	0	1	1	0.0001	690	0.1372
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							12.119

Receptor 300
Azimuth 67.5 - 200
Range 950

MPH	mps	67.5 n1	67.5 n2	nt	f	C	fC
1	0.45	13	13	26	0.0051	200	1.0340
2	0.89	7	7	14	0.0027	700	1.9486
3	1.34	4	4	8	0.0015	950	1.5112
4	1.79	3	3	6	0.0011	1160	1.3839
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							5.8779

Receptor 28
Azimuth 270
Range 2800

MPH	mps	n1	270 n2	nt	f	C	fC
1	0.45	0	105	105	0.0208	250	5.2197
2	0.89	0	166	166	0.0330	450	14.853
3	1.34	0	199	199	0.0395	550	21.763
4	1.79	0	125	125	0.0248	550	13.670
5	2.24	0	64	64	0.0127	500	6.3630
6	2.68	0	37	37	0.0073	450	3.3107
7	3.13	0	16	16	0.0031	400	1.2726
8	3.58	0	8	8	0.0015	365	0.5806
9	4.02	0	7	7	0.0013	330	0.4593
							67.494

Receptor 28
Azimuth 292.
Range 2500

MPH	mps	n1	292.5 n2	nt	f	C	fC
1	0.45	0	37	37	0.0073	275	2.0232
2	0.89	0	41	41	0.0081	475	3.8725
3	1.34	0	35	35	0.0069	600	4.1757
4	1.79	0	15	15	0.0029	640	1.9089
5	2.24	0	6	6	0.0011	600	0.7158
6	2.68	0	5	5	0.0009	550	0.5468
7	3.13	0	2	2	0.0003	500	0.1988
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							13.442

Receptor 28
Azimuth 315
Range 2800

MPH	mps	n1	315 n2	nt	f	C	fC
1	0.45	0	108	108	0.0214	250	5.3688
2	0.89	0	72	72	0.0143	450	6.4426
3	1.34	0	52	52	0.0103	550	5.6870
4	1.79	0	23	23	0.0045	550	2.5154
5	2.24	0	8	8	0.0015	500	0.7953
6	2.68	0	2	2	0.0003	450	0.1789
7	3.13	0	1	1	0.0001	400	0.0795
8	3.58	0	0	0	0	365	0
9	4.02	0	0	0	0	330	0
							21.067

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Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 800

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	300	6.9795
2	0.89	17	51	68	0.0135	700	9.4651
3	1.34	3	18	21	0.0041	1000	4.1757
4	1.79	0	1	1	0.0001	1200	0.2386
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							20.859

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 1200

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	350	8.1427
2	0.89	17	51	68	0.0135	700	9.4651
3	1.34	3	18	21	0.0041	850	3.5494
4	1.79	0	1	1	0.0001	1060	0.2107
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							21.368

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 1600

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	300	6.9795
2	0.89	17	51	68	0.0135	560	7.5720
3	1.34	3	18	21	0.0041	770	3.2153
4	1.79	0	1	1	0.0001	900	0.1789
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							17.945

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 2000

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	280	6.5142
2	0.89	17	51	68	0.0135	480	6.4903
3	1.34	3	18	21	0.0041	670	2.7977
4	1.79	0	1	1	0.0001	760	0.1511
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							15.953

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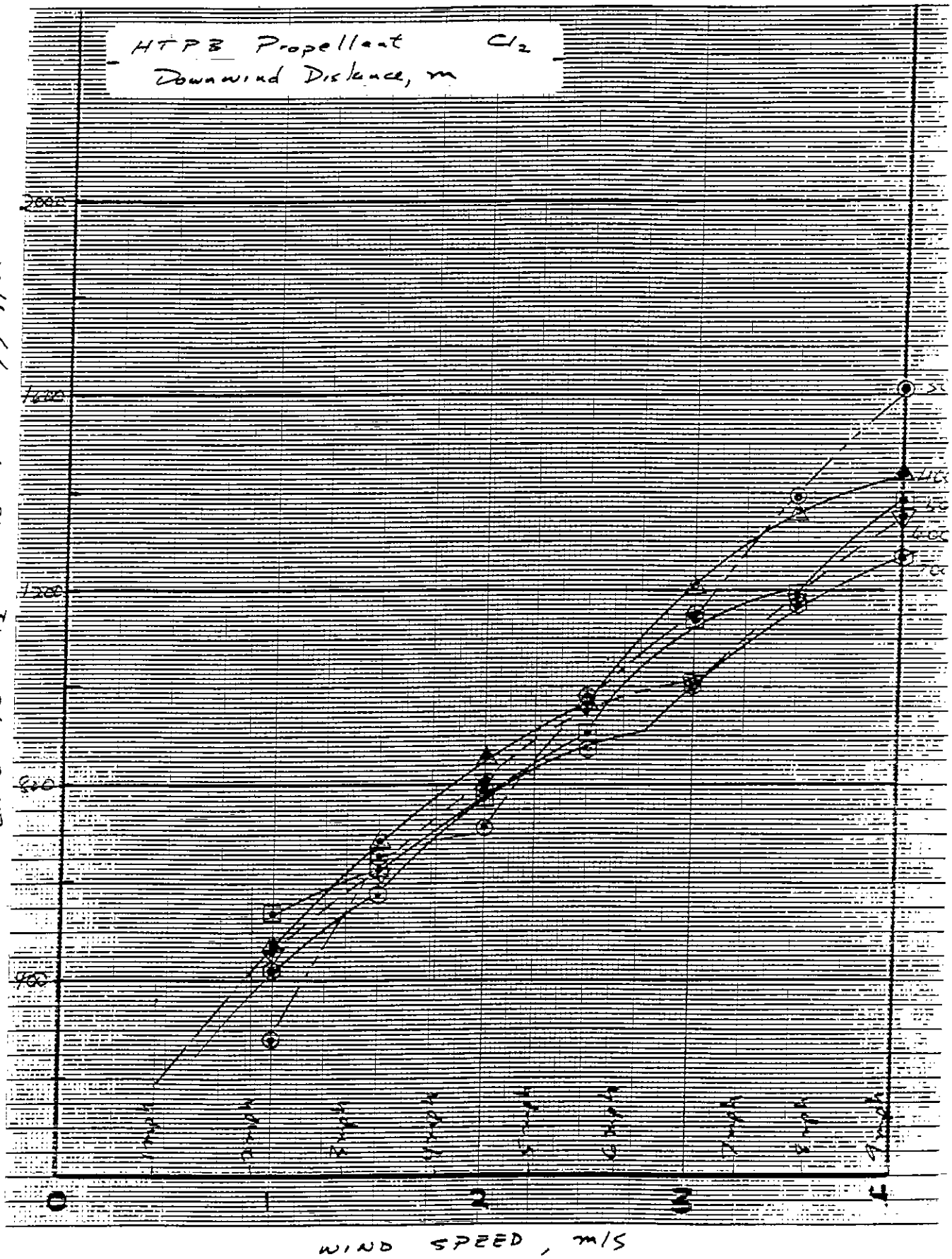
APPENDIX E

HTPB PROPELLANT SUPPORTING DATA

CHLORINE EMISSIONS

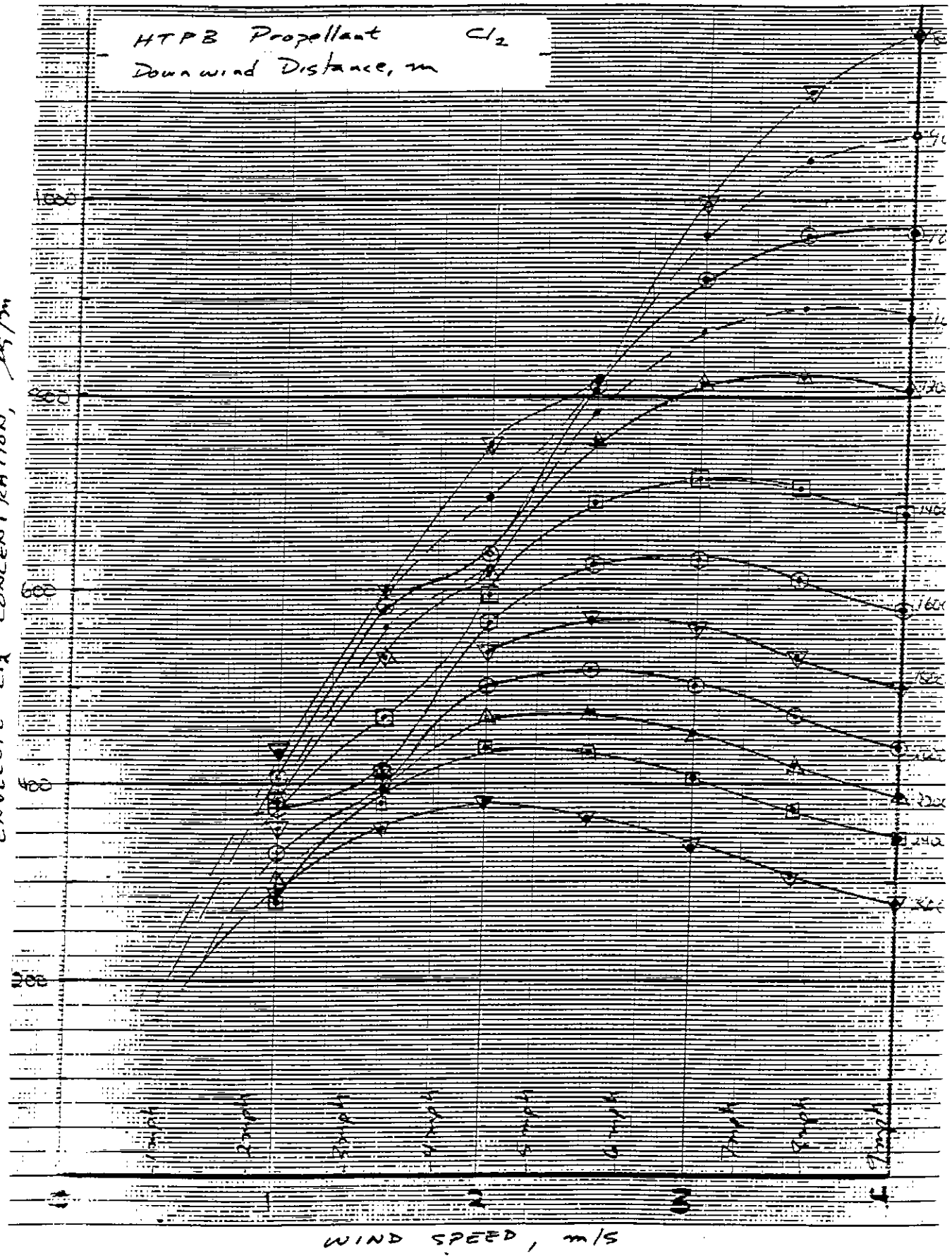
PREDICTED CHLORINE CONCENTRATIONS VERSUS DISTANCE, STABILITY CLASS, & WIND SPEED FOR HTPB PROPELLANT

CLS	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	MAXIMUM VALUES			
mps	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
200	87	691	1175	38	390	1024	1519	22	189	660	1339	14	70	219	540	87	691	1175	1519
300	280	854	898	108	715	1150	1259	53	446	1106	1611	27	163	507	1064	280	715	1150	1611
400	475	692	578	192	804	971	921	85	647	1209	1442	34	241	721	1308	475	854	1209	1442
500	537	478	356	294	768	764	667	128	766	1139	1197	42	329	878	1383	537	768	1139	1383
600	461	307	216	375	672	595	495	178	805	1012	978	51	414	968	1353	461	805	1012	1353
700	369	202	139	420	570	468	379	228	792	878	803	63	488	1000	1271	420	792	1000	1271
800	314	138	94	435	480	375	298	275	750	758	666	76	547	994	1170	435	750	994	1170
900	281	99	66	427	404	305	239	314	695	655	560	90	589	964	1066	427	695	964	1066
1000	256	75	48	407	343	253	196	345	637	569	476	106	617	919	968	407	637	919	968
1100	236	62	37	380	293	212	164	366	581	497	409	117	619	865	881	380	619	865	881
1200	219	56	29	352	253	181	139	379	529	438	355	127	615	812	804	379	615	812	804
1300	205	52	25	324	220	155	119	385	481	388	311	137	607	762	737	385	607	762	737
1400	192	48	22	298	193	135	103	386	439	345	275	147	595	715	677	386	595	715	677
1500	181	45	20	275	170	118	90	382	401	310	245	156	582	671	625	382	582	671	625
1600	171	43	19	254	151	105	79	375	367	279	219	164	566	631	579	375	566	631	579
1700	162	41	18	236	135	93	71	366	336	253	198	172	550	594	538	366	550	594	538
1800	154	39	17	221	121	83	63	355	310	230	179	179	534	560	501	355	534	560	501
1900	147	37	16	208	110	75	57	343	286	210	163	186	517	529	468	343	517	529	468
2000	141	35	16	196	100	68	51	330	264	193	149	192	500	500	438	330	500	500	438
2100								318					484	474	411	318	484	474	411
2200								305					468	449	387	305	468	449	387
2300								293					452	427	365	293	452	427	365
2400								281					437	406	345	281	437	406	345
2500								270					423	387	326	270	423	387	326
2600								259					409	369	309	259	409	369	309
2700								248					395	352	294	248	395	352	294
2800								238					382	336	280	238	382	336	280
2900								229					370	322	266	229	370	322	266
3000								220					358	308	254	220	358	308	254
3500								184					306	254	206	184	306	254	206
4000								158					265	213	171	158	265	213	171



46 1512

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Receptor 1
Azimuth 210 - 222
Range 930 - 1030

MPH	mps	202.5 n1	225 n2	nt	f	C	fC
1	0.45	64	51	115	0.0228	180	4.1161
2	0.89	33	30	63	0.0125	370	4.6351
3	1.34	5	23	28	0.0055	530	2.9508
4	1.79	5	14	19	0.0037	650	2.4557
5	2.24	0	4	4	0.0007	740	0.5885
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							14.746

Receptor 2
Azimuth 230 - 245
Range 450 - 550

MPH	mps	225 n1	247.5 n2	nt	f	C	fC
1	0.45	51	60	111	0.0220	360	7.9459
2	0.89	30	47	77	0.0153	500	7.6555
3	1.34	23	37	60	0.0119	620	7.3970
4	1.79	14	21	35	0.0069	780	5.4285
5	2.24	4	10	14	0.0027	910	2.5333
6	2.68	0	3	3	0.0005	1060	0.6323
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	1	1	0.0001	1440	0.2863
							31.879

Receptor 3
Azimuth 250 - 260
Range 350 - 500

MPH	mps	247.5 n1	270 n2	nt	f	C	fC
1	0.45	60	105	165	0.0328	360	11.811
2	0.89	47	166	213	0.0423	500	21.177
3	1.34	37	199	236	0.0469	620	29.095
4	1.79	21	125	146	0.0290	780	22.645
5	2.24	10	64	74	0.0147	910	13.390
6	2.68	3	37	40	0.0079	1060	8.431
7	3.13	0	16	16	0.0031	1290	4.104
8	3.58	0	8	8	0.0015	1400	2.227
9	4.02	1	7	8	0.0015	1520	2.418
							115.299

Receptor 4
Azimuth 215 - 235
Range 350 - 450

MPH	mps	1/2S n1	225 n2	nt	f	C	fC
1	0.45	62	51	113	0.0224	360	8.0890
2	0.89	40	30	70	0.0139	500	6.9596
3	1.34	21	23	44	0.0087	620	5.4245
4	1.79	13	14	27	0.0053	780	4.1877
5	2.24	5	4	9	0.0017	910	1.6285
6	2.68	2	0	2	0.0002	1060	0.3161
7	3.13	0	0	0	0	1290	0
8	3.58	0	0	0	0	1400	0
9	4.02	1	0	1	0.0000	1520	0.1511
							26.756

Receptor 5
Azimuth 170 - 200
Range 350

MPH	mps	180 n1	202.5 n2	nt	f	C	fC
1	0.45	37	64	101	0.0200	360	7.2300
2	0.89	17	33	50	0.0099	500	4.9711
3	1.34	1	5	6	0.0011	620	0.7397
4	1.79	1	5	6	0.0011	780	0.9306
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							13.871

Receptor 6
Azimuth 150 - 170
Range 500 - 600

MPH	mps	1/2S n1	157.5 n2	nt	f	C	fC
1	0.45	62	56	118	0.0233	360	8.4112
2	0.89	34	12	46	0.0091	500	4.5734
3	1.34	10	2	12	0.0022	600	1.3720
4	1.79	1	1	2	0.0003	620	0.2465
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							14.603

Receptor 7
Azimuth 145 – 155
Range 600 – 700

MPH	mps	135 n1	157.5 n2	nt	f	C	fC
1	0.45	86	56	142	0.0282	200	5.6472
2	0.89	51	12	63	0.0125	400	5.0109
3	1.34	18	2	20	0.0039	570	2.2668
4	1.79	1	1	2	0.0003	720	0.2863
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							13.211

Receptor: Bel Air School
Azimuth 130
Range 2250

MPH	mps	n1	135 n2	nt	f	C	fC
1	0.45	0	86	86	0.0171	160	2.7361
2	0.89	0	51	51	0.0101	290	2.9409
3	1.34	0	18	18	0.0035	370	1.3243
4	1.79	0	1	1	0.0001	440	0.0874
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							7.0888

Receptor 300
Azimuth 67.5 – 200
Range 950

MPH	mps	67.5 n1	67.5 n2	nt	f	C	fC
1	0.45	13	13	26	0.0051	180	0.9306
2	0.89	7	7	14	0.0027	370	1.0300
3	1.34	4	4	8	0.0015	530	0.8431
4	1.79	3	3	6	0.0011	650	0.7755
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							3.5792

Receptor 28
Azimuth 270
Range 2800

MPH	mps	n1	270 n2	nt	f	C	fC
1	0.45	0	105	105	0.0208	160	3.3406
2	0.89	0	166	166	0.0330	275	9.0773
3	1.34	0	199	199	0.0395	340	13.453
4	1.79	0	125	125	0.0248	375	9.3209
5	2.24	0	64	64	0.0127	375	4.7723
6	2.68	0	37	37	0.0073	360	2.6486
7	3.13	0	16	16	0.0031	325	1.0340
8	3.58	0	8	8	0.0015	300	0.4772
9	4.02	0	7	7	0.0013	280	0.3897
							44.514

Receptor 28
Azimuth 292.
Range 2500

MPH	mps	n1	292.5 n2	nt	f	C	fC
1	0.45	0	37	37	0.0073	160	1.1771
2	0.89	0	41	41	0.0081	280	2.2827
3	1.34	0	35	35	0.0069	360	2.5054
4	1.79	0	15	15	0.0029	410	1.2229
5	2.24	0	6	6	0.0011	430	0.5130
6	2.68	0	5	5	0.0009	420	0.4175
7	3.13	0	2	2	0.0003	380	0.1511
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							8.2700

Receptor 28
Azimuth 315
Range 2800

MPH	mps	n1	315 n2	nt	f	C	fC
1	0.45	0	108	108	0.0214	160	3.4360
2	0.89	0	72	72	0.0143	275	3.9371
3	1.34	0	52	52	0.0103	340	3.5156
4	1.79	0	23	23	0.0045	375	1.7150
5	2.24	0	8	8	0.0015	375	0.5965
6	2.68	0	2	2	0.0003	360	0.1431
7	3.13	0	1	1	0.0001	325	0.0646
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							13.408

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 800

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	220	5.1183
2	0.89	17	51	68	0.0135	390	5.2734
3	1.34	3	18	21	0.0041	550	2.2966
4	1.79	0	1	1	0.0001	685	0.1362
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							12.824

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 1200

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	180	4.1877
2	0.89	17	51	68	0.0135	370	5.0029
3	1.34	3	18	21	0.0041	490	2.0461
4	1.79	0	1	1	0.0001	590	0.1173
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							11.354

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 1600

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	180	4.1877
2	0.89	17	51	68	0.0135	370	5.0029
3	1.34	3	18	21	0.0041	400	1.6703
4	1.79	0	1	1	0.0001	500	0.0994
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							10.960

Receptor: Pinto–Bel Air
Azimuth 120 – 130
Range 2000

MPH	mps	112.5 n1	130 n2	nt	f	C	fC
1	0.45	31	86	117	0.0232	160	3.7224
2	0.89	17	51	68	0.0135	280	3.7860
3	1.34	3	18	21	0.0041	380	1.5867
4	1.79	0	1	1	0.0001	470	0.0934
5	2.24	0	0	0	0		0
6	2.68	0	0	0	0		0
7	3.13	0	0	0	0		0
8	3.58	0	0	0	0		0
9	4.02	0	0	0	0		0
							9.1887

ht cl2

Exhibit 1

COMPUTER PREDICTIONS OF POLLUTION PRODUCTS FROM OPEN BURN AND OPEN DETONATION OF NAVY EXPLOSIVES AND PROPELLANTS

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JANUARY 1987

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ABSTRACT

There is a growing need to predict the pollution products at open burn sites. Under the sponsorship of the Ordnance Environmental Support Office, Naval Ordnance Station, Indian Head, a computer program has been developed to predict the combustion products when explosives or like materials are openly burned or detonated. This report explains the theory, assumptions, problem/solution applications of the computer program written for this purpose.

The computer model was challenged using production wastes. The actual data closely followed the predicted data proving the validity of the predictive model.

BACKGROUND

Under the sponsorship of the Ordnance Environmental Support Office at the Naval Ordnance Station, Indian Head, Maryland, a computer program has been developed to predict the pollution products caused by the open burning or open detonation (OB/OD) of explosives and like materials. Since the program is a modification of the Propellant Evaluation Program (PEP), written at the Naval Weapons Center, China Lake[1], a brief history of the PEP program is discussed below. The PEP program was designed and written by the collaboration of many contributors. Work on the program started in 1951 at NWC and continued until 1968.

Combustion products are calculated from high temperature chemical equilibria. To accomplish this, a large set of nonlinear algebraic equations must be simultaneously solved and computer codes must be general enough to handle any particular system. There have been three historic approaches to the problem.

One approach, presented by White et al[2], is the free-energy criterion for chemical equilibrium. This procedure is the method of steepest descent, which is a general method for the numerical solution of nonlinear algebraic equations.

The second approach by Brinkley[3] uses equilibrium constants. For this approach, a basis of subset molecular species is chosen that has as many species as there are chemical elements. From this basis all other species are formed by chemical reaction. A set of equations then establishes the equilibrium relationship of each nonbasis species to the basis. Another set of equations establishes the gram-atom amount of each chemical element. Both sets of equations are solved simultaneously by the Newton-Raphson method, which is a general method for the numerical solution of nonlinear algebraic equations. Huff et al[4] and Browne[5] later introduced the concept of optimized basis, in which the components are present in the greatest possible molar amounts.

The reaction-adjustment method of Villars[6,7] is the third approach. In theory, the chemical system is divided into a number of subsystems, each relating a nonbasis species to the basis. The subsystem with the greatest discrepancy in its equilibrium relationship is corrected stoichiometrically. In this way the gram-atom amounts do not change. Villars' method does not require the inversion of large matrices which simplifies coding. Its speed is greatly dependent on the choice of the basis which is quite slow. The PEP program is a combination of Villars' method and Browne optimum basis method.

The pollution computer program uses many of the PEP program's routines. Modifications of this program were made to calculate pollution products under the special conditions encountered in open burns and open detonations of explosives and propellants. These modifications are described under the general description of the pollution computer program.

THEORY AND ASSUMPTIONS FOR OPEN BURN/OPEN DETONATION CALCULATIONS

The computer program calculates the pollution combustion products under two different conditions:

1. Open Burn (OB) - under these conditions the material is mixed with air and they burn together to form the pollution products.

2. Open Detonation (OD) - under these conditions the material is detonated first, after which air is mixed with the detonation products that react to form the pollution products.

Open Burn

The necessary thermodynamic data for the material's ingredients and air, the weight ratios of material/air and the two pressure values of 1000 and 14.7 psi are read into the computer as input data. The flame temperature, combustion products, moles of gas, entropy, and other pertinent data are calculated for the material/air mixtures under a pressure of 1000 psi. The volume of the combustion products are then expanded to 14.7 psi which causes a temperature drop in the products. At this lower temperature, the products have a different composition from that at 1000 psi. The computer procedure goes through a similar routine it did at 1000 psi to recalculate the combustion products, flame temperature and other variables that changed because of expansion. The products calculated at 14.7 psi are reported as the pollution products in the output data.

Even though the calculations are conducted at 1000 and 14.7 psi, the material does not have to be disposed of under these conditions to predict the pollution products. The calculations are conducted in this manner for the following reasons:

1. It simulates the drop in temperature as the gases cool to ambient conditions.

2. The combustion products "freeze" in composition before they reach ambient temperature.

3. The combustion products of explosives and propellants formed in the combustion calorimeter are in good agreement with the products calculated by the computer[8].

4. The heats of explosion calculated from the PEP computer program closely approximates the actual values determined from calorimetric data[8].

Simulating a Drop in Temperature

Initially, flame temperatures above 3500 K (5840 F) at the burn site can be reached by some materials burned alone or with air. The temperature then cools to the ambient temperature of the surroundings. It is important to account for this drop in temperature, because the composition of the combustion products for the initial high temperature at the burn site will be different from the composition cooled to ambient temperature.

In effect, the combustion product's temperature change can be simulated by calculating the temperature of the material burning under a pressure of 1000 psi and after the combustion products have expanded to 14.7 psi.

Frozen Combustion Products

The composition of the combustion products will continually change with temperature until a "freeze" temperature is reached. Afterwards, the composition of the products remain constant, both quantitatively and qualitatively, even though they continue to cool to ambient temperature. The products are said to "freeze" when they no longer change with temperature. This freeze temperature is unknown and varies with each material burned. In his detonation calorimetric work, Ornellas[9] reported that the frozen temperature is between 1500 to 1800 K for most explosives. The frozen temperature for the combustion products in this study is assumed to be the temperature that is calculated when the products are expanded to 14.7 psi. For most of the explosives and propellants used by the services, this computer program calculates this temperature to be in the range of 1200 to 1500 K.

1700-2200 °F.

Calculated Versus Determined Combustion Products

In this laboratory approximately a dozen explosives and propellants have been burned in a combustion calorimeter under an atmosphere of 450 psi of helium. The combustion products analyzed were in good agreement with the calculated composition of the products after they had been expanded from 1000 to 14.7 psi.

Calculated Versus Determined Heats of Explosion

The heats of explosion have been calculated from the composition of the combustion products, expanding from 1000 to 14.7 psi, from the PEP program for numerous explosives and propellants. In general, there is good agreement between the experimental and calculated values using the PEP output data[8]. The close agreement between the calculated and the determined values for both the combustion products and heats of explosion determined at the NSWC laboratory, is the basis for using the pressure values of 1000 and 14.7 psi.

Detonation Burn

The same input data is used for both the open burn and open detonation calculations. In open burn, the material and the air are mixed and burned together at 1000 psi and then the combustion products of this mixture are expanded to 14.7 psi. In detonation burns, the following conditions are assumed:

1. The material explodes first, forming combustion products that do not initially react with the surrounding air.

2. During the explosion, the hot gases expand, shock waves are created, etc., causing an energy loss of the combustion products.

3. The combustion products at the reduced energy are then reacted with the surrounding air to form the pollution products.

Materials Explode First

In the open burn calculations, the air is mixed with the air initially at 1000 psi and allowed to react together. In open detonations the material explodes, forming combustion products without mixing with air.

Loss of Energy

When an explosive detonates, shock waves and other processes occur that cause a loss of energy and a drop in temperature. The program assumes that this energy is lost before the combustion products react with air at the burn site.

Combustion Products at Reduced Energy

The calculated energy loss is subtracted from the total energy of the explosive before the combustion products are reacted with air. The calculations then follow the open burn procedure discussed above. That is, the combustion products at a reduced energy level are mixed with air at 1000 psi and allowed to expand to 14.7 psi. This is the major difference between open burn and open detonation calculations.

LIMITATIONS IN OPEN BURN/OPEN DETONATION (OB/OD) CALCULATIONS

Material/Air Weight Ratios

A major problem in calculating pollution products is the material/air weight ratio that burns at the site. The weather, quantity of material to dispose of, wind speed, location, etc., are factors that greatly influence the material/air weight ratios.

To circumvent this uncontrollable variable, a series of material/air weight ratios from 100/0 to 10/90 in increments of -10/10 were calculated. The output data shows the trend in the composition of the pollution products as the ratios vary. Even though the approximate ratio isn't known, the calculations show the extremes expected of the products' compositions for disposal of materials by burning.

Formation of Carbon Dioxide and Water

How much carbon goes to carbon dioxide and hydrogen to water would depend upon a number of factors. Two main factors would be the presence of other elements and the freeze temperature. For example, boron carbide, HCl, and HF would form if boron, chlorine and fluorine were present. Some hydrocarbons would likely form in many cases. Above the freeze temperature, most of the residual carbon and hydrogen would form carbon dioxide and water if enough oxygen were present. The ideal conditions would be for this to occur in OB/OD burns.

If analyses of future OB/OD burns could verify that this does occur, then the material/air weight ratios could be varied until all of the residual carbon and hydrogen went to those two products. That particular material/air weight ratio would then be used to predict the combustion products formed.

Even if not verified, the material/air weight ratios should be varied until all the residual carbon and hydrogen are burned to carbon dioxide and water. It would predict what combustion products are formed under ideal conditions for OB/OD burns.

Calculating Temperature Change

As discussed above, the temperature change is simulated by calculating the material burning at 1000 psi and allowing the combustion products to expand to 14.7 psi. These two pressure values chosen were based on experimental data determined at this laboratory. As mentioned, the theoretical combustion products and heats of explosion calculated under these conditions were in good agreement with the experimental calorimetric data for

the gases formed and the heats of explosion determined. Since temperature is a function of both gases formed and heat released, the calculated temperature change between the pressures of 1000 and 14.7 psi is used for predicting pollution products.

The temperature calculated at 1000 psi simulates the initial high flame temperature of the material at the burn site before it expands. This calculated temperature is slightly higher than the calculated flame temperature if ambient pressure were used instead. For example, the flame temperature for TNT is 1992K at 1000 psi, and 1976 K at 14.7 psi (with no expansion). With such close agreement at these two pressures, it wasn't felt necessary to program the computer to obtain an initial flame temperature at ambient pressure before calculating the temperature drop. This is especially true when the initial flame temperature is subject to the conditions of the environment.

Homgeneity of Materials

Often different types of materials are burned together. In such cases, all of the ingredients in the materials are combined and treated as one homogeneous material in the calculations.

Detonation of Materials in Different Containers

Materials come in many types of containers. Those contained in shells, grenades and other metallic casings will be more difficult to predict than in paper containers. Such containers will influence the chemical reactions at the burn site.

DETONATION REACTIONS BEFORE REACTING WITH AIR

Detonation burn calculations are less accurate than open burn calculations. The material explodes before it reacts with the air. For this reason two assumptions concerning pressure changes and loss of energy were made. They are discussed below.

Pressure Changes in Detonations

Unlike an open burn, there is an initial high pressure from the detonation. It is difficult to calculate what products are formed under high pressures. This computer program uses the ideal equations of state for the combustion products that would not apply to gases under such conditions.

Since the objective is to predict pollution products at ambient conditions, these gases would not be of interest. As the combustion products decrease in pressure, their behavior is assumed to obey the ideal equations of state for gases.

Loss of Energy

The detonation of the explosives sets up shock waves, does work against the environment that expends energy. Since energy is a major factor in determining what products are formed, the calculations assume a loss of energy by the combustion products before they react with air. The loss for each material is at best an estimation. The energy consumed in shock waves is reported by Price[10] and Dyson[11] to be 20% to 25% of the total energy of an explosive. The computer program estimates the energy loss to be 25%, plus or minus 5%, depending on the explosive. This percentage can be modified later if and when better experimental data becomes available. As discussed under detonation burn, the combustion products are then calculated at a reduced energy level by the same procedures used in open burn calculations.

DESCRIPTION AND OPERATION OF THE POLLUTION COMPUTER PROGRAM

Modifications of Propellant Evaluation Program

The Propellant Evaluation Program (PEP) was designed for rocket calculations and could not be used in its present form. Since many of PEP's subroutines were compatible for pollution calculations, it was easier to modify this program than to start from scratch. The following major changes were made:

1. INPUT DATA FORMAT - A different format was used for the special type of calculations for pollution work. This format is described below.

2. OUTPUT FORMAT - The PEP output was designed for data important to rocket designs. An example of the output format and data for pollution data is described below.

3. REACTION WITH AIR - The OB/OD burns are mixed with air. the program is designed to automatically mix the materials with air and calculate the results.

