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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.

FIELD TEST SERIES A, B, AND C

VOLUME 1
TEST SUMMARY

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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).

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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

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[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[a]	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* 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• 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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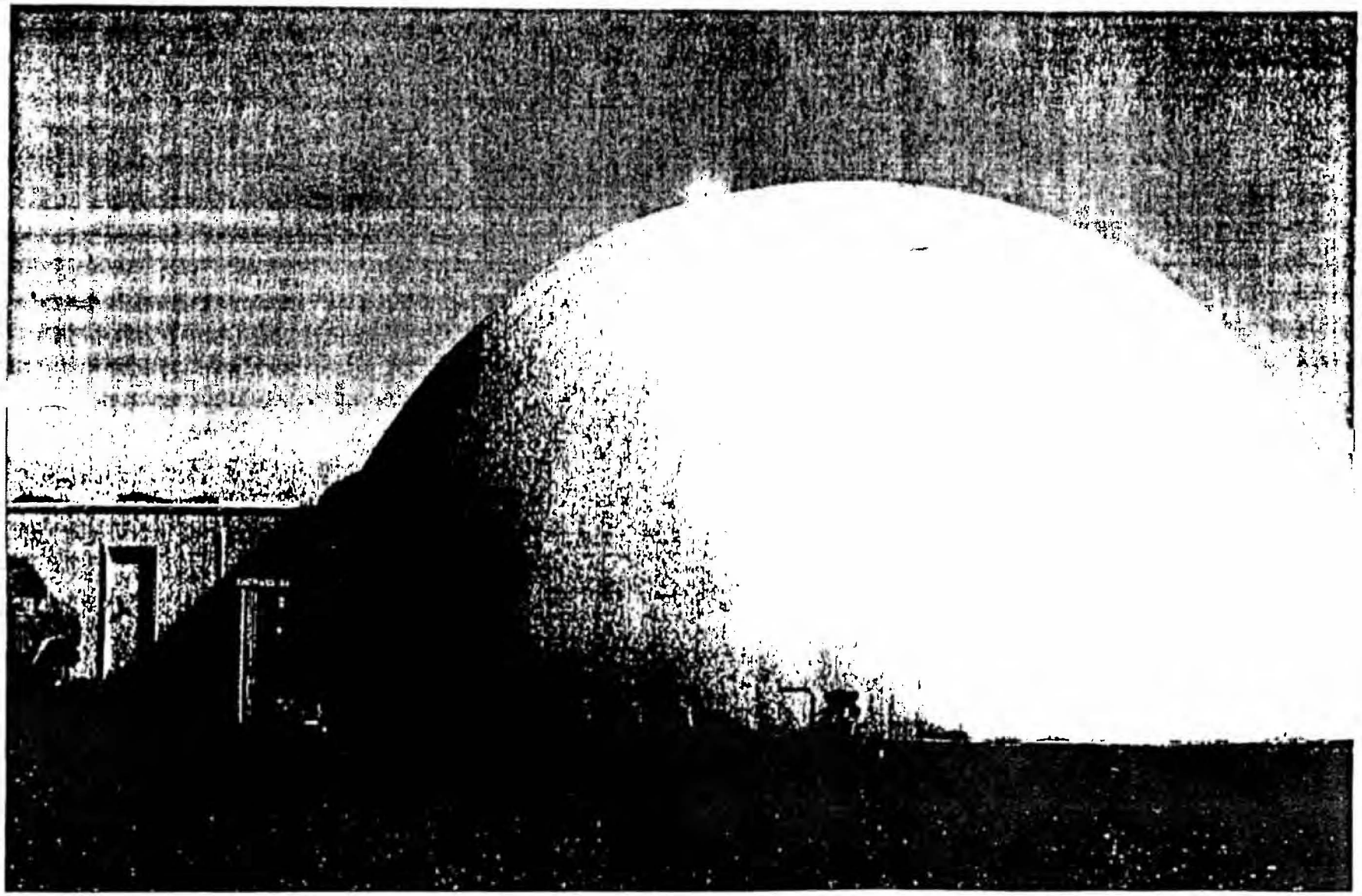

Figure 3.1 SNL BangBox Test Facility Containing Sampling and Real-Time Analysis Equipment.

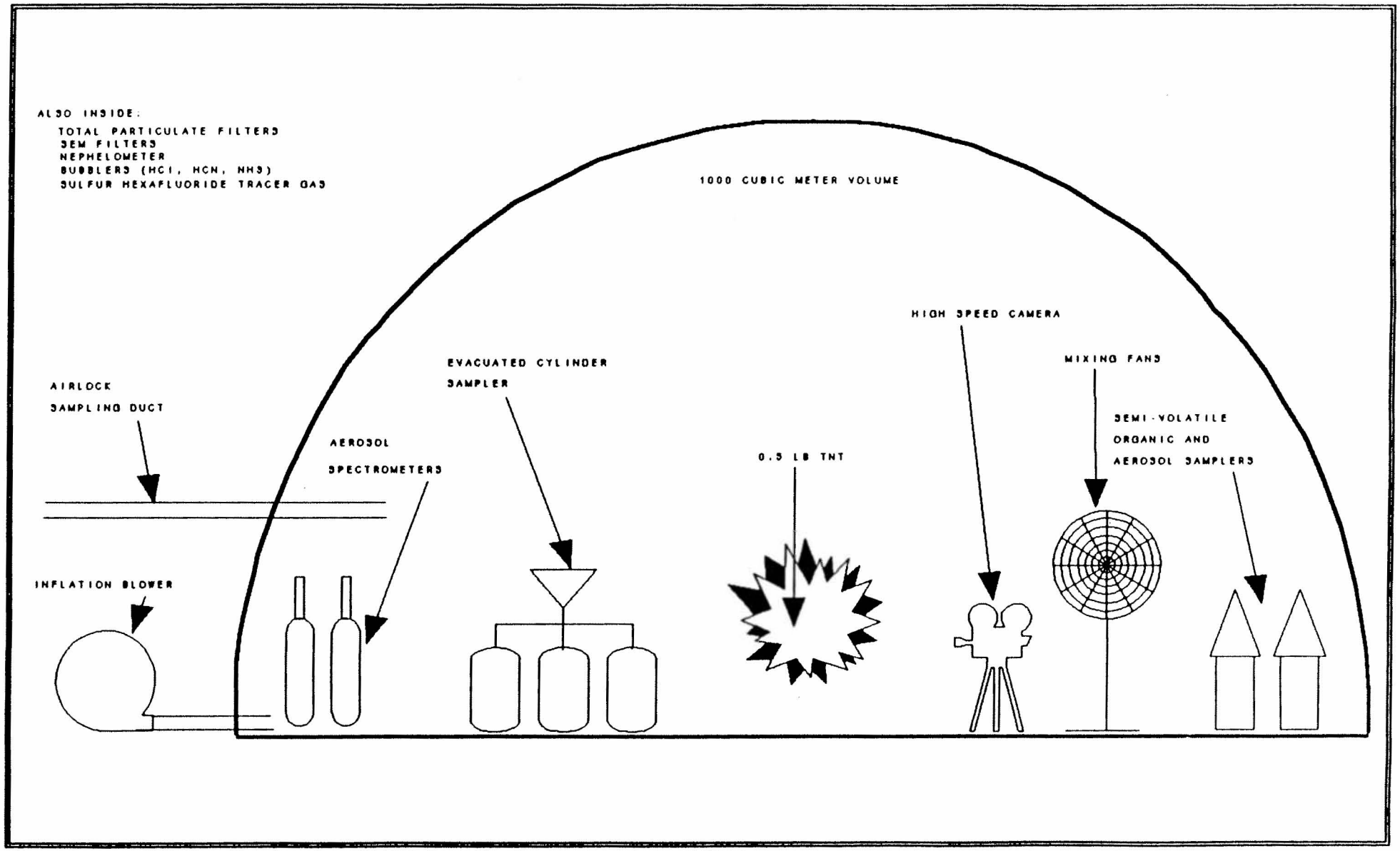

Figure 3.2 SNL BangBox Interior OB/OD Sampling Instrumentation and Equipment.

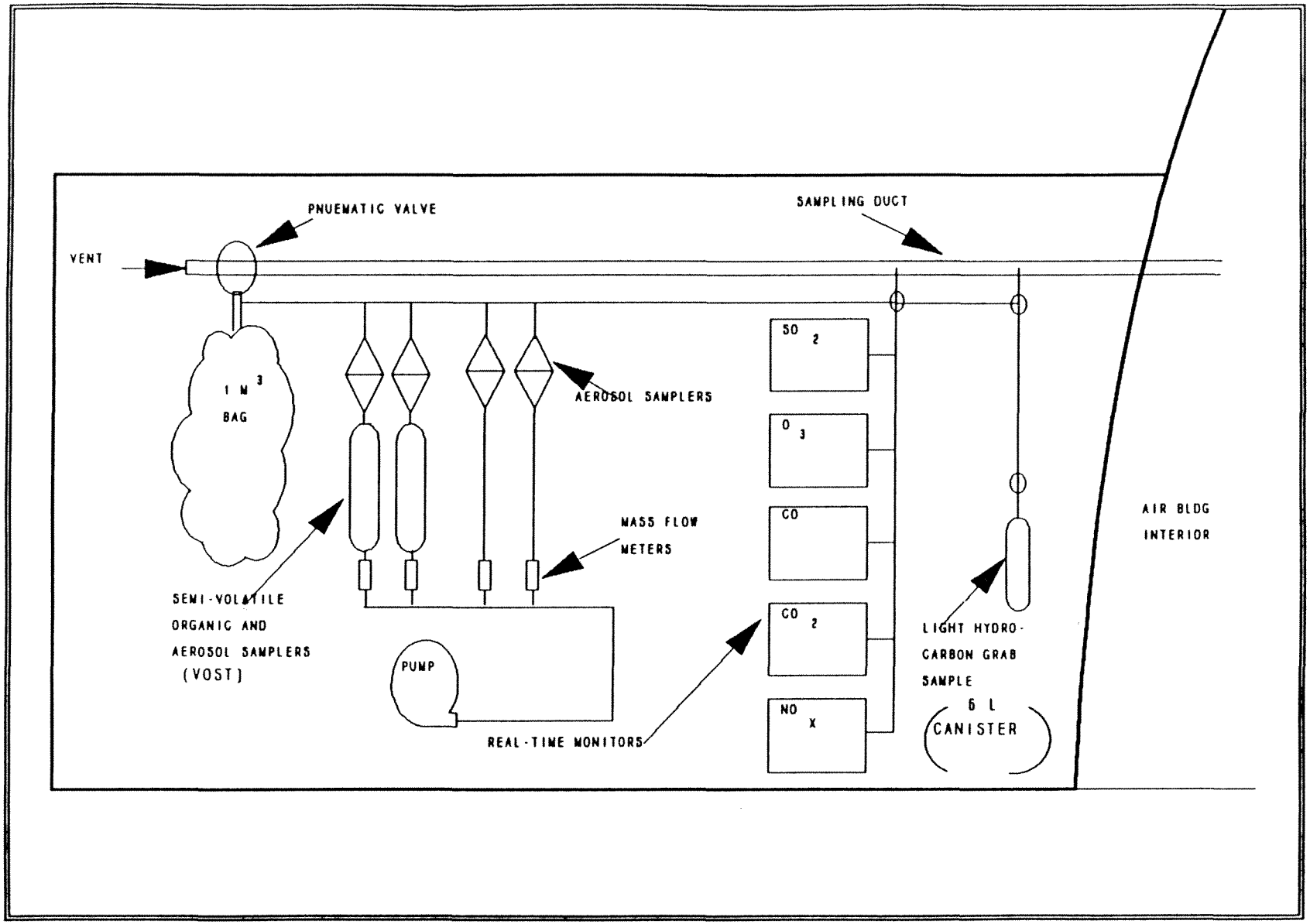

Figure 3.3 BangBox Airlock Instrumentation and Sampling Equipment.

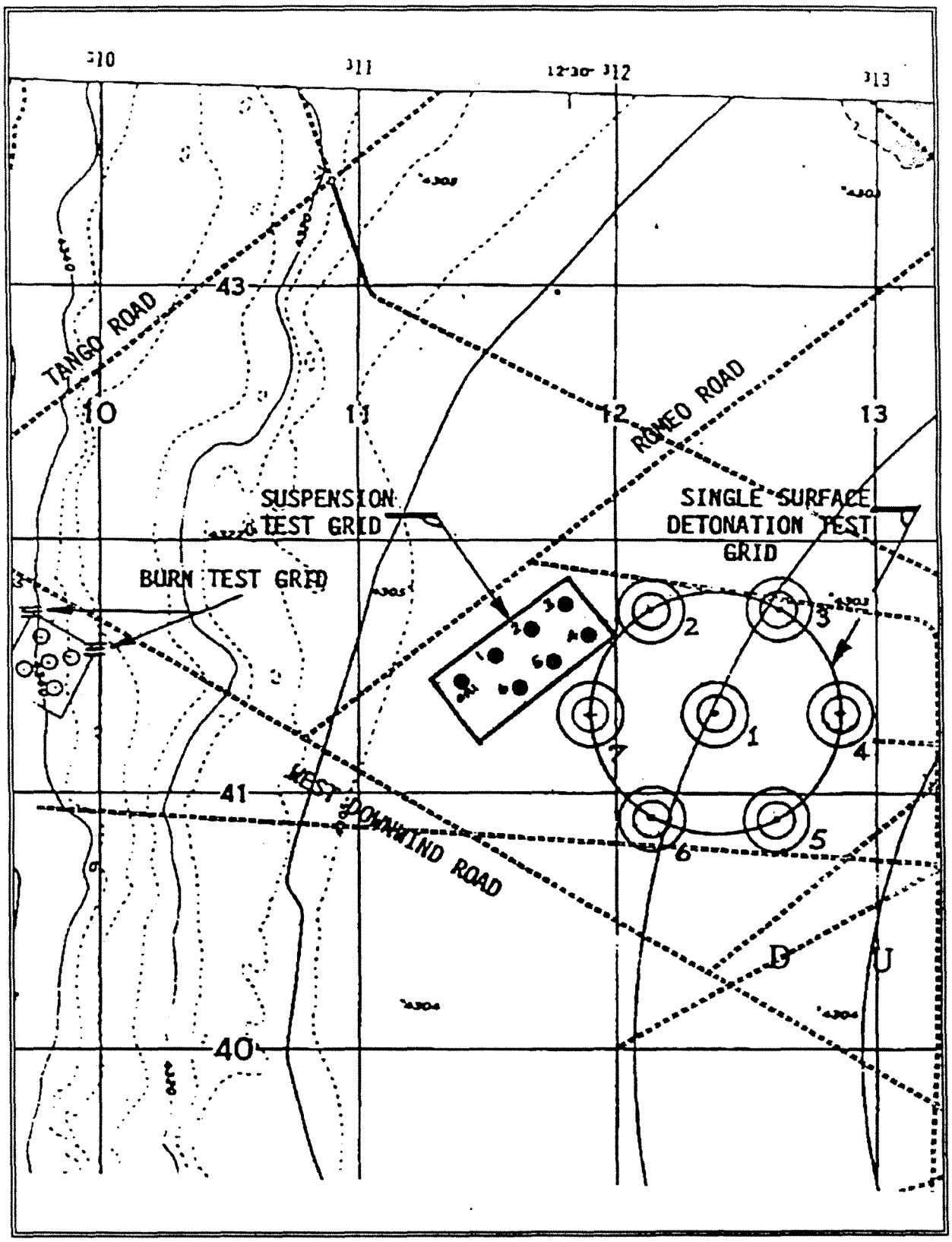

Figure 3.4 OB/OD Test Grid Location.

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.

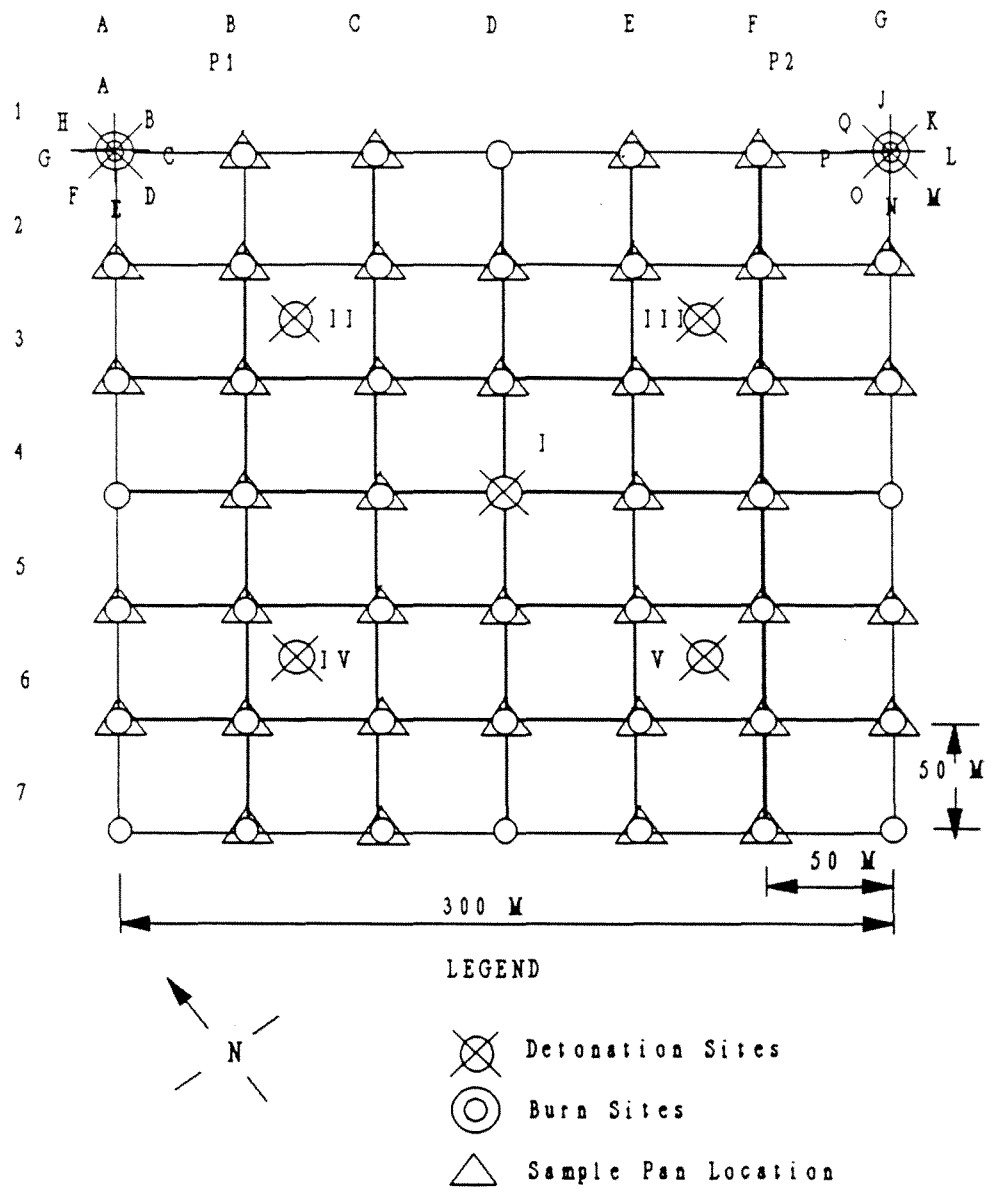

Figure 3.5 OB/OD Phase A Soil and Fallout Sampling Location.