4. ENERGY LOSS IN DETONATIONS - The OD burns are assumed to lose energy before they react with air. A modification of several subroutines was made to account for this loss.

5. OB/OD CALCULATIONS - To facilitate the use of the program, it was designed to do either an OB or OD calculation using the same input data. As described below, only one variable must be changed to accomplish this.

General Description

The main computer program, POLU10, has two auxiliary programs to handle the necessary input data for its operation. The three programs are described as follows:

A. POLU10 - This is the source file for the main program. It is written in the FORTRAN IV language. An explanation of the input data and format is included below. The program was purposely written in FORTRAN IV to facilitate its transfer to other types of computers with the least amount of trouble.

B. PEPAUX - This is the auxiliary source file program that manages the thermodynamic data for the combustion species. The JANNAF Thermochemical Tables[12] is the source for most of this data. Heat capacity equations, entropy and enthalpy constants are stored in this program for over 1400 combustion species. Gases, liquids and solids are included. Thus, the program can predict solids and liquids as well as gaseous pollution products. When this program is run, a binary file of the data is compiled that POLU10 calls in and searches for the appropriate combustion species. The compiled form of the data must be assigned to TAPE 12 when running POLU10.

C. INGDATA - This is the auxiliary source file program that manages the ingredients that compose the propellants, explosives or other materials that are disposed of by burning. The names, heats of formation, densities, and the elemental compositions of the ingredients are included as part of the data handled by this program. The ingredients are selected from numbers by the main program. This eliminates reading in the necessary data for the ingredients every time they are used. Two data files are generated by this program:

1. File on TAPE 11 - This file has the ingredients data arranged in the format used by the main program. the data from this file must be assigned to TAPE 11 before POLU10 is run.

2. File on TAPE 6 - The INGDATA program also prints the ingredients data on TAPE 6. A copy of this file is obtained for reference by the users of the pollution program. It lists the ingredients by numbers. When a particular ingredient is used in the calculations, this number is entered as input data. The data for that ingredient will then be called in by POLU10.

Explanation and Format Data

The data must be entered in the following sequence:

Line 1

Column No.	Data	Description of Data
3	0	This is always 0. It controls the species data coming from PEPAUX.
4	1	1 or 0. When set to 1, the pressure is entered as lb/sq. in (psi). When set to 0, the pressure is entered in atmospheres.
9	1	1 or 0. When set to 1, all of the ingredients are read from TAPE 11 by numbers. When set to 0, some or all of the ingredients are read in directly. This is explained in Line 4.
20	3	0,1,2,3 or 4. This controls what decimal place the concentrations of the combustion products are printed in the output data. Three is recommended.
29-30	1-10	This is the number of ingredients in the propellant or explosive, plus 1 for air. For example, if an explosive has 3 ingredients, this value must be 4 (right adjusted). Ten ingredients is the limit. If more than 10, two or more of the ingredients must be combined into one.

setting	decimal place
0	1xE-5*
1	1xE-10
2	1xE-17
3	1xE-4
4	1xE-25

*E = the exponential of 10

39–40	1–10	This is the number of calculations or runs to be made. The output format limits this number to 10 (right adjusted).
46–47	20	When all of the ingredients are read in by numbers, this is set to 20. If any of the ingredients are not read in by numbers, this number (right adjusted) must equal the number of ingredients not read in by numbers.
48–50	1,2	When set to 1 (right adjusted), the computer does open detonation calculations. When set to 2, the computer does open burn calculations. They both use the same input data and format.
51–53	1,2	When set to 1, the output data for the pollution products are given in grams products/100 g material. When set to 2, the products are also given (both units) in grs products/liter of gases formed at STP (273.15 degrees Kelvin and 1 atmosphere pressure).

Line 2

This line is for naming of the material burned and other identifying information.

Line 3

In a sequence of calculations, the weight percent of air is changed. This line is for the different weights of air that changes with each calculation. As many as ten different weights of air can be entered. Starting at column 1, each weight has a field of 6 columns. Weight 1 goes into columns 1 - 6; weight 2, into columns 7 - 12, etc.

Line 4

The INGDATA file contains data for many of the ingredients that are used in propellants and explosives. If this file does not have the ingredients needed for the calculations, the data for these ingredients can be read in. In Line 1, column 9 must have a value of 0 and columns 46 - 47 must have the number of ingredients (right adjusted) that are read in under the format below.

When adding new ingredients to the INGDATA data file, this same format is used. The INGDATA data can also be entered under the foramt adopted by Cruise at China Lake. The postion of the data under Cruise's format is marked in the data file.

Column No.	Description of Data
1 - 20	Name of the ingredient
21 - 27	Heat of formation of the ingredient in cal/g.
28 - 32	Density of ingredient in lb/cubic inch.
33 - 38	Number of atoms of the first element in the ingredients.
39 - 40	Symbol of the first element (left adjusted).
41 - 46	Number of atoms of the second element in the ingredients.
47 - 48	Symbol of the second element (left adjusted). This sequence continues for a limit of six elements.
49 - 54	Atoms of third element.
55 - 56	Symbol of third element.
57 - 62	Atoms of fourth element.
63 - 64	Symbol of fourth element.
65 - 70	Atoms of fifth element.
71 - 72	Symbol of fifth element.
73 - 78	Atoms of sixth element.
79 - 80	Symbol of sixth element.

Line 5

The numbers assigned to the ingredients by the INGDATA file are entered here. Starting at column 1, each field has 5 columns. The number for the first ingredient goes into columns 1 - 5, the second ingredient into columns 6 - 10, etc. For example, if 23 is assigned to aluminum by the INGDATA file, 23 should go in columns 1 - 5 (right adjsuted). Aluminum is the first ingredient in the material. It is imperative that the ingredient number for air always be the last number in this line. If it is desired to burn the materials in pure oxygen, then the ingredient number for oxygen is used instead of air.

Line 6

Column No.	Data	Description of Data**
1 - 6	1000.	This is the pressure of the chamber in which the material is initially burned. This value is normally 1000 psi for pollution calculations. Atmospheres can be used (see explanation in Line 1). The data in this line is for the first calculation.
7 - 12	14.7	This is the pressure that the combustion products expand to in the calculations. The value 14.7 psi is normally used here. It can also be expressed in atmospheres.
13 - 18	——	This is the weight of the first ingredient. The field for each successive ingredient is 6 columns long. For the second ingredient, columns 19 - 24; the third, columns 25 - 30, etc. The tenth and last ingredient is in columns 67 - 72. The weights of the ingredients are entered with air as the last ingredient. Air is normally set at zero weight percent. Under some circumstances, the initial weight of oxygen is not zero. This is discussed later. The weight of air is automatically increased and the material weights decreased by the same increments in Line 3.
73 - 80	——	This is optional. Additional information can be entered here to help identify the output data. Such information is normally entered in Line 2.

Lines 7 - 15

1 - 6	1000.	The data is the same as in columns 1 - 6 in Line 5.

7 - 12	14.7	The data is the same as in columns 7 - 12 in Line 5. It isn't necessary to enter the weights of the material or air again. The program automatically adjusts these weights with the data in Line 3. The number of these lines is always one less than the total number of calculations made. If 10 calculations are to be computed, enter 9 of these lines with just these two values on each line.

** All numerical data must have a decimal point.

IDENTIFICATION OF NUMBERS OR SAMPLE OF OUTPUT DATA

NO.

1. Identifies the type of calculation. This is either open burn or open detonation.

2. Name of the material burned is identified here.

3. Name of the ingredients in the material.

4. Symbol for the elements in the ingredients. Also, the number of atoms for that element divided by 1000. This number is often in decimal form when the elements are expressed in gram-atoms.

5. Weight of the ingredient in the material.

6. Heat of formation of the ingredient in cal/gr.

7. Density of the ingredient in lbs/cu in.

8. Symbol for the elements that compose the material. Also, the elemental composition of the elements that compose the material. If the atomic wt. of the element is multiplied by the elemental composition, the total mass of the element in the material can be calculated (example: 12.01 x 3.081786 = 37.01 grs of carbon).

9. Weights of the material and air used in the calculations.

10. For open burn calculations: This is the initial flame temperature of the material/air burned before the gases start to cool. The enthalpy of the combustion products is given in kcal/gfw (gfw = gram formula weight). The temperature is expressed in both Kelvin and Fahrenheit degrees.

    For open detonation calculations: This is the temperature of the combustion products after there is a loss of energy due to detonation. The detonation products cool to this temperature before they react with air.

11. The temperature of the combustion products (for both OD/OB burns) after they have expanded from 1000 to 14.7 psi. This is also the "frozen" temperature of the products.

12. The computer can calculate the weights of the combustion products to 1.00E-17. For this work the concentration is rounded off to the value shown.

13. Symbols for the combustion products formed. They are identified in the JANNAF Thermochemical Tables[12]

14. Weights of the products formed in grams products/100 grams of material burned (or lbs products/100 lbs material burned).

15. Total combustion products considered in the calculations. Of the 73 products listed, 12 with concentrations 1.00E-04 or higher are listed above.

SAMPLE OF OUTPUT DATA

OPEN AIR BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR--- (1)
MATERIAL=TNT (2)

(4)

	H	C	N	O		(5)	(6)	(7)
TRINITROTOLUENE	.005	.007	.003	.0000.0000.0000.0000.0000.0000.0000.0000.000		100.000	-70.	.0598
AIR -(O	0.0000.000	.004	.0010.0000.0000.0000.0000.0000.0000.0000.000			0.000	0.	.0004

NUMBER AIOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 — 1.0000

(H)	(C)	(N)	(O)
2.201274	3.001708	1.320744	2.641531 (8)

WT. MATERIAL (9)	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: TNT MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. (K)	1991.507	1967.200	1941.777	2001.193	2143.154	2293.284	2453.924	2621.280	2597.360	1543.744
FLAME TEMP. (F) (10)	3125.312	3081.560	3035.799	3142.748	3398.276	3668.511	3957.663	4258.984	4853.849	2317.330
ENTHALPY KCAL/GFW	-7.750	-6.902	-6.206	-5.450	-4.455	-3.879	-3.183	-2.327	-1.552	-.774

--COMBUSTION CONDITIONS: IN COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. (K)	1045.851	1033.788	1022.852	1060.040	988.850	963.888	1004.619	1100.288	1004.752	583.132
FLAME TEMP. (F)	1421.693	1401.484	1380.293	1355.071	1317.891	1275.599	1340.913	1535.503	1493.154	554.238
ENTHALPY KCAL/GFW (11)	-57.842	-55.964	-54.077	-52.524	-52.033	-52.133	-52.469	-50.207	-49.259	-20.722
T.VOL.GASES--LITERS	100.023	115.040	123.010	135.090	150.110	171.147	203.361	256.038	360.750	750.498

(GASES AT STP)
COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04 (12)

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED----- (14)

CO	57.4357	50.0000	40.5270	42.1414	42.4153	41.4025	32.4555	31.9719	.0000	.0000
N2	10.4999	27.2400	30.2121	52.2923	71.0460	97.3492	136.7753	202.4047	333.0965	720.1532
CO2	10.0577	12.0160	15.2770	10.0797	25.0764	34.0207	52.0557	85.3701	135.6325	135.6325
C4	9.2505	.0000	.0000	.0000	3.2324	1.0016	.0000	.0000	.0000	.0000
H2	1.9636	1.9451	1.9253	1.8972	1.8471	1.7765	1.5239	.0001	.0000	.0000
H2O (13)	1.7593	1.9240	2.1061	2.3585	2.7921	3.4040	4.1710	12.4700	19.0291	19.0291
CH4	.2315	.2313	.2291	.2203	.2345	.2426	.0161	.0000	.0000	.0000
NH3	.0015	.0017	.0017	.0021	.0026	.0026	.0016	.0003	.0000	.0000
CNH	.0004	.0004	.0004	.0004	.0003	.0002	.0001	.0000	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	10.6270	114.3651
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0121	.0000
C4	.0000	0.1310	4.7203	5.0373	.0000	.0000	.0000	.0000	.0000	.0000

LIMITATIONS

Thermodynamic Data for Combustion Products

The program contains an auxiliary data file (PEPAUX) for the combustion products. Heat capacity coefficients, enthalpy and entropy constants are stored for each of the combustion products. Most of the data in this file is from the JANNAF Thermochemical Tables[12]. Currently, there are over 1400 species in this file. It contains compounds in the gaseous, liquid and solid states. The program chooses the compounds to consider in the calculations from the elemental composition of the material burned. If the material contains the elements C, H, O, N, the program searches the library for all species containing these elements and considers them as possible pollution products. The total number of combustion products considered for each calculation is listed in the output data. Obviously, any products formed at the burn site and not in this file cannot appear in the calculations. This library contains most of the species that are formed from explosives and propellants used by the armed services.

The file does not contain a large number of species for the metallic additives that are used in military explosives. There will probably be some products formed from metals that are not in the file. Since aluminum is used extensively, there is an adequate amount of species for this metal under most circumstances.

Most of the species in the thermodynamic file consist of solids and gases. The liquids and solids are identified by asterisks and dollar signs, respectively, in the output data. The PEP program is designed to calculate combustion products at high temperatures. The file does not include organic solvents or other organic compounds that cannot survive high temperatures.

High Temperature Species

Some of the species formed only exist at high temperatures. These species would disappear as ambient temperature is approached. For example, ions would be in this catagory. These species normally disappear in the calculations as more air is added. In evaluating the pollution products, these species are assumed to disappear. For most explosives and propellants these high temperature species comprise only a small percentage of the total.

Temperature Limitations

If the materials burned do not obtain a flame temperature above 300 K, the computer will issue a warning. For example, if a hydrocarbon without oxygen is attempted there will be no reaction above 300 K. This can occur

with a mixture of material and air if there is not sufficient amount of oxygen or fuel to properly react. In such cases several trial runs can be made by changing the material/air ratios until the program runs.

Mixing Air With Materials

In most calculations, the first material/air weight ratios start with 100/0. The computer will accept this ratio as long as the material contains the elements oxygen and nitrogen. If a material, such as a hydrocarbon is burned with zero weight percent of air, the program cannot run. With air as an ingredient, the computer will select those species from the PEPAUX library composed of these two elements. The concentrations of these species cannot be calculated as the elemental composition of oxygen and nitrogen will be zero. When burning hydrocarbons and similar materials, the percent of air cannot be zero.

Precautions With Detonation Calculations

The first material/air weight ratios in a series of detonation calculations must be 100 g material/0 g air, or the material burned alone. The program must use the data from this first calculation to determine the energy loss from the detonation. Since most explosives and propellants contain nitrogen and oxygen, the problem discussed in the paragraph above does not apply. Some materials, (tetrazoles, azides, etc.) do not contain oxygen or nitrogen. For detonation calculations, a small amount of air must be included in the first calculation. The air would be considered as part of the explosive's composition in the first calculation. A minimum percent of air should be used that can be determined by trial and error.

Combustion Products Printed Twice

The thermodynamic data covers a wide temperature range. In some species (notably solid carbon and aluminum oxide), the data is stored as two heat capacity equations to properly cover the temperature range. Therefore, some species appear twice in the output data. When this occurs, one or the other of the symbols representing that species is zero. This does not affect the results.

DISPOSAL OF NAVY WASTE

On 22 May 1986, approximately 7500 lbs of Navy waste propellants were disposed of by openly burning the propellants at Dugway, Utah. The pollution products were investigated by two methods, evaluation by computer calculations and on-site evaluation.

Comparative Analyses, Computer Predictions Versus Actual Emission Data

The composition of the Navy waste that was disposed of at Dugway is given in Table I. Combined, this waste consisted of eight elements. The percentage and total weight of each element is listed in Table II. For example, 2.97% or 222.7 lb of the combined waste consisted of the hydrogen element. Metals are usually a concern at waste disposal sites. The amounts of Al, Zn and Pb in the waste material are also listed. Tables III and IV contain the computer output data for the Navy waste burned in air. The combined composition is read into the computer as Navy waste 1, Navy waste 2, zinc and lead. Since the waste/air weight ratio burned at the site was not known, a series of ten waste/air weight ratios were calculated. The output data lists the pollution products formed and their changes in concentrations for the various waste/air ratios. The fate of the elements is discussed below:

a. HYDROGEN - Most of the hydrogen goes to the formation of H2O, H2, and HCl. As the percentage of air increases, the percentage of water increases at the expense of H2. The HCl concentration remains fairly constant until 30% waste/70% air is reached.

b. CARBON - CO and CO2 are formed with carbon. As the percentage of air increases, the percentage of CO2 increases at the expense of CO.

c. NITROGEN - the predominate product is N2. Some traces of NO2 may exist in the 20% waste/80% air ratio.

d. OXYGEN - Oxygen combines with all of the elements except zinc.

e. ALUMINUM - From the first to the last calculation, all of the aluminum goes to Al2O3$ ($ stands for solid). In most propellants oxygen reacts with aluminum first to completely oxidize it. The Al2O3$ concentration is constant throughout the series. Note that Al2O3$ is shown twice in the output data (the 5th and 27th products). This compound has its thermodynamic data stored in two heat capacity equations. Which equation is used depends upon the temperature.

f. CHLORINE - HCl and the chlorides of zinc and lead are formed. HCl is the most prominent of the chlorine products formed. HCl will immediately be absorbed in any moisture present to form hydrochloric acid.

g. ZINC - Most of the zinc metal will form its chlorides. The chlorides increase with increase in the air weight and at the expense of HCl. The zinc products will be mostly solids.

h. LEAD - Lead reacts similarly to zinc and will form chlorides.

At the end of the output data is a list of the total combustion species considered by the computer. There are 155 (some species listed twice) shown that the computer considered as possible combustion products. Those whose concentrations equaled or were greater than 0.0001 are listed above.

On-Site Evaluation at Dugway, Utah, 22 May 1986

The waste was burned in 5000- and 2500-lb sections. The gaseous clouds formed from these burns were sampled by a helicopter passing through the clouds.

The interscan instruments used to detect the gaseous emissions in the plume were not specific for each individual gas. As a result, some instruments suffered from interferences and would give indications of the presence of a measured gas when it actually was responding to an interferent gas. This was the case for the apparent detection of SO2 and H2S when there were no sulfur compounds in the Navy waste that was burned. The responses on these instruments were due to the presence of HCl which produces a positive reponse on these two instruments. Since the chemical reactions of the detector cells in the instrument are either oxidative or reductive, depending on the instruments, it is possible for an interferent to produce a negative interferent gas. It is likely that the negative values recorded by the Cl2 instrument resulted from a negative interferent gas. Based on the theory that there should be no NO, the response was probably also due to an interferent. (Explanation of the data in Table V is based upon a letter and private communication by Mark Zaugg, Director for Ammunition Equipment, Tooele Army Depot, Tooele, Utah.)

Only a limited amount of the on-site data collected, Table V, was useful for evaluation. The helicopter sampled the two major indicator gases as emissions from the Navy waste:

1. Carbon Monoxide - In Table V, the concentration of CO is 0.07 and .06 lb CO/100 lb Navy waste for the 5000 and 2500 lbs respectively. This concentration of CO falls between the computer values of 40/60 and 30/70 Navy waste/air weight ratios (Tables III and IV).

0-70% Air

2. Hydrogen Chloride - In Table V, the concentration of HCl is 1.19 and 1.21 lb HCl/100 lb Navy waste for 5000 and 2500 lbs respectively. This concentration of HCl falls between the computer values of 20/80 and 10/90 Navy waste/air weight ratios (Tables III and IV).

80-90% AIR

Based on the above data, the climatic conditions experienced and the burn pan configuration at the Dugway site allowed for sufficient oxygen to completely oxidize the Navy manufacturing waste. The composition/ concentrations remained constant above the 60-70% air intake. It is at this point where all of the residual carbon and hydrogen atoms are oxidized to carbon dioxide and water. It is expected that most of the PEP "mixes" of Navy manufacturing waste will be completely oxidized to these two products. For most of the individual Navy propellants, the calculations below show complete oxidation at the 60-70% air intake. Some, like the AA2 and the HEN-12, are completely oxidized with 50-60% air intake. The percentage of air consumed depends upon the initial oxygen content of the material.

In the predictive mode, the metals that are present are considered to be completely oxidized early in the burn, and the remaining oxygen is used to oxidize the residual carbon and hydrogen.

In the interest of a proof continium, a comparative analyses predicted vs actual emission should be made of future burns/detonations of both Army and Navy PEP waste.

CALCULATED EMISSIONS OF INDIVIDUAL NAVY PROPELLANTS AND EXPLOSIVES

Emissions from each individual propellant and explosive were calculated in a manner similar to those in Table III. These calculations predict the pollution emissions of the individual material. They were done for open burn and open detonation conditions. A list of these calculations is given below.

TABLE I

NAVY WASTE BURNED

Propellant	Weight (lbs)	Weight %
NOWIH-80-1 (MK 23)	70	2.8
X256 (MK 12)	1200	48.0
N-60 (Smokey Sam)	20	0.8
N-50 (5" G.P.)	100	4.0
AA2 (MK 90)	410	16.4
AA6 (ZUNI)	240	9.6
N-5 (ASROC and MK 22)	190	7.6
BX-180/BX 185 (MK 18)	5	0.2
BX-180 H (CKU-5/A)	15	0.6
TPH-9001 (CKU-7/A)	30	1.2
PBXN-106 (MK 115)	40	1.6
PBXW-109 (MK 83)	20	0.8
NOSIH 9 BC-10) (MQM-107)	40	1.6
XM39 (LOVA)	70	2.8
PBXN-103	50	2.0

TABLE II

Elemental Composition of Navy Waste

Element	% of Element	Wt. Element in 7500 Lbs
H	2.97	222.7
C	23.28	1746.0
N	13.45	1008.8
O	52.88	3966.0
Al	3.83	287.2
Cl	2.25	168.8
Zn	0.32	24.0
Pb	1.02	76.5

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= NAVY MANUFACTURERS WASTE(OPENLY BURNED MAY 22,1986)

	H	C	N	O	AL	CL	ZN	PB			
NAVY WASTE 1	.001	.001	.000	.001	.000	.0000	.0000	.0000	41.090	-205.	.0556
NAVY WASTE 2	.002	.001	.000	.002	.000	.0000	.0000	.0000	56.771	-200.	.0576
ZINC	0.0000	.0000	.0000	.0000	.0000	.000	.0010	.0000	.322	0.	.2500
LEAD	0.0000	.0000	.0000	.0000	.0000	.0000	.000	.0010	1.017	0.	.4003
AIR -(O	0.0000	.000	.006	.0010	.0000	.0000	.0000	.0000	0.000	0.	.0004

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 — 1.0000

(H)	(C)	(N)	(O)	(AL)	(CL)	(ZN)	(PB)	(			
2.949434	1.930628	.959393	3.385059	.141947	.863549	.004925	.004988				
W. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000	
W. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	3340.304	3323.983	3295.611	3261.834	3215.566	3147.747	3023.982	2731.983	2131.039	1311.640
FLAME TEMP. T(F)	5567.691	5523.769	5472.699	5410.461	5328.619	5206.544	4983.624	4458.025	3376.471	1901.552
ENTHALPY KCAL/GFW	-20.372	-18.335	-16.298	-14.260	-12.223	-10.186	-8.149	-6.112	-4.074	-2.037

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1681.306	1666.469	1651.255	1635.966	1621.148	1608.438	1606.435	1292.828	868.042	462.684
FLAME TEMP. T(F)	2567.895	2540.245	2512.059	2485.339	2458.666	2435.709	2432.182	1866.236	1103.876	373.431
ENTHALPY KCAL/GFW	-102.139	-97.153	-92.177	-87.211	-82.253	-77.272	-72.034	-68.398	-44.068	-25.615
.VOL.GASES--LITERS	89.872	96.888	105.657	116.933	131.967	153.812	184.563	246.532	376.584	766.246
GASES AT STP)										
OMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04										

-----GRAMS PRODUCTS/100 GRAMS (GM/G)MATERIAL BURNED-----

CO	41.9856	39.8389	37.8072	33.1385	27.6186	19.2366	5.4997	.0000	.0000	.0000
CO2	19.3538	22.7259	27.1758	33.2536	41.9391	55.8963	76.6799	85.3289	85.3218	85.3218
N2	13.4391	22.2882	33.1517	47.2321	66.8859	92.2894	131.7144	197.3985	328.8398	723.8911
H2O	12.8589	14.1242	15.6185	17.3747	19.4892	22.8418	25.1893	26.1722	26.1882	26.4908
AL2O3#	7.2365	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HCL	2.2618	2.2578	2.2526	2.2454	2.2344	2.2129	2.1222	1.6818	1.5713	.2819
H2	1.4713	1.3299	1.1638	.9666	.7383	.4454	.1845	.0000	.0000	.0000
PB	.7733	.7682	.7441	.7238	.6925	.6398	.4661	.0000	.0000	.0000
ZN	.3113	.3098	.3078	.3048	.2998	.2898	.2338	.0000	.0000	.0000

TABLE III

PBCL	.2714	.2853	.3022	.3239	.3544	.4049	.5367	.0120	.0000	.0000
ZNCL2	.0222	.0254	.0297	.0359	.0463	.0680	.1030	.6713	.6713	.0000
PBCL2	.0000	.0099	.0113	.0133	.0167	.0236	.0567	1.3251	1.3649	.0000
PBO	.0046	.0051	.0059	.0072	.0096	.0155	.0541	.0203	.0000	.0000
PBN	.0012	.0010	.0009	.0007	.0006	.0004	.0001	.0000	.0000	.0000
CL	.0005	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HO	.0002	.0002	.0002	.0002	.0002	.0003	.0007	.0013	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0012	.0273	1.2015
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0006	.0010	.0002
O2	.0000	.0000	.0000	.0000	1.0000	.0000	.0000	13.5132	40.7050	154.2525
PBCL4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0007
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0526	.0021	.0000
CL	.0000	.0005	.0005	.0004	.0005	.0006	.0012	.0050	.0001	.0000
H	.0000	.0002	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000
PBCL2$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.3645
ZNCL2*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.6712
AL2O3$	.0000	7.2365	7.2365	7.2365	7.2365	7.2365	7.2365	7.2365	7.2365	7.2365
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0000

--LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

0	CO2	N2	H2O	AL2O3$	HCL	H2	FB	ZN	PBCL	ZNCL2	PBCL2	PBO	PBN	CL
	HO	NH3	CNN	PB2	CH2O	CNHO	NO	CHO	ALCL2	CH4	COCL	ALCL3	ALOCL	CL2
2	HOCL	ALCL	O	O2	CH3	NH	NHO	CHCL	CH3CL	OCL	H2O2	CNO	N	C2H2
	COCL2	HO2	NOCL	ALO2	ALO	NHO2	AL	N2H2	C2O	CH2	ALH	ALHO2	C2N2	CH2CL2
4	C2HCL	CHCL	PBCL4	CH	N3	N2H4	C3O2	CN2	NO	N2O4	ALCL2	CHO	ALCL	C2
N	N2O3	AL2O	C	ALO	CCL4	C2CL2	CL	AL2CL6	CHCL3	OCL2	HO	AL2O2	ALHO	C4N2
	C2H4O	CCL2	N2O5	CCL3	O2CL	CN2	ALN	AL2O2	C3	CN	NHO3	H3O	N	C2CL4
ZCL	O3	C4	PB3O4$	AL2O	N2O	PBCL2$	PBCL2*	PBO2$	C2CL6	PBO$	PBO$	PBO*	PBO*	PB$
	AL4C3$	ZNCL2*	ALCL3*	ALCL3$	NH4O4C	AL2O3$	AL2O3*	N2O4$	H2O4*	ZNO$	ALOCL$	ZN$	ZN*	NO3
	C4H10	C4H8	NH4CL$	NH4CL$	NO2	C3H8	C3H6	ALH$	ALC	N2H4*	C2H6	C2H4	AL*	AL$
1	H2O*	H2O*	C$	C$										

TABLE III CONTINUED

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= NAVY MANUFACTURERS WASTE(OPENLY BURNED MAY 22,1986)

	H	C	N	O	AL	CL	ZN	PB			
NAVY WASTE 1	.001	.001	.000	.001	.000	.0000	.0000	.0000	16.337	-205.	.0556
NAVY WASTE 2	.002	.001	.000	.002	.000	.0000	.0000	.0000	22.141	-200.	.0576
ZINC	0.0000	.0000	.0000	.0000	.0000	.000	.0010	.0000	.126	0.	.2500
LEAD	0.0000	.0000	.0000	.0000	.0000	.0000	.000	.0010	.397	0.	.4003
AIR -16	0.0000	.000	.006	.0010	.0000	.0000	.0000	.0000	61.000	0.	.0004
										1.0000	

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

0 (H)	(C)	(N)	(O)	(AL)	(CL)	(ZN)	(PB)				
1.150279	.756065	3.007010	2.095300	.055359	.024704	.001921	.001914				
WT. MATERIAL		39.000	38.000	37.000	36.000	35.000	34.000	33.000	32.000	31.000	
WT. AIR		61.000	62.000	63.000	64.000	65.000	66.000	67.000	68.000	69.000	

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	3005.362	2985.107	2962.917	2938.558	2911.771	2882.277	2849.796	2814.055	2774.820
FLAME TEMP. T(F)	4950.252	4913.793	4873.050	4830.004	4781.788	4728.699	4670.232	4605.900	4535.276
ENTHALPY KCAL/GFW	-7.945	-7.741	-7.530	-7.334	-7.130	-6.926	-6.723	-6.519	-6.315

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1600.600	1612.676	1618.660	1562.248	1515.302	1469.463	1424.376	1379.039	1335.725
FLAME TEMP. T(F)	2436.239	2443.417	2439.787	2352.647	2280.143	2185.633	2104.477	2024.311	1944.904
ENTHALPY KCAL/GFW	-71.440	-70.794	-69.964	-68.775	-67.494	-66.154	-64.769	-63.344	-61.883
T.VOL.GASES--LITERS (GASES AT STP)	188.681	192.841	197.456	203.275	209.445	215.982	222.919	230.295	238.150

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

N2	136.7689	142.0892	147.6831	153.5839	159.8369	166.4628	173.4927	180.9630	188.9150
CO2	79.5772	82.6392	85.2531	85.3000	85.3161	85.3190	85.3201	85.3206	85.3200
H2O	25.4479	25.7960	26.1074	26.1243	26.1372	26.1490	26.1500	26.1656	26.1699
AL2O3*	7.2365	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CO	3.6556	1.7060	.8432	.0002	.0031	.0013	.0005	.0002	.0001
HCL	2.0059	2.0139	1.0190	1.7704	1.7258	1.6836	1.6403	1.6239	1.6009
PBCL	.5658	.5956	.3256	.2049	.1500	.1063	.0693	.0421	.0230
PB	.4104	.3096	.0297	.0072	.0020	.0011	.0004	.0001	.0000
ZNCL2	.2355	.3438	.6522	.6604	.6705	.6710	.6712	.6712	.6712

TABLE IV

ZN	.2090	.1571	.0091	.0014	.0004	.0001	.0000	.0000	.0000
PBO	.0754	.1297	.5007	.4693	.3623	.2501	.1534	.0055	.0432
PBCL2	.0716	.1052	.3201	.5359	.7370	.9301	1.0941	1.2100	1.2039
H2	.0677	.0307	.0008	.0002	.0001	.0000	.0000	.0000	.0000
CL	.0015	.0008	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HO	.0009	.0014	.0009	.0102	.0082	.0061	.0044	.0030	.0020
NO	.0003	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
O2	.0000	.0001	.2276	1.7597	3.4270	5.2033	7.0905	9.0972	11.2340
HOCL	.0000	.0000	.0001	.0003	.0003	.0004	.0005	.0005	.0006
CL2	.0000	.0000	.0001	.0002	.0004	.0005	.0006	.0008	.0010
O	.0000	.0000	.0001	.0001	.0001	.0001	.0000	.0000	.0000
CL	.0000	.0023	.0130	.0171	.0157	.0136	.0112	.0092	.0074
NO	.0000	.0008	.0512	.0710	.0823	.0827	.0777	.0704	.0616
AL2O3*	.0000	7.2365	7.2365	7.2365	7.2365	7.2365	7.2365	7.2365	7.2365

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

N2	CO2	H2O	AL2O3*	CO	HCL	PBCL	PB	ZNCL2	ZN	PBO	PBCL2	N2	CL	HO
NO	PBH	H	O2	PB2	NH3	HOCL	CL2	O	CNHO	COCL	ALOCL	ALCL3	CHO	OCL
ALCL2	CH2O	CNH	NHO	NH2	H2O2	HO2	NH	NOCL	NHO2	ALCL	N	COCL2	CNO	CNCL
ALO2	CH4	PBCL4	N2H2	CH	CH3	ALO	ALHO2	CH3CL	N3	AL2CL6	CHCL3	C2CL2	CCL3	CHCL
ALHO	AL	ALCL2	OCL2	ALCL	N2O5	AL0	AL2O	CCL	O2CL	CHO	NHO3	N2H4	CH2CL2	C2H2
C2O	ALH	O3	CH2	C2N2	CCL2	C2H4O	CH2	CL	NO2CL	HO	CCL4	C2	CN2	C2H
C2N	C2HCL	N2O4	NO3	C3O2	AL2O2	CH	CN	C	AL2O2	H3O	AL2O	N2O	H	NO
N2O3	ALC	PB3O4*	ALH	PBCL2*	PBCL2*	PBO2*	C2CL6	PBO*	PBO*	PBO*	PBO*	PB*	PB*	C2CL4
AL4C3*	ZNCL2*	C4H2	ALCL3*	ALCL3*	NH4OC	AL2O3*	AL2O3*	N2O4*	N2O4*	ZNO*	ALOCL*	ZN*	ZN*	C5
C4H10	C4H8	NH4CL*	NH4CL*	C4	NO2	C3H8	C3H6	ALN*	C3	N2H4*	C2H6	C2H4	AL*	AL*
AL*	H2O*	H2O*	C*	C*										

TABLE IV CONTINUED

TABLE V

Gaseous Emissions Detected by Helicopter from 5000 Lbs of

Navy Manufactureres Waste, Burned 22 May 1986*

Emissions from 5000 Lbs Open Burn

Pass No.	1	2	3	4	5	6	7
GAS	——lb gas /5000 lb Navy Waste——					lb gas/100 lb Navy Waste**	
SO2	31.19	24.85	17.48	9.65	10.92	22.12	0.39
Cl2	-8.63	-10.65	-8.30	-2.67	0.00	-24.49	0.18
HCl	---	76.65	61.84	46.770	43.50	69.25	1.19
NO	23.80	22.53	12.87	6.78	10.23	20.73	0.32
NO2	1.35	5.18	4.48	6.93	13.07	11.92	0.14
H2S	7.01	2.98	3.32	0.00	0.00	0.00	0.09
CO	3.88	2.45	4.37	0.00	0.00	0.00	0.07

Emissions from 2500 Lbs of Navy Waste

SO2	3.07	23.59	17.64	4.52	2.22	---	0.41
Cl2	-4.15	-20.12	-13.02	-2.50	0.00	---	-0.32
HCl	8.44	38.08	65.26	26.98	11.40	---	1.21
NO	2.88	9.96	5.51	1.06	1.56	---	0.17
NO2	0.37	1.94	3.52	4.05	0.00	---	0.08
H2S	0.45	2.06	1.04	0.60	0.00	---	0.03
CO	---	---	1.29	---	1.95	---	0.06

* The open burning of the PEP military wastes, collection of pollution products and cloud sampling was conducted under the direction of Mark M. Zaugg, Ammuniton Equipment Directorate (AED), Tooele Army Depot, Tooele, Utah. This table (Table V) is from the reduction of the helipcopter data by the program SUMMARIZ developed by AED. The columns represent the analyses of six passes made by the helicopter through the cloud plume after the Navy waste was burned.

** The average of total runs.

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LIST OF CALCULATIONS

Title	OB* Calculations NO.	OD Calculations NO.
NOWIH-80-1 (MK23)	1	18
X256 (MK 12)	2	19
N-60 (SMOKEY SAM)	3	20
N-50 (5" G.P.)	4	21
N-5 (ASROC and MK22)	5	22
AA2 (MK 90)	6	23
AA6 (Zuni)	7	24
HEN-12 (RAPEC/SEAGNAT)	8	25
BX-180/BX 185 (MK 18 BOOSTER)	9	26
BX-180/BX 185 (MK 18 SUSTAINER)	10	27
BX-180 H (CKU-5/A SUSTAINER)	11	28
TPH-9001 (CKU-7/A SUSTAINER)	12	29
PBXN-106 (MK 115)	13	30
NOSIH (BC-10) (MQM-107)	14	31
XM39 (LOVA)	15	32
PBXN-103	16	33
PBX(AF) -108	17	34

* OB = Open Burn Data: OD = Open Detonation Data.

** Composition of explosives are given in calculations.

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= NOWIH-88-1(MK23)

	H	C	N	O	AL	P	CL	FE			
R-45M	.011	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000						14.220	-0.	.0329
DER-736	.000	.0040.000	.0020.0000.000 .0000.0000.0000.0000.0000.000						.710	-402.	.0401
ERL 0510	.007	.005	.000	.0010.0000.0000.0000.0000.0000.0000.0000.000					.990	-196.	.0361
VANOX-200	.007	.006	.000	.0010.000	.0000.0000.0000.0000.0000.0000.0000.000				.620	-259.	.0361
LECITHIN(LECTI)	.011	.0060.000	.0010.000	.0000.0000.0000.0000.0000.0000.0000.000					.400	-516.	.0376
CARBON (GRAPHITE)	0.000	.0010.0000.0000.0000.0000.0000.0000.0000.0000.000							.500	0.	.0017
IRON OXIDE- FEO	0.0000.0000.000	.0010.0000.0000.000	.0010.0000.0000.0000.000						.500	-905.	.2059
ALUMINUM --AL	0.0000.0000.0000.000	.0010.0000.0000.0000.0000.0000.0000.000							2.000	0.	.0976
AP	.0040.000	.001	.0040.0000.000 .0010.0000.0000.0000.0000.000						80.000	-602.	.0705
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000						0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.940 1.0000

0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(
4.491064	1.222408	.685863	2.770823	.074129	.002000	.002734	.000959	

WT. MATERIAL	99.940	89.946	79.952	69.958	59.964	49.970	39.976	29.982	19.988	9.994
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2731.261	2753.022	2777.253	2800.451	2818.939	2810.005	2654.408	2253.210	1714.497	1076.412
FLAME TEMP. T(F)	4456.870	4497.400	4539.656	4581.411	4614.690	4598.609	4318.535	3596.392	2626.694	1478.141
ENTHALPY KCAL/GFW	-49.492	-44.543	-39.593	-34.644	-29.695	-24.746	-19.797	-14.848	-9.898	-4.949

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI

FLAME TEMP. T(K)	1253.480	1267.374	1282.326	1298.557	1316.553	1338.392	1247.848	949.831	665.438	369.987
FLAME TEMP. T(F)	1796.865	1821.073	1848.787	1878.802	1910.396	1949.706	1705.206	1250.295	738.374	206.577
ENTHALPY KCAL/GFW	-116.445	-109.979	-103.526	-97.092	-90.682	-84.265	-74.458	-58.837	-42.129	-24.318
1.VOL.GASES--LITERS	94.077	101.099	109.078	121.161	136.287	157.272	192.128	256.901	385.168	773.583
(GASES AT STP)										
COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04										

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

HCL	24.4029	24.4029	24.4029	24.4029	24.4028	24.4026	24.6523	23.8722	11.6165	.2290
CO2	21.8698	23.2641	26.1738	30.1947	36.0255	45.1812	53.8349	53.8349	53.8349	53.8349
CO	28.8538	19.4569	17.6858	15.8459	11.3349	5.5077	.0000	.0000	.0000	.0000
H20	17.3785	19.1195	21.2379	23.8471	27.1338	31.3289	34.3885	34.7783	37.5524	40.3667

N2	9.6131	18.3794	29.3375	43.4264	62.2116	88.5189	127.9512	193.7061	325.2835	719.6914
AL2O3$	3.7814	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H2	1.9113	1.7156	1.4705	1.1066	.8188	.3494	.0000	.0000	.0000	.0000
FECL2	.0005	.0008	.0011	.0013	.0015	.0014	.0206	.0001	.0000	.0000
P406	.1149	.1149	.1149	.1149	.1149	.1149	.0000	.0000	.0000	.0000
FE2CL4	.0010	.0014	.0011	.0009	.0007	.0005	.0000	.0000	.0000	.0000
FECL3	.0005	.0005	.0005	.0006	.0006	.0009	.0166	.0022	.0000	.0000
NH3	.0003	.0003	.0003	.0002	.0001	.0000	.0000	.0000	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0006	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.1796	1.7752	12.9215	23.9994
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0061	.0112	.0078	.0002
02	.0000	.0000	.0000	.0000	.0000	.0000	4.5131	21.0017	54.5612	157.8766
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0001	.0000	.0000
CL	.0000	.0000	.0000	.0001	.0001	.0003	.0406	.0034	.0000	.0000
P4010	.0000	.0000	.0000	.0000	.0000	.0000	.1403	.1403	.0001	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.5513	.5560	.5560
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.5299	.0036	.0000	.0000
AL2O3$	.0000	3.7814	3.7814	3.7814	3.7814	3.7814	3.7814	3.7814	3.7814	3.7814
PH3O4*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.2046	.2048
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0001	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0101	.0032	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

HCL	CO2	CO	H2O	N2	AL2O3$	H2	FECL2	P406	FE2CL4	FECL3	NH3	CH4	CL	FEH2O2
CNH	CH2O	PN	ALCL3	CNHO	H	P02	HO	CL2	CH3CL	COCL	PO	CHO	ALCL2	FECL
CH3	PH3	PH2	FE	NH2	HOCL	NO	CPH	CNCL	C2H4	COCL2	FE2CL6	C2H2	PH	ALOCL
PCL	POCL3	PCL3	P2	CH2CL2	FEO	ALCL	C2H6	P	NH	O2	O	NHO	H2O2	OCL
CNO	C2HCL	CN	N2H2	C2N2	NOCL	CCL2	CHCL3	N	CH2	AL2CL6	N2O4	O3	C3O2	C2N
C2O	N2H4	NH3	NO2CL	PCL5	HO2	C2CL2	NHO2	C2H	CL	CHCL	CN2	C3	HO	CP
C2CL4	CCL3	NO3	N2O5	C2H4O	CCL4	CN	C2	CN2	C4N2	AL2O2	ALHO	N3	H3O	ALCL2
ALO2	CH	ALH	ALHO2	ALC	AL	ALO	OCL2	H	N2O3	N2O	P4O10	CHO	CCL	P4O10$
C2CL6	FE3O4$	FE3O4$	C	P3N5$	FECL3$	FECL3*	FE2O3$	FE2O3$	AL4C3$	ALCL3*	ALCL3$	FECL2$	FECL2*	P4
NH4O4C	FEH3O3	AL2O3$	AL2O3*	PH3O4$	PH3O4*	N2O4$	N2O4*	FEH2O2	AL2O2	ALOCL$	FEO$	FEO$	FEO*	AL2O
AL2O	O2CL	ALCL	C5	C4H10	C4H8	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	C4
NO2	C3H8	ALO	C3H6	ALN	ALN$	N2H4*	P$	P$	P*	NO	AL*	AL$	AL*	H2O*
H2O*	C$	C$												

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= X256 (MK 12)

	H	C	N	O	AL	FB			
ITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000	49.090	-625.	.0600		
ITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000	33.600	-392.	.0570		
RIACETIN - TA	.014	.0090.000	.0060.0000.0000.0000.0000.0000.0000.0000.000	7.620	-1335.	.0420			
NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000	1.450	83.	.0494		
LAD SALICYLATE	.010	.0140.000	.0060.000	.0010.0000.0000.0000.0000.0000.0000.000	1.030	-864.	.0561		
EADETHYLHEXOAT-PBEH	.030	.0150.000	.0040.000	.0010.0000.0000.0000.0000.0000.0000.000	.390	-694.	.0470		
BRES	.006	.0070.000	.0050.000	.0010.0000.0000.0000.0000.0000.0000.000	1.440	-603.	.0525		
LUMINUM --AL	0.0000.0000.0000.000	.0010.0000.0000.0000.0000.0000.0000.000	3.700	0.	.0976				
AIR -(G	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000	0.000	0.	.0004			

RAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 1.0000

(H)	(C)	(N)	(O)	(AL)	(PB)	(				
2.763753	2.038053	.986124	3.412906	.140104	.000407					
. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000
. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

--COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI--

LAME TEMP. T(K)	2744.513	2771.950	2800.764	2830.260	2857.035	2872.093	2823.924	2523.293	1935.075	1197.407
LAME TEMP. T(F)	4400.723	4538.124	4581.975	4635.068	4684.703	4711.000	4623.663	4082.527	3025.176	1696.076
NTHALPY KCAL/GFW	-57.245	-51.520	-45.796	-40.071	-34.347	-28.622	-22.898	-17.173	-11.449	-5.724

--COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI --

AME TEMP. T(K)	1291.745	1306.121	1321.430	1337.817	1355.666	1376.020	1404.664	1140.157	775.411	415.241
AME TEMP. T(F)	1065.741	1091.617	1919.174	1940.671	1900.790	2017.437	2060.996	1607.283	936.339	200.033
NTHALPY KCAL/GFW	-120.595	-113.701	-106.903	-100.205	-93.454	-86.724	-79.077	-65.047	-47.334	-27.076
VOL.GASES--LITERS	80.500	95.526	104.290	115.576	130.613	151.666	183.244	245.245	375.225	765.007
GASES AT STP)										

OMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

--GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO	40.2390	30.1026	35.3400	31.6256	26.3782	18.4712	5.4586	.0000	.0000	.0000
CO2	26.1557	29.5127	33.0535	37.6095	47.9343	60.3579	80.0159	89.3799	89.3799	89.3799
N2	12.6927	21.4539	32.4053	46.4858	65.2597	91.5432	130.9603	196.6604	328.0936	722.3458
H2O	10.4061	11.6778	13.2005	15.0720	17.3670	20.2192	23.7406	24.0958	24.0959	24.0959
AL2O3$	7.1425	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

OB CALCULATION NO. 2

PB	1.7390	1.7396	1.7392	1.7306	1.7371	1.7320	1.6942	.0001	.0000	.0000
H2	1.6213	1.4790	1.3070	1.0993	.8425	.5233	.1204	.0000	.0000	.0000
PBH	.0012	.0012	.0011	.0010	.0009	.0007	.0003	.0000	.0000	.0000
PBO	.0009	.0012	.0017	.0025	.0043	.0092	.0512	.6414	.0000	.0000
PB2	.0003	.0003	.0002	.0002	.0002	.0001	.0001	.0000	.0000	.0000
NH3	.0003	.0003	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000
CH4	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	13.3519	48.6109	154.3154
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.9214
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0101	.0005	.0000
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.2351	1.0766	.0000
AL2O3$	.0000	7.1425	7.1425	7.1425	7.1425	7.1425	7.1425	7.1425	7.1425	7.1425
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	CO2	N2	H2O	AL2O3$	PB	H2	PBH	PBO	PB2	NH3	CH4	CNH	CH2O	CNHO
H	HO	CHO	CH3	NH2	NO	C2H2	C2H4	C2H6	NH	O	O2	NHO	CNO	CN
H2O2	C2N2	N2H2	N	CH2	C2O	C2H	O3	C3O2	N2H4	NHO3	N2O4	HO2	NHO2	CN2
HO	CN	C4N2	NO3	ALHO	C2H4O	C2	CN2	C2N	N3	H3O	CH	ALO2	ALH	AL
N2O5	ALO	AL2O2	ALC	ALHO2	CHO	H	N2O3	N2O	C	C3	PB3O4$	NO	PBO2$	PBO$
PBO$	PBO*	PBO*	PB$	PB*	AL4C3$	AL2O3$	AL2O3*	N2O4$	N2O4*	AL2O2	AL2O	AL2O	C5	C4H10
C4H8	C4	NO2	C3H8	ALO	C3H6	ALN	ALN$	N2H4*	AL*	AL$	AL*	H2O*	H2O*	C$
C$														

OB CALCULATION NO. 2 CONTINUED

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= N-60 (SMOKEY SAM)

	H	C	N	O	CL	FE	ZN				
R-45M	.011	.0070	.000	.0000	.0000	.0000	.0000	.0000	.0000	11.970	-0.	.0329
DIOCTYL ADIPATE	.042	.0220	.000	.0040	.0000	.0000	.0000	.0000	.0000	3.000	-733.	.0332
IRON OXIDE	0.0000	.0000	.000	.0030	.000	.0020	.0000	.0000	.0000	1.000	-1235.	.1093
)INC	0.0000	.0000	.0000	.0000	.0000	.000	.0010	.0000	.0000	40.000	0.	.2500
AP	.0040	.000	.001	.004	.0010	.0000	.0000	.0000	.0000	44.000	-602.	.0705
AIR -10	0.0000	.000	.006	.0010	.0000	.0000	.0000	.0000	.0000	0.000	0.	.0004

NORMALIZATION AMOUNTS FOR MATERIAL WEIGHT OF 99.970 1.0000

(H)	(C)	(N)	(O)	(CL)	(FE)	(ZN)
3.140468	1.051402	.374478	1.559062	.374478	.012523	.611000

WT. MATERIAL	99.970	89.973	79.976	69.979	59.982	49.985	39.988	29.991	19.994	9.997
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	1476.259	1538.352	1642.630	1817.820	1998.054	2189.289	2383.599	2389.913	1795.589	1094.869
FLAME TEMP. T(F)	2197.867	2295.234	2497.340	2812.698	3130.536	3401.320	3831.079	3698.443	2772.517	1511.364
ENTHALPY KCAL/GFW	-29.911	-26.920	-23.929	-20.937	-17.946	-14.955	-11.964	-8.973	-5.982	-2.991

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1020.527	1015.137	1037.703	1077.206	1118.018	1161.555	1212.944	1000.791	734.901	390.710
FLAME TEMP. T(F)	1377.549	1367.846	1400.465	1479.571	1554.473	1631.480	1723.899	1500.425	863.566	243.079
ENTHALPY KCAL/GFW	-61.574	-59.035	-58.267	-56.961	-55.901	-55.124	-54.858	-58.574	-57.184	-22.118
T.VOL.GASES--LITERS (GASES AT STP)	75.046	82.748	92.784	104.431	119.559	140.668	172.382	238.768	360.915	758.378

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

ZNO	32.6676	33.3134	33.1520	32.1000	30.7159	29.5241	30.4011	36.2040	36.8374	34.5634
ZNCL2	24.6316	24.5834	24.2623	24.0897	23.7356	23.4553	23.1705	22.6415	8.5025	.0000
CO	23.8461	24.7649	23.7558	21.6010	18.5854	13.9557	6.6915	.0000	.0000	.0000
H2	5.2455	14.0884	24.9632	39.0405	57.0207	84.1206	123.5500	189.2024	328.7426	715.1122
CO2	4.2156	5.0096	8.6017	12.1704	17.2075	24.3596	35.7734	46.2871	46.2871	46.2871
H2	2.7264	2.7151	2.6311	2.3581	1.9289	1.3269	.5366	.0000	.0000	.0000
H2O	2.0759	2.6038	4.3913	7.0570	10.9630	16.2384	23.2653	27.9893	27.9059	28.3696
ZN	1.9514	1.4948	1.7394	2.6993	3.9491	5.0411	4.4050	.0000	.0000	.0000

OB CALCULATION NO. 3

CH4	.0850	.5710	.1312	.0150	.0014	.0001	.0000	.0000	.0000	.0000
FE$	.6985	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
C$	.6530	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HCL	.4777	.5459	.6735	.0001	.9542	1.1836	1.2510	1.5402	1.0774	.0011
FECL2	.0026	.0034	.0058	.0060	.0070	.0007	.0099	.0000	.0000	.0000
NH3	.0021	.0031	.0030	.0022	.0013	.0006	.0001	.0000	.0000	.0000
CNH	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0025	.1566	.0003
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0012	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0002	.0000
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0009	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	0.3653	43.5950	149.4115
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0003	1.0003
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0003	.0000	.0000
ZNCL2*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	13.1336	25.5245
FEO$	.0000	.0000	.0000	.0962	.0957	.0951	.0944	.0000	.0000	.0000
FE$	.0000	.6902	.6971	.0000	.0000	.0000	.0000	.0000	.0000	.0000
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

ZNO$	ZNCL2	CO	N2	CO2	H2	H2O	ZN	CH4	FE$	C$	HCL	FECL2	NH3	CNH
H2O	C2H4	C2H6	CNHO	CH3CL	FE2CL4	CH3	C2H2	FEH2O2	FECL3	H	C3H6	CL	CHO	C3HB
H2	COCL	HO	FE	CNCL	FECL	CL2	C2N2	C4HB	CH2CL2	C2HCL	NO	HOCL	C4H10	COCL2
E2CL6	C2H4O	OCL2	CCL2	NH	CN2	FEO	NO	CN	C3O2	C2H	C2CL2	CNO	CN	CH2
HCL3	N2H2	C4	N2H4	CCL3	N2O4	C2	N3	C2O	O2CL	NHO	C4N2	CCL4	C3	HO
2CL4	CL	NHO3	C	O	H2O2	NO2CL	CCL	O2	CHCL	N	O3	N2O5	C2N	OCL
2O	H	CN2	NOCL	NO3	C2CL6	FE3O4$	FE3O4$	FECL3$	FECL3*	FE2O3$	FE2O3$	ZNCL2*	NHO2	FECL2$
ECL2*	NH4O4C	FEH3O3	N2O4$	N2O4*	FEH2O2	N2O3	FEO$	FEO$	FEO*	ZN$	ZN*	C5	FE$	FE$
E$	FE*	FE$	NH4CL$	NH4CL$	CH	NO2	HO2	N2H4*	CHO	H3O	H2O*	H2O*	C$	

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= N-50 (5" O.P.)

	H	C	N	O	AL	CL	FE				
R-45M	.011	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000					11.000	-0.	.0329	
PHENOL	.006	.0060.000	.0010.0000.0000.0000.0000.0000.0000.0000.000					.150	-394.	.0307	
DIPHENYLAMINE - DPA	.011	.012	.0010.0000.0000.0000.0000.0000.0000.0000.000					.150	170.	.0419	
(DIME)N,N-B-2-HY-ET-M	.007	.004	.001	.0020.0000.0000.0000.0000.0000.0000.0000.000				.200	-830.	.0444	
IRON OXIDE	0.0000.0000.000		.0030.0000.000		.0020.0000.0000.0000.0000.000			.200	-1235.	.1093	
ALUMINUM --AL	0.0000.0000.0000.000			.0010.0000.0000.0000.0000.0000.0000.000				10.000	0.	.0976	
AP	.0040.000	.001	.0040.000	.0010.0000.0000.0000.0000.0000.0000.000				65.000	-602.	.0705	
ISODECYL PELARGONATE	.030	.0190.000	.0020.0000.0000.0000.0000.0000.0000.0000.000					.060	-707.	.0314	
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000					0.000	0.	.0004	
										1.0000	

0GRAM ATOM AMOUNTS FOR MATERIAL	(H)	(C)	(N)	(O)	(AL)	(CL)	(FE)	(			
	3.450651	.034507	.555847	2.231766	.667161	.553206	.002505				
WT. MATERIAL	94.760	85.204	75.000	66.332	56.056	47.300	37.904	20.420	10.952	9.476	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

--COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	3570.345	3556.036	3522.303	3474.498	3406.272	3300.707	3107.704	2780.711	2117.056	1297.939
FLAME TEMP. T(F)	5901.621	5941.465	5000.007	5794.683	5671.089	5401.873	5134.611	4416.200	3352.741	1076.072
ENTHALPY KCAL/GFW	-39.600	-35.640	-31.600	-27.720	-23.760	-19.800	-15.840	-11.000	-7.920	-3.960

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI-

FLAME TEMP. T(K)	2302.249	2270.000	2199.406	2116.121	2031.425	1950.009	1031.201	1335.416	002.525	469.100
FLAME TEMP. T(F)	3604.647	3642.504	3499.530	3349.617	3197.164	3050.615	2036.905	1944.340	1129.145	304.995
ENTHALPY KCAL/GFW	-115.066	-109.994	-103.992	-97.041	-91.540	-05.044	-77.320	-63.457	-46.461	-27.003
T.VOL.GASES--LITERS (GASES AT STP)	02.046	09.431	90.597	110.433	126.257	140.450	102.934	251.356	300.052	796.979

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

--- GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

AL2O3$	35.0419	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CO	23.3217	22.6529	21.5750	19.0039	16.6556	10.5962	.0930	.0000	.0000	.0000
HCL	20.7993	20.0204	20.9059	20.9560	20.9902	20.9999	20.5492	20.9122	10.0040	1.3372
N2	0.2164	17.4617	29.0106	43.0776	63.6896	91.4261	132.9565	202.3349	341.0572	757.1109
H2O	6.6764	9.0207	11.0125	15.1615	19.1221	23.6017	27.7420	27.7095	20.4000	32.5470

OB CALCULATION NO. 4

H2	2.3360	2.0750	1.7677	1.3961	.9551	.4555	.0030	.0000	.0000	.0000
CO2	2.1189	3.1696	4.0833	7.6462	12.5920	22.1134	30.6140	30.7621	30.7621	30.7621
FECL2	.3077	.3122	.3242	.3292	.3321	.3332	.3323	.0610	.0000	.0000
CL	.2421	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALCL2	.0600	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H	.0192	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HO	.0165	.0214	.0183	.0152	.0125	.0119	.0004	.0024	.0000	.0000
ALCL	.0142	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FE	.0110	.0090	.0044	.0010	.0006	.0001	.0000	.0000	.0000	.0000
ALOCL	.0004	.0060	.0024	.0009	.0003	.0001	.0000	.0000	.0000	.0000
ALCL3	.0062	.0035	.0017	.0000	.0004	.0002	.0001	.0000	.0000	.0000
FECL	.0011	.0010	.0006	.0003	.0001	.0000	.0000	.0000	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FEHO2	.0003	.0004	.0006	.0007	.0009	.0009	.0000	.0000	.0000	.0000
CL2	.0002	.0002	.0002	.0002	.0002	.0002	.0140	.2050	3.1047	19.3907
FEO	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000
O	.0002	.0002	.0001	.0001	.0001	.0001	.0015	.0000	.0000	.0000
FECL3	.0001	.0001	.0001	.0001	.0001	.0002	.0021	.0170	.0007	.0000
O2	.0000	.0001	.0001	.0001	.0001	.0003	1.3502	19.9714	56.5006	164.5063
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0020	.0095	.0110	.0012
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0009	.0011	.0001	.0000
ALCL2	.0000	.0308	.0186	.0034	.0010	.0002	.0000	.0000	.0000	.0000
CL	.0000	.2400	.1793	.1339	.1024	.0932	.5146	.1000	.0017	.0000
ALCL	.0000	.0066	.0016	.0003	.0001	.0000	.0000	.0000	.0000	.0000
NO	.0000	.0016	.0017	.0018	.0010	.0027	.1629	.0050	.0029	.0000
H	.0000	.0169	.0106	.0062	.0032	.0014	.0001	.0000	.0000	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.2107	.2111
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.1642	.0000	.0000
AL2O3$	.0000	35.0659	35.0036	35.0097	35.0917	35.0924	35.0926	35.0926	35.0926	35.0926
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

AL2O3$	CO	HCL	N2	H2O	H2	CO2	FECL2	CL	ALCL2	H	NO	ALCL	FE	ALOCL
ALCL3	FECL	NO	FEH2O2	CL2	FEO	O	FECL3	O2	NH3	CNO	COCL	CHO	HOCL	AL
CH2O	ALO	NH2	CNHO	OCL	NH	ALO2	FE2CL4	ALH	N	AL2O	NHO	CH4	H2O2	CNCL
HO2	ALHO2	CH3	CN	NOCL	CNO	AL2O2	COCL2	CH3CL	NHO2	C2H2	CH2	C2O	N2H2	ALN
CHCL	AL2CL6	CH	C	C2H	OCL2	CH2CL2	N3	C2HCL	CCL	CN2	O2CL	C2N2	CCL2	C2N
FE2CL6	N2H4	O3	CHCL3	C3O2	CN2	C2CL2	ALC	NO2CL	CCL3	C2	ALCL2	N2O3	CL	CN
C4N2	AL2O	C2CL4	ALCL	CCL4	HO	C3	NHO3	C2H4O	H3O	N2O4	NO	ALO	AL2O2	CHO
NO3	H	N2O5	C2CL6	FE3O4$	FE3O4$	FECL3$	FECL3*	FE2O3$	FE2O3$	AL4C3$	ALCL3*	ALCL3$	FECL2$	FECL2*
NH4O4C	FEH3O3	AL2O3$	AL2O3*	N2O4$	N2O4*	FEH2O2	ALOCL$	FEO$	FEO$	FEO*	C5	C4H10	N2O	C4HO
FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	C4	NO2	C3HO	ALHO	C3H6	ALN$	N2H4*
C2H6	C2H4	AL*	AL$	AL*	H2O*	H2O*	C$	C$						

OB CALCULATION NO. 4 CONTINUED

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= N-5 (ASROC AND MK22)

	H	C	N	O	PB						
NITROCELLULOSE(12.6)	.000	.006	.002	.0100	.0000	.0000	.0000	.0000	.0000	50.000	-625.	.0600
NITROGLYCERIN - NG	.005	.003	.003	.0090	.0000	.0000	.0000	.0000	.0000	34.900	-392.	.0570
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020	.0000	.0000	.0000	.0000	.0000	2.000	83.	.0494
DIETHYL PHTHALATE	.014	.0120	.000	.0040	.0000	.0000	.0000	.0000	.0000	10.500	-810.	.0406
LEAD SALICYLATE	.010	.0140	.000	.006	.0010	.0000	.0000	.0000	.0000	2.400	-864.	.0361
CANDELLIA WAX	.012	.0070	.000	.0000	.0000	.0000	.0000	.0000	.0000	.200	-142.	.0343
AIR (G	0.0000	.000	.006	.0010	.0000	.0000	.0000	.0000	.0000	0.000	0.	.0004
											1.0000	

OGRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

0 (H)	(C)	(N)	(O)	(PB)	(						
2.903240	2.324052	.929421	3.430551	.004905							
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

--COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2251.626	2319.273	2391.040	2467.391	2548.522	2632.750	2703.805	2561.751	1973.305	1221.160
FLAME TEMP. T(F)	3593.527	3715.291	3844.471	3981.904	4127.940	4279.551	4406.152	4151.752	3092.692	1730.689
ENTHALPY KCAL/GFW	-55.373	-49.035	-44.298	-38.761	-33.224	-27.686	-22.149	-16.612	-11.075	-5.537

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	991.374	1012.130	1043.517	1081.466	1123.207	1168.659	1219.018	1162.387	789.006	423.507
FLAME TEMP. T(F)	1325.073	1362.440	1418.931	1487.239	1562.516	1644.186	1736.272	1632.897	960.954	302.913
ENTHALPY KCAL/GFW	-110.000	-104.320	-98.656	-92.999	-87.353	-81.720	-76.123	-66.916	-48.041	-27.436
T.VOL..GASES--LITERS (GASES AT STP)	95.490	102.957	111.914	123.230	138.204	159.338	190.917	247.773	377.753	767.599

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (OS/O)MATERIAL BURNED-----

CO	43.2697	41.6814	39.2970	36.1301	31.6560	24.9836	13.6914	.0000	.0000	.0000
CO2	33.6577	36.7195	40.5218	45.5423	52.5706	63.1903	80.0071	102.3191	102.3191	102.3191
N2	13.0177	21.7709	32.7306	46.8113	65.5856	91.0693	131.2946	196.9960	320.4199	722.6713
H2O	6.5632	7.7756	9.4523	11.6315	14.4101	18.0128	22.7076	26.8729	26.8730	26.8730
H2	2.2104	2.1151	1.9442	1.7045	1.3935	.9915	.4661	.0000	.0000	.0000
PB*	1.0210	1.0130	.9927	.9397	.8807	.4779	.0000	.0000	.0000	.0000
CH4	.2463	.0857	.0195	.0033	.0004	.0000	.0000	.0000	.0000	.0000

OB CALCULATION NO. 5

PB	.0112	.0191	.0403	.0932	.2242	.5546	1.0306	.0002	.0000	.0000
NH3	.0019	.0019	.0016	.0011	.0007	.0003	.0001	.0000	.0000	.0000
PBH	.0000	.0000	.0000	.0000	.0001	.0002	.0002	.0000	.0000	.0000
PBO	.0000	.0000	.0000	.0000	.0000	.0003	.0022	.0972	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	6.0180	41.2746	146.9973
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.1373
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.2153	1.1127	.0000
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0137	.0006	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	CO2	N2	H2O	H2	PB*	CH4	PB	NH3	CNH	CH2O	CNHO	PBH	C2H4	C2H6
PBO	PB2	CH3	C2H2	H	C3H6	NH2	HO	C3H8	NO	C2N2	C4H8	C2H4O	CNO	CN
NH	CN2	N3	N2H2	NHO	N2O4	C2N	C3O2	N2H4	C	C3	C4N2	HO	CN	C2H
C2O	H2O2	NO3	N2O5	CN2	O	C4H10	O2	H	N2O	N2O3	NHO3	N	C2	PB3O4$
O3	PBO2$	PBO$	PBO$	PBO*	PBO*	PB$	C5	N2O4$	N2O4*	NHO2	C4	NO2	H3O	HO2
N2H4*	NO	CHO	CHO	H2O*	H2O*	CH2	CH	C$	C$					