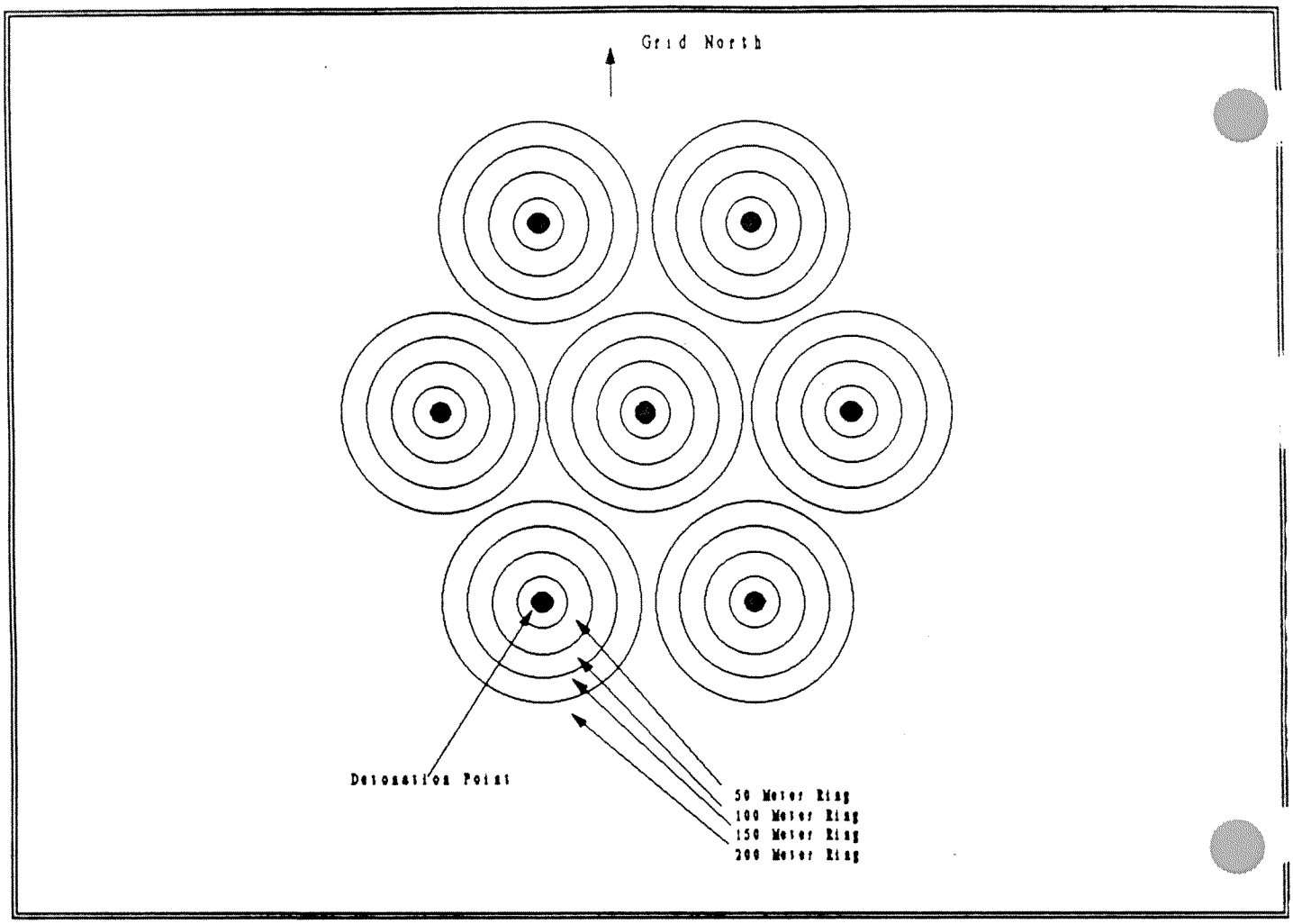

Figure 3.6 OB/OD Phase B Surface TNT Detonation Location Relationships.

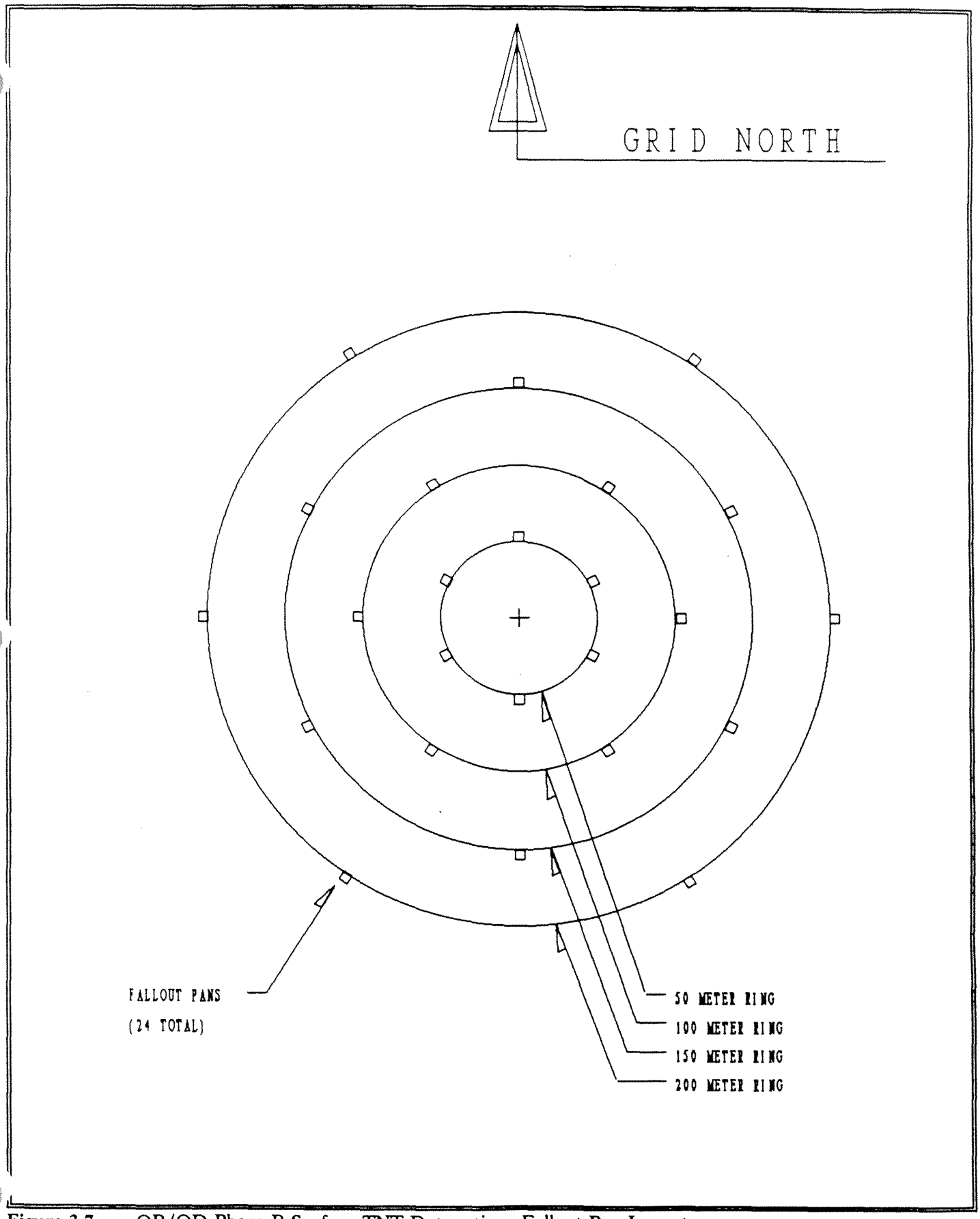

Figure 3.7 OB/OD Phase B Surface TNT Detonations Fallout Pan Layout.

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.

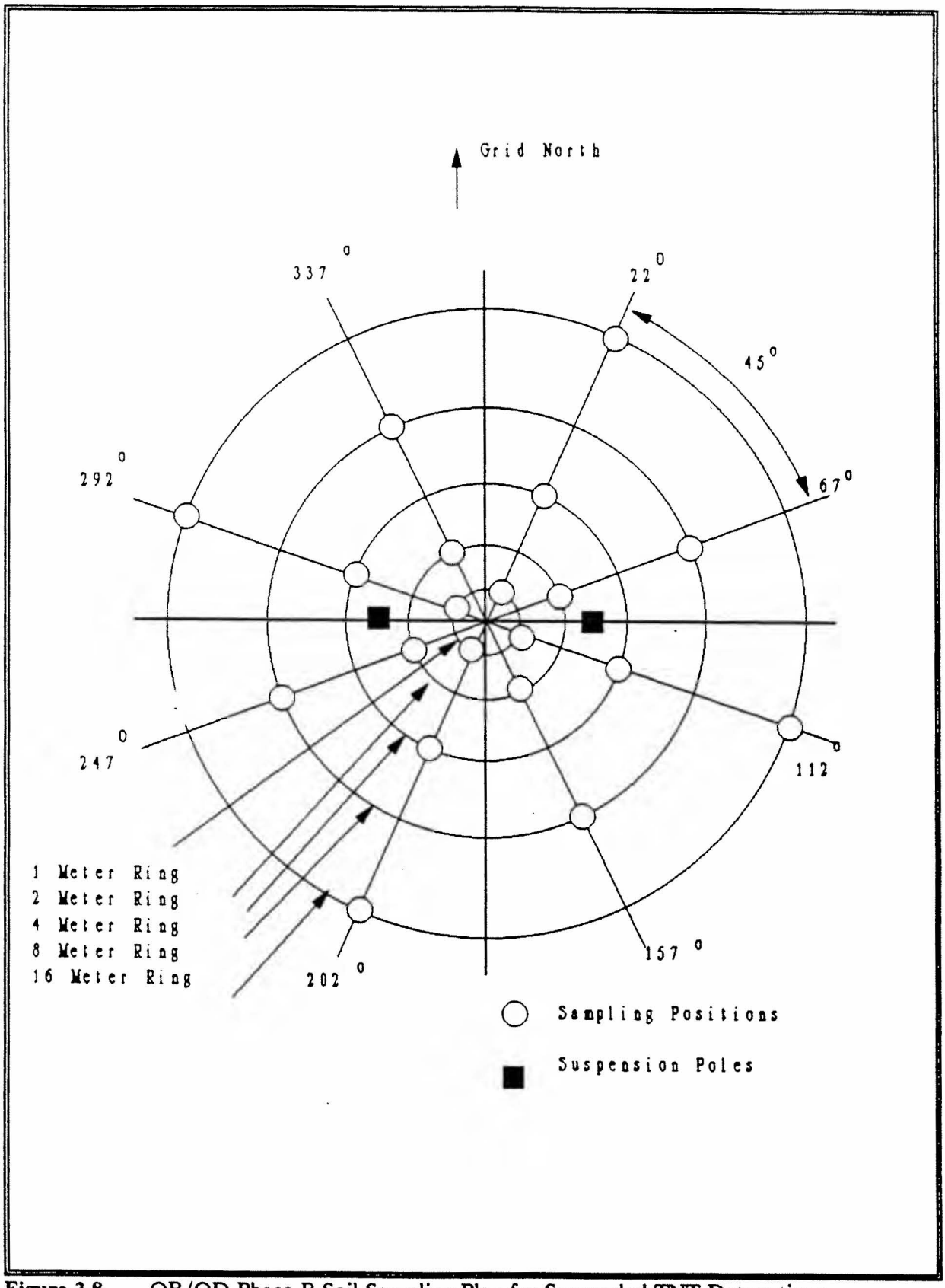

Figure 3.8 OB/OD Phase B Soil Sampling Plan for Suspended TNT Detonations.

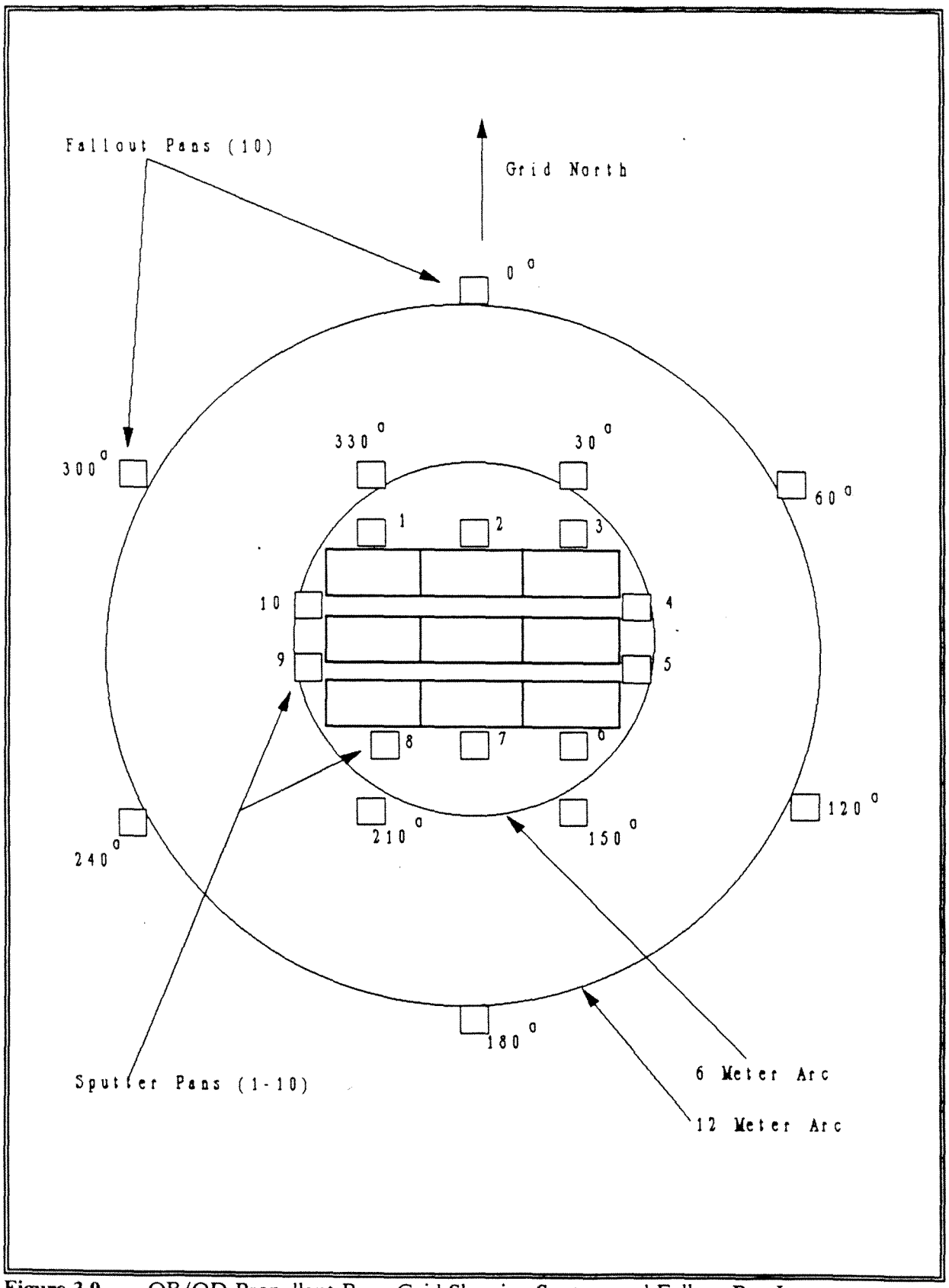

Figure 3.9 OB/OD Propellant Burn Grid Showing Sputter and Fallout Pan Layout.

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.