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= AA2 (MK 90)

	H	C	N	O	CU	PB						
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000							51.000	-625.	.0600
NITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000							30.600	-392.	.0570
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000							2.000	83.	.0494
DNTA	.022	.0120.000		.0040.0000.0000.0000.0000.0000.0000.0000.000							1.600	-894.	.0361
PBNA	.006	.0070.000		.0050.000	.0010.0000.0000.0000.0000.0000.0000.0000.000						.000	-603.	.0525
LOSAL	.006	.0070.000		.004	.0010.0000.0000.0000.0000.0000.0000.0000.000						3.200	871.	.0361
CANDELLIA WAX	.012	.0070.000		.0000.0000.0000.0000.0000.0000.0000.0000.000							.100	-142.	.0343
TRIACETIN - TA	.014	.0098.000		.0060.0000.0000.0000.0000.0000.0000.0000.000							1.600	-1335.	.0420
AIR -(0	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000							0.000	0.	.0004
												1.0000	

OXIDATION AMOUNTS FOR MATERIAL WEIGHT OF 90.900

0 (H)	(C)	(N)	(O)	(CU)	(PB)	(						
2.725300	2.019275	.987293	3.543491	.014701	.002120							
WT. MATERIAL		90.900	89.810	79.120	69.230	59.340	49.450	39.560	29.670	19.780	9.890	
WT. AIR		0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

--- COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2730.860	2766.701	2796.010	2824.825	2845.257	2830.800	2721.674	2342.696	1779.321	1107.002
FLAME TEMP. T(F)	4469.122	4520.085	4573.418	4623.846	4662.063	4650.441	4439.613	3757.453	2743.377	1533.204
ENTHALPY KCAL/GFW	-53.750	-48.382	-43.006	-37.631	-32.255	-26.879	-21.503	-16.127	-10.752	-5.376

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI--

FLAME TEMP. T(K)	1260.308	1204.394	1301.517	1320.038	1340.564	1364.336	1340.207	1015.962	698.516	375.044
FLAME TEMP. T(F)	1823.699	1852.510	1883.331	1916.669	1953.615	1996.404	1967.517	1369.332	785.530	217.120
ENTHALPY KCAL/GFW	-116.452	-110.092	-103.744	-97.411	-91.092	-84.751	-78.784	-60.993	-43.761	-25.052
1.VOL.GASES--LITERS (GASES AT STP)	80.317	95.413	104.202	115.686	130.898	152.177	185.251	251.847	382.433	776.736

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	36.0659	39.6056	44.2134	50.4314	59.2173	72.4399	89.0583	89.0587	89.0587	89.0587
CO	34.2366	31.9038	29.0511	25.0937	19.9019	11.0863	.0003	.0000	.0000	.0000
H2	13.9836	22.0422	33.9155	48.1525	67.1352	93.7118	133.5641	200.0110	332.0926	731.5200
H20	11.8021	14.2206	15.6067	17.4412	19.5779	22.1915	24.0225	24.0233	24.0233	24.0233
N2	1.3227	1.1055	1.0224	.0260	.5069	.2945	.0000	.0000	.0000	.0000

OB CALCULATION NO. 6

CU$	.9445	.9445	.9445	.9445	.9444	.0000	.0000	.0000	.0000	.0000
PB	.4437	.4436	.4434	.4432	.4425	.4402	.0011	.0000	.0000	.0000
PBO	.0003	.0004	.0006	.0009	.0016	.0042	.4773	.0211	.0000	.0000
PBH	.0003	.0002	.0002	.0002	.0002	.0001	.0000	.0000	.0000	.0000
NH3	.0002	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000
CU	.0000	.0000	.0000	.0001	.0001	.0003	.0000	.0000	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0013	.0000	.0000	.0000
CUO	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	1.0573	19.5602	55.2010	162.1041
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.4899	.0000
PBO2$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.5120
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.4574	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0227	.0064	.0001	.0000
CU2O$	.0000	.0000	.0000	.0000	.0000	.0000	1.0632	.0000	.0000	.0000
CUO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.1024	1.1024	1.1024
CU*	.0000	.0000	.0000	.0000	.0000	.9443	.0000	.0000	.0000	.0000
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	CO	N2	H2O	H2	CU$	PB	PBO	PBH	NH3	CH4	PB2	CU	CNH	CH2O
CNHO	H	HO	CHO	CH3	NH2	CU2	NO	CUO	C2H2	C2H4	NH	C2H6	O2	O
NHO	CNO	H2O2	CN	C2N2	N2H2	N	C3O2	CH2	C2O	C2N	NHO3	N2H4	C2H	HO2
NHO2	CN2	C3	N2O5	HO	NO3	C2H4O	CN2	C4N2	C2	N3	H3O	CN	CH	N2O3
H	CHO	N2O	N2O4	PB3O4$	C	PBO2$	PBO$	PBO$	PBO*	PBO*	PB$	PB*	NO	CU2O$
CU2O*	CUH2O2	N2O4$	N2O4*	CUO$	CUO$	C4	CU*	C5	C4H10	C4H8	O3	NO2	C3H8	C3H6
N2H4*	H2O*	H2O*	C$	C$										

OB CALCULATION NO. 6 CONTINUED

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= AA6 (ZUNI)

	H	C	N	O	AL	CU	PB			
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000				49.000	-625.	.0600
NITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000				30.000	-392.	.0570
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000				2.000	83.	.0494
DNTA	.022	.0120.000	.0040.0000.0000.0000.0000.0000.0000.0000.000					2.000	-894.	.0361
PBRES	.006	.0070.000	.0050.0000.000	.0010.0000.0000.0000.0000.000				.550	-603.	.0125
CUSAL	.006	.0070.000	.0040.000	.0010.0000.0000.0000.0000.0000.000				2.750	-871.	.0361
CANDELLIA WAX	.012	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000					.100	-142.	.0343
TRIACETIN - TA	.014	.0090.000	.0060.0000.0000.0000.0000.0000.0000.0000.000					3.250	-1335.	.0420
ALUMINUM --AL	0.0000.0000.0000.000	.0010.0000.0000.0000.0000.0000.0000.000						1.500	0.	.0976
AIR -(O	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000					0.000	0.	.0004
									1.0000	

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.950

0 (H)	(C)	(N)	(O)	(AL)	(CU)	(PB)	(					
2.002040	2.047649	.971947	3.519463	.055597	.012634	.001450						
WT. MATERIAL		99.950	89.955	79.960	69.965	59.970	49.975	39.980	29.985	19.990	9.995	
WT. AIR		0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2739.411	2767.436	2796.515	2825.543	2850.729	2857.441	2780.258	2440.865	1865.361	1157.596
FLAME TEMP. T(F)	4471.540	4521.985	4574.328	4626.577	4671.911	4683.995	4545.864	3934.150	2898.250	1624.272
ENTHALPY KCAL/GFW	-54.585	-49.126	-43.668	-38.209	-32.751	-27.292	-21.834	-16.375	-10.917	-5.458

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1270.872	1293.960	1318.090	1327.460	1346.561	1360.140	1403.822	1084.539	735.519	397.305
FLAME TEMP. T(F)	1842.569	1869.742	1898.761	1938.028	1964.409	2003.267	2067.479	1492.771	864.533	255.748
ENTHALPY KCAL/GFW	-118.552	-111.962	-105.386	-98.828	-92.291	-85.759	-78.943	-63.551	-45.601	-26.104
T.VOL.GASES--LITERS	89.277	96.299	105.075	116.359	131.403	152.466	184.061	248.055	378.073	768.208
(GASES AT STP)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (OS/O)MATERIAL BURNED-----

CO	37.2059	35.0394	32.2142	28.3979	23.0235	14.9287	1.6587	.0000	.0000	.0000
CO2	31.7050	35.1100	39.5409	45.5453	53.9895	66.7002	87.5706	98.1642	98.1642	98.1642
N2	13.6216	22.3071	33.3441	47.4316	66.2149	92.5115	131.9563	197.6923	329.1083	723.6200
H2O	12.0475	13.3013	14.7935	16.5936	18.8099	21.5455	24.9165	25.2534	25.2534	25.2534

OB CALCULATION NO. 7

AL203$	2.0357	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
N2	1.4777	1.3374	1.1704	.9690	.7210	.4149	.0377	.0000	.0000	.0000
CU$	.0032	.0031	.0031	.0031	.0030	.0000	.0000	.0000	.0000	.0000
PB	.3010	.3010	.3017	.3015	.3012	.3002	.2748	.0000	.0000	.0000
NH3	.0003	.0002	.0002	.0002	.0001	.0000	.0000	.0000	.0000	.0000
PBH	.0002	.0002	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000
PBO	.0002	.0002	.0003	.0005	.0009	.0020	.0295	.1403	.0000	.0000
CU	.0000	.0000	.0001	.0001	.0001	.0003	.0007	.0000	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	14.1619	51.4274	157.2294
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.3333	.3333
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0115	.0002	.0000
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.1052	.0000	.0000
AL203$	.0000	2.0357	2.0357	2.0357	2.0357	2.0357	2.0357	2.0357	2.0357	2.0357
CUO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0054	1.0054	1.0054
CU*	.0000	.0000	.0000	.0000	.0000	.0029	.0025	.0000	.0000	.0000
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	CO2	N2	H2O	AL203$	H2	CU$	PB	NH3	PBH	PBO	CH4	CU	CNH	PB2
CH2O	CNHO	H	HO	CHO	CH3	CU2	NH2	NO	C2H2	CUO	C2H4	C2H6	NH	O
O2	NHO	CHO	H2O2	CN	C2N2	N2H2	N	CH2	N2O4	C2O	O3	ALO	C2H	C3O2
NHO3	N2H4	HO2	NHO2	C3	CN2	HO	CN	NO3	C2H4O	C4N2	ALHO	C2	CN2	C2N
H3O	H3	AL2O2	CH	ALO2	ALH	ALC	AL	ALHO2	ALO	N2O3	H	CHO	N2O	PB3O4$
C	NO	PBO2$	PBO$	PBO$	PBO*	PBO*	PB$	PB*	AL4C3$	CU2O$	CU2O*	N2O5	AL203$	AL203*
CUH2O2	N2O4$	N2O4*	AL2O2	CUO$	CUO$	AL2O	AL2O	CU*	C5	C4H10	C4H8	C4	NO2	C3H8
C3H6	ALN	ALN$	N2H4*	AL*	AL$	AL*	H2O*	H2O*	C$	C$				

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= HEN-12(RAPEC/SEAGMAT)

	H	C	N	O	CU	PB						
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000						49.000	-625.	.0600
NITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000						40.600	-392.	.0570
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000						2.000	83.	.0494
DNPA	.022	.0120.000	.0040.0000.0000.0000.0000.0000.0000.0000.000							3.300	-094.	.0361
PBRES	.006	.0070.000	.0050.000	.0010.0000.0000.0000.0000.0000.000						2.500	-603.	.0325
EUSAL	.006	.0070.000	.004	.0010.0000.0000.0000.0000.0000.0000.000						2.500	-871.	.0361
CANDELLIA WAX	.012	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000							.100	-142.	.0343
AIR -(O	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000							0.000	0.	.0004
											1.0000	

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

0 (H)	(C)	(N)	(O)	(CU)	(PB)	(
2.701454	2.033253	.995725	3.545250	.011406	.006625	

WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2723.425	2753.152	2783.666	2813.480	2837.740	2837.602	2734.466	2365.295	1797.519	1110.746
FLAME TEMP. T(F)	4442.765	4496.273	4551.198	4604.870	4648.533	4648.428	4462.638	3798.130	2776.134	1554.343
ENTHALPY KCAL/GFW	-53.229	-47.986	-42.583	-37.260	-31.937	-26.614	-21.291	-15.969	-10.646	-5.323

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1254.143	1269.641	1287.646	1307.115	1328.614	1353.904	1365.771	1030.404	700.500	388.644
FLAME TEMP. T(F)	1798.858	1825.953	1858.363	1893.486	1932.186	1977.626	1998.988	1395.471	881.500	225.759
ENTHALPY KCAL/GFW	-116.145	-109.815	-103.498	-97.196	-90.900	-84.607	-77.237	-61.417	-44.026	-25.238
1.VOL.GASES--LITERS	88.412	95.429	104.281	115.479	130.517	151.569	183.676	240.729	370.585	768.525
(GASES AT STP)										
COMBUSTION PRODUCTS ROUNDED OFF TO	1.00E-04									

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	35.3912	38.8528	43.3213	49.3538	57.8846	70.7222	89.4847	89.4855	89.4855	89.4855
CO	34.4204	32.2253	29.3814	25.5425	20.1126	11.9420	.0005	.0000	.0000	.0000
N2	13.9479	22.7090	33.6605	47.7489	66.5149	92.7983	132.2151	197.9206	329.3489	723.6001
H2O	12.7529	13.9818	15.4602	17.2436	19.4212	22.1838	25.0545	25.0553	25.0553	25.0553
H2	1.3766	1.2391	1.0737	.8741	.6384	.3383	.0000	.0000	.0000	.0000
PB	1.1093	1.3710	1.3706	1.3699	1.3683	1.3624	.0057	.0000	.0000	.0000
CU0	.7298	.7298	.7298	.7297	.7297	.7296	.0000	.0000	.0000	.0000

PB*	.2622	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
PBH	.0006	.0000	.0007	.0006	.0005	.0004	.0000	.0000	.0000	.0000
PBO	.0006	.0010	.0015	.0023	.0042	.0108	1.4727	.0319	.0000	.0000
NH3	.0003	.0002	.0002	.0002	.0001	.0000	.0000	.0000	.0000	.0000
PB2	.0001	.0002	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000
CU	.0000	.0000	.0000	.0001	.0001	.0002	.0001	.0000	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0014	.0000	.0000	.0000
CUO	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.9259	18.4642	53.6823	159.4313
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.5142	1.5142
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.4470	.0000	.0000
CU2O$	.0000	.0000	.0000	.0000	.0000	.0000	.0214	.0000	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0178	.0072	.0001	.0000
CUO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.9136	.9136	.9136
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	CO	N2	H2O	H2	PB	CU$	PB*	PBH	PBO	NH3	PB2	CH4	CNH	CU
CH2O	CNHO	H	HO	CHO	CH3	NH2	CU2	NO	C2H4	C2H2	CUO	C2H6	NH	O2
O	NHO	CNO	H2O2	CN	C2N2	N2H2	N	CH2	O3	C2N	C2O	NHO3	C3O2	N2H4
C2H	NHO2	HO2	CN2	C3	N2O5	HO	NO3	C2H4O	C4N2	C2	CN2	H3O	N3	CN
CH	N2O3	H	CHO	N2O	N2O4	PB3O4$	PBO2$	PBO$	PBO$	PBO*	PBO*	PB$	C	CU2O$
CU2O*	NO	CUH2O2	C4	N2O4$	N2O4*	CUO$	CUO$	CU*	C5	C4H10	C4H8	NO2	C3H8	C3H6
N2H4*	H2O*	H2O*	C$	C$										

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL* BX-108/BX 105 (MK 18 BOOSTER)

	H	C	N	O	AL	P	CL	FE				
BUTAREZ	.811	.0070.000	.0000.0000.0000.0000.0000.0000.0000.000						17.000	160.	.0329	
IRON OXIDE	0.0000.0000.000		.0030.0000.0000.000		.0020.0000.0000.0000.000				2.200	-1235.	.1093	
ALUMINUM --AL	0.0000.0000.0000.000		.0010.0000.0000.0000.0000.0000.0000.000						1.500	0.	.0976	
EPON-812	.021	.0120.000	.0060.0000.0000.0000.0000.0000.0000.0000.000						.300	-1245.	.0441	
AP	.0040.000	.001	.0040.0000.000		.0010.0000.0000.0000.0000.000				79.000	-602.	.0705	
MAPO	.010	.009	.003	.0010.000	.0010.0000.0000.0000.0000.0000.000				.300	-322.	.0390	
AIR -(0	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000					0.000	0.	.0004	
										1.0000		

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.300

0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(			
4.579758	1.255830	.676539	2.762566	.055597	.001394	.672350	.027552				
WT. MATERIAL	100.300	90.270	80.240	70.210	60.180	50.150	40.120	30.090	20.060	10.030	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2661.077	2689.304	2719.004	2749.864	2778.851	2798.372	2677.577	2205.721	1744.552	1094.235
FLAME TEMP. T(F)	4330.538	4381.348	4434.951	4490.354	4542.532	4563.269	4360.238	3654.698	2600.793	1510.223
ENTHALPY KCAL/GFW	-47.995	-43.195	-38.396	-33.596	-28.797	-23.997	-19.198	-14.398	-9.599	-4.799

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1202.267	1219.188	1237.395	1257.128	1278.746	1303.658	1200.238	972.924	679.360	377.445
FLAME TEMP. T(F)	1704.681	1735.123	1767.918	1803.417	1842.342	1887.185	1845.829	1291.863	763.462	220.001
ENTHALPY KCAL/GFW	-113.695	-107.588	-101.333	-95.175	-89.041	-82.926	-74.039	-59.256	-42.469	-24.517
T.VOL.GASES--LITERS	95.041	102.039	110.786	122.031	137.824	158.818	191.489	256.888	384.826	770.924
(GASES AT STP)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

HCL	22.4485	22.4485	22.4485	22.4485	22.4485	22.4535	24.2469	23.0188	12.4718	.2758
CO2	21.5116	23.5016	26.3099	30.0631	35.5386	44.1858	55.1853	55.1854	55.1854	55.1854
CO	21.3803	20.0632	18.3269	15.9382	12.4533	7.0007	.0000	.0000	.0000	.0000
H2O	16.7231	18.5136	20.6944	23.3978	26.0896	31.2138	35.1401	35.4449	30.0117	41.0253
N2	9.4482	10.1031	29.1018	43.1402	61.0500	80.0629	127.3625	192.0002	323.9061	716.9700
FECL2	3.4340	3.4445	3.4531	3.4601	3.4655	3.4469	.0502	.0001	.0000	.0000
AL2O36	2.8258	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

OB CALCULATION NO. 9

H2	2.1100	1.9105	1.6665	1.3640	.9822	.4890	.0000	.0000	.0000	.0000
P406	.0764	.0764	.0764	.0764	.0764	.0764	.0000	.0000	.0000	.0000
FE2CL4	.0466	.0362	.0275	.0203	.0147	.0099	.0000	.0000	.0000	.0000
FECL3	.0010	.0010	.0019	.0019	.0021	.0027	.0173	.0025	.0000	.0000
NH3	.0005	.0005	.0004	.0003	.0002	.0001	.0000	.0000	.0000	.0000
CH4	.0003	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FEH2O2	.0000	.0000	.0001	.0001	.0002	.0003	.0000	.0000	.0000	.0000
PO2	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.1069	1.3004	11.6366	23.5002
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0043	.0106	.0002	.0003
O2	.0000	.0000	.0000	.0000	.0000	.0000	2.3002	19.6753	52.5093	155.2677
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0001	.0000	.0000
CL	.0000	.0000	.0000	.0000	.0000	.0001	.0425	.0044	.0000	.0000
P4O10	.0000	.0000	.0000	.0000	.0000	.0000	.0985	.0906	.0009	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.1934	2.1934
FE2O3*	.0000	.0000	.0000	.0000	.0000	.0000	2.1533	2.1921	.0000	.0000
AL2O3*	.0000	2.0250	2.0250	2.0250	2.0250	2.0250	2.0250	2.0250	2.0250	2.0250
PH3O4*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.1350	.1362
FEO$	.0000	.0000	.0000	.0000	.0000	.0130	.0000	.0000	.0000	.0000
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0001	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0164	.0040	.0001	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

HCL	CO2	CO	H2O	N2	FECL2	AL2O3$	H2	P406	FE2CL4	FECL3	NH3	CH4	FEH2O2	CNN
CL	CH2O	CNHO	ALCL3	PH	H	CH3CL	PO2	HO	CL2	COCL	CHO	FECL	CH3	PO
ALCL2	FE	PH3	FE2CL6	NH2	PH2	CPH	HOCL	C2H4	NO	CNCL	C2H2	COCL2	C2H6	POCL3
PCL3	PH	CH2CL2	PCL	ALOCL	FEO	P2	ALCL	NH	P	NHO	O	O2	C2HCL	CNO
H2O2	OCL	CN	C2N2	N2H2	CHCL3	CCL2	ALN	C3O2	CH2	N2O4	C2N	NOCL	AL2CL6	N2H4
N	C2O	O3	C2CL2	CL	PCL5	NHO3	C2H	NO2CL	CHCL	NHO2	HO2	CN2	C3	HO
C2CL4	CCL3	CP	C2H4O	N2O5	NO3	CCL4	CN	C4N2	AL2O2	C2	CN2	N3	H3O	ALHO
P4O10	H	CH	ALCL2	ALC	ALH	ALO2	ALHO2	OCL2	AL	N2O3	ALO	P4O10$	N2O	C2CL6
FE3O4$	FE3O4*	P3N5*	FECL3$	FECL3*	FE2O3$	FE2O3*	AL4C3$	ALCL3*	ALCL3$	FECL2$	FECL2*	P4	NH4O4C	CHO
FEH3O3	AL2O3$	AL2O3*	PH3O4$	PH3O4*	N2O4$	N2O4*	FEH2O2	AL2O2	ALOCL$	FEO$	FEO*	AL2O	AL2O	
O2CL	ALCL	C5	C4H10	C4H8	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	C4	CCL
NO2	C3H8	ALO	C3H6	ALN$	N2H4*	P$	P$	P*	NO	AL*	AL$	AL*	C	N2O*
N2O*	C$	C$												

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= BX-100/BX 105 (MK 10 SUSTAINER)

	H	C	N	O	AL	F	CL	FE				
BUTAREZ	.011	.0070	.000	.0000	.0000	.0000	.0000	.0000	15.000	160.	.0329	
IRON OXIDE	0.	.0000	.000	.0030	.0000	.0000	.000	.0020	1.600	-1235.	.1893	
IRON OXIDE	0.	.0000	.000	.0030	.0000	.0000	.000	.0020	2.500	-1235.	.1893	
ALUMINUM --AL	0.	.0000	.0000	.000	.0010	.0000	.0000	.0000	1.500	0.	.0976	
EPON-812	.021	.0120	.000	.0060	.0000	.0000	.0000	.0000	.300	-1245.	.0441	
AP	.0040	.000	.001	.0040	.0000	.000	.0010	.0000	79.000	-602.	.0705	
MAPO	.010	.007	.003	.0010	.000	.0010	.0000	.0000	.300	-322.	.0190	
AIR -(0	0.	.0000	.000	.006	.0010	.0000	.0000	.0000	0.000	0.	.0004	
										1.0000		

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.200

0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(			
4.363155	1.111189	.676539	2.795491	.055597	.001394	.672350	.051346				
WT. MATERIAL	100.200	90.100	80.160	70.140	60.120	50.100	40.080	30.060	20.040	10.020	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2793.720	2810.553	2827.100	2840.840	2842.020	2784.089	2543.370	2133.157	1629.602	1026.706
FLAME TEMP. T(F)	4569.310	4599.596	4629.395	4654.126	4656.251	4553.400	4118.601	3380.282	2474.020	1380.671
ENTHALPY KCAL/0FW	-50.662	-45.596	-40.530	-35.464	-30.397	-25.331	-20.265	-15.199	-10.132	-5.066

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1315.506	1325.704	1336.059	1340.999	1363.061	1385.927	1172.730	893.869	620.316	349.900
FLAME TEMP. T(F)	1900.512	1927.011	1946.944	1960.790	1994.110	2035.268	1651.529	1149.564	671.569	170.579
ENTHALPY KCAL/0FW	-116.049	-110.348	-103.046	-97.378	-90.907	-84.270	-71.615	-56.566	-40.536	-23.454
T.VOL.GASES--LITERS	89.701	96.737	105.527	116.822	131.074	152.648	190.663	255.130	382.000	770.693
(GASES AT STP)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/0)MATERIAL BURNED-----

HCL	21.4695	21.5747	21.6895	21.8166	21.9582	22.1017	24.0596	21.6069	0.9496	.1304
C02	21.2657	23.5457	26.5712	30.7691	36.9397	46.5468	40.0069	40.0069	40.0069	40.0069
H20	19.0591	21.5406	23.5747	26.0609	29.1668	33.0075	33.2790	33.0048	36.9753	39.1550
CO	17.5207	16.0776	14.1520	11.4002	7.5530	1.4305	.0000	.0000	.0000	.0000
N2	9.4579	10.2015	29.1311	43.1034	61.9199	00.1509	127.4906	193.0730	324.2293	717.6935
FECL2	5.1741	4.9900	4.0057	4.5903	4.3400	4.0969	.0075	.0000	.0000	.0000

OB CALCULATION NO. 10

AL203$	2.0287	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H2	1.5735	1.3024	1.1517	.0698	.5105	.0047	.0000	.0000	.0000	.0000
FE0$	.7277	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
P406	.0765	.0765	.0765	.0765	.0764	.0764	.0000	.0000	.0000	.0000
FE2CL4	.0354	.0270	.0212	.0157	.0111	.0070	.0000	.0000	.0000	.0000
FECL3	.0020	.0020	.0020	.0029	.0034	.0072	.0110	.0012	.0000	.0000
NH3	.0002	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000
FEH202	.0002	.0002	.0003	.0004	.0005	.0000	.0000	.0000	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.3534	2.7703	15.0057	24.6653
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0083	.0116	.0063	.0001
02	.0000	.0000	.0000	.0000	.0000	.0000	0.6326	25.6879	50.0915	161.6955
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0001	.0000	.0000
CL	.0000	.0001	.0001	.0001	.0002	.0009	.0264	.0016	.0000	.0000
P4010	.0000	.0000	.0000	.0000	.0000	.0000	.0987	.0987	.0000	.0000
FE304$	.0000	.0000	.0000	.0000	.0000	1.4524	.0000	.0000	.0000	.0000
FE203$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	4.0912	4.0910	4.0910
FE203$	.0000	.0000	.0000	.0000	.0000	.0000	4.0012	.0000	.0000	.0000
AL203$	.0000	2.0287	2.0287	2.0287	2.0287	2.0287	2.0287	2.0287	2.0287	2.0287
PH304*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.1363	.1363
FE0$	.0000	.0313	.9444	1.0696	1.2092	.0000	.0000	.0000	.0000	.0000
N02	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0001	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0144	.0017	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

HCL	C02	H20	CO	N2	FECL2	AL203$	H2	FE0$	P406	FE2CL4	FECL3	NH3	FEH202	CL
CH4	PN	CNH	ALCL3	CH20	H	P02	CNHO	HO	CL2	FECL	PO	COCL	FE	ALCL2
CHO	CH3CL	HOCL	NO	PH2	PH3	NH2	CH3	FE2CL6	CPH	FEO	CNCL	ALOCL	COCL2	PH
PCL	POCL3	PCL3	C2H2	P2	ALCL	C2H4	P	02	NH	0	CH2CL2	NHO	OCL	H202
CNO	C2H6	CN	N2H2	NOCL	C2HCL	N	C2N2	N204	HO2	CH2	NHO3	ALO	CHCL3	NH02
N02CL	AL2CL6	C20	C2N	C302	N2H4	CN	CHCL	C2H	CL	PCL5	C2CL2	CN2	N03	CP
HO	CCL3	C3	C2CL4	N205	ALO2	N3	ALH02	CN2	ALO	CCL4	AL	C2H40	ALN	C2
CH	OCL2	ALHO	AL202	H30	N203	ALC	ALCL2	CCL2	C4N2	P4010	H	N20	CCL	C
CHO	P4010$	C2CL6	FE304$	FE304$	P3N5$	FECL3$	FECL3*	FE203$	FE203$	AL4C3$	ALCL3*	ALCL3$	FECL2$	FECL2*
P4	NH404C	FEH303	AL203$	AL203*	PH304$	PH304*	N204$	N204*	FEH202	AL202	ALOCL$	FE0$	FE0*	AL20
AL20	02CL	ALCL	C5	C4H10	C4H8	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	C4
03	N02	C3H8	C3H6	ALN	ALN$	N2H4*	P$	P$	P*	NO	AL*	AL$	AL*	H20*
H20*	C$	C$												

OD CALCULATION NO. 10 CONTINUED

FECL2	3.1565	3.1594	3.1619	3.1640	3.1658	3.1666	.0165	.0000	.0000	.0000
H2	1.0107	1.6207	1.3010	1.0864	.7154	.2429	.0000	.0000	.0000	.0000
P406	.0511	.0511	.0511	.0511	.0511	.0511	.0000	.0000	.0000	.0000
FE2CL4	.0171	.0141	.0116	.0092	.0071	.0052	.0000	.0000	.0000	.0000
FECL3	.0017	.0010	.0010	.0019	.0022	.0035	.0140	.0017	.0000	.0000
NH3	.0003	.0003	.0002	.0002	.0001	.0000	.0000	.0000	.0000	.0000
FEH2O2	.0001	.0001	.0001	.0002	.0003	.0004	.0000	.0000	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.2351	2.0630	13.7072	23.9550
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0071	.0115	.0074	.0002
O2	.0000	.0000	.0000	.0000	.0000	.0000	6.2614	23.4866	56.1125	159.5515
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0001	.0000	.0000
CL	.0000	.0000	.0001	.0001	.0002	.0004	.0348	.0026	.0000	.0000
P4O10	.0000	.0000	.0000	.0000	.0000	.0000	.0659	.0659	.0000	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.9991	2.0000	2.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	1.9827	.0000	.0000	.0000
AL2O3$	.0000	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791
PH3O4*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0910	.0911
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0001	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0173	.0025	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

HCL	CO2	H2O	CO	N2	AL2O3$	FECL2	H2	P406	FE2CL4	FECL3	NH3	FEH2O2	CH4	CL
CNH	CH2O	PN	ALCL3	CNHO	H	PO2	HO	CL2	PO	COCL	FECL	CH3CL	CHO	ALCL2
FE	CH3	PH3	HOCL	NH2	PH2	NO	CPH	FE2CL6	CNCL	COCL2	ALOCL	FEO	PH	PCL
C2H2	POCL3	C2H4	PCL3	P2	ALCL	CH2CL2	P	NH	O2	O	NHO	C2H6	H2O2	OCL
CNO	CN	C2HCL	N2H2	NOCL	C2N2	N	CH2	CHCL3	AL2CL6	HO2	NHO3	C2N	C3O2	NO2CL
C2O	N2H4	NHO2	CN	CHCL	C2H	CL	C2CL2	PCL5	CN2	CP	N2O4	C3	HO	NO3
CCL3	C2CL4	N2O5	C2H4O	CCL4	ALO2	CN2	N3	C2	ALHO2	ALHO	ALH	ALO	AL	AL2O2
CH	H3O	C4N2	ALCL2	OCL2	ALC	CCL2	N2O3	N2O	H	P4O10	CCL	CHO	C	P4O10$
C2CL6	FE3O4$	FE3O4$	P3N5$	FECL3$	FECL3*	FE2O3$	FE2O3$	AL4C3$	ALCL3*	ALCL3$	FECL2$	FECL2*	P4	NH4O4C
FEH3O3	AL2O3$	AL2O3*	PH3O4$	PH3O4*	N2O4$	N2O4*	FEH2O2	AL2O2	ALCL	ALOCL$	FEO$	FEO$	FEO*	AL2O
AL2O	O2CL	C5	C4H10	C4H8	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	C4	O3
NO2	C3H8	ALO	C3H6	ALN	ALN$	N2H4*	P$	P$	P*	NO	AL*	AL$	AL*	H2O*
H2O*	C$	C$												

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= BX-100 H (CKU-5/A SUSTAINER)

	H	C	N	O	AL	P	CL	FE			
BUTAREZ	.011	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000						12.400	160.	.0329
HEXADECANE	.034	.0160.0000.0000.0000.0000.0000.0000.0000.0000.000							3.100	-402.	.0200
EPON-812	.021	.0120.000	.0060.0000.0000.0000.0000.0000.0000.0000.000						.300	-1245.	.0441
ALUMINUM --AL	0.0000.0000.0000.000		.0010.0000.0000.0000.0000.0000.0000.000						2.000	0.	.0976
IRON OXIDE	0.0000.0000.000		.0030.0000.0000.000		.0020.0000.0000.0000.000				2.000	-1235.	.1093
AP	.0040.000	.001	.0040.0000.000		.0010.0000.0000.0000.0000.000				80.000	-602.	.0705
MAPO	.010	.009	.003	.0010.000	.0010.0000.0000.0000.0000.0000.000				.200	-322.	.0390
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000						0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 1.0000