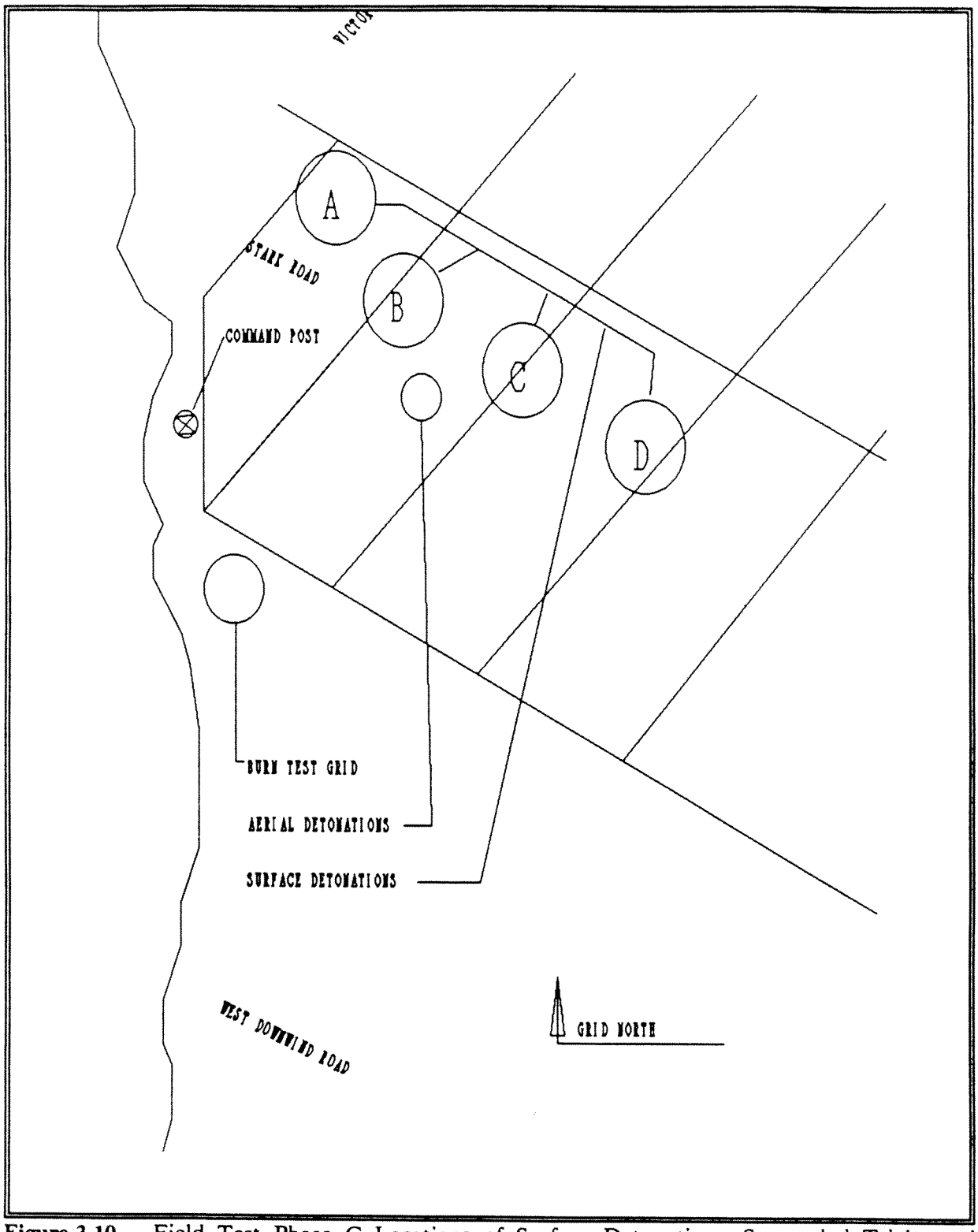

Figure 3.10 Field Test Phase C Locations of Surface Detonations, Suspended Trials, and Propellant Burns.

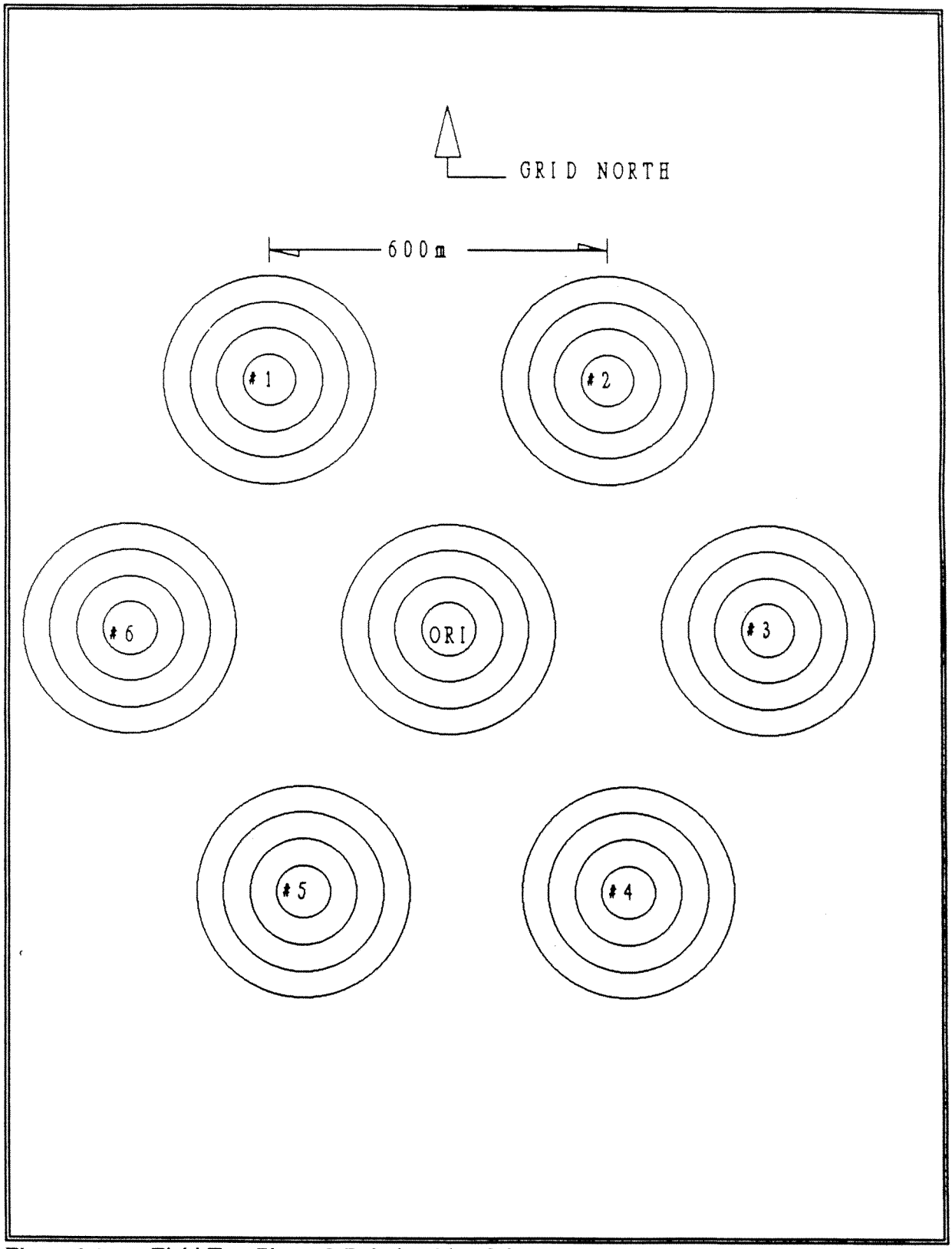

Figure 3.11 Field Test Phase C Relationship of the Seven Surface Detonation Sites Contained in Sites A, B, C, and,D of Fig. 3.10.

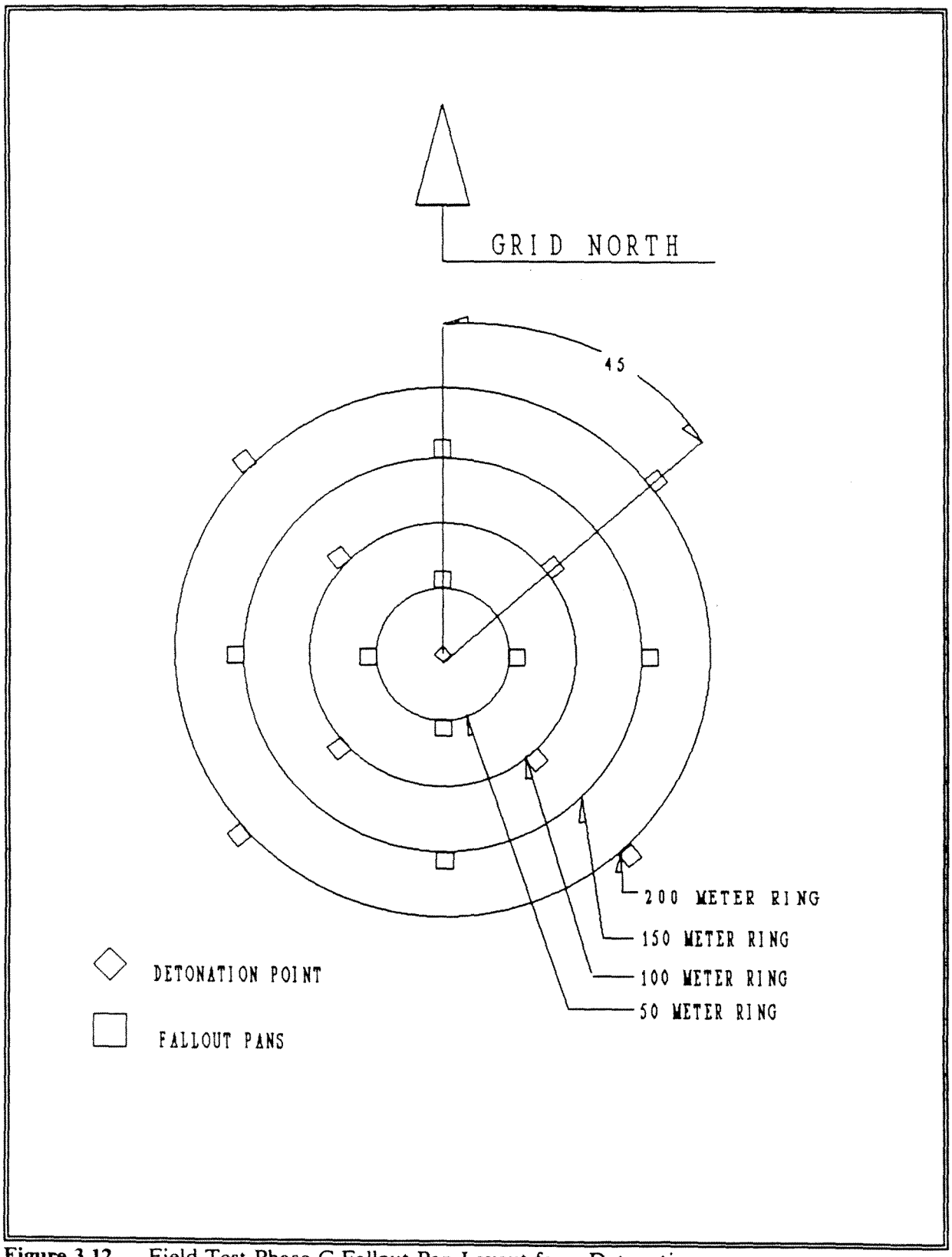

Figure 3.12 Field Test Phase C Fallout Pan Layout for a Detonation.

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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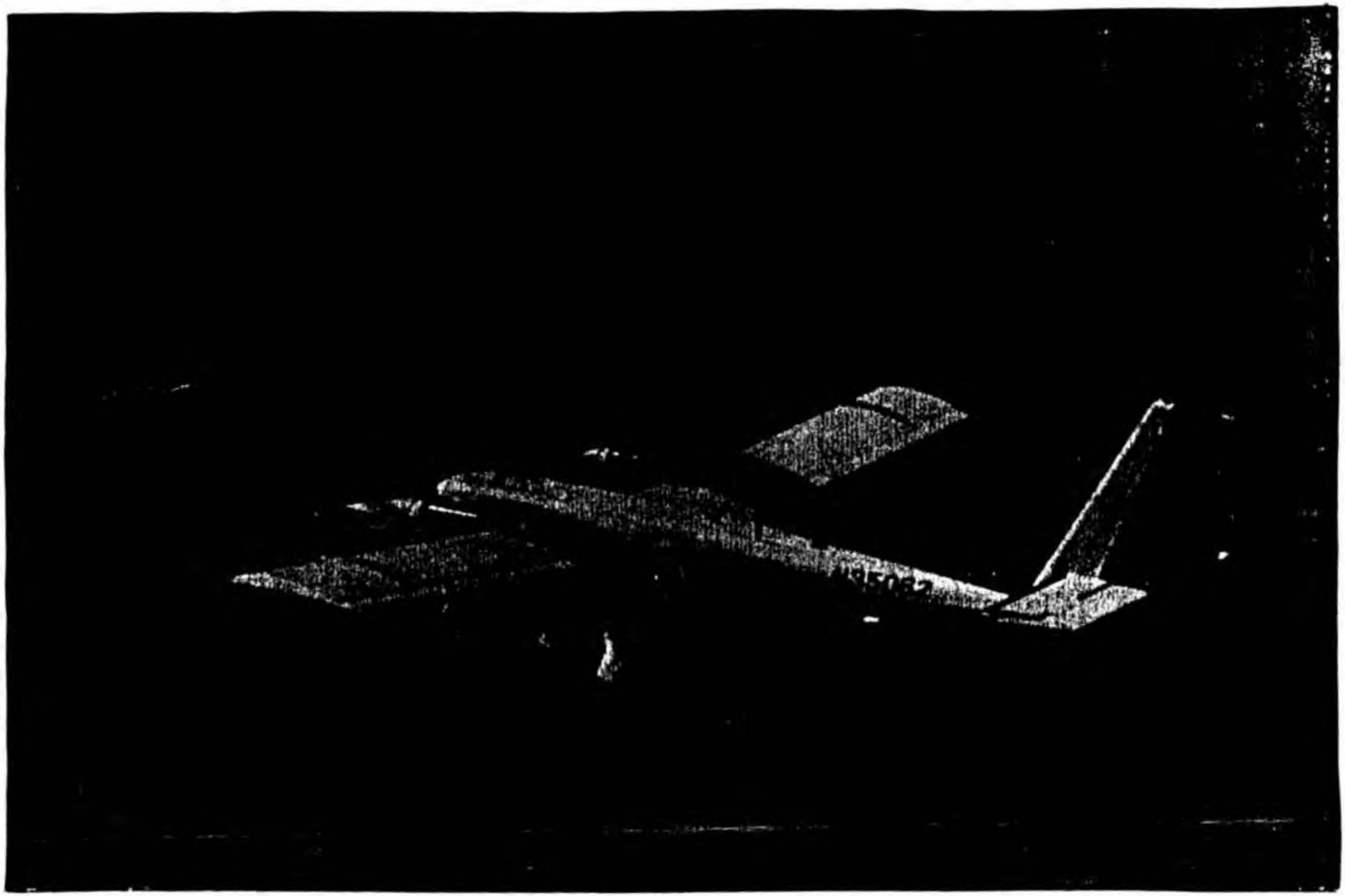

Figure 3.13 SNL Twin Otter Instrumented Fixed-Wing Aircraft for Open-Air OB/OD Sampling and Real-Time Gas Analysis.

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.

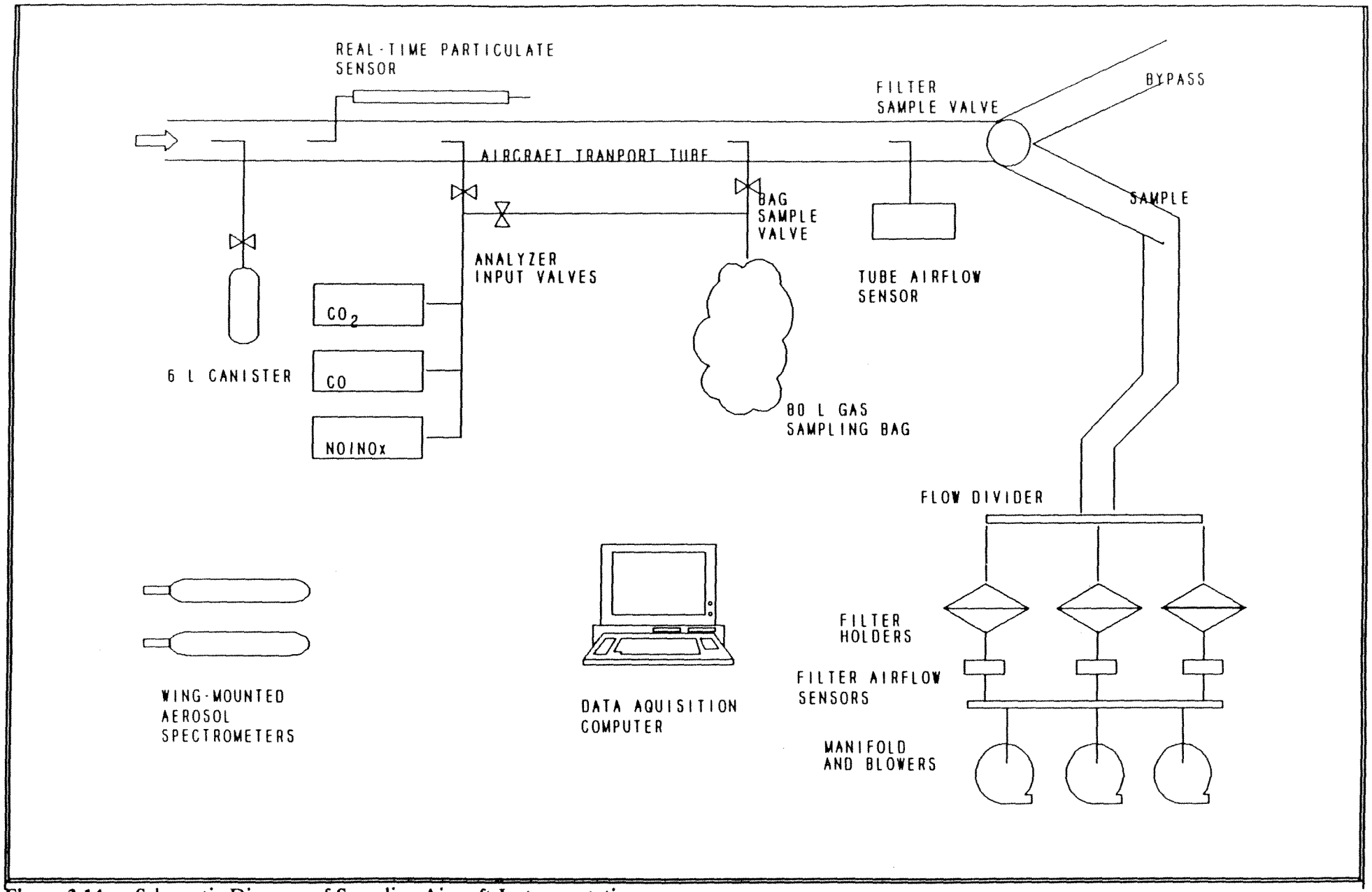

Figure 3.14 Schematic Diagram of Sampling Aircraft Instrumentation.

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_x, 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* (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

*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
Diethylphthalate	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 $\pm$0.2%, CO @ 100 ppbv $\pm$3%, and CO_2 @ 345 ppmv $\pm$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 amo · : 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 x 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, $[D_{ij}]$ = 797 x 10^{-6}mg/m^3 of 2,4-dinitrotoluene, $[C_j]$ = 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. Summ: 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	150×10^{-9}	8400×10^{-9}	BD[c]
2,6-Dinitrotoluene	19×10^{-9}	7100×10^{-9}	BD
2,4,6-Trinitrotoluene	220×10^{-9}	150×10^{-9}	60×10^{-9}
2-Nitronaphthalene	80×10^{-9}	270×10^{-9}	BD
N-Nitrosodiphenylamine	BD	4.4×10^{-9}	BD
1,3,5-Trinitrobenzene	BD	BD	BD
2-Nitrodiphenylamine	BD	N/A[d]	BD
1-Nitropyrene	BD	39×10^{-9}	BD
Naphthalene	BD	3700×10^{-9}	2600×10^{-9}
Benz[a]anthracene	2.2×10^{-9}	160×10^{-9}	100×10^{-9}
Benzo[a]pyrene	BD	240×10^{-9}	BD
Pyrene	BD	N/A	220×10^{-9}
Phenol	BD	5200×10^{-9}	BD
Dibenzofuran	BD	85×10^{-9}	180×10^{-9}
Diphenylamine	N/A	7.7×10^{-9}	170×10^{-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., 150×10^{-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 (μg/kg)[c]	Geometric Mean[d] (μg/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
	[illegible]	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/m² 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/m² of terrain)	NA	NA	0.47	0.15	BD	BD
Maximum (μg/m²)	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 suffic 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	19[illegible]

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	450×10^{-9}
2,6-Dinitrotoluene	24×10^{-9}
2,4,6-Trinitrotoluene	250×10^{-9}
2-Nitronaphthalene	86×10^{-9}
N-Nitrosodiphenylamine	36×10^{-9}
1,3,5-Trinitrobenzene	59×10^{-9}
2-Nitrodiphenylamine	72×10^{-9}
1-Nitropyrene	56×10^{-9}
RDX	BD[c]
Naphthalene	420×10^{-9}
Benz[a]anthracene	7.4×10^{-9}
Benzo[a]pyrene	14×10^{-9}
Pyrene	210×10^{-9}
Phenol	---[d]
Dibenzofuran	BD
Diphenylamine	66×10^{-9}

[a]Emission factors are expressed in terms of 10^{-9} for ease of comparison, e.g., 450×10^{-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 [illegible]	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/m^2)[c]	Geometric Mean[d] (ng/m^2)
	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 m^2 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/m²)[c]	Geometric Mean[d] (ng/m²)
	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^{-8}, 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 parti 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 (~ 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}	BD	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^{-9}	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.

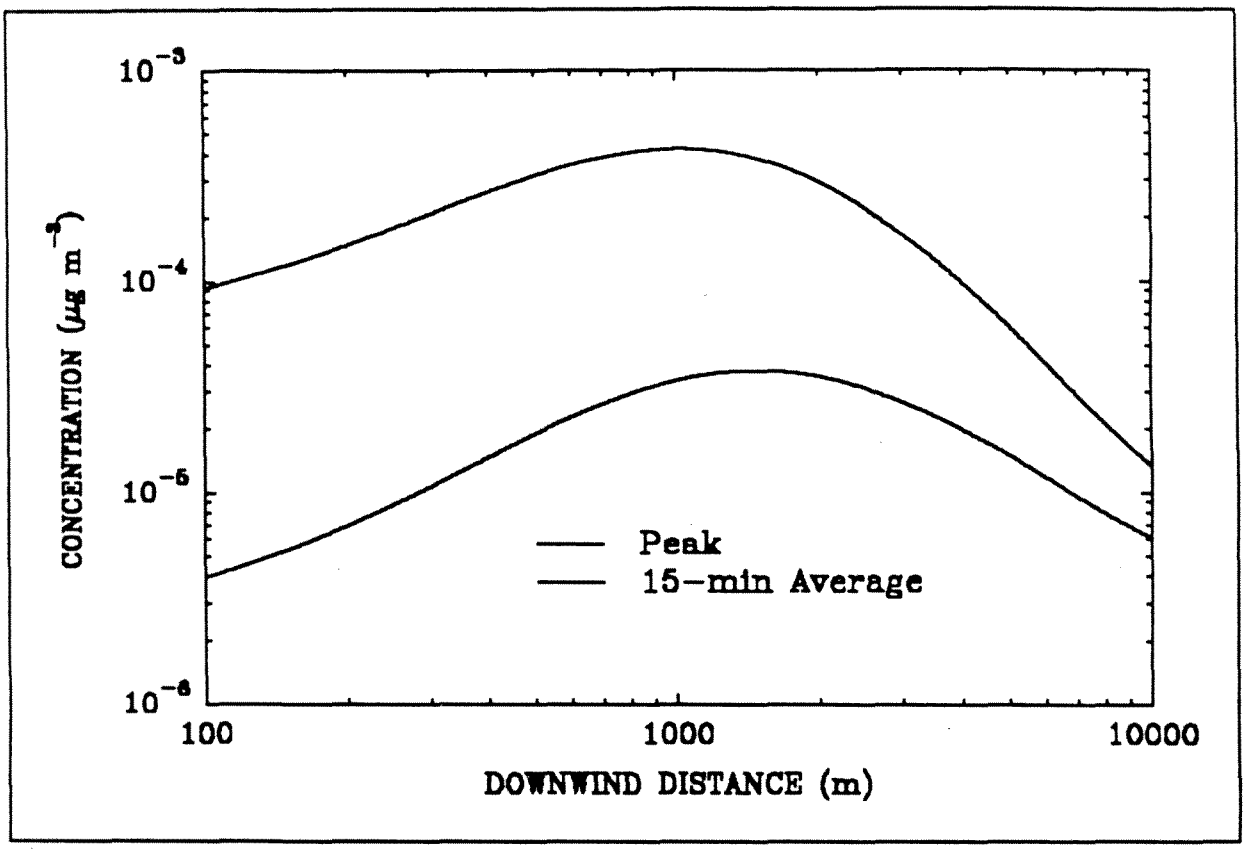

Figure 4.1 Ground Level Peak and 15 min Average Concentration of Benzo[a]pyrene Downwind of a 1000-kg Surface Detonation of TNT.

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's 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[illegible]			72.8	BD	1455	BD	BD	BD	BD	BD	2050	476	BD	27.1	BD	271

*Below [illegible]tion.

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.

$$M = \frac{S}{\frac{V_{si} + V_{sf}}{2} - \frac{V_{si} + V_{sf}}{2}}$$

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.

$$C = (V_{sam} - \frac{V_{zi} + V_{zf}}{2}) * M$$

where C is the bag concentration in ppm, V_{sam} 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-2b 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 a final span gas reading.

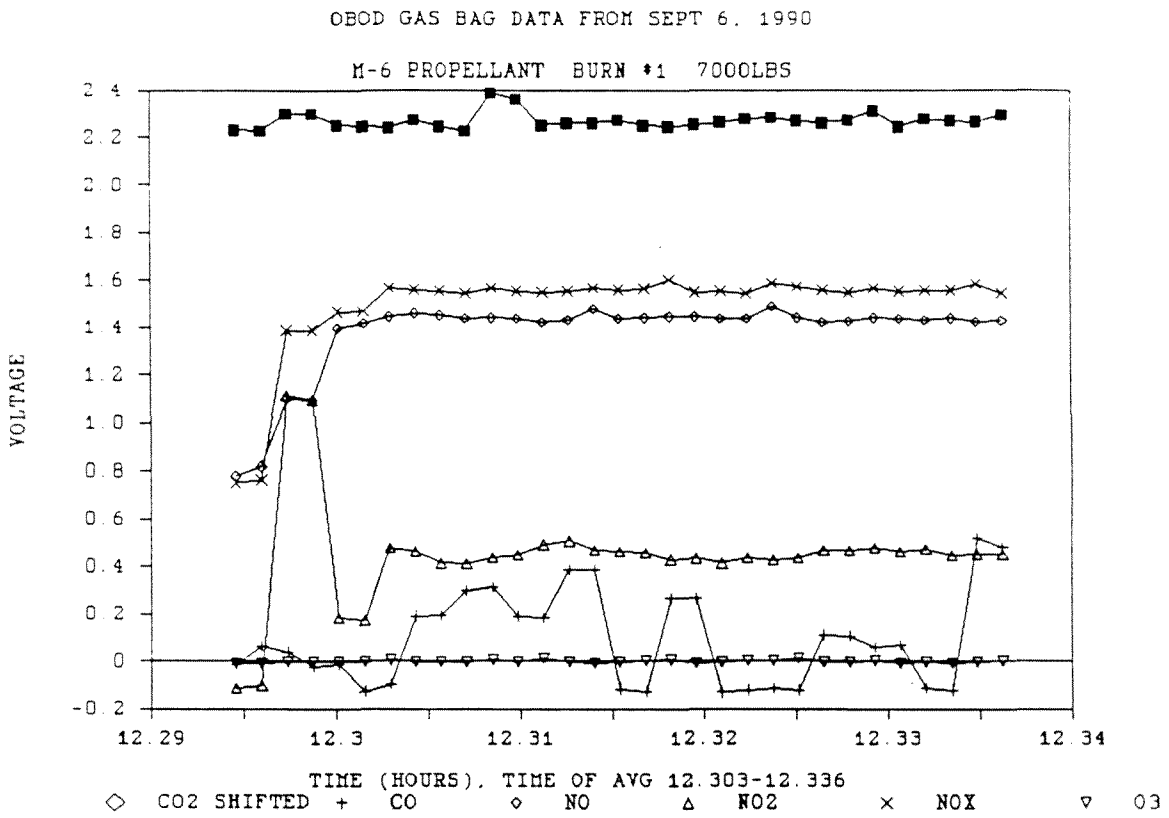

Figure C-1 Raw Voltage Data From Gas Instruments While Sampling From Bag Following The First M-1 Propellant Test.

■ valve open position voltage

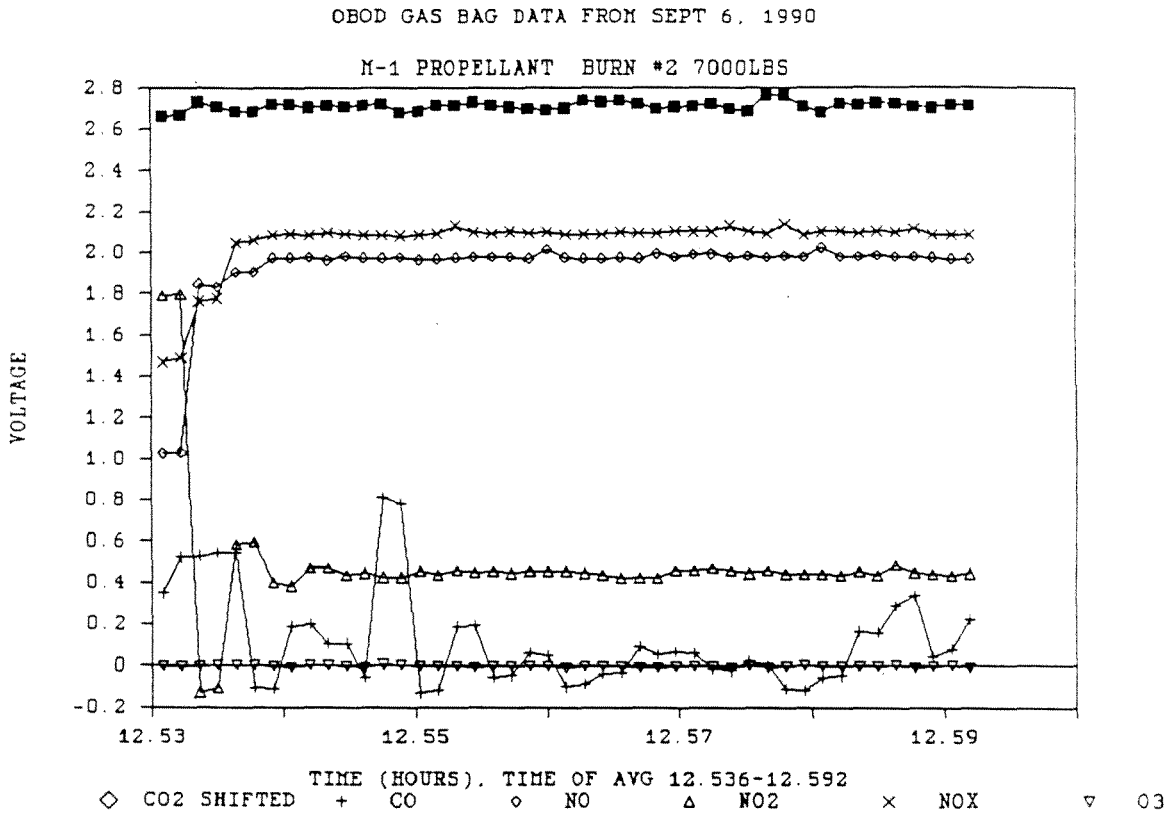

Figure C-2 Raw Voltage Data From Gas Instrument While Sampling From Bag Following Second M-1 Propellant Burn.

■ 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		Can # SDA168 Tube	
Location: OBOD		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		Can # SDA168 Tube	
Location: OBOD		Sample # 168	
Compound	**$\mu g/m^3$**	**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		Can # SDA1168 Tube	
Location: OBOD		Sample # 168	
Compound	**$\mu g/m^3$**	**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		Can # SDA184 Tube	
Location: OBOD		Sample # 184	
CO 78, ppm $CH_4$1778 ppm	**$\mu g/m^3$**	**ppbv-c**	**Percent**
Total Identified Hydrocarbons	16.8	28.1	31.5
Alkanes (Parafins)	10.8	18.0	20.2
Alkenes (Olefins)	2.1	3.5	3.9
Aromatics	3.9	6.5	7.3
Terpenes		0.0	0.0
Total Unidentified Hydrocarbons	36.7	61.3	68.6
Total Nonmethane Hydrocarbons	53.5	89.3	100.1
Compounds	**$\mu g/m^3$**	**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		Can # SDA184 Tube	
Location: OBOD		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		Can # SDA184 Tube	
Location: OBOD		Sample # 184	
Compound	**$\mu g/m^3$**	**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.

$$EF_x = \frac{\left(\frac{M_t}{V_t} - \frac{M_b}{V_b}\right) f_c}{C_{tot}}$$

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_{tot} = 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 nitrocellulose.
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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Appendix R

Tooele Burn Pan Study

D/AE TEST REPORT 03-86

DIRECTORATE FOR AMMUNITION EQUIPMENT
TOOELE ARMY DEPOT
TOOELE, UTAH 84074-5004

EVALUATION OF OPEN BURNING TRAYS

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Turner's

AUG 28 REC'D 86

XG-132

EVALUATION OF OPEN BURNING TRAYS

FINAL REPORT

March 1986

AMMUNITION EQUIPMENT DIRECTORATE

TOOELE ARMY DEPOT

TOOELE, UTAH 84074

PCN per Bryan
pg 7(a)

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SUMMARY

The U.S. Army Defense Ammunition Center and School, at Savanna, Illinois, commissioned the Ammunition Equipment Directorate to fabricate and test three open burning equipment items. The items consisted of a steel rectangular tray, a steel tray with a water filled outer shell, and a stainless steel grate. This equipment was tested by burning combinations of rocket propellant, TNT, and a mixture of combustible dunnage with wet propellant and TNT (in dunnage grate only). The planned testing of the rectangular tray with a modified wall, which was originally requested, was not done because the tray was destroyed by the preceding tests. An aluminum tray cover was fabricated and tested for fit and ease of use, and performed well.

Nine tests were conducted and the temperature and warpage data were collected and are included in this report.

The items tested performed successfully except for the use of the rectangular tray to burn TNT. The rectangular or "control" tray was severely warped during the first test in which TNT was burned. During the second test using one-third as much TNT, the tray was irreparably damaged. The burning of TNT in the water jacketed tray caused only minor warpage of the upper edge.

For each test in which propellant was burned, a small amount of propellant residue had been thrown from the tray and was scattered on the ground near the tray walls.

The results of these tests indicate that the rectangular tray is suitable for open burning of propellants, and the dunnage grate is satisfactory for burning dunnage with either TNT or propellant. The water jacketed tray withstood TNT burning much better than the control tray. It sustained only minor damage. The rectangular tray was unsuitable for burning TNT.

INTRODUCTION

This report summarizes the results obtained from testing three tray designs for burning propellants and high explosives. A grate for burning dunnage was also tested. The objective was to test and evaluate the prototypes, and generate temperature and warpage data for use in design modifications.

DESCRIPTION OF EQUIPMENT TESTED

1. Rectangular Tray

This tray is a simple rectangular box with dimensions 4 ft. W x 16 ft. L x 1 ft. H (Figure 1). The tray is supported by two 4 in. x 4 in. I-Beams and is attached at both ends with sliding tie down assemblies to allow for axial expansion and contraction. Both the rectangular tray and the water jacketed tray were fabricated from ASTM A 285 grade C steel plate of 1/4 in. thickness. The tray was tested by burning M26 triple based propellant and flaked TNT.

2. Water Jacketed Tray

This tray consisted of an outer shell and an inner trough supported by 2 in. x 2 in. rectangular tubing. The inner trough was welded to the outer shell, and a series of vents were cut into the upper outer shell walls (Figure 2). The tray was designed to hold about 60 gallons of water between the shell and trough. Each end of the tray is supported by two 4 in. x 4 in. I-beams. The tray was tested with a 1 inch, 2 inch, and 3 inch layer of TNT, successively.

3. Dunnage Grate

The Dunnage Grate (Figure 3) was fabricated with 1 in. x 11 guage stainless steel square tubing. The grate assembly was designed to fit into the rectangular tray and to be used to burn mixtures of either wet explosives or wet propellant with dunnage. This assembly was tested by burning dunnage with both wet M26 propellant, and wet, flaked TNT.