0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(							
4.572700	1.137999	.603656	2.706022	.074129	.000929	.600860	.025047								
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000					
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000					

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2765.075	2704.317	2004.001	2022.503	2034.002	2007.709	2614.495	2207.277	1604.599	1050.757
FLAME TEMP. T(F)	4517.735	4552.371	4587.001	4621.250	4641.004	4594.476	4246.692	3513.699	2571.078	1446.363
ENTHALPY KCAL/GFW	-50.547	-45.492	-40.437	-35.303	-30.328	-25.273	-20.219	-15.164	-10.109	-5.055

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1204.626	1296.261	1300.015	1322.514	1337.933	1350.104	1210.323	920.700	651.620	362.072
FLAME TEMP. T(F)	1852.927	1873.071	1896.467	1921.125	1940.079	1905.107	1733.502	1212.410	713.516	193.770
ENTHALPY KCAL/GFW	-117.907	-111.356	-104.740	-98.142	-91.566	-84.940	-73.771	-58.267	-41.723	-24.090
T.VOL.GASES--LITERS	92.907	100.005	100.777	120.055	135.093	156.145	192.411	257.100	385.230	773.551
(GASES AT S(P)										
COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04										

-----GRAMS PRODUCTS/100 GRAMS (GS/0)MATERIAL BURNED-----

HCL	23.0000	23.0000	23.0000	23.0000	23.0000	23.0004	24.5261	22.6935	10.7250	.1910
CO2	20.5364	22.6794	25.5433	29.4015	35.2332	44.3096	50.0044	50.0045	50.0045	50.0045
H2O	19.2550	21.0246	23.1598	25.0003	29.1159	33.3307	35.1307	35.5029	30.5149	41.1184
CO	10.0059	17.4421	15.6193	13.1120	9.4521	3.6754	.0000	.0000	.0000	.0000
N2	9.5764	10.3375	29.2090	43.3695	62.1434	00.4269	127.0439	193.5592	324.9775	719.2206
AL203$	3.7791	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL*IPH-9881 (CKU-7/A SUSTAINER)

	H	C	N	O	AL	F	CL	FE			
BUTAREZ	.011	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000						14.000	140.	.0329
LECITHIN(LECT)	.011	.0060.000	.0010.000	.0000.0000.0000.0000.0000.0000.000					.100	-516.	.0376
IRON OXIDE	0.0000.0000.000		.0030.0000.0000.000		.0020.0000.0000.0000.0000.000				1.000	-1235.	.1093
ALUMINUM --AL	0.0000.0000.0000.000		.0010.0000.0000.0000.0000.0000.0000.0000.000						2.000	0.	.0976
IP-90-B(THIOKOL)	.011	.0050.000	.0020.0000.0000.0000.0000.0000.0000.0000.000						1.600	-1229.	.0351
AP	.0040.000	.001	.0040.0000.000	.0010.0000.0000.0000.0000.000					00.000	-602.	.0705
ERL 0510	.007	.005	.000	.0010.0000.0000.0000.0000.0000.0000.0000.000					.500	-196.	.0161
AIR -(G	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000					0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 1.0000

0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(						
4.463457	1.128704	.602669	2.010854	.074129	.000224	.000068	.022542							
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000				
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000				

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2025.300	2039.342	2052.971	2063.032	2063.360	2013.013	2590.496	2100.295	1661.272	1045.432
FLAME TEMP. T(F)	4626.154	4651.416	4675.947	4695.497	4694.663	4684.023	4203.492	3465.131	2530.089	1422.377
ENTHALPY KCAL/GFW	-50.220	-45.205	-40.103	-35.160	-30.137	-25.114	-20.091	-15.060	-10.046	-5.023

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1327.522	1336.501	1346.247	1357.030	1369.635	1389.006	1196.526	912.900	641.200	357.217
FLAME TEMP. T(F)	1930.140	1946.302	1963.045	1983.253	2005.943	2040.010	1694.347	1183.021	694.761	183.590
ENTHALPY KCAL/GFW	-110.401	-111.084	-105.143	-98.499	-91.069	-85.127	-72.017	-57.406	-41.160	-23.790
1.VOL.GASES--LITERS (GASES AT STP)	91.539	98.556	107.328	118.606	133.644	154.696	192.004	256.737	384.007	773.243

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

HCL	23.1035	23.1035	23.1035	23.1035	23.1034	23.1025	24.4646	22.3370	9.9450	.1626
CO2	20.7650	23.0422	26.0079	30.2791	36.4020	46.0620	49.6754	49.6754	49.6754	49.6754
H2O	19.7961	21.5899	23.5707	26.1077	29.2714	33.2540	34.1617	34.6069	37.7420	48.1686
CO	10.4001	14.9500	15.0124	12.3449	8.4479	2.2993	.0000	.0000	.0000	.0000
N2	9.5627	18.3230	29.2752	43.3557	62.1296	88.4130	127.0304	193.5456	324.9637	719.2140
AL2O3$	3.7791	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

OB CALCULATION NO. 12

FECL2	2.0467	2.0481	2.0492	2.0502	2.0510	2.0504	.0114	.0000	.0000	.0000
H2	1.6431	1.4513	1.2207	.9368	.5020	.1371	.0000	.0000	.0000	.0000
P406	.0123	.0123	.0123	.0123	.0123	.0123	.0000	.0000	.0000	.0000
FE2CL4	.0094	.0000	.0060	.0056	.0044	.0032	.0000	.0000	.0000	.0000
FECL3	.0016	.0017	.0017	.0018	.0022	.0041	.0132	.0015	.0000	.0000
NH3	.0002	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000
FEH2O2	.0001	.0001	.0002	.0002	.0003	.0005	.0000	.0000	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.3011	2.4109	14.4660	23.9833
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0110	.0069	.0002
O2	.0000	.0000	.0000	.0000	.0000	.0000	7.9041	25.0655	57.5902	161.2021
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0001	.0000	.0000
CL	.0000	.0001	.0001	.0002	.0003	.0000	.0315	.0822	.0000	.0000
P4O10	.0000	.0000	.0000	.0000	.0000	.0000	.0159	.0159	.0000	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.7992	1.0000	1.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	1.7863	.0000	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0165	.0822	.0000	.0000
AL2O3$	.0000	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791
PH3O4*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0220	.0220
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0001	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

HCL	CO2	H2O	CO	N2	AL2O3$	FECL2	H2	P4O6	FE2CL4	FECL3	NH3	FEH2O2	CL	CH4
CNH	ALCL3	PN	CH2O	H	CNHO	PO2	HO	CL2	PO	FECL	COCL	ALCL2	FE	CHO
CH3CL	NO	HOCL	NH2	PH2	PH3	CH3	CPH	FE2CL6	ALOCL	CNCL	FEO	COCL2	PCL	PH
POCL3	PCL3	ALCL	C2H2	P2	C2H4	P	O2	NH	O	CH2CL2	NHO	OCL	H2O2	CNO
C2H6	CN	NOCL	N2H2	C2HCL	N	C2N2	HO2	CH2	N2O4	NHO3	CHCL3	AL2CL6	NHO2	NO2CL
ALO	C2O	C2N	C3O2	N2H4	CN	CNCL	C2H	CL	C2CL2	CN2	NO3	CP	PCL5	CCL3
C3	HO	C2CL4	N2O5	ALO2	ALHO2	ALO	N3	AL	ALH	CN2	CCL4	ALHO	C2H4O	C2
CH	OCL2	H3O	ALCL2	ALC	AL2O2	N2O3	CCL2	C4N2	N2O	H	CCL	C	P4O10	CHO
ALCL	P4O10$	C2CL6	FE3O4$	FE3O4$	P3N5$	FECL3$	FECL3*	FE2O3$	FE2O3$	AL4C3$	NO	O2CL	ALCL3*	ALCL3$
FECL2$	FECL2*	P4	NH4O4C	FEH3O3	AL2O3$	AL2O3*	PH3O4$	PH3O4*	N2O4$	N2O4*	FEH2O2	AL2O2	ALOCL$	FEO$
FEO$	FEO*	AL2O	AL2O	C5	C4H10	C4H8	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$
C4	O3	NO2	C3H8	C3H6	ALN	ALN$	N2H4*	P$	P$	P*	AL*	AL$	AL*	H2O*
H2O*	C$	C$												

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= PBXN-106 (MK 115)

		H	C	N	O	FE			
RDX	-(G)	.006	.003	.006	.0060.0000.0000.0000.0000.0000.0000.0000.000		75.000	72.	.0656
FEAA		.014	.0100.000	.004	.0010.0000.0000.0000.0000.0000.0000.0000.000		.010	-023.	.0376
PHNANFP		.013	.016	.0010.0000.0000.0000.0000.0000.0000.0000.0000.000			.250	-174.	.0397
50X80NPA + 50X80NPF		.004	.002	.001	.0030.0000.0000.0000.0000.0000.0000.0000.000		10.500	-474.	.0499
TRIMETHYLOLPROPANE		.014	.0060.000	.0030.0000.0000.0000.0000.0000.0000.0000.000			2.540	-1329.	.0434
POLYETHYLENE GLYCOL		.004	.0020.000	.0010.0000.0000.0000.0000.0000.0000.0000.000			.430	-1047.	.0397
IDICY		.006	.009	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000		3.220	-33.	.0325
AIR	-(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000			0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.950 1.0000

0 (H)	(C)	(N)	(O)	(FE)	(						
3.200722	1.765289	2.295803	2.709362	.000039							
WT. MATERIAL		99.950	89.955	79.960	69.965	59.970	49.975	39.980	29.985	19.990	9.995
WT. AIR		0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2696.331	2724.699	2755.040	2787.347	2820.617	2849.002	2835.256	2579.745	1979.015	1225.306
FLAME TEMP. T(F)	4393.996	4445.058	4499.607	4557.025	4617.710	4660.803	4644.062	4184.141	3104.268	1746.151
ENTHALPY KCAL/0FW	-7.311	-6.580	-5.848	-5.117	-4.386	-3.655	-2.924	-2.193	-1.462	-.731

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1129.413	1151.091	1176.162	1202.353	1230.703	1262.211	1300.053	1134.314	775.310	420.692
FLAME TEMP. T(F)	1573.543	1614.004	1657.691	1704.036	1756.089	1812.500	1800.696	1582.365	936.150	297.045
ENTHALPY KCAL/GFW	-75.961	-73.640	-71.319	-69.006	-66.709	-64.439	-62.151	-53.799	-39.075	-22.051
T.VOL.GASES--LITERS	101.489	100.440	117.221	120.506	143.551	164.614	196.209	256.260	386.305	776.440
(GASES AT STP)										
COMBUSTION PRODUCTS ROUNDED OFF TO	1.00E-04									

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO	36.1245	34.3789	32.1500	29.1004	25.0155	18.6696	7.9900	.0000	.0000	.0000
N2	32.1757	40.9414	51.0985	65.9861	84.7696	111.0663	150.5113	216.2457	347.7352	742.1030
CO2	28.9589	23.7219	27.2151	31.0697	38.4264	48.3972	65.1770	77.7310	77.7310	77.7310
H2O	8.4436	9.9552	11.0330	14.1018	17.1707	21.0313	26.0757	28.9105	28.9106	28.9106
H2	2.2895	2.1213	1.9116	1.6489	1.3145	.0026	.3101	.0000	.0000	.0000
CH4	.0055	.0019	.0006	.0001	.0000	.0000	.0000	.0000	.0000	.0000

OB CALCULATION NO. 13

FE0$	.0020	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
NH3	.0013	.0011	.0009	.0006	.0004	.0002	.0000	.0000	.0000	.0000
FEH2O2	.0000	.0000	.0000	.0000	.0001	.0001	.0002	.0000	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	10.5365	45.0115	151.6136
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0150	.0005	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0031	.0031
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0031	.0000	.0000
FE0$	.0000	.0020	.0020	.0020	.0020	.0027	.0027	.0000	.0000	.0000
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	N2	CO2	H2O	H2	CH4	FE0$	NH3	CNH	CH2O	CNHO	FEH2O2	H	CH3	C2H4
CHO	HO	C2H6	C2H2	NH2	FE	NO	FEO	C2N2	C3H6	NH	CNO	CN	NHO	N2H2
C3H8	O	H2O2	CH2	N2O4	N2H4	O2	C3O2	C2H	C2O	CN2	C4N2	N	O3	NHO3
HO	C2H4O	N2O5	NHO2	C2	CN	H3O	HO2	NO3	C2N	CN2	H	CHO	N3	CH
C3	N2O	N2O3	NO	FE3O4$	FE3O4$	C5	FE2O3$	FE2O3$	FEH3O3	N2O4$	N2O4*	FEH2O2	FE0$	FEO*
C4H10	C4H8	FE$	FE$	FE$	FE$	FE*	FE$	C4	NO2	N2H4*	H2O*	H2O*	C	C$
C$														

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= NOSIH(BC-10) (MOM-107)

	H	C	N	O	AL	CL	FE				
R-45M	.011	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000					0.400	-0.	.0329	
DIOCTYL ADIPATE	.042	.0220.000	.0040.0000.0000.0000.0000.0000.0000.0000.000					3.000	-733.	.0332	
(DHE)N,N-B-2-HY-ET-M	.007	.004	.001	.0020.0000.0000.0000.0000.0000.0000.0000.000				.300	-830.	.0444	
ALUMINUM --AL	0.0000.0000.0000.000			.0010.0000.0000.0000.0000.0000.0000.000				44.000	0.	.0976	
AP	.0040.000	.001	.0040.000	.0010.0000.0000.0000.0000.0000.000				43.100	-602.	.0705	
IRON OXIDE	0.0000.0000.000			.0030.0000.000	.0020.0000.0000.0000.0000.000			1.200	-1235.	.1093	
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000					0.000	0.	.0004	
0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000									1.0000		
0 (H)	(C)	(N)	(O)	(AL)	(CL)	(FE)	(				
2.740760	.002997	.369450	1.535226	1.630830	.366010	.015020					
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2840.406	2973.600	2999.750	3000.539	3339.000	3620.059	3714.198	3589.260	2927.434	1000.060
FLAME TEMP. T(F)	4653.331	4893.225	4940.151	4941.570	5550.944	6050.146	6226.156	5857.202	4089.901	2926.140
ENTHALPY KCAL/GFW	-29.866	-26.880	-23.893	-20.906	-17.920	-14.933	-11.947	-8.960	-5.973	-2.987

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	2187.975	2321.050	2322.135	2322.754	2301.077	2310.291	2321.425	2200.011	1559.095	754.532
FLAME TEMP. T(F)	3470.954	3719.945	3720.443	3721.557	3682.539	3713.524	3719.165	3502.059	2346.971	890.750
ENTHALPY KCAL/GFW	-85.169	-86.119	-84.593	-82.832	-81.662	-81.925	-79.578	-73.300	-60.263	-36.435
T.VOL.GASES--LITERS	73.030	83.376	91.959	103.220	110.140	130.760	170.656	223.072	345.713	734.955
(GASES AT STP)										
COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04										

-----GRAMS PRODUCTS/100 GRAMS (GS/0)MATERIAL BURNED-----

AL2O3♦	25.8474	23.6372	14.2316	35.0033	40.0492	69.7165	63.3579	.0000	.0000	.0000
ALCL	22.0389	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CO	19.1924	22.4160	22.4102	22.4107	22.4109	22.4695	21.5440	11.9741	.0011	.0000
ALN♦	14.9402	23.4289	20.4904	14.5253	6.9520	.0000	.0000	.0000	.0000	.0000
AL2O	6.2686	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
AL4C3♦	5.3773	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H2	2.7448	2.7349	2.7312	2.7208	2.7264	2.6734	1.9279	.4343	.0000	.0000

OB CALCULATION NO. 14

AL	1.7369	1.2992	.9119	.0415	.6429	.1175	.0000	.0000	.0000	.0000
ALCL2	.5716	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FE*	.4940	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FE	.3450	.0374	.0360	.0356	.0341	.7793	.2605	.0404	.0000	.0000
ALH	.2186	.1190	.0700	.0671	.0404	.0070	.0000	.0000	.0000	.0000
HCL	.0774	.2539	.3750	.4356	.5327	2.3464	12.3211	12.0339	12.0307	9.0353
C2H2	.0530	.0013	.0005	.0003	.0002	.0000	.0000	.0000	.0000	.0000
N2	.0460	5.0929	17.0447	33.9630	65.3259	84.0150	123.4406	109.1401	320.3976	714.0267
CNH	.0302	.0702	.0775	.0775	.0775	.0105	.0001	.0000	.0000	.0000
H	.0099	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CH4	.0021	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000
ALOCL	.0010	.0051	.0069	.0081	.0006	.0230	.0107	.0017	.0000	.0000
CH3	.0006	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H2O	.0005	.0033	.0046	.0053	.0057	.0230	4.2323	17.7064	21.5794	22.5277
C2H	.0005	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CL	.0004	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FECL2	.0004	.0029	.0056	.0064	.0095	.1273	1.2097	1.7621	.3265	.0000
ALCL3	.0004	.0012	.0022	.0025	.0035	.0341	.0019	.0001	.0000	.0000
FECL	.0002	.0010	.0014	.0015	.0017	.0063	.0117	.0040	.0000	.0000
CO2	.0001	.0008	.0012	.0014	.0015	.0063	1.4093	16.5270	35.3309	35.3407
NH3	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0000	.0000	.0000
NO	.0000	.0008	.0000	.0000	.0000	.0001	.0107	.0046	.0190	.0000
FEO	.0000	.0000	.0000	.0000	.0000	.0000	.0034	.0070	.0000	.0000
O	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0021	.0005	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0003	.0430	4.2160
FECL3	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0004	.0091	.0000
FEH2O2	.0000	.0000	.0000	.0000	.0000	.0000	.0013	.0225	.0003	.0000
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0055	.0067
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0022	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	24.6399	129.7054
AL2O	.0000	3.6549	2.1041	1.0570	1.2516	.1198	.0000	.0000	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0040	.0406	.3024	.0000
CL	.0000	.0020	.0044	.0056	.0067	.0357	.2486	.3154	.2925	.0002
ALCL	.0000	21.1725	20.5201	20.3065	19.8027	13.1704	.0239	.0002	.0000	.0000
ALCL2	.0000	1.0046	1.3460	1.4295	1.6007	4.2706	.0428	.0010	.0000	.0000
H	.0000	.0214	.0229	.0240	.0243	.0280	.0276	.0008	.0000	.0000
FE2O3@	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.2000
FE2O3@	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.9096	.0000
AL2O3@	.0000	.0000	.0000	.0000	5.4615	.0000	.0000	03.1303	03.1401	03.1401
AL2O3*	.0000	4.5480	20.9112	7.5166	.0000	.0000	19.7327	.0000	.0000	.0000
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0005
ALO	.0000	.0003	.0003	.0003	.0002	.0002	.0000	.0000	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED----

AL2O3$	ALCL	CO	ALN$	AL2O	AL4C3$	N2	AL	ALCL2	FE*	FE	ALH	HCL	C2H2	N2
CNH	H	CH4	ALOCL	CH3	H2O	C2H	CL	FECL2	ALCL3	FECL	CO2	ALO	CHO	CN
CN2O	NH3	AL2O2	ALC	C2HCL	CH2	HO	C2N	C2O	ALN	C2N2	FEO	CNHO	NH2	CHCL
CH3CL	CH	NH	COCL	C3	C	N	C2	O	CL2	ALO2	HO	CHCL	FECL3	CNO
C4N2	FEH2O2	ALHO2	C3O2	CN2	C5	C4	CCL	HOCL	C2CL2	FE2CL4	CH2CL2	NHO	N2H2	OCL
AL2CL6	C2H4O	CN2	O2	COCL2	CCL2	NO2CL	NH3	H2O2	CHCL3	H3O	AL2O	HO2	AL2O2	OCL2
N2H4	HO3	NO	ALHO	CL	NHO2	N2O3	ALCL	ALCL2	FE2CL6	H	HO	CCL3	NOCL	CN
C2CL6	FE3O4$	FE3O4$	C2CL4	FECL3$	FECL3*	FE2O3$	FE2O3$	CCL4	ALCL3*	ALCL3$	FECL2$	FECL2*	NH4O4C	N2O5
FEH3O3	AL2O3$	AL2O3*	N2O4	N2O4$	N2O4*	FEH2O2	ALOCL$	FEO$	FEO$	FEO*	O2CL	C4H10	C4HB	FE$
FE$	FE$	FE$	FE$	NH4CL$	NH4CL$	O3	NO2	C3HB	H2O	ALO	C3H6	N3	N2H4*	C2H6
CHO	C2H4	AL*	AL$	AL*	H2O*	H2O*	C$	C$						

OB CALCULATION NO. 14 CONTINUED

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= XM39 (LOVA)

	H	C	N	O								
CELLULOSE ACET BUTYR	.007	.0050.000	.0020.0000.0000.0000.0000.0000.0000.0000.000								12.000	-1100.	.0434
ETHYL CENTRALITE-EC	0.000	.0170.0000.0000.0000.0000.0000.0000.0000.0000.000									.500	-117.	.0451
RDX -(G)	.006	.003	.006	.0060.0000.0000.0000.0000.0000.0000.0000.0000.000							76.000	72.	.0656
ACETYL TRIETHYL CIT	.022	.0140.000	.0000.0000.0000.0000.0000.0000.0000.0000.000								7.500	-1250.	.0361
NITROCELLULOSE(12.6)	.008	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.0000.000							4.000	-625.	.0600
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000								0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 1.0000

0 (H)	(C)	(N)	(O)	(
3.507034	2.029643	2.000830	2.676651	

WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2104.551	2177.473	2255.227	2338.552	2428.463	2526.065	2628.947	2642.286	2805.959	1290.344
FLAME TEMP. T(F)	3328.793	3460.051	3600.000	3749.993	3911.033	4087.517	4272.704	4296.715	3295.326	1863.220
ENTHALPY KCAL/GFW	-20.637	-18.574	-16.510	-14.446	-12.382	-10.319	-8.255	-6.191	-4.127	-2.064

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI--

FLAME TEMP. T(K)	965.943	956.698	950.669	970.823	1010.915	1072.476	1132.767	1208.503	834.505	449.286
FLAME TEMP. T(F)	1279.297	1262.643	1266.285	1301.841	1374.648	1471.057	1579.580	1715.905	1042.852	349.314
ENTHALPY KCAL/GFW	-76.021	-74.298	-71.888	-69.550	-67.247	-64.950	-62.679	-60.270	-44.010	-25.467
1.VOL.GASES--LITERS (GASES AT STP)	105.788	112.886	122.521	134.917	150.325	171.483	203.865	255.697	385.095	775.035

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GG/G)MATERIAL BURNED-----

CO	39.0201	38.9135	37.7439	35.5138	32.0260	26.7150	18.0109	.0970	.0000	.0000
N2	29.2560	38.0175	48.9609	63.0500	81.0251	108.1096	147.5354	213.2443	344.6600	730.9124
CO2	21.8037	24.7509	28.4614	33.0609	38.9503	47.3486	61.0151	87.9160	89.3266	89.3266
H2O	5.2094	5.5767	6.5908	8.5201	11.6113	16.0902	22.4018	31.2354	31.5914	31.5914
H2	2.7235	2.6024	2.6528	2.5383	2.2382	1.7341	1.0282	.0390	.0000	.0000
C$	.9951	.2507	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CH4	.9868	.9864	.5692	.1699	.0283	.0012	.0000	.0000	.0000	.0000
NH3	.0044	.0048	.0049	.0041	.0026	.0013	.0004	.0000	.0000	.0000

OB CALCULATION NO. 15

CNH	.0002	.0002	.0001	.0001	.0001	.0008	.0000	.0000	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	34.4200	140.1696
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0011	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	N2	CO2	H2O	H2	C$	CH4	NH3	CNH	CH2O	CNHO	C2H6	C2H4	CH3	C2H2
H	C3H6	C3H8	NH2	HO	C2N2	C4H8	NO	C4H10	C2H4O	C3O2	N2H2	C4N2	NH	C2O
C2H	NHO	CN2	CH2	C2N	N2O4	CH	N3	CN	C3	N2H4	HO	NHO3	C	CN
O3	H2O2	CN2	N2O5	H	C5	NO3	O	O2	N2O	C2	N2O4$	N2O4*	N2O3	C4
NHO2	NO2	CNO	HO2	N2H4*	NO	CHO	CHO	H3O	H2O*	H2O*	N	C$		

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= PBXN-103

	H	C	N	O	AL	CL				
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000			6.000	-625.	.0600	
AP	.0040.000	.001	.0040.000	.0010.0000.0000.0000.0000.0000.000			40.000	-602.	.0705	
ALUMINUM --AL	0.0000.0000.0000.000			.0010.0000.0000.0000.0000.0000.0000.000			27.000	0.	.0976	
RESORCINOL - RES	.006	.0060.000	.0020.0000.0000.0000.0000.0000.0000.0000.000				.200	-777.	.0460	
METRIOL TRINITRATE	.009	.005	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000			23.000	-406.	.0531	
TEGDN	.012	.006	.002	.0000.0000.0000.0000.0000.0000.0000.0000.000			2.500	-637.	.0470	
ETHYL CENTRALITE-EC	0.000	.0170.0000.0000.0000.0000.0000.0000.0000.0000.000					1.300	-117.	.0451	
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000				0.000	0.	.0004	
									1.0000	

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

0 (H)	(C)	(N)	(O)	(AL)	(CL)	(F
2.475120	.764460	.605646	2.477990	1.000741	.340434	

WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	4090.979	4055.501	3990.025	3909.719	3780.604	3597.101	3331.310	2907.507	2301.109	1409.760
FLAME TEMP. T(F)	6904.362	6840.502	6737.044	6570.095	6345.030	6015.382	5536.959	4774.256	3682.739	2070.168
ENTHALPY KCAL/GFW	-39.050	-35.145	-31.240	-27.335	-23.430	-19.525	-15.620	-11.715	-7.810	-3.905

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	2805.406	2809.530	2714.577	2683.758	2479.241	2341.726	2138.220	1555.043	1005.604	520.667
FLAME TEMP. T(F)	4734.475	4597.769	4426.039	4227.365	4003.234	3755.707	3389.410	2339.678	1350.687	477.000
ENTHALPY KCAL/GFW	-110.387	-112.953	-107.235	-101.146	-94.653	-87.567	-79.819	-66.361	-49.450	-28.036
T.VOL.GASES--LITERS	70.023	76.647	84.960	95.025	110.544	131.542	167.065	231.505	361.330	749.734
(GASES AT STP)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

AL2O3*	49.9394	50.6002	50.0677	50.9669	51.0010	51.0133	.0000	.0000	.0000	.0000
CO	20.6027	20.1401	19.2042	17.4630	13.9865	6.9090	.5167	.0000	.0000	.0000
HCL	10.1530	10.7045	11.1760	11.4395	11.6053	11.6025	11.2204	12.0920	11.6332	1.6576
N2	9.5930	10.3474	29.2912	43.3642	62.1200	88.3753	127.5321	193.4561	324.9995	719.2565
H2O	3.6060	5.5169	8.0501	11.1256	14.5322	17.7197	19.2517	19.2990	19.4200	21.0062
H2	1.6379	1.4428	1.1050	.0675	.5081	.1673	.0106	.0000	.0000	.0000

OB CALCULATION NO. 16

CL	1.3400	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CO2	1.1477	1.9077	3.4700	6.2053	11.6609	22.7079	32.8328	33.6433	33.6446	33.6446
ALCL	.0193	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALCL2	.3702	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALOCL	.2501	.1501	.0790	.0360	.0150	.0052	.0007	.0000	.0000	.0000
NO	.2020	.2503	.2772	.2779	.2636	.2690	.3214	.0161	.0000	.0000
H	.1607	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
O	.0235	.0255	.0230	.0197	.0159	.0167	.0309	.0004	.0000	.0000
NO	.0225	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
AL	.0161	.0036	.0006	.0001	.0000	.0000	.0000	.0000	.0000	.0000
ALO	.0067	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
AL2O	.0040	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
O2	.0047	.0089	.0140	.0234	.0422	.1666	5.3572	23.2007	50.5896	162.0777
ALCL3	.0046	.0026	.0014	.0007	.0004	.0002	.0001	.0000	.0000	.0000
ALO2	.0019	.0013	.0007	.0003	.0001	.0000	.0000	.0000	.0000	.0000
CL2	.0006	.0006	.0006	.0006	.0007	.0012	.0072	.0521	.7475	10.4500
ALH	.0006	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
OCL	.0001	.0002	.0002	.0002	.0002	.0004	.0035	.0023	.0002	.0000
HOCL	.0001	.0002	.0002	.0003	.0004	.0006	.0032	.0061	.0079	.0015
CHO	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HO2	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000
CL	.0000	1.2411	1.0758	.9030	.7715	.7833	1.1403	.2552	.0062	.0000
NO	.0000	.0308	.0552	.0711	.0928	.1702	.7449	.2032	.0127	.0000
H	.0000	.1227	.0837	.0498	.0243	.0080	.0000	.0000	.0000	.0000
ALCL2	.0000	.1631	.0635	.0225	.0068	.0000	.0015	.0001	.0000	.0000
AL2O3$	.0000	.0000	.0000	.0000	.0000	.0000	51.0173	51.0178	51.0178	51.0178
AL2O	.0000	.0007	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALCL	.0000	.2717	.0763	.0176	.0029	.0002	.0000	.0000	.0000	.0000
ALO	.0000	.0026	.0000	.0002	.0000	.0000	.0000	.0000	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

AL2O3*	CO	HCL	N2	H2O	H2	CL	CO2	ALCL	ALCL2	ALOCL	HO	H	O	NO
AL	ALO	AL2O	O2	ALCL3	ALO2	CL2	ALH	OCL	HOCL	CHO	N	COCL	NH	AL2O2
CNH	NH3	NH2	ALHO2	NHO	CH2O	CNHO	HO2	H2O2	CN	NOCL	ALN	CNO	CNCL	CH3
NH2O2	C	CH4	COCL2	CH	C2O	CH2	CHCL	N2H2	N3	OCL2	O2CL	C2H2	CH3CL	CCL
C2H	O3	ALC	CN2	AL2CL6	C2N	C2HCL	CCL2	C2N2	CH2CL2	CN2	NO2CL	NH3	C2	N2H4
NO3	ALHO	C3O2	C2CL2	CNCL3	CCL3	CL	NO	C4N2	H3O	C3	HO	CHO	N2O4	C2CL4
AL2O2	H	CCL4	C2H4O	C5	N2O3	ALCL2	C2CL6	N2O5	AL4C3$	ALCL3*	ALCL3$	NH4O4C	AL2O3$	AL2O3$
N2O4$	N2O4*	N2O	ALOCL$	AL2O	ALCL	C4H10	C4H8	NH4CL$	NH4CL$	C4	NO2	C3H8	ALO	C3H6
ALN$	N2H4*	C2H6	C2H4	AL*	AL$	AL*	CN	H2O*	H2O*	C$	C$			

OPEN BURN----MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
MATERIAL= PBX(AF) -108

	H	C	N	O	S					
RDX -(S)	.006	.003	.006	.0060.0000.0000.0000.0000.0000.0000.0000.000		82.000	72.	.0656		
PHENOL	.006	.0060.000	.0010.0000.0000.0000.0000.0000.0000.0000.000			.500	-394.	.0307		
ISODECYL PELARGONATE	.038	.0190.000	.0020.0000.0000.0000.0000.0000.0000.0000.000			5.300	-707.	.0314		
PPG	.006	.0030.000	.0010.0000.0000.0000.0000.0000.0000.0000.000			10.700	-875.	.0362		
TDICY	.006	.009	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000			.610	-33.	.0325	
HEXAMETHYL-DIISO-HDI	.007	.005	.001	.0010.0000.0000.0000.0000.0000.0000.0000.000			.250	-321.	.0325	
FAPI	.006	.008	.001	.0010.0000.0000.0000.0000.0000.0000.0000.000			.375	-270.	.0361	
SULFUR	0.0000.0000.0000.000	.0010.0000.0000.0000.0000.0000.0000.000					.100	0.	.0739	
CUBANE	.000	.0000.0000.0000.0000.0000.0000.0000.0000.000					.100	1335.	.0372	
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000				0.000	0.	.0004	

OGRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.935 1.0000

B (H)	(C)	(N)	(O)	(S)	(
4.090371	2.103154	2.227745	2.452792	.003119	

WT. MATERIAL	99.935	89.941	79.948	69.954	59.961	49.968	39.974	29.981	19.987	9.993
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	1953.007	2033.253	2110.495	2210.134	2309.102	2417.096	2535.760	2652.726	2274.985	1400.379
FLAME TEMP. T(F)	3057.453	3200.455	3353.090	3510.841	3697.128	3891.373	4104.982	4315.507	3635.429	2075.682
ENTHALPY KCAL/GFW	-7.436	-6.693	-5.949	-5.205	-4.462	-3.718	-2.975	-2.231	-1.487	-.744

----COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	975.700	966.821	956.308	944.313	957.072	1001.846	1060.463	1145.739	933.590	499.641
FLAME TEMP. T(F)	1297.805	1280.878	1261.954	1240.363	1264.769	1343.923	1463.833	1602.930	1221.863	439.953
ENTHALPY KCAL/GFW	-64.528	-62.942	-61.535	-60.317	-59.258	-58.278	-57.310	-56.377	-45.762	-26.564
1.VOL.GASES--LITERS	115.043	122.065	130.037	142.157	159.248	181.265	212.954	265.622	307.667	777.755
(GASES AT STP)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO	39.2044	39.6213	39.7078	39.6595	37.0640	32.6166	25.0952	10.7795	.0000	.0000
N2	31.2221	39.9005	50.9466	65.0350	83.0226	110.1251	149.5776	215.3299	346.0300	741.3401
CO2	16.9023	19.4733	22.7027	27.2050	33.3669	41.2033	53.1062	75.6004	92.6221	92.6221
H2O	5.0465	5.4301	5.9314	6.5031	8.9472	13.2690	20.2774	30.9267	36.0700	36.0130
H2	3.2745	3.2307	3.1750	3.1052	3.0243	2.6261	1.8502	.6590	.0000	.0000

OB CALCULATION NO. 17

C$	2.9642	2.1400	1.1641	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CH4	1.1120	1.1117	1.1135	1.1007	.3704	.0319	.0000	.0000	.0000	.0000
H2S	.1035	.1034	.1034	.1033	.1034	.1034	.1031	.1022	.0000	.0000
NH3	.0853	.0850	.0863	.0860	.0860	.0836	.0814	.0802	.0000	.0000
C6O	.0050	.0052	.0053	.0054	.0052	.0052	.0057	.0060	.0000	.0000
CNH	.0002	.0002	.0002	.0002	.0001	.0001	.0000	.0000	.0000	.0000
SO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.1990	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0036	.0000
H2SO4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.3061
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	23.7334	129.5033

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	N2	CO2	H2O	H2	C$	CH4	H2S	NH3	C6O	CNH	CH2O	C2H6	CNHO	C2H4
HS	C62	CS	CH3	S2	C2H2	H	C3H6	SO2	C3H8	NH2	SO	NO	S	S2O
C2N2	NS	C4H8	HO	C4H10	C2H4O	SO3	C3	NO	C3O2	NH	CN	H2SO4	C4	C2H
C2N	HO2	CN2	NHO2	CH	N2H4	HO	N3	N2O4	CS	CN	NHO3	C	NHO	H
O3	H2O2	CN2	C4N2	N2O5	N2O	S8	NO3	C2O	N2SO4*	N2O4$	N2O4*	N2O3	NO2	CNO
S$	S*	N2H4*	O2	N2H2	CHO	CHO	C2	H3O	H2O*	H2O*	O	CH2	N	C$

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= NOWIH-80-1(MK23)

	H	C	N	O	AL	P	CL	FE			
R-45M	.011	.0070.000	.0000.0000	.0000.0000	.0000.0000	.0000.0000	.0000.0000	.0000.000	14.220	-0.	.0329
DER-736	.008	.0040.000	.0020.0000	.000	.0000.0000	.0000.0000	.0000.0000	.008	.710	-402.	.0401
ERL 0510	.007	.005	.000	.0010.0000	.0000.0000	.0000.0000	.0000.0000	.000	.990	-196.	.0361
VANOX-200	.007	.006	.000	.0010.000	.0000.0000	.0000.0000	.0000.0000	.000	.620	-259.	.0361
LECITHIN(LECIT)	.011	.0060.000	.0010.000	.0000.0000	.0000.0000	.0000.0000	.0000.0000	.000	.400	-516.	.0376
CARBON (GRAPHITE)	0.000	.0010.0000	.0000.0000	.0000.0000	.0000.0000	.0000.0000	.0000.0000	.000	.500	0.	.0017
IRON OXIDE- FEO	0.0000	.0000.000	.0010.0000	.0000.000	.0010.0000	.0000.0000	.0000.000		.500	-905.	.2059
ALUMINUM --AL	0.0000	.0000.0000	.0000.000	.0010.0000	.0000.0000	.0000.0000	.0000.000		2.000	0.	.0976
AP	.0040	.000	.001	.0040.0000	.000	.0010.0000	.0000.0000	.0000.000	00.000	-602.	.0705
AIR -(0	0.0000	.000	.006	.0010.0000	.0000.0000	.0000.0000	.0000.0000	.000	0.000	0.	.0004
										1.0000	

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.940

0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(			
4.491064	1.222480	.685063	2.770823	.074129	.002000	.682734	.006959				
WT. MATERIAL		99.940	89.946	79.952	69.950	59.964	49.970	39.976	29.982	19.988	
WT. AIR		0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1275.013	1396.993	1545.430	1706.247	1878.963	2063.916	2046.006	1694.622	1297.650
FLAME TEMP. T(F)	1837.064	2055.180	2322.374	2611.044	2922.733	3255.648	3223.410	2598.919	1876.369
ENTHALPY KCAL/GFW	-116.445	-104.730	-93.100	-81.463	-69.025	-58.188	-46.550	-34.913	-23.275

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	789.534	794.255	799.567	807.114	830.199	893.600	872.543	684.774	487.717
FLAME TEMP. T(F)	961.762	970.259	979.821	993.404	1034.950	1149.224	1111.177	773.194	418.491
ENTHALPY KCAL/GFW	-149.167	-138.467	-128.100	-118.266	-108.699	-99.356	-86.309	-67.895	-47.245
T.VOL.GASES--LITERS (GASES AT STP)	84.960	93.563	104.770	118.642	135.840	157.343	191.077	255.477	383.731

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (0S/0)MATERIAL BURNED-----

CO2	37.0572	39.2009	41.3162	43.9296	46.8218	50.1378	53.0349	53.0349	53.0349
HCL	24.4030	24.4030	24.4030	24.4030	24.4030	24.6509	23.1067	14.0495	2.3212

OD CALCULATION NO. 18

H2O	15.0213	15.6175	17.0051	19.2319	22.0500	29.2391	34.7787	36.9515	39.0496
N2	9.6893	10.3745	29.3310	43.4207	62.2070	80.5102	127.9595	193.7076	325.2036
CO	4.1540	4.6155	4.7069	4.7302	4.2402	2.3524	.0000	.0000	.0000
AL2O3$	3.7014	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CH4	3.2540	2.6989	1.0217	.0969	.1279	.0004	.0000	.0000	.0000
H2	1.3556	1.4301	1.4842	1.4764	1.2643	.5762	.0000	.0000	.0000
FECL2$	.0489	.0379	.0220	.7925	.6525	.0000	.0000	.0000	.0000
C$	.3610	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
P406	.1149	.1149	.1149	.1149	.1149	.1149	.0000	.0000	.0000
FECL2	.0293	.0306	.0520	.0765	.1006	.4092	.0000	.0000	.0000
NH3	.0049	.0064	.0072	.0071	.0047	.0009	.0000	.0000	.0000
FE2CL4	.0044	.0061	.0006	.0136	.0414	.0419	.0000	.0000	.0000
FECL3	.0000	.0001	.0001	.0001	.0002	.0005	.0013	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	1.7408	10.5564	21.9641
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0058	.0070	.0017
P4010	.0000	.0000	.0000	.0000	.0000	.0000	.1403	.0001	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	4.1762	19.0244	52.5230
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.5553	.5560	.5560
AL2O3$	.0000	3.7014	3.7014	3.7014	3.7014	3.7014	3.7014	3.7014	3.7014
PH3O4*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.2046	.2040
FEO$	.0000	.0000	.0000	.0000	.0000	.2443	.0000	.0000	.0000
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0007	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	HCL	H2O	N2	CO	AL2O3$	CH4	H2	FECL2$	C$	P406	FECL2	NH3	FE2CL4	FECL3
C2H6	CH3CL	CNH	CN2O	CNHO	C2H4	CH3	C3H8	FE2CL6	ALCL3	C3H6	FEH2O2	CL	C2H2	CH2CL2
COCL	CL2	H	PN	COCL2	CNCL	NH2	PH3	C4H10	C4H8	HO	POCL3	CPH	HOCL	PO2
FE	C2N2	C2H	PH2	C2H4O	C4N2	CHCL3	CN2	NHO2	CP	PH	PCL	N2H4	CCL	CH
HO2	NH	C3O2	ALOCL	CCL4	AL2CL6	N3	NHO	CCL2	CN	P2	FEO	PCL3	N2O2	C2H
ALCL	P	CCL3	C2O	C2CL2	CN2	OCL	P4O10	PCL5	O	O2	OCL2	C2CL4	NOCL	C
P4O10$	C2CL6	FE3O4$	FE3O4$	P3N5$	FECL3$	FECL3*	FE2O3$	FE2O3$	C2HCL	AL4C3$	ALCL3*	ALCL3$	FECL2*	P4
C3	NH4O4C	N2O5	FEH3O3	AL2O3$	AL2O3*	PH3O4$	PH3O4*	ALCL2	ALCL2	N2O4$	N2O4*	N2O4	FECL	FEH2O2
AL2O2	AL2O2	NO2CL	ALOCL$	N2O3	FEO$	FEO$	FEO*	AL2O	AL2O	O2CL	NH3	ALCL	NO3	CS
ALHO2	ALO2	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	CHCL	C4	O3	PO	NO2
N2O	ALHO	ALO	ALO	CHO	ALN$	ALN	ALC	NO	CL	N2H4*	P$	P$	P*	H2H2
NO	CHO	CHO	ALH	AL*	AL$	AL*	AL	CN	C2	N	H3O	H2O*	H2O*	HO
CH2	C$	H												

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= X256 (MK 12)

	H	C	N	O	AL	FR			
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000	49.090	-625.	.0600		
NITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000	33.600	-392.	.0570		
TRIACETIN - TA	.014	.0090.000	.0060.0000.0000.0000.0000.0000.0000.0000.000		7.620	-1335.	.0420		
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000	1.450	83.	.0494		
LEAD SALICYLATE	.010	.0140.000	.0060.000	.0010.0000.0000.0000.0000.0000.000	1.030	-864.	.0361		
ETADIHYLHEXOAT-FRCH	.030	.0160.000	.0040.000	.0010.0000.0000.0000.0000.0000.000	.390	-694.	.0470		
FBRES	.006	.0070.000	.0050.000	.0010.0000.0000.0000.0000.0000.000	1.440	-603.	.0325		
ALUMINUM --AL	0.0000.0000.0000.000			.0010.0000.0000.0000.0000.0000.0000.000	3.700	0.	.0976		
AIR -(O	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000	0.000	0.	.0004		

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 — 1.0000

0 (H)	(C)	(N)	(O)	(AL)	(FR)	(					
2.763753	2.030053	.986124	3.412906	.140104	.000407						
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1324.523	1446.953	1596.806	1757.633	1933.093	2119.670	2306.072	2045.200	1547.569	976.023
FLAME TEMP. T(F)	1924.741	2145.116	2414.851	2704.339	3020.168	3356.006	3691.529	3221.975	2326.225	1290.082
ENTHALPY KCAL/GFW	-120.595	-108.536	-96.476	-84.417	-72.357	-60.298	-48.238	-36.179	-24.119	-12.060

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	882.443	879.792	875.861	868.126	892.250	950.657	1041.909	872.417	594.242	328.045
FLAME TEMP. T(F)	1128.990	1124.226	1115.709	1103.226	1146.650	1266.183	1416.101	1110.951	610.235	131.001
ENTHALPY KCAL/GFW	-152.940	-141.846	-131.176	-120.936	-111.068	-101.489	-91.049	-74.211	-52.300	-29.239
T.VOL.GASES--LITERS (GASES AT STP)	85.457	92.640	101.563	113.023	130.157	151.658	183.244	245.245	375.867	765.070

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	45.7946	48.3488	51.7073	56.5105	61.7245	69.2525	83.1192	89.3799	89.3799	89.3799
CO	17.7015	18.5465	19.1533	19.3248	17.3193	12.0863	3.9846	.0000	.0000	.0000
N2	12.6904	21.4518	32.4020	46.4021	65.2569	91.5423	130.9602	196.6764	328.0930	722.3450

OD CALCULATION NO. 19

H2O	0.0233	0.0340	0.9370	9.2050	11.9047	16.5014	22.0099	24.0959	24.0959	24.0959
AL2O3$	7.1425	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
C$	3.4007	2.4740	1.3159	.0000	.0000	.0000	.0000	.0000	.0000	.0000
PB*	1.7415	1.7415	1.7415	1.7416	1.7409	1.7339	1.6789	.0000	.0000	.0000
H2	1.5241	1.5377	1.5390	1.5260	1.4126	.9296	.2334	.0000	.0000	.0000
CH4	1.0096	1.0300	.9759	.9106	.1615	.0022	.0000	.0000	.0000	.0000
NH3	.0031	.0037	.0042	.0046	.0035	.0011	.0001	.0000	.0000	.0000
PB	.0006	.0006	.0006	.0005	.0012	.0002	.0632	.0000	.0000	.0000
PBO	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	13.3611	48.5664	154.2357
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.9214	.0000
PBO2$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	2.0111
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0765	.0000	.0000
AL2O3$	.0000	7.1425	7.1425	7.1425	7.1425	7.1425	7.1425	7.1425	7.1425	7.1425
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0009	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	CO	N2	H2O	AL2O3$	C$	PB*	H2	CH4	NH3	PB	CNH	C2H6	CH2O	CNHO
C2H4	PBH	CH3	PBO	C2H2	PB2	C3H6	C3H8	H	NH2	HO	C4H8	C4H10	C2N2	NO
C4N2	C2	C2N	C3O2	HO2	NN	N2H4	NHO2	C	CN	N3	NHO	C2H	CH	C2O
H2O2	C2H4O	ALHO2	CN2	O	O2	CH2	ALO2	C3	PB3O4$	N	PBO2$	PBO$	PBO*	PBO*
PBO*	PB$	AL4C3$	N2O5	AL2O3$	AL2O3*	N2O4	N2O4$	N2O4*	AL2O2	AL2O2	N2O3	AL2O	AL2O	NHO3
NO3	C5	C4	O3	NO2	N2O	ALHO	ALO	ALO	CNO	ALN$	ALN	ALC	N2H4*	N2H2
HO	CHO	CHO	ALH	AL	AL*	AL$	AL*	CN	H3O	H2O*	H2O*	HO	CH2	C$
H														

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= N-60 (SMOKEY SAM)

	H	C	N	O	CL	FE	ZN				
R-45M	.011	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000					11.970	-0.	.0329	
DIOCTYL ADIPATE	.042	.0220.000	.0040.0000.0000.0000.0000.0000.0000.0000.000					3.000	-733.	.0332	
IRON OXIDE	0.0000.0000.000		.0030.000	.0020.0000.0000.0000.0000.0000.000				1.000	-1235.	.1093	
ZINC	0.0000.0000.0000.0000.0000.000			.0010.0000.0000.0000.0000.000				40.000	0.	.2500	
AP	.0040.000		.001	.004	.0010.0000.0000.0000.0000.0000.0000.000			44.000	-602.	.0705	
AIR -(0	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000				0.000	0.	.0004	
GORAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.970										1.0000	
B (H)	(C)	(N)	(O)	(CL)	(FE)	(ZN)	(				
3.140460	1.051402	.374470	1.559062	.374470	.012523	.611000					
WT. MATERIAL	99.970	89.973	79.976	69.979	59.982	49.985	39.988	29.991	19.994	9.997	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1274.554	1297.699	1343.068	1438.395	1562.904	1710.000	2010.554	2126.114	1500.903	900.617
FLAME TEMP. T(F)	1834.797	1876.457	1958.123	2129.711	2353.972	2634.504	3173.997	3367.605	2400.626	1305.710
ENTHALPY KCAL/GFW	-61.574	-55.400	-49.244	-43.009	-36.933	-30.770	-24.622	-18.467	-12.311	-6.156

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	892.230	890.946	888.889	884.677	886.975	941.642	1033.795	934.199	653.301	344.747
FLAME TEMP. T(F)	1146.620	1144.303	1140.600	1133.019	1137.156	1235.556	1401.431	1222.157	716.606	161.145
ENTHALPY KCAL/GFW	-83.634	-79.000	-74.535	-70.394	-66.824	-63.770	-61.362	-54.001	-39.700	-23.230
T.VOL.GASES--LITERS	71.261	70.927	80.312	100.137	117.202	140.642	172.363	230.077	360.523	750.370
(GASES AT STP)										
COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04										

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

ZNO$	35.6519	35.6695	35.6922	35.7293	35.8389	35.9681	35.9655	36.6068	35.3601	34.5620
ZNCL2	23.6799	23.6479	23.6077	23.5456	23.3601	23.0741	22.0893	21.9603	.5774	.0000
CO2	10.7183	12.6956	15.2568	18.7681	23.4200	28.6963	37.2170	46.2071	46.2071	46.2071
CO	0.0393	9.3381	10.0595	12.4703	13.0406	11.1416	5.7727	.0000	.0000	.0000
H2O	6.0328	6.2215	6.4497	6.7795	0.2503	13.0706	21.4597	27.9024	28.2009	28.3699
N2	5.2441	14.0865	24.9605	39.0446	57.0242	84.1184	123.5577	189.2055	328.7427	715.1122

OD CALCULATION NO. 20

C$	4.6027	3.6785	2.4098	.9796	.0000	.0000	.0000	.0000	.0000	.0000
CH4	2.2134	1.9832	1.7678	1.5761	.8637	.8318	.0000	.0000	.0000	.0000
H2	1.9153	1.9513	1.9793	1.9894	2.0011	1.6674	.7330	.0000	.0000	.0000
HCL	.9067	1.0038	1.0253	1.0506	1.1579	1.3184	1.4511	1.0921	.6516	.0001
FEO$	.0983	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ZN	.0184	.0116	.0126	.0125	.0136	.0469	.1761	.0000	.0000	.0000
NH3	.0030	.0055	.0064	.0069	.0069	.0034	.0005	.0000	.0000	.0000
FECL2	.0031	.0031	.0031	.0030	.0030	.0039	.0056	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0113	.0610	.0000
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0006	.0004	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	0.3670	43.6168	149.4116
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0003	1.0003	1.0003
ZNCL2*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	23.6128	25.5269
FEO$	.0000	.0983	.0983	.0984	.0984	.0979	.0969	.0000	.0000	.0000
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0016	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

ZNO$	ZNCL2	CO2	CO	H2O	N2	C$	CH4	H2	HCL	FEO$	ZN	NH3	FECL2	C2H6
CNH	FE2CL4	CH2O	C2H4	CH3CL	CNHO	FECL3	FEH2O2	CH3	C3H6	C3H8	C2H2	CL	H	COCL
NH2	HO	CNCL	CH2CL2	C4H8	CL2	C4H10	FECL	COCL2	FE	HOCL	C2N2	FE2CL6	C2HCL	NO
C2H4O	N2H4	C4N2	NH	CHCL3	C3O2	OCL	CN	FEO	C2H	NHO	NHO2	O2	C2N	CHCL
C2O	H2O2	CCL	HO2	O	NHO3	CCL4	C2CL2	C2CL6	FE3O4$	FE3O4$	C2CL4	FECL3$	FECL3*	NOCL
FE2O3$	FE2O3$	N	ZNCL2*	FECL2$	FECL2*	CCL3	NH4O4C	CN2	N2O5	FEH3O3	N3	N2O4$	N2O4*	N2O4
FEH2O2	OCL2	CCL2	NO2CL	N2O3	FEO$	FEO*	O2CL	ZN$	ZN*	NO3	C5	FE$	FE$	FE$
FE$	FE*	FE$	NH4CL$	NH4CL$	C4	O3	NO2	N2O	CNO	CN2	C3	CL	N2H4*	N2H2
NO	CHO	CHO	CN	C2	H3O	H2O*	H2O*	NO	CN2	CH	C$	C	H	

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= N-50 (5" G.P.)

	H	C	N	O	AL	CL	FE					
R-45M	.011	.0070	.000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	11.000	-0.	.0329
PHENOL	.006	.0060	.000	.0010	.0000	.0000	.0000	.0000	.0000	.0000	.150	-394.	.0387
DIPHENYLAMINE - DPA	.011	.012	.0010	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.150	170.	.0419
(DHE)N,N-B-2-HY-ET-M	.007	.004	.001	.0020	.0000	.0000	.0000	.0000	.0000	.0000	.200	-838.	.0444
IRON OXIDE	0.0000	.0000	.000	.0030	.0000	.000	.0020	.0000	.0000	.0000	.200	-1235.	.1093
ALUMINUM --AL	0.0000	.0000	.0000	.000	.0010	.0000	.0000	.0000	.0000	.0000	10.000	0.	.0976
AP	.0040	.000	.001	.0040	.000	.0010	.0000	.0000	.0000	.0000	65.000	-602.	.0705
ISODECYL PELARGONATE	.030	.0190	.000	.0020	.0000	.0000	.0000	.0000	.0000	.0000	.060	-707.	.0314
AIR -(0	0.0000	.000	.006	.0010	.0000	.0000	.0000	.0000	.0000	.0000	0.000	0.	.0004
												1.0000	

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 94.760

0 (H)	(C)	(N)	(O)	(AL)	(CL)	(FE)	(					
3.458651	.034507	.555047	2.231766	.667161	.553206	.002505						
WT. MATERIAL	94.760	85.284	75.808	66.332	56.856	47.380	37.904	28.428	18.952	9.476		
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000		

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	2322.593	2371.692	2435.120	2501.083	2572.389	2643.185	2684.752	2258.031	1695.383	1056.315
FLAME TEMP. T(F)	3721.267	3809.646	3923.016	4043.989	4170.757	4298.188	4229.154	3592.896	2592.145	1441.967
ENTHALPY KCAL/GFW	-115.866	-98.815	-87.035	-76.856	-65.877	-54.897	-43.918	-32.938	-21.959	-10.979

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1217.203	1328.255	1335.364	1350.559	1366.006	1382.184	1362.823	1006.527	683.425	369.697
FLAME TEMP. T(F)	1731.565	1917.060	1944.256	1971.606	1999.410	2028.531	1993.682	1352.348	770.765	206.055
ENTHALPY KCAL/GFW	-161.548	-147.388	-136.548	-125.766	-115.053	-104.442	-92.986	-73.439	-52.211	-29.502
T.VOL.GASES--LITERS	81.748	89.151	98.408	110.318	126.179	148.396	182.785	251.285	386.911	796.882
(GASES AT STP)										

CONBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

AL2O3#	35.8926	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CO	21.1833	20.4615	18.9393	16.8213	13.6494	8.4074	.0002	.0000	.0000	.0000
HCL	21.8953	21.8953	21.8953	21.8952	21.8952	21.8950	21.8568	20.1575	10.6712	.1087

OD CALCULATION NO. 21

N2	0.2163	17.4620	29.0191	43.0702	63.6983	91.4272	133.0223	202.3710	341.0506	757.1109
CO2	5.4726	6.6124	9.0044	12.3324	17.3161	25.5524	30.7619	30.7621	30.7621	30.7621
H2O	5.2995	7.6230	10.1341	13.2595	17.2031	22.2000	27.6752	27.0972	30.2410	32.0317
H2	2.5023	2.2428	1.9619	1.6122.	1.1709	.6100	.0000	.0000	.0000	.0000
FECL2	.3344	.3340	.3340	.3340	.3340	.3340	.1546	.0002	.0000	.0000
CH4	.0022	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
NH3	.0007	.0005	.0005	.0003	.0002	.0001	.0000	.0000	.0000	.0000
FE2CL4	.0005	.0002	.0001	.0001	.0001	.0001	.0000	.0000	.0000	.0000
FECL3	.0002	.0002	.0002	.0002	.0002	.0002	.0225	.0032	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.0594	1.0042	10.3105	20.5161
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0015	.0000	.0000	.0000
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0031	.0095	.0072	.0002
O2	.0000	.0000	.0000	.0000	.0000	.0000	1.4577	19.0359	54.9565	164.2545
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0001	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0220	.0059	.0001	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.2111	.2111
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.1026	.2894	.0000	.0000
AL2O3$	.0000	35.8926	35.8926	35.8926	35.8926	35.8926	35.8926	35.8926	35.8926	35.8926
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000
CL	.0000	.0000	.0001	.0001	.0002	.0003	.0620	.0064	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

AL2O3$	CO	HCL	N2	CO2	H2O	H2	FECL2	CH4	NH3	FE2CL4	FECL3	CNN	CH2O	ALCL3
CL	CNHO	CH3CL	N	FEH2O2	CH3	ALCL2	CL2	COCL	CHO	HO	C2H4	C2H2	NH2	FECL
CNCL	FE	C2H6	HOCL	NO	C0CL2	CH2CL2	FE2CL6	ALOCL	ALCL	C2HCL	NH	FEO	C2N2	CN
C3H6	CNO	NHO	O	AL2CL6	N2H2	O2	OCL	CH2	H2O2	NO2CL	C2H	C3O2	CHCL3	C2N
C2O	NHO3	OCL2	AL2O2	O3	N2H4	NO	N	C2CL2	CN2	CCL2	NOCL	CCL	N3	CHCL
AL2O	C3	CHO	C4N2	C	C2H4O	ALN	NO3	O2CL	HO2	NHO2	C2CL4	CN2	CCL3	N2O3
N2O	CCL4	CH	ALH	C2	AL	H3O	ALO	AlO2	ALHO2	ALCL	C2CL6	FE3O4$	FE3O4$	ALC
ALHO	FECL3$	FECL3*	FE2O3$	FE2O3$	AL4C3$	ALCL3*	ALCL3$	FECL2$	FECL2*	NH4O4C	N2O5	FEH3O3	AL2O3$	AL2O3*
ALCL2	N2O4$	N2O4*	N2O4	FEH2O2	AL2O2	C4	ALOCL$	FEO$	FEO$	FEO*	AL2O	C5	C4H10	C4H8
FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	NO2	C3H8	ALO	ALN$	CL	N2H4*	AL*
AL$	AL*	CN	H2O*	H2O*	HO	C$	C$	N						

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= N-5 (ASROC AND MK22)

	H	C	N	O	PB			
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000		50.000	-625.	.0600
NITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000		34.900	-392.	.0570
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000		2.000	83.	.0494
DIETHYL PHTHALATE	.014	.0120.000		.0040.0000.0000.0000.0000.0000.0000.0000.000		10.500	-810.	.0406
LEAD SALICYLATE	.010	.0140.000		.006 .0010.0000.0000.0000.0000.0000.0000.000		2.400	-864.	.0361
CANDELLIA WAX	.012	.0070.000		.0000.0000.0000.0000.0000.0000.0000.0000.000		.200	-142.	.0343
AIR -(O	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000		0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 1.0000

0 (H)	(C)	(N)	(O)	(PB)	(
2.983240	2.324052	.929421	3.430551	.004985	

WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1107.377	1226.729	1319.203	1494.318	1694.995	1913.206	2146.610	2160.906	1643.904	1032.729
FLAME TEMP. T(F)	1677.078	1740.713	1915.309	2230.372	2591.592	2904.515	3404.490	3444.774	2499.620	1399.513
ENTHALPY KCAL/GFW	-110.000	-99.000	-88.000	-77.000	-66.000	-55.000	-44.000	-33.000	-22.000	-11.000

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	854.709	856.045	856.460	854.227	847.952	856.041	934.266	929.196	634.403	340.561
FLAME TEMP. T(F)	1079.077	1081.482	1082.228	1078.208	1066.913	1081.474	1222.279	1213.153	602.526	160.010
ENTHALPY KCAL/GFW	-141.627	-131.131	-120.000	-111.172	-102.143	-93.760	-85.775	-74.133	-52.335	-29.305
1.VOL.GASES--LITERS (GASES AT STP)	92.279	99.568	108.611	120.131	135.371	158.358	190.913	247.773	377.659	767.637

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	52.0762	54.4666	57.5352	61.7991	68.0032	76.0533	87.1711	102.3191	102.3191	102.3191
CO	13.0700	14.3945	15.8290	17.0099	17.5959	16.1807	9.6393	.0000	.0000	.0000
N2	13.0164	21.7770	32.7200	46.0000	65.5016	91.8657	131.2939	197.0026	328.4202	722.6713
H2O	10.9076	10.7440	10.6175	10.6197	10.0336	13.1377	20.1030	26.8730	26.8730	26.8730
C$	7.0641	5.9168	4.5370	2.9319	1.0419	.0000	.0000	.0000	.0000	.0000

N2	1.4357	1.4783	1.5169	1.5303	1.5326	1.4486	.7571	.0000	.0000	.0000
CH4	1.3934	1.2960	1.1900	1.1121	1.0394	.3484	.0010	.0000	.0000	.0000
PB*	1.0327	1.0326	1.0326	1.0326	1.0326	1.0324	1.0273	.0000	.0000	.0000
NH3	.0035	.0042	.0048	.0052	.0055	.0047	.0009	.0000	.0000	.0000
PB	.0003	.0003	.0003	.0004	.0003	.0005	.0057	.0000	.0000	.0000
PBO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0012	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	6.0246	41.2404	146.9441
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.1393	.0000
PBO2$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.1925
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.1115	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0013	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	CO	N2	H2O	C$	H2	CH4	PB*	NH3	PB	C2H6	CNN	CH2O	CNNO	C2H4
PBH	CH3	PBO	C3H6	C3H8	C2H2	PB2	H	NH2	HO	C4H8	C4H10	C2N2	NO	C2H4O
O	O2	CH	N3	C2N	N	C2	CN2	NH02	C4N2	C3	N2H4	HO2	C	CN2
C3O2	NH	NHO	CN	H2O2	C2H	PB3O4$	C2O	PBO2$	PBO$	PBO$	PBO*	PBO*	PB$	N2O5
N2O4$	N2O4*	N2O4	N2O3	NH03	NO3	C5	C4	O3	NO2	H2O	CNO	N2H4*	N2H2	NO
CHO	CHO	CN	H3O	H2O*	H2O*	HO	CH2	C$	H					

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL* AA2 (MK 90)

	H	C	N	O	CU	PB						
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000							51.000	-625.	.0600
NITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000							30.600	-392.	.0570
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000							2.000	03.	.0494
DNPA	.022	.0120.000	.0040.0000.0000.0000.0000.0000.0000.0000.000								1.600	-094.	.0361
FBRES	.006	.0070.000	.0050.000	.0010.0000.0000.0000.0000.0000.0000.000							.000	-603.	.0325
CUSAL	.006	.0070.000	.004	.0010.0000.0000.0000.0000.0000.0000.0000.000							3.200	-071.	.0361
CANDELLIA WAX	.012	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000								.100	-142.	.0343
TRIACETIN - TA	.014	.0090.000	.0060.0000.0000.0000.0000.0000.0000.0000.000								1.600	-1335.	.0420
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000								0.000	0.	.0004
0GRAM ATOM AMOUNTS FOR MATERIAL	WEIGHT OF	90.900										1.0000	
0 (H)	(C)	(N)	(O)	(CU)	(PB)	(							
2.725300	2.019275	.907293	3.543491	.014701	.002120								
WT. MATERIAL	90.900	89.010	79.120	69.230	59.340	49.450	39.560	29.670	19.780				
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000				

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1207.329	1447.654	1603.080	1770.373	1947.720	2134.117	2219.606	1036.743	1395.552
FLAME TEMP. T(F)	1857.793	2146.376	2426.150	2727.272	3046.511	3382.011	3536.036	2046.737	2052.593
ENTHALPY KCAL/GFW	-116.452	-103.654	-92.137	-80.620	-69.103	-57.586	-46.060	-34.551	-23.034

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	046.911	049.463	045.576	047.382	070.962	950.024	990.005	751.201	516.402
FLAME TEMP. T(F)	1065.040	1069.633	1062.637	1065.007	1122.732	1250.643	1322.753	892.762	470.267
ENTHALPY KCAL/GFW	-147.951	-136.700	-126.715	-117.154	-107.910	-98.051	-00.303	-60.747	-40.361
T.VOL.GASES--LITERS	04.002	92.235	101.260	113.016	130.702	152.175	105.334	251.047	302.433
(GASES AT STP)									
COMBUSTION PRODUCTS ROUNDED OFF TO	1.00E-04								

-----GRAMS PRODUCTS/100 GRAMS (GS/0)MATERIAL BURNED-----

CO2	56.2304	50.6207	62.2420	66.5143	71.1959	78.5099	09.0507	09.0507	09.0507
N2	13.9011	22.0392	33.9120	40.1490	67.1331	93.7106	133.5741	200.0139	332.0927
CO	12.1104	13.5079	14.0010	13.6946	11.7625	7.2225	.0000	.0000	.0000

H2O	10.7127	10.4927	10.5673	11.6858	14.7409	19.7874	24.8233	24.8233	24.8233
C$	3.8607	1.8495	.7021	.0000	.0000	.0000	.0000	.0000	.0000
H2	1.2781	1.3178	1.3242	1.3188	1.1182	.5723	.0000	.0000	.0000
CH4	1.2265	1.1342	1.0755	.6662	.0662	.0083	.0000	.0000	.0000
CU$	.9445	.9445	.9445	.9445	.9445	.9445	.0000	.0000	.0000
PB*	.4440	.4440	.4440	.4439	.4433	.4375	.0000	.0000	.0000
NH3	.0033	.0039	.0044	.0044	.0027	.0006	.0000	.0000	.0000
PB	.0002	.0002	.0002	.0003	.0009	.0067	.0000	.0000	.0000
PBO	.0000	.0000	.0000	.0000	.0000	.0000	.0071	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	1.7502	19.5715	55.2019
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.4099
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.4714	.4705	.0000
CUO$	.0000	.0000	.0000	.0000	.0000	.0000	1.1024	1.1024	1.1024
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0012	.0001	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	N2	CO	H2O	C$	H2	CH4	CU$	PB*	NH3	PB	C2H6	CNN	CH2O	CNHO
C2H4	PBN	CH3	PBO	C3H6	C3H8	C2H2	PB2	N	CU	NH2	HO	C4H8	C4H10	HO2
C2H4O	C2	CU2	NHO2	C3O2	N2H4	NH	CN2	C	N3	CUO	CN	NHO	CH	C2N
C2H	H2O2	C2O	C4N2	O	O2	NO	C2N2	CN2	PB3O4$	PBO2$	PBO$	PBO$	PBO*	PBO*
PB$	CU2O$	CU2O*	N2O5	CUN2O2	N2O4$	N2O4*	N2O4	CUO$	CUO$	N2O3	N	CU*	NHO3	NO3
C5	C4	O3	NO2	N2O	CNO	C3	N2H4*	N2H2	NO	CHO	CHO	CN	H3O	H2O*
H2O*	HO	CH2	C$	N										

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= AA6 (ZUNI)

	H	C	N	O	AL	CU	PB			
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000	.0000.0000.0000.0000.000	49.000	-625.	.0600		
NITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000	.0000.0000.0000.0000.000	30.000	-392.	.0570		
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000	.0000.0000.0000.0000.000	2.000	83.	.0494		
DNPA	.022	.0120.000	.0040.0000.0000.0000	.0000.0000.0000.0000.000	2.000	-094.	.0361			
PBRES	.006	.0070.000	.0050.0000.000	.0010.0000.0000.0000	.0000.0000.000	.550	-603.	.0325		
CUSAL	.006	.0070.000	.0040.000	.0010.0000.0000.0000	.0000.0000.0000.000	2.750	-071.	.0361		
CANDELLIA WAX	.012	.0070.000	.0000.0000.0000.0000	.0000.0000.0000.0000.000	.100	-142.	.0343			
TRIACETIN - 1A	.014	.0090.000	.0060.0000.0000.0000	.0000.0000.0000.0000.000	3.250	-1335.	.0420			
ALUMINUM --AL	0.0000.0000.0000.000	.0010.0000.0000.0000	.0000.0000.0000.0000.000	1.500	0.	.0976				
AIR -(0	0.0000.000	.006	.0010.0000.0000.0000	.0000.0000.0000.0000.000	0.000	0.	.0004			

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.950 1.0000

0 (H)	(C)	(N)	(O)	(AL)	(CU)	(PB)	(
2.002040	2.047649	.971947	3.519463	.055597	.012634	.001450	

WT. MATERIAL	99.950	89.955	79.960	69.965	59.970	49.975	39.980	29.985	19.990	9.995
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1301.154	1427.316	1581.012	1747.208	1924.244	2111.701	2287.102	1930.705	1472.154	933.492
FLAME TEMP. T(F)	1802.670	2109.760	2306.421	2605.574	3004.240	3341.805	3657.304	3030.413	2190.477	1220.005
ENTHALPY KCAL/GFW	-110.552	-106.644	-94.794	-82.945	-71.096	-59.246	-47.397	-35.548	-23.699	-11.849

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	862.295	860.799	856.933	853.231	877.537	944.575	1029.130	888.700	554.847	310.352
FLAME TEMP. T(F)	1092.731	1090.039	1083.800	1076.415	1120.166	1240.035	1393.033	996.261	537.805	99.234
ENTHALPY KCAL/GFW	-150.892	-139.974	-129.520	-119.526	-109.091	-100.463	-91.114	-71.795	-50.531	-28.264
1.VOL.GASES--LITERS (GASES AT STP)	85.920	93.137	102.888	113.887	130.999	152.461	184.060	248.855	378.073	767.935

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	52.0110	54.6074	58.1070	62.6980	67.5502	74.6073	80.3306	90.1642	90.1642	90.1642
CO	14.4969	15.3610	15.9370	15.9419	14.1378	9.0479	1.1619	.0000	.0000	.0000

H2	13.6191	22.3041	33.3406	47.4270	66.2122	92.5187	131.9563	197.6975	329.1005	723.6200
H2O	10.0295	9.9949	10.0603	10.5620	12.4162	10.2009	24.6045	25.2534	25.2534	25.0257
C$	3.3006	2.2720	1.1140	.0000	.0000	.0000	.0000	.0000	.0000	.0000
AL2O3$	2.0357	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H2	1.4024	1.4232	1.4299	1.4216	1.2000	.7797	.0726	.0000	.0000	.0000
CH4	1.1961	1.1202	1.0604	.0015	.1431	.0013	.0000	.0000	.0000	.0000
CU$	.0032	.0032	.0032	.0032	.0032	.0032	.0032	.0000	.0000	.0000
PB*	.3019	.3018	.3018	.3018	.3014	.2963	.2532	.0000	.0000	.0000
NH3	.0033	.0039	.0044	.0047	.0034	.0018	.0000	.0000	.0000	.0000
PB	.0003	.0003	.0003	.0003	.0008	.0059	.0489	.0000	.0000	.0000
PBO	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	16.1679	51.4276	157.2130
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.3333	.0000
PBO2$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.3408
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.3255	.0000	.0000
AL2O3$	.0000	2.0357	2.0357	2.0357	2.0357	2.0357	2.0357	2.0357	2.0357	2.0357
CUH2O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.2331
CUO$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0054	1.0054	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	CO	N2	H2O	C$	AL2O3$	H2	CH4	CU$	PB*	NH3	PB	CNN	C2H6	CH2O
CNHO	C2H4	PBN	CH3	PBO	C3H6	C2H2	C3H8	PB2	H	CU	NH2	HO	C4H8	C4H10
C2N2	NO	C4N2	C2H4O	HO2	CN2	CU2	C2	C2N	C3O2	N2H4	NH	C	N3	CN
CUO	NHO	CH	C2H	H2O2	C2O	NHO2	CN2	O	ALHO2	O2	C3	PB3O4$	ALO2	PBO2$
PBO$	PBO$	PBO*	PBO*	PB$	N	AL4C3$	CU2O$	CU2O*	N2O5	AL2O3$	AL2O3*	CUH2O2	N2O4$	N2O4*
N2O4	AL2O2	AL2O2	CUO$	CUO$	N2O3	AL2O	AL2O	CU*	NHO3	NO3	C5	C4	O3	NO2
N2O	ALHO	ALO	ALO	CNO	ALN$	ALN	ALC	N2H4*	N2H2	NO	CHO	CHO	ALH	AL*
AL$	AL*	AL	CN	H3O	H2O*	H2O*	HO	CH2	C$	H				

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= HEN-12(RAPEC/SEADNAF)

	H	C	N	O	CU	PB				
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000			49.000	-625.	.0600	
NITROGLYCERIN - NG	.005	.003	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000			40.600	-392.	.0570	
2-NITRODIPHENYLAMINE	.010	.012	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000			2.000	83.	.0494	
DNPA	.022	.0120.000		.0040.0000.0000.0000.0000.0000.0000.0000.000			3.300	-894.	.0361	
PBRES	.006	.0070.000		.0050.000	.0010.0000.0000.0000.0000.0000.000		2.500	-603.	.0325	
CUSAL	.006	.0070.000		.004	.0010.0000.0000.0000.0000.0000.0000.000		2.500	-071.	.0361	
CANDELLIA WAX	.012	.0070.000		.0000.0000.0000.0000.0000.0000.0000.0000.000			.100	-142.	.0343	
AIR -(0	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000			0.000	0.	.0004	
0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000									1.0000	
0 (H) (C) (N) (O) (CU) (PB) (										
2.701454 2.033253 .995725 3.545250 .011406 .006625										
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1200.459	1400.250	1563.982	1730.973	1911.955	2102.789	2229.451	1849.705	1405.982
FLAME TEMP. T(F)	1845.426	2075.450	2355.767	2656.351	2982.119	3325.620	3553.612	2870.870	2071.368
ENTHALPY KCAL/GFW	-116.145	-104.531	-92.916	-81.302	-69.687	-58.073	-46.458	-34.844	-23.229

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	847.520	846.605	843.490	841.806	867.162	936.197	1008.803	759.440	522.140
FLAME TEMP. T(F)	1066.136	1064.634	1059.081	1055.851	1101.492	1225.754	1342.189	907.592	480.466
ENTHALPY KCAL/GFW	-147.092	-137.295	-127.146	-117.446	-108.118	-99.000	-89.123	-69.396	-48.819
1.VOL.GASES--LITERS (GASES AT STP)	84.986	92.125	101.076	113.184	130.173	151.566	183.739	248.729	378.585

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	55.3854	50.0378	61.5716	66.0110	70.6217	77.5127	89.4855	89.4855	89.4855
N2	13.9454	22.7068	33.6570	47.7372	66.5123	92.7977	132.2230	197.9319	329.3490
CO	12.1151	12.9466	13.5153	13.4610	11.7941	7.6189	.0000	.0000	.0000
H2O	10.7349	10.6747	10.7234	11.3757	14.3439	19.3258	25.0553	25.0553	25.0553

OD CALCULATION NO. 25

C$	3.1740	2.1470	.9877	.0000	.0000	.0000	.0000	.0000	.0000
PB*	1.3727	1.3726	1.3726	1.3726	1.3722	1.3681	.0000	.0000	.0000
H2	1.2872	1.3120	1.3227	1.3171	1.1676	.6400	.0000	.0000	.0000
CH4	1.2519	1.1796	1.1153	.0470	.1213	.0007	.0000	.0000	.0000
CU$	.7298	.7298	.7298	.7298	.7298	.7298	.0000	.0000	.0000
NH3	.0033	.0040	.0045	.0047	.0032	.0000	.0000	.0000	.0000
PB	.0002	.0002	.0002	.0002	.0006	.0047	.0000	.0000	.0000
PBO	.0000	.0000	.0000	.0000	.0000	.0000	.0090	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.8420	18.4600	53.6024
PB3O4$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.5142
PBO$	.0000	.0000	.0000	.0000	.0000	.0000	1.4690	1.4709	.0000
CUO$	.0000	.0000	.0000	.0000	.0000	.0000	.9136	.9136	.9136
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0009	.0002	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	N2	CO	H2O	C$	PB*	H2	CH4	CU$	NH3	PB	C2H6	CNH	CH2O	CNHO
C2H4	PBH	CH3	PBO	C3H6	C3H8	C2H2	PB2	H	CU	NH2	HO	C4H8	C4H10	C2H4O
HO2	C4N2	CU2	NHO2	C2N	C3O2	N2H4	NH	CN2	CUO	CN	NHO	N3	C2N	H2O2
NO	C2N2	C2O	O	O2	PB3O4$	CN2	PBO2$	PBO$	PBO$	PBO*	PBO*	PB$	CU2O$	CU2O*
N2O5	CUH2O2	N2O4$	N2O4*	N2O4	CUO$	CUO$	N2O3	CU*	NHO3	NO3	C5	C4	O3	N
NO2	N2O	CNO	C3	N2H4*	N2H2	NO	CHO	CHO	CN	C2	H3O	H2O*	H2O*	HO
CH2	CH	C$	C	H										

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= BX-100/BX 105 (MK 18 BOOSTER)

	H	C	N	O	AL	P	CL	FE			
BUTAREZ	.011	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000						17.000	160.	.0329
IRON OXIDE	0.0000.0000.000		.0030.0000.0000.000		.0020.0000.0000.0000.000				2.200	-1235.	.1093
ALUMINUM --AL	0.0000.0000.0000.000		.0010.0000.0000.0000.0000.0000.0000.000						1.500	0.	.0976
EPON-812	.021	.0120.000	.0060.0000.0000.0000.0000.0000.0000.0000.000						.300	-1245.	.0441
AP	.0040.000		.001	.0040.0000.000		.0010.0000.0000.0000.0000.000			79.000	-602.	.0705
MAPO	.010	.009	.003	.0010.000		.0010.0000.0000.0000.0000.0000.000			.300	-322.	.0398
AIR -(0	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000					0.000	0.	.0004
0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.300										1.0000	
0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(			
4.579758	1.255838	.676539	2.762566	.055597	.001394	.672358	.027552				
WT. MATERIAL	100.300	90.270	80.240	70.210	60.180	50.150	40.120	30.090	20.060		
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000		

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1247.390	1343.521	1491.057	1655.404	1832.602	2023.393	2099.714	1745.122	1336.021
FLAME TEMP. T(F)	1785.916	1958.937	2224.582	2520.328	2839.203	3182.708	3320.004	2681.020	1945.437
ENTHALPY KCAL/GFW	-113.695	-102.632	-91.220	-79.825	-68.421	-57.018	-45.614	-34.211	-22.807

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	793.119	795.709	801.370	808.463	827.101	877.038	906.888	788.221	584.760
FLAME TEMP. T(F)	968.214	972.876	983.066	995.833	1029.383	1119.269	1172.984	815.397	449.168
ENTHALPY KCAL/GFW	-146.347	-136.029	-125.869	-116.122	-106.763	-97.704	-86.884	-67.476	-47.540
T.VOL.GASES--LITERS (GASES AT STP)	85.530	93.577	104.882	118.066	136.363	158.549	191.354	254.984	382.558

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	36.7006	39.1747	41.2752	43.9142	46.9718	50.3778	55.1054	55.1054	55.1054
HCL	22.4408	22.4408	22.4408	22.4408	22.4408	24.2164	23.4627	15.5175	2.9203
H2O	15.2158	15.5255	16.9351	18.9947	22.3918	28.2138	35.3343	37.2684	40.3698
N2	9.4444	10.1701	29.0968	43.1342	61.8535	80.0617	127.3699	192.0821	323.9861
CO	4.3007	4.8605	5.1223	5.1538	4.7708	3.0055	.0000	.0000	.0000

FECL2$	3.4437	3.4352	3.4174	3.3876	3.2748	.0000	.0000	.0000	.0000
CH4	3.3964	3.0232	2.1076	1.1201	.2329	.0022	.0000	.0000	.0000
AL2O3$	2.0258	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H2	1.4252	1.4840	1.5562	1.5719	1.4171	.7752	.0000	.0000	.0000
C$	.5994	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
P4O6	.0764	.0764	.0764	.0764	.0764	.0764	.0000	.0000	.0000
FECL2	.0332	.0404	.0553	.0000	.1700	.3519	.0000	.0000	.0000
FE2CL4	.0052	.0065	.0093	.0145	.0365	.0435	.0000	.0000	.0000
NH3	.0051	.0066	.0076	.0077	.0057	.0015	.0000	.0000	.0000
FECL3	.0000	.0000	.0001	.0001	.0002	.0004	.0019	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.9492	8.6749	20.9190
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0042	.0073	.0020
P4O10	.0000	.0000	.0000	.0000	.0000	.0000	.0906	.0037	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	2.2852	10.0337	50.4160
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	2.1925	2.1934	2.1934
AL2O3$	.0000	2.0258	2.0258	2.0258	2.0258	2.0258	2.0258	2.0258	2.0258
PH3O4*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.1310	.1362
FEO$	.0000	.0000	.0000	.0000	.0000	1.7494	.0000	.0000	.0000
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0010	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0001	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	HCL	H2O	N2	CO	FECL2$	CH4	AL2O3$	H2	C$	P4O6	FECL2	FE2CL4	NH3	FECL3
C2H6	CH3CL	CNH	CH2O	CHNO	C2H4	CH3	C3H8	FE2CL6	ALCL3	FEH2O2	C3H6	CL	C2H2	CH2CL2
COCL	H	CL2	PN	COCL2	NH2	CNCL	PH3	C4H10	C4H8	HO	POCL3	CPH	HOCL	PO2
NO	C2N2	PH2	C2H4O	FE	N	C2N	CHCL3	C4N2	N2H4	NHO2	CN2	PH	CCL3	FCL
PCL5	CP	C3O2	CCL	NH	HO2	PCL3	CCL4	CH	AL2CL6	ALOCL	NHO	N3	CN	CCL2
P2	C2H	H2O2	FEO	ALCL	P	C2CL2	C2O	C2HCL	OCL	ALCL2	C2CL4	P4O10	CN2	O
OCL2	P4O10$	O2	C2CL6	FE3O4$	FE3O4*	NOCL	P3N5$	FECL3$	FECL3*	FE2O3$	FE2O3$	AL4C3$	ALCL3*	ALCL3$
FECL2*	P4	NH4O4C	N2O5	FEH3O3	AL2O3$	AL2O3*	PH3O4$	PH3O4*	ALCL2	N2O4$	N2O4*	N2O4	FECL	FEH2O2
AL2O2	AL2O2	NO2CL	ALOCL$	N2O3	FEO$	FEO$	FEO*	AL2O	AL2O	O2CL	NHO3	ALCL	NO3	C5
ALHO2	ALO2	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	CHCL	C4	O3	PO	NO2
N2O	ALHO	ALO	ALO	CNO	ALN$	ALN	ALC	C3	CL	C	N2H4*	F$	F$	P*
N2H2	HO	CHO	CHO	ALH	AL*	AL$	AL*	AL	CN	C2	H3O	N2O*	H2O*	HO
CH2	C$	H												

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= BX-100/BX 105 (MK 10 SUSTAINER)

	H	C	N	O	AL	F	CL	FE			
BUTAREZ	.011	.0070.000	.0000.0000.0000.0000.0000.0000.0000.0000.000						15.000	160.	.0329
IRON OXIDE	0.0000.0000.000		.0030.0000.0000.000		.0020.0000.0000.0000.000				1.600	-1235.	.1093
IRON OXIDE	0.0000;0000.000		.0030.0000.0000.000		.0020.0000.0000.0000.000				2.500	-1235.	.1093
ALUMINUM --AL	0.0000.0000.0000.000		.0010.0000.0000.0000.0000.0000.0000.000						1.500	0.	.0976
EPON-812	.021	.0120.000	.0060.0000.0000.0000.0000.0000.0000.0000.000						.300	-1245.	.0441
AP	.0040.000		.001	.0040.0000.000		.0010.0000.0000.0000.0000.000			79.000	-602.	.0705
MAPO	.010	.007	.003	.0010.000		.0010.0000.0000.0000.0000.0000.000			.300	-322.	.0390
AIR -(0	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000					0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.200 1.0000

0 (H)	(C)	(N)	(O)	(AL)	(F)	(CL)	(FE)	(		
4.363155	1.111109	.676539	2.795491	.055597	.001394	.672358	.051346			
WT. MATERIAL	100.200	90.100	80.160	70.140	60.120	50.100	40.080	30.060	20.040	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1323.761	1449.503	1596.774	1755.560	1925.772	2104.330	1090.019	1574.039	1200.211
FLAME TEMP. T(F)	1923.371	2149.705	2414.794	2700.600	3006.990	3328.409	2944.074	2375.310	1715.301
ENTHALPY KCAL/GFW	-116.049	-105.374	-93.666	-81.950	-70.249	-50.541	-46.033	-35.125	-23.416

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	794.149	799.474	007.701	025.926	051.475	923.073	002.244	632.734	440.994
FLAME TEMP. T(F)	970.067	979.654	994.462	1027.260	1073.255	1203.572	984.639	679.522	340.790
ENTHALPY KCAL/GFW	-149.166	-130.771	-120.500	-110.714	-109.121	-99.719	-03.333	-64.720	-45.575
T.VOL.GASES--LITERS (GASES AT STP)	02.000	91.707	102.694	115.060	132.541	152.060	190.099	253.340	301.701

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

C02	36.2632	37.9131	39.0500	41.9937	44.4007	47.7550	40.0069	40.0069	40.0069
HCL	20.7314	20.7314	20.7314	20.7313	24.2535	24.2616	20.4442	10.1237	1.2344
H20	16.5799	17.7402	19.3003	21.9917	25.5550	31.0024	34.1733	36.6054	38.0022
N2	9.4541	10.1967	29.1240	43.1794	61.0101				

FECL2✱	6.4570	6.4434	6.4166	6.3276	.0000	.0000	.0000	.0000	.0000
CO	3.0285	4.0090	4.1154	3.9480	2.7000	.6695	.0000	.0000	.0000
AL2O3✱	2.0207	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CH4	2.3843	1.6744	.9040	.2219	.0110	.0000	.0000	.0000	.0000
H2	1.3600	1.4003	1.4101	1.2987	.0561	.1599	.0000	.0000	.0000
P406	.0765	.0765	.0765	.0765	.0765	.0765	.0000	.0000	.0000
FECL2	.0335	.0449	.0671	.1300	.3049	.3421	.0000	.0000	.0000
FE2CL4	.0053	.0075	.0121	.0293	.0605	.0167	.0000	.0000	.0000
NH3	.0040	.0060	.0063	.0050	.0022	.0001	.0000	.0000	.0000
FECL3	.0000	.0001	.0001	.0001	.0004	.0000	.0004	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	3.9077	13.9445	22.5913
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0072	.0055	.0009
P4O10	.0000	.0000	.0000	.0000	.0000	.0000	.0987	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	7.0442	23.1699	56.3997
FE3O4✱	.0000	.0000	.0000	.0000	.0000	3.7363	.0000	.0000	.0000
FE2O3✱	.0000	.0000	.0000	.0000	.0000	.0000	4.0916	4.0910	4.0910
AL2O3✱	.0000	2.0207	2.0207	2.0207	2.0207	2.0207	2.0207	2.0207	2.0207
PH3O4✱	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.1363	.1363
FEO✱	.0000	.0000	.0000	.0000	3.4701	.0000	.0000	.0000	.0000
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	HCL	H2O	N2	FECL2✱	CO	AL2O3✱	CH4	H2	P406	FECL2	FE2CL4	NH3	FECL3	C2H6
CH3CL	CHN	CH2O	CHNO	C2H4	CH3	FE2CL6	FEN2O2	C3H8	ALCL3	C3H6	CL	C2H2	CH2CL2	COCL
N	CL2	PN	NH2	COCL2	CNCL	PH3	NO	C4H8	C4H10	POCL3	HOCL	CPN	PO2	C2CL2
C2N2	PH2	ALO	C4N2	C2H4O	CH2	CH	PCL	PH	CHCL3	ALO2	HO2	CCL	CP	NH
C2N	N2H4	ALOCL	NHO	PCL5	FEO	C3O2	AL2CL6	N3	CN	P4O10	P2	H2O2	ALCL	CCL4
P	PCL3	ALHO2	CCL3	C2H	OCL	O2	O	C2O	CN2	C	NOCL	C2CL4	C3	ALH
OCL2	C2HCL	N	P4O10✱	C2CL6	FE3O4✱	FE3O4✱	P3N5✱	FECL3✱	FECL3✱	FE2O3✱	FE2O3✱	AL4C3✱	ALCL3✱	ALCL3✱
FECL2✱	P4	NHO2	NO	NH4O4C	N2O5	FEN3O3	AL2O3✱	AL2O3✱	PH3O4✱	PH3O4✱	ALCL2	ALCL2	N2O4	N2O4✱
N2O4✱	FECL	FEH2O2	AL2O2	AL2O2	CCL2	NO2CL	ALOCL✱	N2O3	FEO✱	FEO✱	FEO✱	AL2O	AL2O	O2CL
NHO3	ALCL	NO3	C5	C2	FE	FE✱	FE✱	FE✱	FE✱	FE✱	FE✱	NH4CL✱	NH4CL✱	CHCL
C4	O3	PO	NO2	N2O	ALHO	ALO	CNO	ALN	ALN✱	ALC	CL	N2H4✱	P✱	P✱
P✱	N2H2	NO	CHO	CHO	AL	AL✱	AL✱	AL✱	CN	H3O	H2O✱	H2O✱	HO	CH2
C✱	C✱	H												

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= BX-100 H (CKU-5/A SUSTAINER)

	H	C	N	O	AL	P	CL	FE			
BUTAREZ	.011	.0870.000	.0000.0000.0000.0000.0000.0000.0000.0000.000						12.400	160.	.0379
HEXADECANE	.034	.0160.0000.0000.0000.0000.0000.0000.0000.0000.0000.000							3.100	-402.	.0200
EPON-812	.021	.0120.000	.0060.0000.0000.0000.0000.0000.0000.0000.0000.000						.300	-1245.	.0441
ALUMINUM --AL	0.0000.0000.0000.000		.0010.0000.0000.0000.0000.0000.0000.0000.000						2.000	0.	.0976
IRON OXIDE	0.0000.0000.000		.0030.0000.0000.000		.0020.0000.0000.0000.000				2.000	-1235.	.1093
AP	.0040.000	.001	.0040.0000.000		.0010.0000.0000.0000.0000.000				80.000	-602.	.0705
MAPO	.010	.009	.003	.0010.000	.0010.0000.0000.0000.0000.0000.000				.200	-322.	.0390
AIR -(G	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000					0.000	0.	.0004

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 1.0000

0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(			
4.572700	1.137999	.683656	2.706022	.074129	.000929	.600060	.025047				
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000		
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000		

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1290.461	1424.003	1570.441	1720.460	1090.209	2000.073	1977.000	1644.766	1261.004
FLAME TEMP. T(F)	1077.030	2103.949	2367.394	2651.042	2957.521	3204.732	3099.350	2501.179	1010.406
ENTHALPY KCAL/GFW	-117.907	-106.100	-94.309	-82.591	-70.792	-58.993	-47.195	-35.396	-23.597

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	700.049	794.705	000.970	811.742	041.675	905.044	042.312	662.620	471.019
FLAME TEMP. T(F)	960.520	971.069	902.347	1001.736	1055.615	1171.119	1056.761	733.330	309.073
ENTHALPY KCAL/GFW	-150.036	-140.070	-129.675	-119.619	-109.066	-100.315	-05.744	-66.579	-46.065
T.VOL.GASES--LITERS	04.557	93.750	104.043	110.400	135.194	156.304	192.051	255.531	303.065

(GASES AT STP)
COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (OS/G)MATERIAL BURNED-----

CO2	35.9090	37.5791	39.6219	42.0320	44.4059	47.6134	50.0045	50.0045	50.0045
HCL	23.0012	23.0012	23.0012	23.0012	23.7500	24.5757	22.2636	12.5493	1.0469
H2O	16.3446	17.4301	10.9726	21.2917	25.1905	31.4679	35.6099	30.0646	40.7093
N2	9.5724	10.3324	29.7043	44.3442					

OP CALCULATION

AL2O3$	3.7791	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CO	3.7634	4.0649	4.2808	4.1472	3.4070	1.5726	.0000	.0000	.0000
FECL2$	3.1424	3.1296	3.1114	3.0694	1.5252	.0000	.0000	.0000	.0000
CH4	3.0115	2.2304	1.4033	.5600	.0437	.0001	.0000	.0000	.0000
H2	1.3067	1.4613	1.4965	1.4490	1.1221	.4006	.0000	.0000	.0000
P406	.0511	.0511	.0511	.0511	.0511	.0511	.0000	.0000	.0000
FECL2	.0204	.0392	.0544	.0890	.2690	.4053	.0000	.0000	.0000
NH3	.0052	.0065	.0072	.0066	.0036	.0005	.0000	.0000	.0000
FE2CL4	.0043	.0062	.0092	.0166	.0651	.0323	.0000	.0000	.0000
FECL3	.0000	.0000	.0001	.0001	.0003	.0006	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	2.4079	11.9347	22.3448
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0066	.0065	.0014
P4010	.0000	.0000	.0000	.0000	.0000	.0000	.0659	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	5.7694	21.2631	54.1655
FE3O4$	.0000	.0000	.0000	.0000	.0000	1.6664	.0000	.0000	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	1.9996	2.0000	2.0000
AL2O3@	.0000	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791
PH3O4*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0911	.0911
FEO$	.0000	.0000	.0000	.0000	.7456	.0000	.0000	.0000	.0000
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0005	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	HCL	H2O	N2	AL2O3$	CO	FECL2$	CH4	H2	P406	FECL2	NH3	FE2CL4	FECL3	C2H6
CH3CL	CNH	CH2O	CNHO	C2H4	CH3	FE2CL6	C3H8	ALCL3	FEH2O2	C3H6	CL	C2H2	CH2CL2	COCL
H	CL2	PN	COCL2	NH2	CNCL	PH3	HO	C4H10	C4H8	POCL3	HOCL	CPH	PO2	C2N2
ALO	NHO2	PH2	C2N4O	C4N2	CHCL3	CN2	PH	PCL	CH	N2H4	ALO2	C2N	NH	CCL
CP	ALOCL	C3O2	HO2	NHO	AL2CL6	CCL2	FEO	PCL5	N3	CN	P2	N2O2	P4O10	ALCL
PCL3	P	C2H	CCL3	ALHO2	C2O	OCL	CCL4	O	C2CL2	O2	CN2	C2CL4	ALH	C
NOCL	C3	OCL2	P4O10$	C2CL6	FE3O4$	FE3O4*	C2HCL	P3N5$	FECL3$	FECL3*	FE2O3$	FE2O3$	AL4C3$	ALCL3*
ALCL3$	FECL2*	P4	NH4O4C	N2O5	FEH3O3	AL2O3$	AL2O3*	PH3O4$	PH3O4*	ALCL2	ALCL2	AL2O	N2O4	N2O4$
N2O4*	FECL	FEH2O2	AL2O2	AL2O2	N	NO2CL	ALOCL$	N2O3	FEO$	FEO$	FEO*	AL2O	O2CL	NH3O
ALCL	NO3	C5	FE	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$	CHCL	C4	O3
PO	NO2	N2O	ALHO	NO	ALO	CNO	ALN	ALN$	ALC	CL	N2H4*	P$	P$	P*
N2H2	NO	CHO	CHO	AL	AL*	AL$	AL*	CN	C2	H3O	H2O*	H2O*	HO	CH2
C$	C$	H												

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL=IPH-9001 (CKU-7/A SUSTAINER)

	H	C	N	O	AL	F	CL	FE				
BUTAREZ	.011	.0070.000	.0000.0000.0000	.0000.0000.0000	.0000.0000.0000	.0000.0000.0000	.0000.0000.0000	.0000.0000.0000	14.000	160.	.0329	
LECITHIN(LECT)	.011	.0060.000	.0010.000	.0000.0000.0000	.0000.0000.0000	.0000.0000.0000	.0000.0000.0000	.0000.0000.0000	.100	-516.	.0376	
IRON OXIDE	0.0000.0000.000	.0030.0000.0000.000	.0020.0000.0000.0000.000						1.000	-1235.	.1093	
ALUMINUM --AL	0.0000.0000.0000.000	.0010.0000.0000.0000.0000.0000.0000.000							2.000	0.	.0976	
IP-90-B(THIOKOL)	.011	.0050.000	.0020.0000.0000.0000.0000.0000.0000.0000.000						1.600	-1229.	.0351	
AP	.0040.000	.001	.0040.0000.000	.0010.0000.0000.0000.0000.000					00.000	-602.	.0705	
ERL 0510	.007	.005	.000	.0010.0000.0000.0000.0000.0000.0000.0000.000					.500	-196.	.0361	
AIR -(G	0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000						0.000	0.	.0004	
0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000										1.0000		
0 (H)	(C)	(N)	(O)	(AL)	(P)	(CL)	(FE)	(				
4.463457	1.120704	.602669	2.010054	.074129	.000224	.600060	.022542					
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000			
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000			