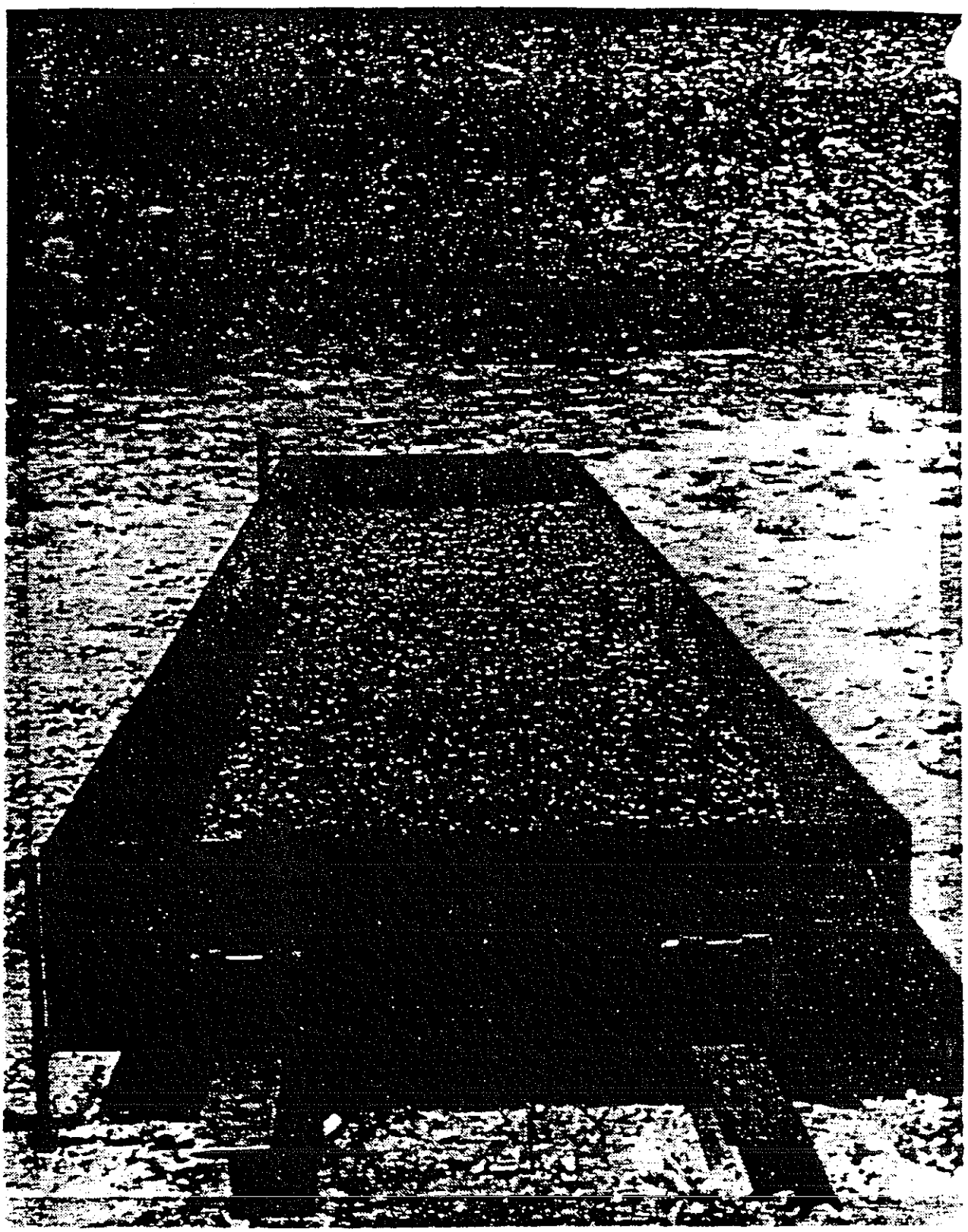


Fig. 1 Rectangular Tray with Propellant

Minor modifications to the original USADACS designs (DWGS AC - 00000346-350) were made in order to simplify construction, correctly align drains, and to obtain a proper fit of the components. The overall design, dimensions, and materials were unchanged.

4. Modified Rectangular Tray

It was planned to re-test the rectangular tray after replacing one of the long sides with a modified side wall containing several configurations of louvers and vents. The intention was to test how the effect of cooling, by natural convection, influences tray wall temperatures and warpage. Unfortunately, the rectangular tray was severely damaged and it was not feasible to weld the louvered side onto the control tray. Therefore, this design modification was not tested.

TEST METHODS

AED Test Plan 08-85 provides a comprehensive description of the planned test procedures, equipment, and facilities. The following information is either additional, or supersedes that contained in the test plan.

All of the testing was conducted at the AED test facility, site number six (Figure 4).

In Table 1, the tests conducted are summarized in chronological order.

TABLE 1. OPEN BURNING EQUIPMENT TESTS

TEST #	EQUIPMENT	MATERIALS BURNED
1	Rectangular Tray	Propellant, 3 in. Layer
2	Rectangular Tray	Propellant, 3 in. Layer
3	Rectangular Tray	TNT, 3 in. Layer
4	Rectangular Tray	TNT, 1 in. Layer
5	Dunnage Grate	Dunnage-25 cu. ft. Wet Propellant-155 lb (Dry Wt.)
6	Dunnage Grate	Dunnage-30 Cu. Ft. Wet TNT-185 lb (Dry Wt.)
7	Jacketed Tray	TNT, 1 in. Layer
8	Jacketed Tray	TNT, 2 in. Layer
9	Jacketed Tray	TNT, 3 in. Layer

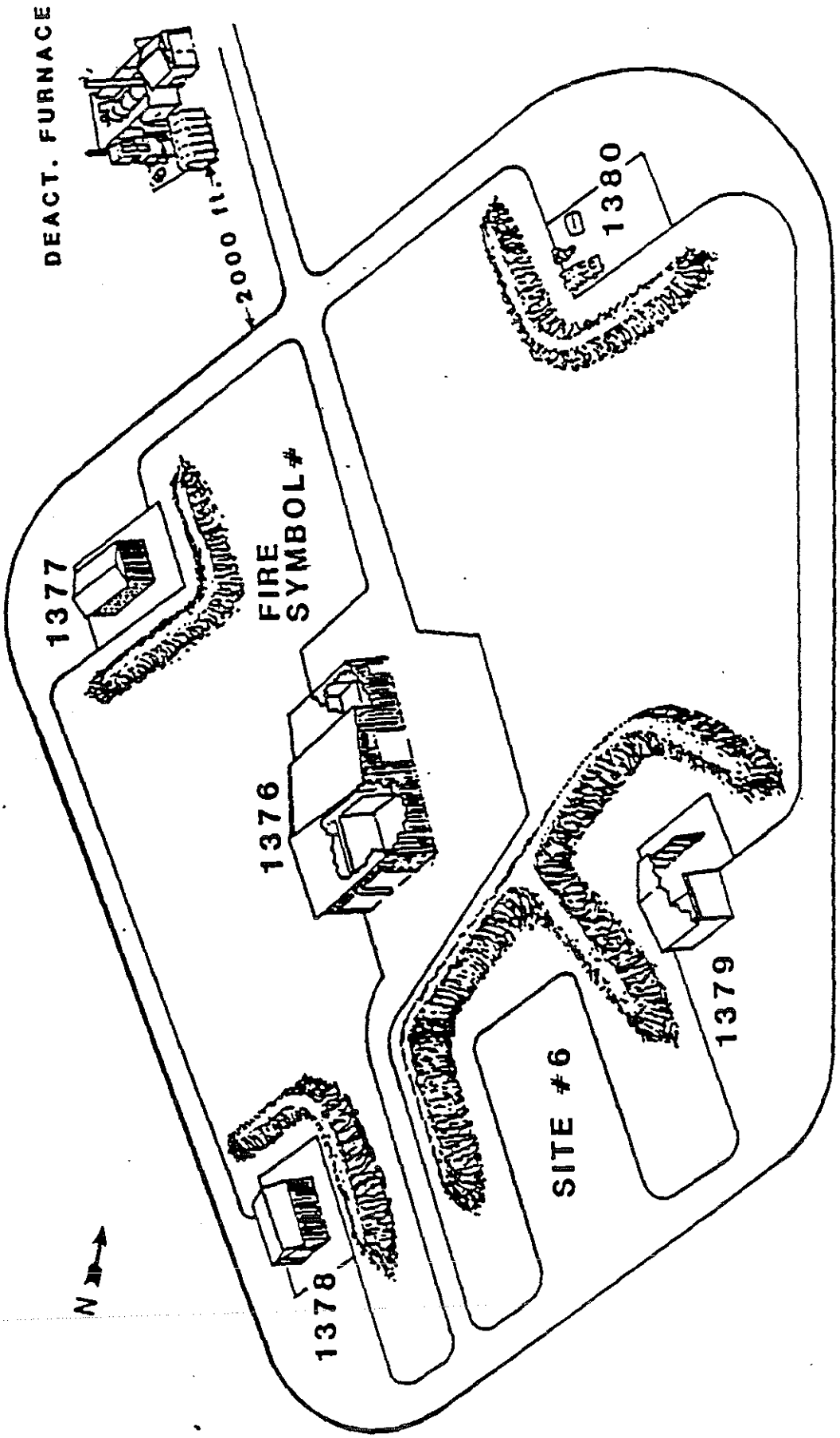
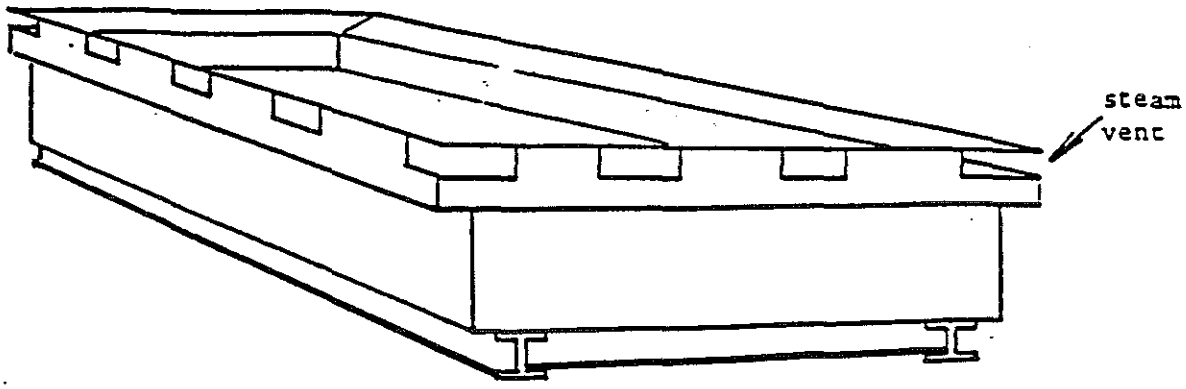
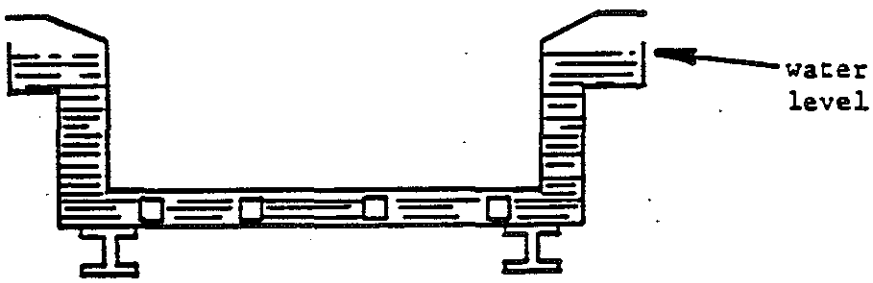


Fig.4 AED Test Facility



Water Jacketed Tray



Cross Section

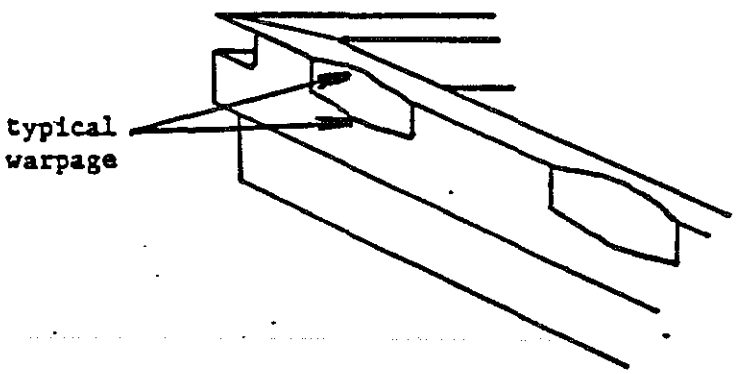


Fig.2 Water Jacketed Tray

Fig. 3 Dunnage Grate and Rectangular Tray

Thermocouples (TC's) were installed in one end and one side of the dunnage grate (Figure 5). The placement of the TC's was intended to yield representative temperatures of the different areas of the grate, utilizing the symmetry of the dunnage grate. Since the grate was placed in the center of the rectangular tray during testing, four thermocouples were utilized in the tray to monitor tray temperatures as well. The placement of thermocouples in the jacketed tray is described in Figure 8.

A wooden screed was used to level the explosives or propellants in the trays. Each test burn was initiated with an M55 rocket igniter and several handfuls of dry excelsior. Immediately prior to each burn the wind direction and speed was measured with an axial vane anemometer.

TEST RESULTS

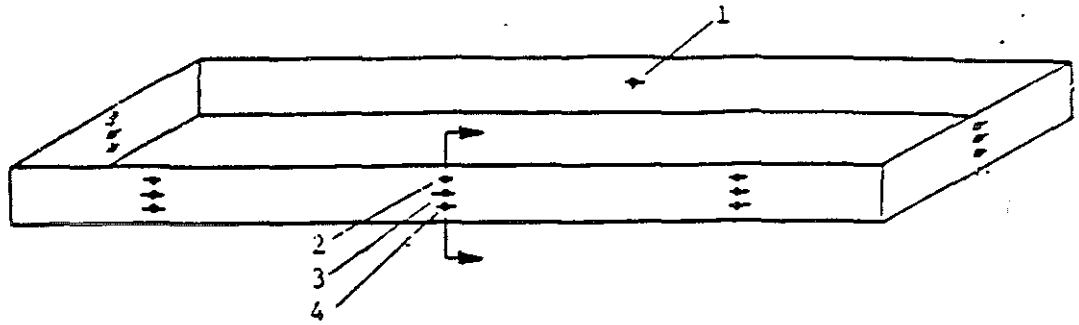
A summary of the test data is given in Table 2. In the Table, the maximum tray temperatures are given, as well as the "average maximum temperatures" of the tray surfaces. The average maximum temperature for each test is the arithmetic mean of the maximum temperatures recorded by each thermocouple.

For the propellant burns (Tests 1 & 2) the combustion was so rapid that the maximum temperatures were reached essentially simultaneously. For the much slower TNT and dunnage burns, the maximum temperatures at each TC did not occur simultaneously; rather, they occured when the moving combustion zone was in close proximity to the thermocouples.

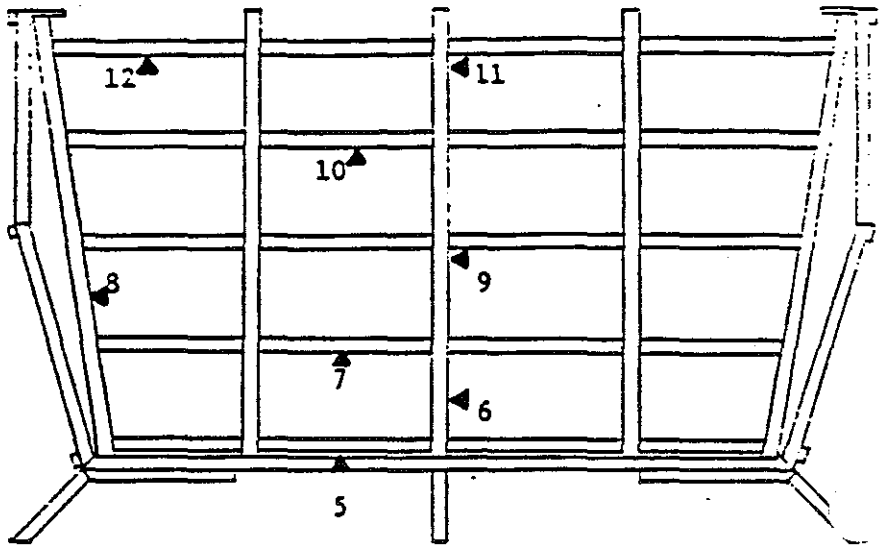
The data of Table 2 shows that the burning of TNT produces significantly higher temperatures for longer periods of time than does the burning of propellant. A detailed synopsis of the test results, including temperature profiles and warpage data is given in the appendix. The temperature profiles illustrate that the heating of the tray components is more uneven when TNT or dunnage is burned than when propellant is burned.

The salient result of these tests is that TNT burning is destructive to the rectangular control tray. Figure 6 illustrates the extensive warpage

RECTANGULAR TRAY



DUNNAGE GRATE (END VIEW)



19 bottom front
20 bottom middle
21 bottom rear
(along centerline)

DUNNAGE GRATE (SIDE VIEW)

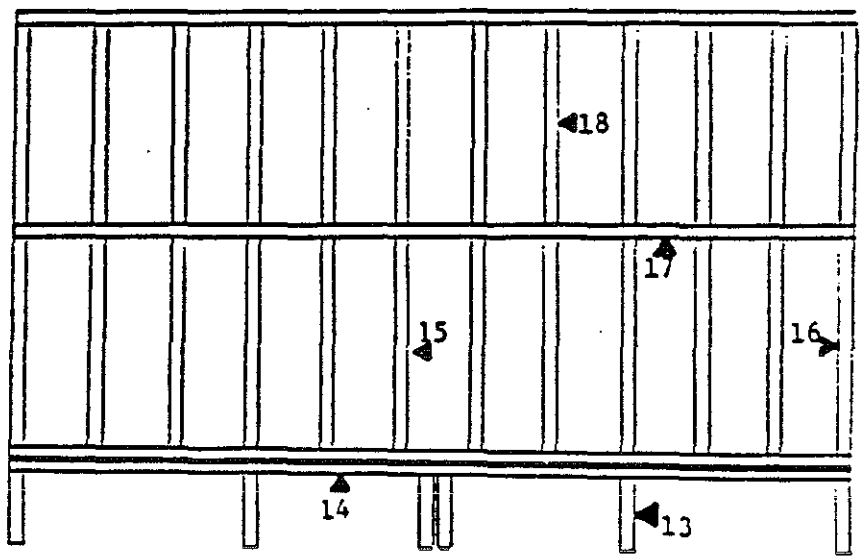


Fig. 5 Thermocouple placement, dunnage grate / rectangular tray

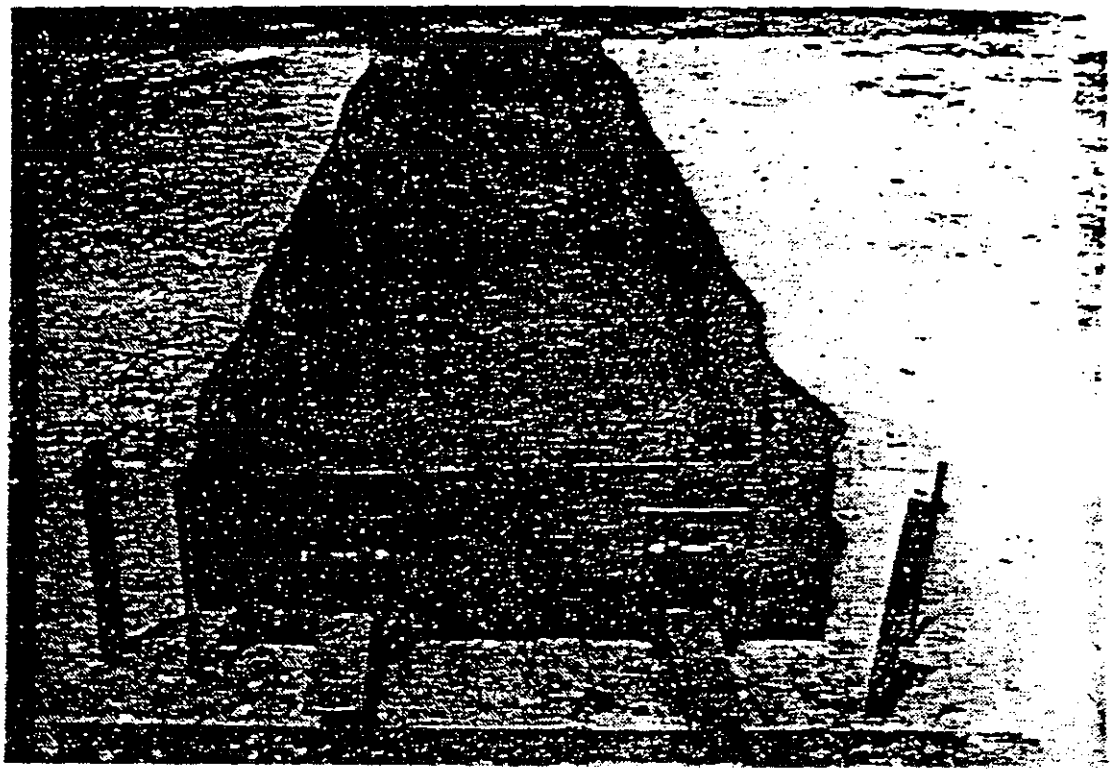


Fig. 6a Tray Warpage

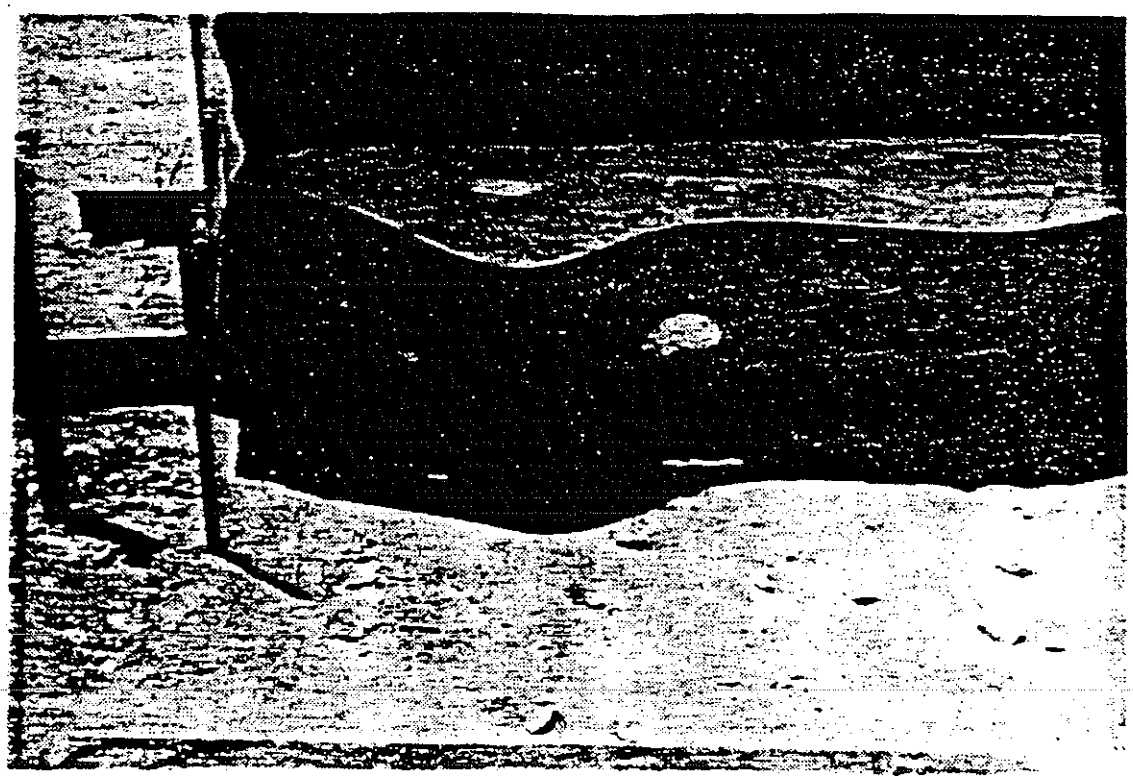


Fig. 6b Severe Heat Destruction

and structural damage that resulted from test No. 3 (a three inch layer of TNT burned in the control tray).

In addition to the tests summarized in Table 2, the jacketed tray was used by AED personnel to burn some excess explosive D. The temperatures were recorded for 2 out of 4 of these burns, and the temperature results were similar to those from burning flaked TNT in the jacketed tray (tests 7, 8, 9). No further damage to the tray was observed, as a result of these 4 additional burns.

CONCLUSIONS

1. Rectangular Tray

The basic design is probably adequate for burning propellant. However, the expected life when used on a production basis is unknown. Improvement is needed to control propellant that is ejected during burning since the purpose of the tray is to contain the residue.

The burning of TNT in this tray design is not feasible. Extreme temperatures cause severe thermal stresses which result in permanent warpage and metal destruction. Based on the results of these tests, two factors appear to be related to tray warpage - temperature and structural support of tray walls.

The tray cover designed by USADACS required two persons to put it into place. The cover consists of two halves, but only one half was built and tested. Overall, the cover design was suitable. However, after the control tray warped, the cover no longer fit properly.

2. Water Jacketed Tray

This tray design performed well for TNT burning, and it is assumed that it would also perform well for propellant burning. The water jacket prevented extreme temperatures from developing during the TNT burn tests (see Table 2). The effect of the water jacket in moderating the wall

TABLE 2. Summary of Data

Test #1 (3" Propellant), Rectangular Tray

Amount Burned	16 cu ft, (610 lb)	Hottest Tray Wall Temp	242.4° F
Duration of Burn	9 sec	Flame Temp	1210.2° F (From TC)
Evidence of Tray Damage	None	Avg. Max. Temp of Tray Surfaces	192.06
Type & Amount of Residue	None	Ambient Temp	90.5° F (Shade)
		Wind Speed	353 ft/min (.0114) = 4.01 mph

Test #2 (3" Propellant), Rectangular Tray

Amount Burned	16 cu ft, (610 lb)	Hottest Tray Surf. Temp	255.4° F
Duration of Burn	12 sec	Flame Temp	1471.8° F (TC #21)
Tray Damage	None	Avg. Max. Temp of Tray Surfaces	182.23° F
Amount of Residue	1-1/2 cu in	Ambient Temp	84.1 (Shade)
		Wind Speed	922 ft/min (.0114) = 10.5 mph

Test #3 (3" Flaked TNT) Rectangular Tray

Amount Burned	16 cu ft, (733 lb)	Hottest Tray Surf. Temp	2461.3° F
Duration of Burn	37 min-14 sec	Flame Temp	Greater than 2000° F
Tray Damage	Extensive	Avg. Max. Temp ofMetal Surfaces	1461.8° F
Amount of Residue	318 cu. in.	Ambient Temp	88.6° F
		Wind Speed	3.05 mph

Test #4 (1" Layer TNT) Rectangular Tray

Amount Burned	255 lb	Hottest Tray Wall Temp	1260° F
Duration of Burn	13 min 55 sec	Flame Temp	1743.1° F
Evidence of Tray Damage	Extensive	Avg. Max. Temp of Tray Surfaces	807.7° F
		Ambient Temp	94° F
		Wind Speed	300 ft/min (.0114) (3.42 mph)

Test #5 Dunnage Grate (3" Wet Propellant)

Amount Burned	25 cu ft dunnage + 155 lb Propellant (Wet, 20% H_2O)		
		Hottest Grating Temp	1083.8
Duration of Burn	1 hr 2 min 25 sec	Hottest Tray Temp	543.5
Grate/Tray Damage	None	Avg. Max. Temp of Grate	682.2° F
Type/Amount of Residue	Approx-1.5 - 2 cu ft Charcoal, Metal Banding, Nails, Fiberglass, etc.	Avg. Max. Temp of Tray	509.62° F
		Ambient Temp	83.4° F
		Wind Speed	169 ft/min (1.93 mph)

Test #6 Dunnage Grate (3" 20% Wet, Flaked TNT)

Amount Burned	(30 cu ft dunnage + 185 lb TNT)		
		Hottest Grating Temp	2121.2° F
Duration of Burn	1 hr 26 min 21 sec	Hottest Tray Temp	1257° F
Grate/Tray Damage	None	Avg. Max. Temp (Grate)	1645.4° F
Type/Amount of Residue	Approx 1 cu ft (See Test #5)	Avg. Max. Temp (Tray)	1062.4° F
		Ambient Temp	81.9° F
		Wind Speed	255 ft/min (2.91 mph)

TABLE 2. Summary of Data (cont'd)

Test #7 Jacketed Tray (1" TNT)

Amount Burned	82 1/2 lb	Hottest Tray Temp	1019.9
Duration of Burn	6 min 16 sec	Avg. Max. Temp	335.9° F
Tray Damage	Slight Warpage of Top Edge	Ambient Temp	73.6° F
Type/Amount of Residue	200-300 cu in	Wind Speed	689 ft/min (7.85 mph)

Test #8 Jacketed Tray (2" TNT)

Amount Burned	170 lb	Hottest Tray Temp	1024.1° F
Duration of Burn	13 min 31 sec	Avg. Max. Temp	367.6° F
Tray Damage	Slight Warpage of Top Edge	Ambient Temp	68.2° F
Type/Amount of Residue	200-300 cu in	Wind Speed	0

Test #9 Jacketed Tray (3" TNT)

Amount Burned	255 lb TNT	Hottest Tray Temp	1385° F
Duration of Burn	13 min 31 sec	Avg. Max. Temp	396.4° F
Tray Damage	Slight/Moderate Warpage of Top		
		Ambient Temp	73° F
Type/Amount of Residue	200-300 cu in	Wind Speed	104 ft/min (1.19 mph)

temperature is indicated by the fact that the hottest temperature readings were from thermocouples located closest to areas of the tray not in contact with the water jacket.

TEST	THERMOCOUPLE	MAXIMUM TEMPERATURE
#7 (1" TNT)	#2,	1019.9 °F
#8 (2" TNT)	#5,	1024.1 °F
#9 (3" TNT)	#2,	1378.4 °F

(See Figure 7 for location of Thermocouples)

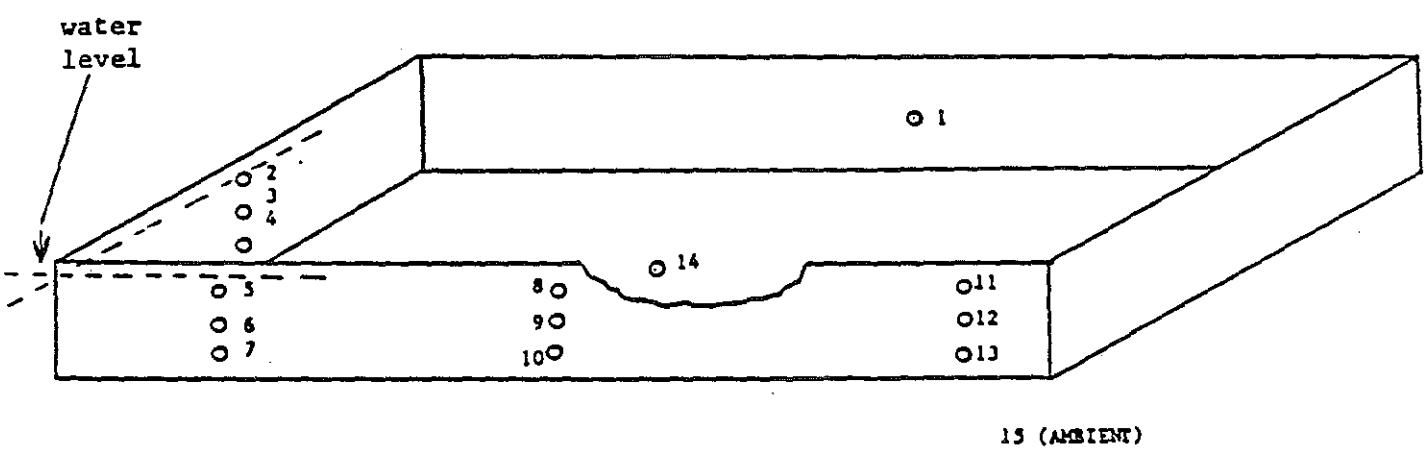


Fig. 7 Thermocouple placement, jacketed tray
(inner trough shown only)

The only damage sustained by the tray during testing was mild warpage of the upper edge around the vent openings (see Figure 2). These upper edge areas of the tray were the farthest removed from the water jacket, which functioned as a heat sink, and presumably reached higher temperatures than the rest of the tray. The metal plate around the vent openings is also less rigidly supported than the rest of the tray.

3. Dunnage Grate

The grate design performed well in the two tests in which dunnage mixed with propellant and explosive were burned. The structure sustained no detectable damage as a result of the tests. There was a minor difficulty in that the pellets of propellant were not adequately contained in the grate. A small amount of the pellets fell through the dunnage and on to the bottom of the tray. After the burn, the pellets that fell from the grate had settled in pockets of water (from the wet propellant) in the tray bottom, and were unburned.

In addition to the requirements specified in the Scope of Work, USADACS informally requested that AED also provide suggestions of how to improve the trays. The suggestions below were based entirely on the experience of testing the trays. It is emphasized that the suggestions were not researched, are first impressions, and are not to be construed as official recommendations of AED.

Problem	Suggestion
Propellant ejected from tray	Design a screening feature, install apron around tray from which the residue can be easily collected.
Warpage, metal destruction from TNT burning (Control Tray)	Line tray with refractory material. add a supporting framework to resist deformations of the tray walls.
Containment of propellant in dunnage grate	Improve loading procedure, design a screen in bottom of grate.

APPENDIX
DETAILED RESULTS OF TESTS

DETAILED RESULTS OF TESTS

Test #1: 3 in. Layer (610 lb) of M-26 Propellant

The combustion commenced immediately after the igniter was fired. The reaction zone moved rapidly away from the ignition point and was extremely vigorous. The burn was short lived and produced a moderate amount of grey-white smoke. The intensity of the flame touched off small grass fires in the immediate area.

The tray dimensions were not changed, and no distortion, or metal surface damage occured as a result of the test. Little residue was found inside the tray, but a small amount of propellant had been ejected from tray and burned on the ground.

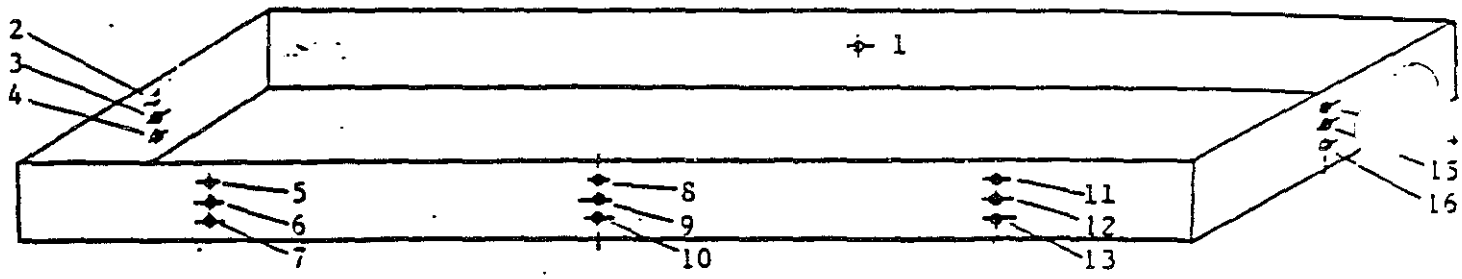
The positioning of the thermocouples in the rectangular tray are given in Figure 8. In Figure 9, the temperature profiles at one end of the tray are shown.

Test #2: 3 in. Layer (610 lb) of M-26 Propellant

Results identical to Test No.1, no tray damage.

Test #3: 3 in. Layer of Flaked TNT

The combustion of TNT was totally differant that with propellant. The burn was very slow to initiate, and about 20 minutes had passed before the reaction attained peak intensity (as judged by the appearance of the flames and smoke). A voluminous quantity of opaque black smoke was generated. The tray and nearby ground were soiled with black soot. The duration of the burn was about 40 minutes, and the combustion zone advanced very slowly across the tray. The combustion was not nearly as violent as it was with propellant. It appeared as though the TNT melted and became a liquid as it burned.