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1334.213	1464.705	1609.920	1765.701	1932.940	2110.901	1930.362	1604.063	1231.061
FLAME TEMP. T(F)	1942.104	2177.213	2430.470	2719.006	3019.907	3340.222	3015.251	2429.353	1756.510
ENTHALPY KCAL/GFW	-110.481	-106.633	-94.704	-82.936	-71.000	-59.240	-47.392	-35.544	-23.696

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	791.143	796.011	803.514	817.137	850.344	920.796	817.743	644.589	450.272
FLAME TEMP. T(F)	964.650	974.061	986.926	1011.447	1071.219	1190.032	1012.537	700.717	365.490
ENTHALPY KCAL/GFW	-151.460	-140.742	-130.357	-120.294	-110.495	-100.059	-84.043	-65.064	-46.353
1.VOL.GASES--LITERS (GASES AT STP)	84.139	93.230	104.191	117.597	134.024	154.039	191.596	255.011	383.504

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GG/G)MATERIAL BURNED-----

CO2	36.4287	38.0009	40.1001	42.3945	44.7352	48.0969	49.6754	49.6754	49.6754
HCL	23.1030	23.1030	23.1030	23.1030	24.6075	24.5904	21.3500	11.1433	1.4710
H2O	16.3523	17.4050	19.0000	21.5400	25.5201	31.0500	37.0205		

OD CALCULATION NO. 29

CO	3.8161	4.0544	4.1416	4.0096	3.1135	1.0046	.0000	.0000	.0000
AL2O3$	3.7791	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FECL2$	2.8220	2.8009	2.7806	2.7308	.0000	.0000	.0000	.0000	.0000
CH4	2.6431	1.9814	1.1184	.3576	.0176	.0000	.0000	.0000	.0000
H2	1.3633	1.4227	1.4398	1.3560	.9574	.2431	.0000	.0000	.0000
FECL2	.0308	.0410	.0508	.1059	.3106	.3093	.0000	.0000	.0000
P406	.0123	.0123	.0123	.0123	.0123	.0123	.0000	.0000	.0000
NH3	.0049	.0062	.0067	.0057	.0026	.0002	.0000	.0000	.0000
FE2CL4	.0047	.0060	.0101	.0207	.0719	.0226	.0000	.0000	.0000
FECL3	.0000	.0001	.0001	.0001	.0004	.0000	.0006	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	3.3604	13.3023	22.7104
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0071	.0060	.0011
O2	.0000	.0000	.0000	.0000	.0000	.0000	7.2276	22.6116	55.7401
P4O10	.0000	.0000	.0000	.0000	.0000	.0000	.0159	.0000	.0000
FE3O4$	.0000	.0000	.0000	.0000	.0000	1.4000	.0000	.0000	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	1.7997	1.0000	1.0000
AL2O3$	.0000	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791	3.7791
PH3O4*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0220	.0220
FEO$	.0000	.0000	.0000	.0000	1.4027	.0000	.0000	.0000	.0000
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	HCL	H2O	N2	CO	AL2O3$	FECL2$	CH4	H2	FECL2	P4O6	NH3	FE2CL4	FECL3	C2H6
CH3CL	CNH	CH2O	CNHO	C2H4	CH3	FE2CL6	C3H8	ALCL3	FEH2O2	C3H6	CL	C2H2	CH2CL2	COCL
CL2	H	PN	COCL2	NH2	CNCL	PH3	HO	C4H10	C4H8	POCL3	HOCL	CPH	C4N2	FO2
C2N2	P4	HO2	PH2	CN2	CH	C2H4O	PCL	PH	CHCL3	CCL	C2N	NH	CP	N2H4
ALOCL	ALH	NHO	FEO	C3O2	N3	AL2CL6	CN	H2O2	CCL4	P2	AL	ALCL	P	ALHO2
PCL3	C2H	CCL3	ALO	OCL	O	O2	C2O	CN2	ALO2	C	O2CL	C2CL2	NOCL	C3
C2CL4	OCL2	C2HCL	N	P4O10	P4O10$	C2CL6	FE3O4$	FE3O4*	PCL5	P3N5$	FECL3$	FECL3*	NHO2	FE2O3$
FE2O3$	NO	AL4C3$	ALCL3*	ALCL3$	FECL2*	NH4O4C	C2	N2O5	FEH3O3	AL2O3$	AL2O3*	PH3O4$	PH3O4*	ALCL2
ALCL2	N2O4	N2O4$	N2O4*	FECL	FEH2O2	AL2O2	AL2O2	CCL2	NO2CL	ALOCL$	N2O3	FEO$	FEO$	FEO*
AL2O	AL2O	NHO3	ALCL	NO3	C5	FE	FE$	FE$	FE$	FE$	FE*	FE$	NH4CL$	NH4CL$
CHCL	C4	O3	PO	NO2	N2O	ALHO	ALO	CNO	ALN	ALN$	ALC	CL	N2H4*	P$
P$	P*	N2H2	NO	CHO	CHO	AL*	AL$	AL*	CN	H3O	H2O*	H2O*	HO.	CH2
C$	C$	H												

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= PBXN-106 (MK 115)

		H	C	N	O	FE					
RDX -(S)		.006	.003	.006	.0060.0000.0000.0000.0000.0000.0000.0000.000		75.000	72.	.0656		
FEAA		.014	.0100.000	.004	.0010.0000.0000.0000.0000.0000.0000.000		.010	-823.	.0376		
FINANFP		.013	.016	.0010.0000.0000.0000.0000.0000.0000.0000.000			.250	-174.	.0397		
50%BDNPA + 50%BDNPF		.004	.002	.001	.0030.0000.0000.0000.0000.0000.0000.0000.000		10.500	-474.	.0499		
TRIMETHYLOLPROPANE		.014	.0060.000	.0030.0000.0000.0000.0000.0000.0000.0000.000			2.540	-1329.	.0434		
POLYETHYLENE GLYCOL		.004	.0020.000	.0010.0000.0000.0000.0000.0000.0000.0000.000			.430	-1047.	.0397		
IDICY		.006	.009	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000		3.220	-33.	.0325		
AIR -(G		0.0000.000	.006	.0010.0000.0000.0000.0000.0000.0000.0000.000			0.000	0.	.0004		
0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.950									1.0000		
0 (H)	(C)	(N)	(O)	(FE)	(						
3.200722	1.765209	2.295083	2.789362	.000039							
WT. MATERIAL	99.950	89.955	79.960	69.965	59.970	49.975	39.980	29.985	19.990	9.995	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1239.637	1306.046	1441.336	1611.233	1795.344	1993.069	2207.766	2062.815	1565.314	987.000
FLAME TEMP. T(F)	1771.947	1892.923	2135.004	2440.819	2772.210	3129.564	3514.578	3253.667	2350.166	1310.655
ENTHALPY KCAL/GFW	-75.961	-68.331	-60.739	-53.146	-45.554	-37.962	-30.369	-22.777	-15.185	-7.592

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	838.991	848.707	840.703	837.569	832.877	857.032	937.806	847.102	585.040	327.002
FLAME TEMP. T(F)	1050.704	1054.817	1053.065	1048.224	1039.779	1083.258	1220.795	1065.520	593.607	130.644
ENTHALPY KCAL/GFW	-110.734	-103.531	-96.699	-90.370	-84.508	-79.260	-74.178	-62.530	-44.329	-25.160
1.VOL.GASES--LITERS	96.254	103.645	112.763	124.342	140.895	164.190	196.200	256.260	386.305	776.448
(GASES AT STP)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	38.0240	41.3154	44.5469	48.9437	54.8023	61.0534	70.2046	77.7310	77.7310	77.7310
N2	32.1714	40.9367	51.0934	65.9807	84.7639	111.0626	150.5108	216.2524	347.7355	742.1030
H2O	11.0821	10.9159	10.9248	11.0903	11.0101	16.0105	24.0170	20.9106	20.9106	20.9106
CO	9.4025	10.4023	11.5003	12.2409	12.3909	10.3532	4.7900	.0000	.0000	.0000

C$	5.2041	4.1605	2.9336	1.4919	.0000	.0000	.0000	.0000	.0000	.0000
CH4	1.0468	1.7135	1.5912	1.4854	1.2321	.1497	.0001	.0000	.0000	.0000
H2	1.5398	1.5026	1.6124	1.6195	1.6026	1.4051	.5403	.0000	.0000	.0000
NH3	.0065	.0068	.0070	.0073	.0073	.0047	.0006	.0000	.0000	.0000
FE0$	.0020	.0000	.0000	.0000	.0000	.0000	.0000	.0031	.0031	.0031
FE203$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	10.5442	45.0118	151.6136
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FE0$	.0000	.0020	.0020	.0020	.0020	.0020	.0020	.0000	.0000	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0006	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	H2	H20	CO	C$	CH4	H2	NH3	FE0$	C2H6	CNH	CH20	CNHO	C2H4	FEH202
CH3	C3H8	C3H6	C2H2	H	NH2	HO	C4H8	C4H10	C2N2	C2N	NO	C2H4O	CN2	NH02
FE	N	HO2	N2H4	CH	C4N2	C3O2	NH	NHO	CN	N3	FEO	H2O2	C2H	C2O
FE304$	FE304$	FE203$	FE203$	O	N2O5	FEH3O3	O2	N2O4$	N2O4*	N2O4	FEH2O2	N2O3	FE0$	FEO*
NH03	NO3	C5	FE$	FE$	FE$	FE$	FE*	FE$	C4	O3	NO2	N2O	CNO	CN2
C3	N2H4*	N2H2	NO	CHO	CHO	CN	C2	H3O	H2O*	H2O*	HO	CH2	C$	C
H														

OD CALCULATION NO. 30 CONTINUED

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= NOSIH(BC-18) (MOM-107)

	H	C	N	O	AL	CL	FE			
R-45M	.011	.0870.000	.0000.0000	.0000.0000	.0000.0000	.0000.0000	.0000.0000	0.400	-0.	.0329
DIOCTYL ADIPATE	.042	.0220.000	.0040.0000	.0000.0000	.0000.0000	.0000.0000	.0000.0000	3.000	-733.	.0332
(DHE)N,N-B-2-HY-ET-N	.007	.004	.001	.0020.0000	.0000.0000	.0000.0000	.0000.0000	.300	-830.	.0444
ALUMINUM --AL	0.0000	.0000.0000	.000	.0010.0000	.0000.0000	.0000.0000	.0000.0000	44.000	0.	.0976
AP	.0040	.000	.001	.0040.000	.0010.0000	.0000.0000	.0000.0000	43.100	-602.	.0705
IRON OXIDE	0.0000	.0000.000	.0030.0000	.000	.0020.0000	.0000.0000	.0000.0000	1.200	-1235.	.1093
AIR -(0	0.0000	.000	.006	.0010.0000	.0000.0000	.0000.0000	.0000.0000	0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 1.0000

0 (H)	(C)	(N)	(O)	(AL)	(CL)	(FE)	(					
2.748768	.002997	.369450	1.535226	1.630030	.366010	.015020						
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000		
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000		

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	2644.264	2705.033	2030.973	2065.340	2006.295	3134.425	3320.019	3222.742	2669.533	1707.640
FLAME TEMP. T(F)	4300.275	4553.660	4650.752	4698.226	4735.932	5102.565	5532.475	5341.535	4345.760	2614.367
ENTHALPY KCAL/GFW	-05.169	-76.652	-60.135	-59.610	-51.101	-42.504	-34.060	-25.551	-17.034	-8.517

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	2107.356	2069.446	2001.002	2071.064	2054.137	2022.215	2050.635	1910.777	1374.194	674.232
FLAME TEMP. T(F)	3333.041	3265.603	3207.900	3269.956	3230.047	3100.506	3246.143	2979.998	2014.149	754.210
ENTHALPY KCAL/GFW	-120.700	-124.333	-110.177	-111.062	-105.502	-99.659	-93.520	-03.500	-66.052	-30.636
T.VOL.GASES--LITERS	73.533	01.090	90.574	101.000	116.791	137.764	170.256	222.021	345.604	734.577

(GASES AT STP)
COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

AL2O3$	30.1056	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALCL	21.0076	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALN$	15.0442	31.7476	27.6270	21.7035	13.5764	2.1996	.0000	.0000	.0000	.0000
CO	10.9209	22.3454	22.3442	22.3429	22.3436	22.3424	21.4233	11.3415	.0001	.0000
C$	3.9959	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

AL4C3$	3.5572	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H2	2.7519	2.7320	2.7104	2.7102	2.7031	2.6930	1.9606	.4719	.0000	.0000
AL2O	1.5030	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALCL2	1.3206	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FE*	.7064	.7034	.6350	.5979	.5601	.5422	.0000	.0000	.0000	.0000
AL	.5400	.0297	.0206	.0157	.0118	.0073	.0000	.0000	.0000	.0000
FE	.1324	.1065	.1413	.1514	.1526	.1340	.0342	.0022	.0000	.0000
HCL	.1202	1.0119	1.4704	1.7600	2.0337	2.3066	12.2627	12.2398	13.1340	6.5797
ALH	.0030	.0045	.0020	.0020	.0014	.0008	.0000	.0000	.0000	.0000
C2H2	.0616	.0091	.0023	.0012	.0007	.0005	.0000	.0000	.0000	.0000
CNN	.0259	.1196	.1367	.1406	.1411	.1429	.0001	.0000	.0000	.0000
N2	.0203	3.0243	15.3740	31.4778	53.0209	83.1995	123.4583	189.1581	328.5061	714.0271
H	.0056	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CH4	.0041	.0016	.0006	.0004	.0003	.0002	.0000	.0000	.0000	.0000
ALCL3	.0020	.0977	.1366	.1636	.1915	.2460	.0008	.0000	.0000	.0000
FECL2	.0009	.0655	.1410	.2010	.2666	.3657	1.0222	1.0004	.0500	.0000
CH3	.0007	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000
ALOCL	.0007	.0010	.0026	.0027	.0027	.0024	.0006	.0000	.0000	.0000
CL	.0004	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H2O	.0003	.0016	.0026	.0031	.0033	.0032	4.1532	17.5034	21.5132	23.1346
C2N	.0003	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FECL	.0001	.0009	.0015	.0018	.0020	.0020	.0025	.0004	.0000	.0000
CO2	.0000	.0005	.0008	.0009	.0010	.0010	1.6001	17.5209	35.3406	35.3407
NH3	.0000	.0001	.0001	.0001	.0002	.0002	.0001	.0000	.0000	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0027	.0072	.0036	.0008
FEO	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0002	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0060	6.6050
FECL3	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0005	.0060	.0000
FEH2O2	.0000	.0000	.0000	.0000	.0000	.0000	.0007	.0073	.0000	.0000
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0057	.0050
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0011	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	24.7052	129.1674
ALCL2	.0000	7.0034	7.6403	7.9507	8.2051	8.5059	.0059	.0001	.0000	.0000
AL2O	.0000	.0300	.0170	.0117	.0077	.0039	.0000	.0000	.0000	.0000
ALCL	.0000	12.0204	10.2739	9.2021	8.4002	7.1438	.0011	.0000	.0000	.0000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.2000
FE2O3$	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.1650	.0000
AL2O3$	.0000	30.0371	36.2017	44.3076	55.0047	69.9835	83.1355	83.1400	83.1401	83.1401
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003
CL	.0000	.0026	.0044	.0054	.0062	.0066	.0563	.0485	.1115	.0000
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0004	.0021	.1501	.0001
H	.0000	.0040	.0056	.0057	.0056	.0051	.0062	.0013	.0000	.0000

LIST OF TOTAL COMBUSTION PRODUCTS CONSIDER

AL2O3$	ALCL	ALN$	CO	C$	AL4C3$	H2	AL2O	ALCL2	FE*	AL	FE	HCL	ALH	C2H2
CNH	N2	H	CH4	ALCL3	FECL2	CH3	ALOCL	CL	H2O	C2H	FECL	CO2	ALO	CHO
NH3	CH2O	CN	C2HCL	AL2O2	CH2	ALC	CH3CL	HO	C2N2	C2N	C2O	CNHO	NH2	CNCL
ALN	FEO	COCL	CH	C3	NH	C	CL2	N	FECL3	C2	CHCL	O	NO	ALO2
C4N2	CNO	FEH2O2	FE2CL4	C3O2	ALHO2	AL2CL6	C5	C2CL2	CCL	CN2	C4	CH2CL2	HOCL	NHO
N2H2	OCL	C2H4O	COCL2	CN2	O2	CCL2	CCL3	FE2CL6	H2O2	NOCL	N2H4	ALCL2	HO2	NO2CL
N3	AL2O	CHCL3	C2CL4	ALHO	CCL4	NHO2	ALCL	OCL2	O2CL	C2CL6	FE3O4$	FE3O4$	FECL3$	FECL3*
FE2O3$	FE2O3$	ALCL3*	ALCL3$	FECL2$	FECL2*	NH4O4C	N2O5	FEH3O3	AL2O3$	AL2O3*	N2O4	N2O4$	N2O4*	FEH2O2
AL2O2	ALOCL$	N2O3	FEO$	FEO$	FEO*	NHO3	NO3	C4H10	C4H8	FE$	FE$	FE$	FE$	FE$
NH4CL$	NH4CL$	O3	NO2	C3H8	N2O	ALO	C3H6	CL	N2H4*	C2H6	NO	CHO	C2H4	AL*
AL$	AL*	CN	H3O	H2O*	H2O*	HO	C$	H						

OD CALCULATION NO. 31 CONTINUED

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= XM39 (LOVA)

	H	C	N	O								
CELLULOSE ACET BUTYR	.007	.0050	.000	.0020	.0000	.0000	.0000	.0000	.0000	.0000	12.000	-1100.	.0434
ETHYL CENTRALITE-EC	0.000	.0170	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.500	-117.	.0451
RDX -(S)	.006	.003	.006	.0060	.0000	.0000	.0000	.0000	.0000	.0000	76.000	72.	.0656
ACETYL TRIETHYL CIT	.022	.0140	.000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	7.500	-1250.	.0361
NITROCELLULOSE(12.6)	.008	.006	.002	.0100	.0000	.0000	.0000	.0000	.0000	.0000	4.000	-625.	.0600
AIR -(0	0.0000	.000	.006	.0010	.0000	.0000	.0000	.0000	.0000	.0000	0.000	0.	.0004
												1.0000	

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000
0 (H) (C) (N) (O) (

3.587034	2.029643	2.000830	2.676651							
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1192.729	1207.886	1254.504	1360.744	1568.492	1792.599	2036.714	2279.898	1756.470	1099.290
FLAME TEMP. T(F)	1607.513	1713.212	1798.707	2004.340	2363.806	2767.279	3206.606	3644.417	2702.245	1519.337
ENTHALPY KCAL/GFW	-76.821	-69.139	-61.457	-53.775	-46.093	-38.411	-30.728	-23.046	-15.364	-7.682

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	833.019	836.401	839.602	841.392	839.237	831.263	862.731	971.913	670.361	372.706
FLAME TEMP. T(F)	1040.035	1046.122	1051.884	1055.106	1051.226	1036.073	1093.515	1298.044	761.650	211.614
ENTHALPY KCAL/GFW	-110.748	-103.318	-95.991	-88.971	-82.622	-77.073	-72.243	-67.703	-48.429	-27.398
T.VOL.GASES--LITERS	102.604	109.517	118.008	130.573	146.031	167.424	202.018	255.697	385.095	775.035
(GASES AT STP)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	37.5708	40.0416	43.1019	47.1128	52.0152	61.3989	71.2288	88.3737	89.3266	89.3266
N2	29.2545	30.0154	40.9666	63.0460	81.0205	100.1038	147.5321	213.2443	344.6613	738.9124
H20	12.0429	11.0923	11.7477	11.6754	11.0346	12.3512	10.3104	31.0400	31.5914	31.5914
C0	0.0224	7.7630	6.4336	4.7773	2.7721	.2579	.0000	.0000	.0000	.0000
CO	0.4172	9.6304	11.1024	12.7212	14.0309	14.6437	11.3670	.6065	.0000	.0000
CH4	2.2504	2.0000	1.0979	1.7209	1.5705	1.4400	.0066	.0000	.0000	.0000

H2	1.6186	1.6000	1.7421	1.7947	1.0146	1.7074	1.4627	.0600	.0000	.0000
NH3	.0072	.0075	.0070	.0000	.0002	.0003	.0045	.0000	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	34.4206	140.1696

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	N2	H2O	C*	CO	CH4	H2	NH3	C2H6	CNH	CH2O	CNHO	C2H4	CH3	C3H8
C3H6	C2H2	H	NH2	HO	C4H8	C4H10	HO2	C2N2	O	C4N2	CH	O2	N3	NO
C2H4O	C2N	C2	N	C3	CN2	N2H4	NHO2	CN2	C	C3O2	NH	NHO	CN	H2O2
C2H	C2O	N2O5	N2O4*	N2O4*	N2O4	N2O3	NHO3	NO3	C5	C4	O3	NO2	N2O	CNO
N2H4*	N2H2	NO	CHO	CHO	CN	H3O	H2O*	H2O*	HO	CH2	C*	H		

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= PBXN-103

	H	C	N	O	AL	CL						
NITROCELLULOSE(12.6)	.000	.006	.002	.0100.0000.0000.0000.0000.0000.0000.0000.000						6.000	-625.	.0600
AP	.0040.000		.001	.0040.000	.0010.0000.0000.0000.0000.0000.000					40.000	-602.	.0705
ALUMINUM --AL	0.0000.0000.0000.000				.0010.0000.0000.0000.0000.0000.0000.000					27.000	0.	.0976
RESORCINOL - RES	.006	.0060.000		.0020.0000.0000.0000.0000.0000.0000.0000.000						.200	-777.	.0460
METRIOL TRINITRATE	.009	.005	.003	.0090.0000.0000.0000.0000.0000.0000.0000.000						23.000	-406.	.0531
TEGDN	.012	.006	.002	.0000.0000.0000.0000.0000.0000.0000.0000.000						2.500	-637.	.0470
ETHYL CENTRALITE-EC	0.000	.0170.0000.0000.0000.0000.0000.0000.0000.0000.0000.000								1.300	-117.	.0451
AIR -(0	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000						0.000	0.	.0004
											1.0000	

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

0 (H)	(C)	(N)	(O)	(AL)	(CL)	(					
2.475120	.764460	.605646	2.477990	1.000741	.340434						
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000	
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	3120.129	3122.009	3110.135	3107.422	3085.272	3020.725	2794.722	2337.057	1846.036	1139.543
FLAME TEMP. T(F)	5156.032	5161.655	5153.244	5133.960	5094.090	4977.905	4571.100	3747.303	2863.465	1591.777
ENTHALPY KCAL/GFW	-110.307	-106.477	-94.646	-82.015	-70.904	-59.154	-47.323	-35.492	-23.661	-11.831

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	2213.505	2143.537	2071.527	1998.694	1926.931	1061.022	1601.506	1162.422	769.626	407.510
FLAME TEMP. T(F)	3525.054	3398.967	3269.348	3138.250	3009.076	2890.440	2423.311	1632.960	925.927	274.133
ENTHALPY KCAL/GFW	-172.505	-160.892	-149.162	-137.335	-125.422	-113.358	-90.292	-70.603	-56.200	-31.719
T.VOL.GASES--LITERS	67.795	74.775	83.517	94.773	109.797	130.845	166.513	231.431	360.000	749.522
(GASES AT STP)										

CONBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/0)MATERIAL BURNED-----

AL2O3	50.9957	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CO	20.5965	19.0455	18.6411	16.5937	12.0020	5.0196	.0027	.0000	.0000	.0000
HCL	12.2936	12.3350	12.3572	12.3707	12.3776	12.3711	12.1715	12.1306	8.7699	-.2704
N2	9.6043	10.3654	29.3160	43.3972	62.1710	80.4540	127.0147	193.5750	325.0051	719.2565

00 CALCULATION NO. 22

H2O	3.3079	5.4619	7.9929	10.9284	14.2118	17.6051	19.2798	19.2981	20.1285	22.2271
H2	1.7756	1.5364	1.2549	.9277	.5611	.1822	.0001	.0000	.0000	.0000
CO2	1.2032	2.4632	4.3556	7.5725	13.4030	24.5000	33.6484	33.6446	33.6446	33.6446
CL	.0099	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALCL2	.0277	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H	.0091	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALCL	.0059	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HO	.0045	.0051	.0050	.0046	.0044	.0055	.0150	.0002	.0000	.0000
ALCL3	.0031	.0011	.0004	.0002	.0001	.0000	.0000	.0000	.0000	.0000
ALOCL	.0025	.0010	.0004	.0001	.0000	.0000	.0000	.0000	.0000	.0000
NO	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CL2	.0001	.0001	.0001	.0000	.0001	.0001	.0272	.2495	3.5390	11.7999
O	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0000	.0000	.0000
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0036	.0064	.0062	.0003
O2	.0000	.0000	.0000	.0000	.0000	.0002	5.6009	23.3616	57.0001	161.7754
OCL	.0000	.0000	.0000	.0000	.0000	.0000	.0010	.0003	.0000	.0000
ALCL	.0000	.0011	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000
ALCL2	.0000	.0072	.0020	.0006	.0001	.0000	.0000	.0000	.0000	.0000
NO	.0000	.0004	.0005	.0005	.0007	.0016	.1395	.0269	.0005	.0000
CL	.0000	.0695	.0530	.0413	.0351	.0415	.2053	.0214	.0001	.0000
AL2O3$	.0000	51.0121	51.0162	51.0173	51.0176	51.0177	51.0178	51.0178	51.0178	51.0178
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0002	.0000
H	.0000	.0060	.0037	.0021	.0011	.0004	.0000	.0000	.0000	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

AL2O3$	CO	HCL	N2	H2O	H2	CO2	CL	ALCL2	H	ALCL	HO	ALCL3	ALOCL	NO
CL2	CNH	NH3	O	CHO	COCL	HOCL	O2	CH2O	CNHO	AL	NH2	NH	ALO	OCL
ALH	ALO2	N	AL2O	CH4	NHO	CNCL	CH3	CN	H2O2	CNO	ALHO2	HO2	NOCL	COCL2
CH3CL	AL2O2	C2H2	CH2	NHO2	C2O	N2H2	CHCL	ALN	AL2CL6	CH	C2H	C	CH2CL2	C2HCL
N3	C2N2	CN2	OCL2	CCL	C2N	CCL2	O2CL	N2H4	C3O2	CHCL3	CN2	C2CL2	ALCL	ALC
NO3	O3	CCL3	C2	ALHO	CHO	NO2CL	C4N2	NHO3	H3O	ALCL2	C3	AL2O	C2H4O	N2O3
CCL4	NO	C2CL4	ALO	CL	CS	N2O4	C2CL6	AL4C3$	ALCL3*	ALCL3$	NH4O4C	N2O5	AL2O3$	AL2O3*
N2O4$	N2O4*	AL2O2	ALOCL$	C4H10	C4H8	NH4CL$	NH4CL$	C4	NO2	C3H8	N2O	C3H6	ALN$	N2H4*
C2H6	C2H4	AL*	AL$	AL*	CN	H2O*	H2O*	HO	C$	C$	H			

DETONATION BURN---MATERIAL DETONATES BEFORE REACTING WITH AIR---
MATERIAL= PBX(AF) -100

	H	C	N	O	S			
RDX -(S)	.006	.003	.006	.0060.0000.0000.0000.0000.0000.0000.0000.000		82.000	72.	.0656
PHENOL	.006	.0060.000	.0010.0000.0000.0000.0000.0000.0000.0000.000			.500	-394.	.0307
ISODECYL PELARGONATE	.038	.0190.000	.0020.0000.0000.0000.0000.0000.0000.0000.000			5.300	-707.	.0314
PPG	.006	.0030.000	.0010.0000.0000.0000.0000.0000.0000.0000.000			10.700	-875.	.0362
TDICY	.006	.009	.002	.0020.0000.0000.0000.0000.0000.0000.0000.000		.610	-33.	.0325
HEXAMETHYL-DIISO-HDI	.007	.005	.001	.0010.0000.0000.0000.0000.0000.0000.0000.000		.250	-321.	.0325
PAPI	.006	.000	.001	.0010.0000.0000.0000.0000.0000.0000.0000.000		.375	-270.	.0361
SULFUR	0.0000.0000.0000.000			.0010.0000.0000.0000.0000.0000.0000.000		.100	0.	.0749
CUDANE	.000	.0000.0000.0000.0000.0000.0000.0000.0000.0000.000				.100	1335.	.0372
AIR -(0	0.0000.000		.006	.0010.0000.0000.0000.0000.0000.0000.0000.000		0.000	0.	.0004

0GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 99.935 1.0000

0 (H)	(C)	(N)	(O)	(S)	(					
4.090371	2.103154	2.227745	2.452792	.003119						
WT. MATERIAL	99.935	89.941	79.948	69.954	59.961	49.968	39.974	29.981	19.987	9.993
WT. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000

---COMBUSTION CONDITIONS: AIR IS MIXED WITH THE MATERIAL'S COMBUSTION PRODUCTS AFTER---
---THE MATERIAL HAS EXPLODED. (WT. MATERIAL/WT. AIR IS SHOWN ABOVE)---

FLAME TEMP. T(K)	1289.139	1219.041	1240.698	1301.402	1450.554	1686.107	1937.229	2214.207	1956.332	1218.993
FLAME TEMP. T(F)	1717.051	1734.073	1773.057	1883.124	2165.997	2575.592	3027.612	3526.316	3061.997	1734.787
ENTHALPY KCAL/GFW	-64.528	-58.030	-51.589	-45.140	-38.692	-32.243	-25.795	-19.346	-12.897	-6.449

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS BELOW ARE FROM THE MATERIAL/AIR---
---MIXTURES ABOVE AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	836.459	839.571	842.814	845.688	846.825	848.937	848.258	925.052	775.942	421.832
FLAME TEMP. T(F)	1046.226	1051.827	1057.665	1062.688	1063.448	1054.286	1053.064	1207.133	937.296	299.898
ENTHALPY KCAL/GFW	-108.418	-94.007	-87.654	-81.459	-75.726	-70.861	-66.928	-63.635	-58.365	-28.564
T.VOL.GASES--LITERS	109.841	117.502	126.952	138.924	154.611	176.197	210.517	265.619	387.657	777.755
(GASES AT STP)										
COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04										

-----GRAMS PRODUCTS/100 GRAMS (GS/G)MATERIAL BURNED-----

CO2	31.9381	34.3442	37.3268	41.1691	46.4845	54.5335	66.1636	81.1972	92.6221	92.6221
N2	31.2191	39.9856	50.9439	65.0333	83.0193	110.1197	149.5712	215.3291	346.0424	741.3481

H2O	12.6005	12.6036	12.5895	12.4439	12.5299	12.9960	15.9388	20.6693	36.0651	36.0130
C$	10.7497	9.7557	8.4005	6.0321	4.7207	2.0797	.0000	.0000	.0000	.0000
CO	8.3660	9.5527	11.0403	12.8754	14.7971	16.1760	15.3227	7.2600	.0000	.0000
CH4	2.9690	2.7412	2.5006	2.2551	2.0264	1.0403	.0679	.0006	.0000	.0000
H2	1.9517	2.0186	2.0095	2.1506	2.2064	2.2010	2.1163	.9111	.0000	.0000
H2S	.1053	.1052	.1050	.1049	.1047	.1045	.1046	.1044	.0000	.0000
NH3	.0090	.0095	.0098	.0099	.0101	.0102	.0092	.0012	.0000	.0000
CSO	.0019	.0021	.0023	.0026	.0029	.0032	.0032	.0034	.0000	.0000
SO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.1024	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	23.7309	129.5033
H2SO4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0269	.3061
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0003	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	N2	H2O	C$	CO	CH4	H2	H2S	NH3	CSO	C2H6	CNN	CH2O	CNHO	C2H4
HS	CS2	CH3	S2	C3H8	CS	C3H6	C2H2	SO2	H	NN2	SO	HO	S2O	C4H8
C4H10	S	NS	C2N2	NHO2	SO3	C2	O2	NJ	NO	C3	C2H4O	HO2	C2N	N
C4N2	CN2	H2SO4	N2H4	CN2	C	C3O2	NH	CH	NHO	CN	H2O2	C2H	SH	C2O
N2OS	H2SO4*	N2O4	N2O4$	N2O4*	N2O3	NHO3	NO3	C5	C4	O3	NO2	N2O	O	CNO
S$	S*	N2H4*	N2H2	NO	CHO	CHO	CN	H3O	H2O*	H2O*	HO	CH2	C$	H