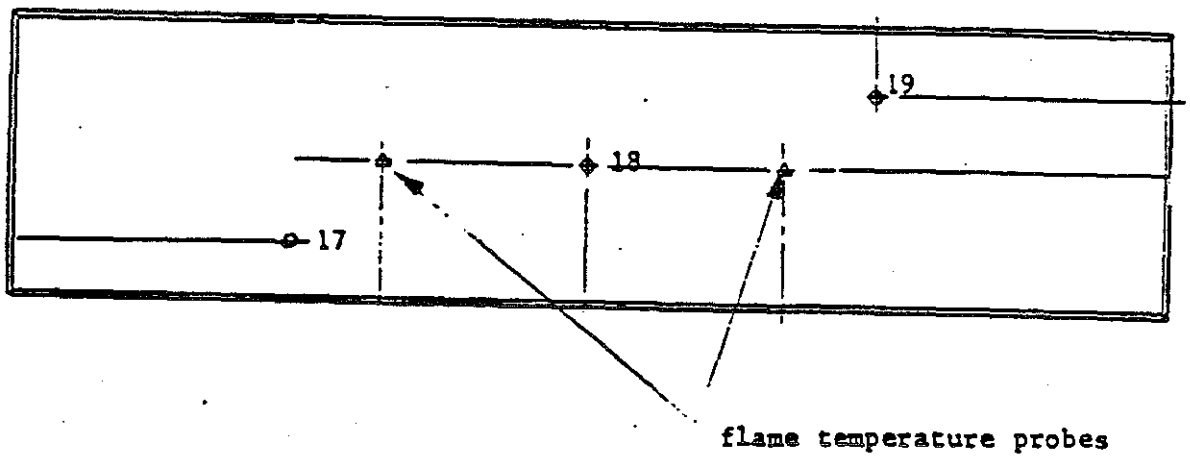


Fig. 8 Numbering of Thermocouples ,
rectangular tray

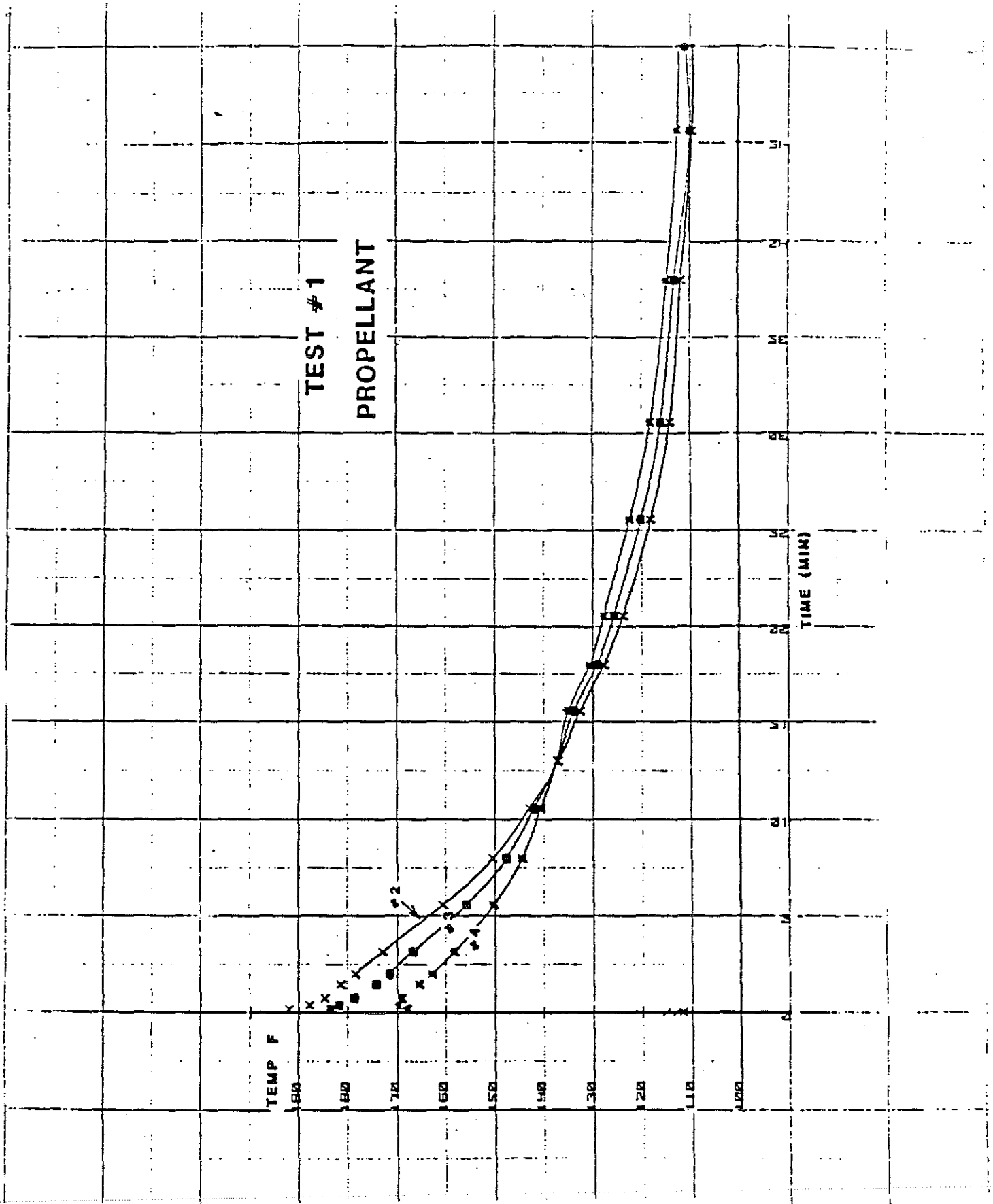


Fig. 9 Temperature profiles,
test no. 1

The tray was extensively damaged during this test. Considerable warpage and metal fusion was evident on the walls and floor. Melting was so severe that holes formed in one end of the tray. During the test, one part of the tray was glowing red. In a later inspection the fused areas had a grey, brittle, flaked appearance and drips of molten metal were present.

Measurements of tray warpage are given in Figure 10. Warpage excursions of one side wall and the floor were measured at 2 foot intervals. The most extreme warpage and damage occured in the other side wall which was not measured. In general, the walls moved out from the center of the tray and the floor bowed upward in the center, forming a convex shape. When viewed from the side at ground level, the tray had buckled upward about 1-1/2 inches above the I beams in the center.

The temperature profiles of the tray walls are shown in Figures 11 A, B, C, and those of the tray floor in Figure 11 D. The different shapes of these curves illustrate the slow movement of the combustion zone and the resulting uneven localized heating.

The portion of the tray which sustained the most damage coincided with the ignition location. A depression in the tray floor was present at this location.

Test #4: 1 in. Layer of TNT

Prior to this test the 4 foot section of severely damaged wall was repaired by cutting out the damaged section, and welding new plate of the same material into place.

A lesser amount of TNT was burned so that quantity of TNT burned could be related to tray temperatures and warpage. Also there was concern about the tray becoming totally destroyed. Of course, since the tray was already warped before this test, the degree of warpage resulting from the smaller amount of TNT could not be directly related. The burn was initiated from the center of the tray.

The burn progressed similarly as in Test No. 3, except it was shorter in duration and the average and maximum tray temperatures were lower (see Table 2 of report). As in the previous test, the maximum wall temperatures were in close proximity to the ignition point (1260°F (TC#1), 1037°F (TC#8)). In this test and the previous test, the flames lingered in the depression of the tray floor, suggesting that molten TNT was pooling and burning in the low area.

The tray warpage measurements given in Figure 12 are relative to the previous warpage (i.e., the total warpage in relation to the original dimensions is found by adding the measurements of Figures 12 and 14). The warpage occured in the same direction but with a smaller magnitude. The repaired section of the tray had again become severely warped and metal fusion had occurred.

Test #5 (Dunnage Grate with Dunnage and Wet Propellant)

Due to the cylindrical shape of the propellant pellets, it was difficult to keep the propellant on top of the bed of dunnage. About 5% of the propellent sifted through or rolled off of the dunnage onto the tray.

Because the tray bottom was warped from previous testing, the grate was unstable and rocked back and forth. Large stones were placed between the tray and the grate to provide stability.

The propellant burned violently and ignited immediately as it did in Tests 1 and 2. The wetness didn't seem to effect the rate of the burning.

The propellant was consumed within several seconds after the ignition. The dunnage continued to burn for about an hour leaving a small pile of charcoal, nails, ash, fiberglass and metal banding.

The grate and tray reached moderatly high temperatures (Table 2), but no warpage of the grate or additional tray warpage had occurred.

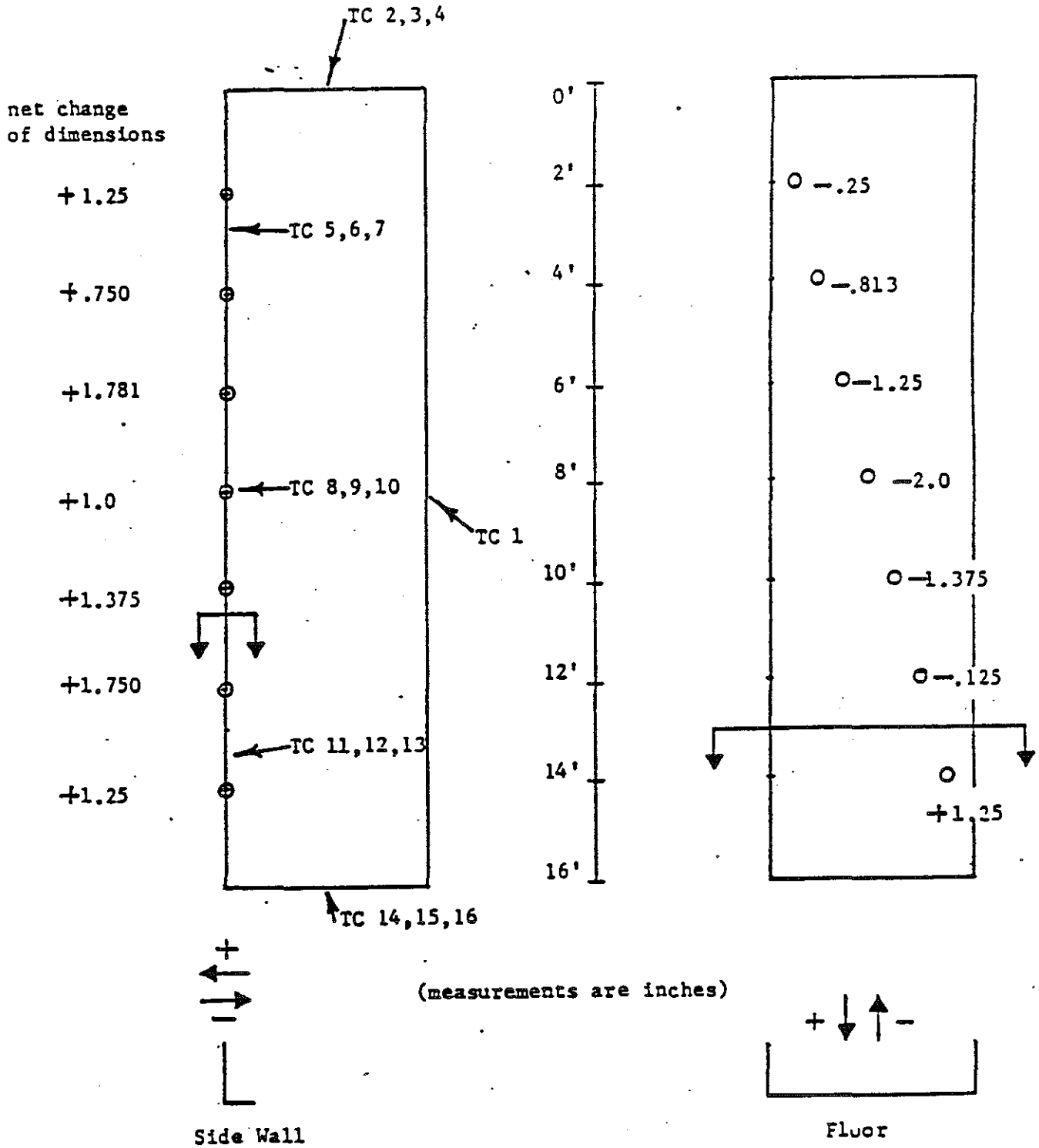


Fig. 10 Tray Warpage, Test 3

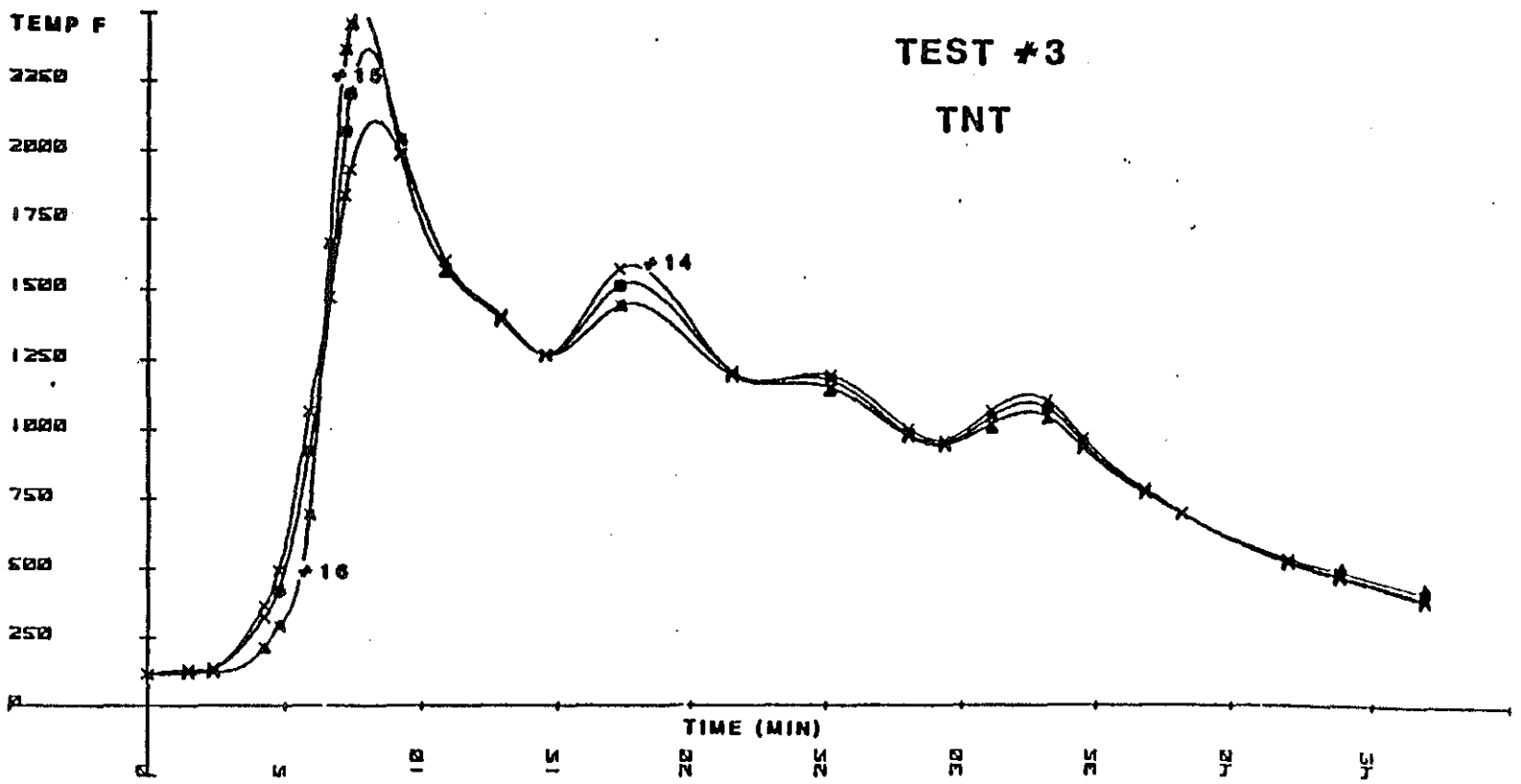


Fig. 11a Temperature profiles,
Test 3

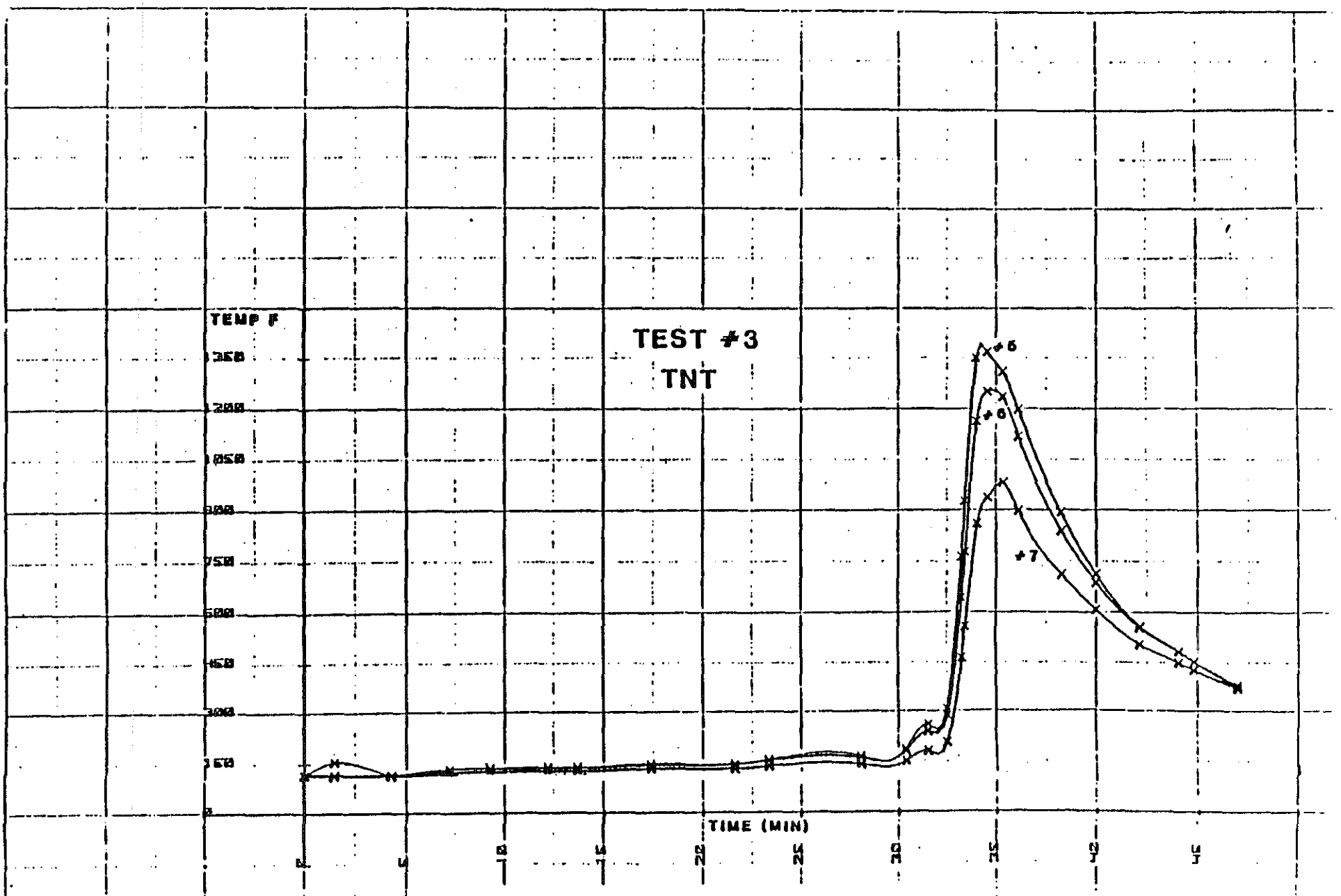


Fig. 11b Temperature profiles,
Test 3

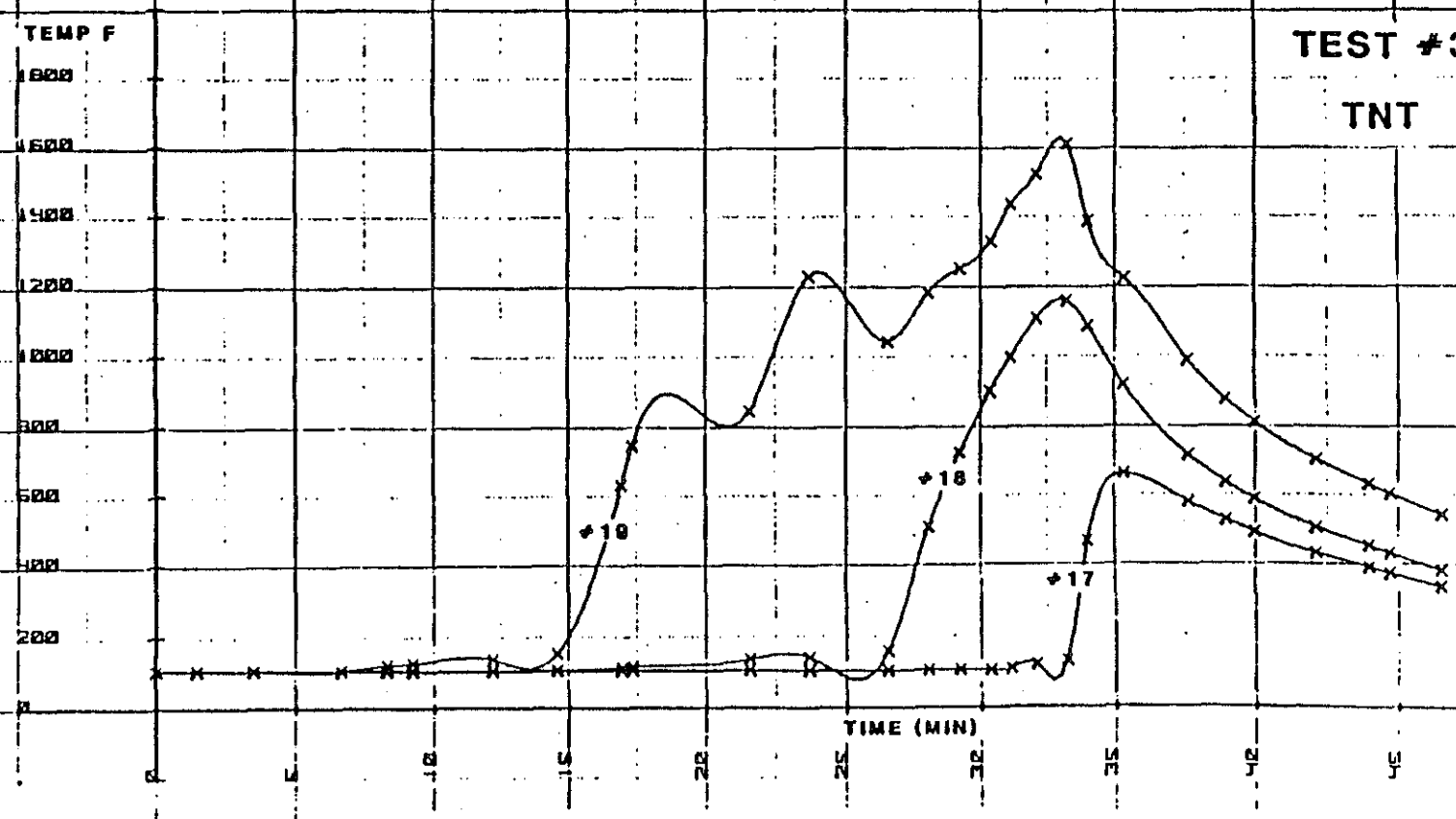


Fig. 11c Temperature profiles,
Test 3 (floor)

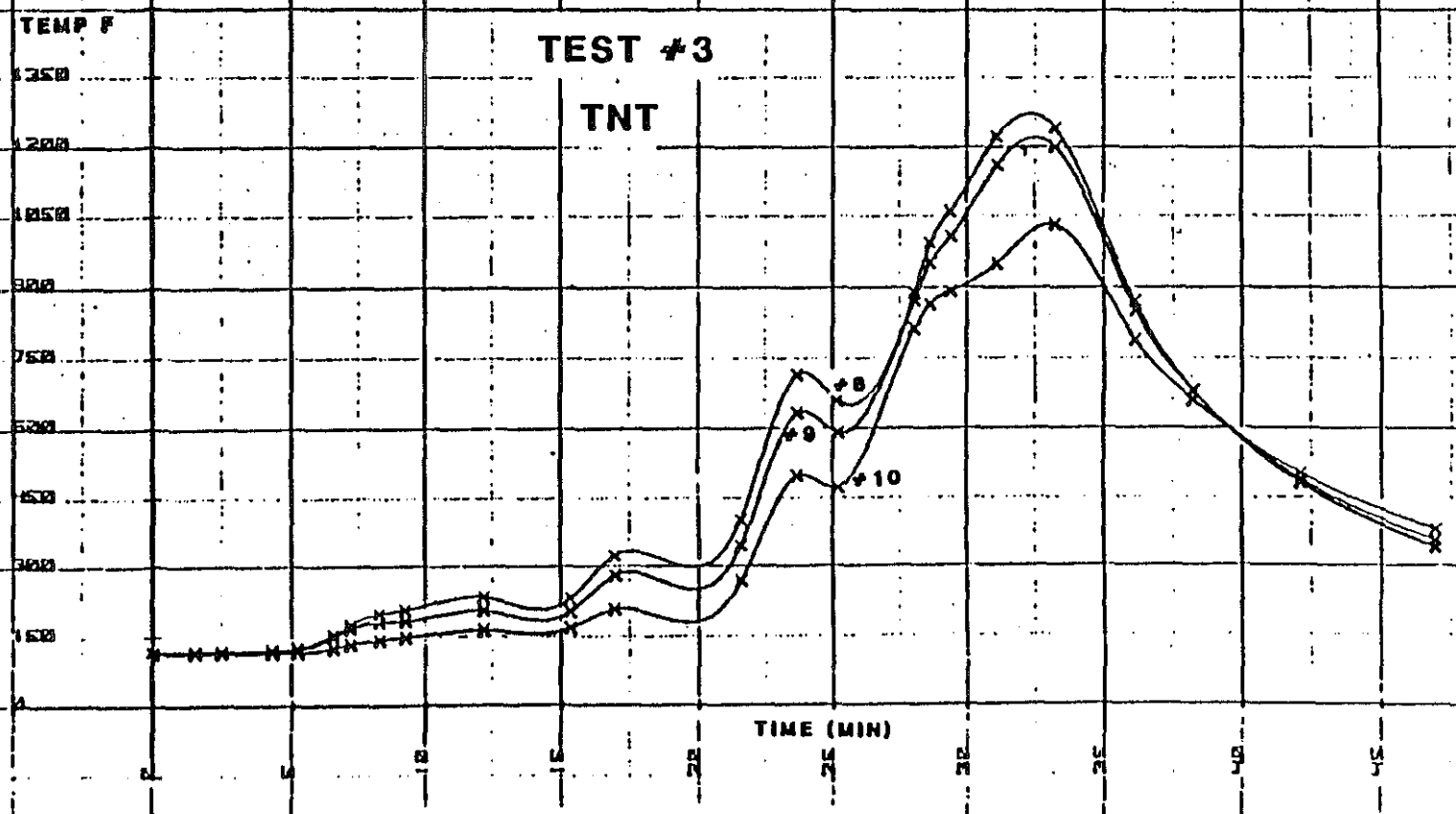


Fig. 11d Temperature profiles,
Test 3

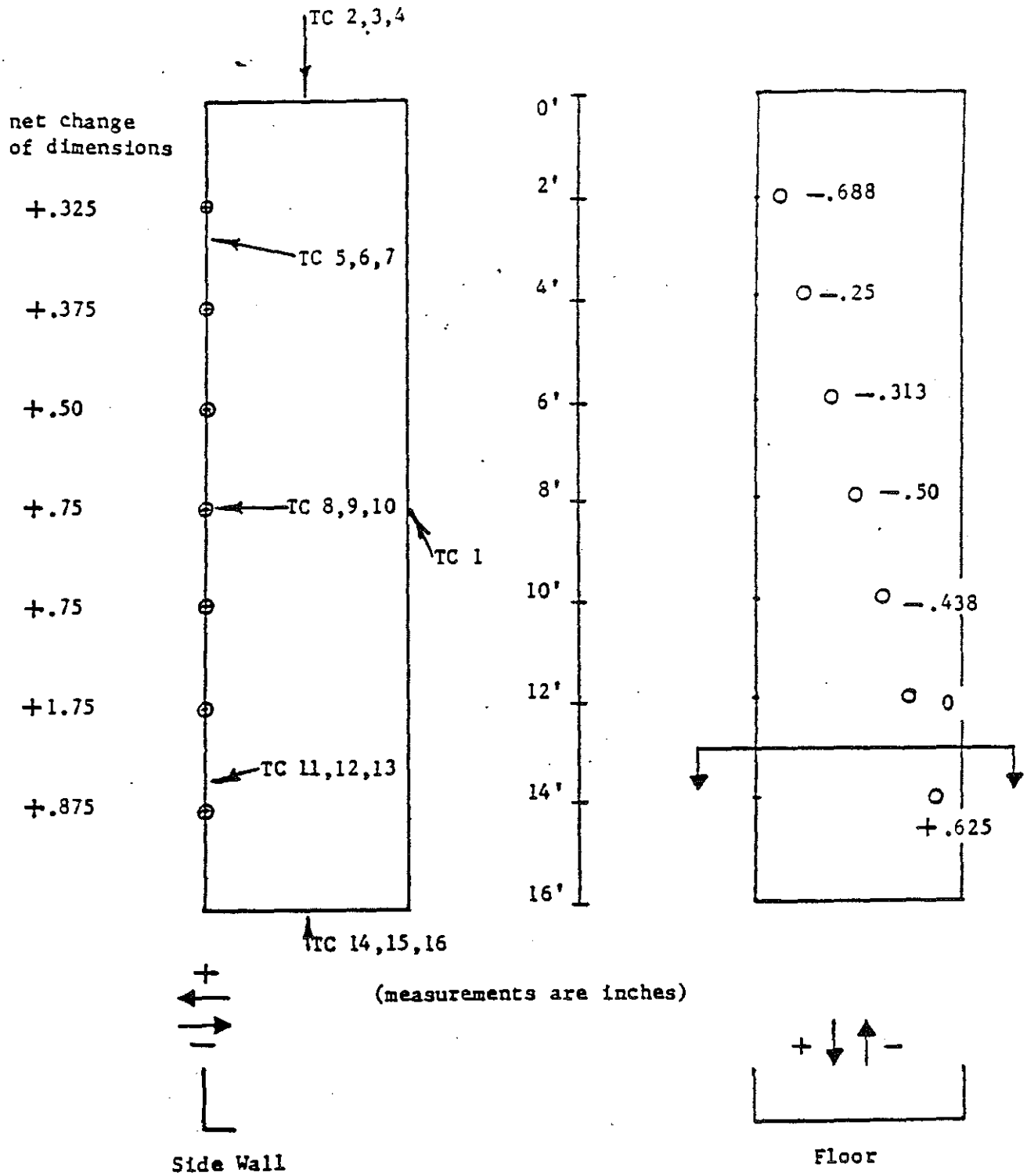


Fig. 12 Tray Warpage, Test 4

Test #6 (Dunnage Grate With Dunnage and Wet Flaked TNT)

The wet TNT was easier to place on the dunnage bed and did not tend to spill or fall off as much as the propellant.

The explosive/dunnage mixture was slow to catch fire and the wetness apparently did not effect the burning rate for TNT. As in the other TNT burns, a black, opaque plume of smoke was generated.

The maximum temperatures that were measured in the grate and the tray were much hotter (see Table 2) than those of the previous test. Nevertheless, no grate or tray damage (additional warpage or metal surface damage) was detected.

Test #7, 8, 9 (Water Jacketed Tray, Flaked TNT)

In Tests 7, 8, and 9, layers of TNT having 1, 2, 3 inches of depth, respectively, were burned in the water jacketed tray. In each of the tests, the maximum and average temperatures were about 50-75 percent lower than those attained with the plain tray in Tests 3 and 4 (see Table 2).

During these tests no steam or boiling of the cooling water was observed. The water level fell by about 1/8 inch after each burn and cool down period.

The highest temperatures were measured at locations that were either on or above the water line, indicating that the water jacket played an important role in reducing the tray wall temperature.

The tray damage from each of these tests was minor and was limited to warpage of the top edge directly over each of the vents. The rest of the tray was not damaged or warped at all.

Appendix S - HWAD Dispersion Modeling

DISPERSION MODELING IMPACT ANALYSIS
HAWTHORNE ARMY DEPOT
CLASS II AIR QUALITY IMPACT ANALYSIS

SOC CORPORATION
HAWTHORNE, NEVADA

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1.0 AIR QUALITY IMPACT ANALYSIS

1.1 INTRODUCTION

Tetra Tech EM, Inc. (Tetra Tech) completed this dispersion modeling impact analysis for the Hawthorne Army Depot (HWAD) in support of a Class I-B Operating Permit to Construct Modification Application for HWAD. HWAD currently operates under a Title V operating permit issued by Nevada's Department of Environmental Protection (NDEP). The permit must be renewed every five years. As part of the Operating Permit to Construct Modification Application, dispersion modeling is required to demonstrate that the facility complies with ambient air quality standards. This document presents the results of the dispersion modeling conducted to evaluate potential Class II air quality impacts from air emission sources located at HWAD.

The impact analysis estimates the air quality impact of potential emissions of nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), and fine particulate matter with aerodynamic diameter 10 microns or less (PM_{10}) from HWAD activities. The HWAD activities included in the modeling are the Main Base; Old Bomb; the Plasma Arc Ordnance Demilitarization System (PODS), the Bulk Energetics Demilitarization System (BEDS), the Hot Gas Demilitarization System (Hot Gas), the RF-9 demilitarization system (RF-9), the soil vapor extraction (SVE) system, and a pallet heater. Tetra Tech completed the dispersion modeling in accordance with the guidance and protocols outlined in the NDEP *Permit Guidance: Modeling Guidelines* (NDEP 2008), and EPA's *Guideline on Air Quality Models (Revised)* (EPA 2005).

Modeling was conducted to determine whether potential impacts from HWAD air emissions are below the National Ambient Air Quality Standards (NAAQS) and the Nevada Ambient Air Quality Standards. Table 1-1 shows the NAAQS and Nevada standards that HWAD must meet to demonstrate compliance.

TABLE 1-1
AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging Period	National Ambient Air Quality Standard ($\mu g/m^3$)	Nevada Ambient Air Quality Standard ($\mu g/m^3$)
Nitrogen Dioxide	Annual	100	100
Sulfur Dioxide	Annual	80	80
	24-hour	365[a]	365
	3-hour	1,300[a]	1,300
Carbon Monoxide	8-hour	10,000[a]	10,000[b]
	1-hour	40,000[a]	40,000
PM_{10}	Annual	n/a	50
	24-hour	150[a]	150
Ozone	1-hour	235[a]	235

Notes:
$\mu g/m^3$ = micrograms per cubic meter
PM_{10} = Particulate matter with aerodynamic diameter less than or equal to 10 microns
a Not to be exceeded more than once per calendar year
b 7,000 $\mu g/m^3$ at areas equal to or greater than 5,000 feet above Mean Sea Level

The following sections describe the procedures used for the dispersion modeling analyses. Modeling for Old Bomb was previously completed using the Open Burn/Open Detonation Dispersion Model (OBODM). Because the Old Bomb facility and activities at the facility have not changed, this previously completed modeling will be incorporated into this modeling analysis. The maximum modeled impacts from Old Bomb will be added to the maximum modeled base-wide AERMOD impacts, regardless of the location of maximum impacts.

This document identifies the technical approach used for the dispersion modeling impact analysis. Dispersion modeling estimates the ambient air quality impacts from HWAD operations. Modeling was performed to estimate the total pollutant concentrations resulting from pollutant emission sources located at HWAD. The modeling evaluated impacts of SO_2, PM_{10}, NO_2 and CO for comparison with the NAAQS. Modeled concentrations of NO_x were converted to NO_2 by multiplying by the U.S. Environmental Protection Agency (EPA) empirically derived scaling factor of 0.75. Modeled concentrations were estimated for each criteria pollutant and applicable averaging periods.

1.2 MODELING METHODOLOGY

The dispersion modeling analysis was performed to estimate the total pollutant concentrations resulting from HWAD operations. The modeling evaluated impacts of SO_2, PM_{10}, CO and NO_2 for comparison with the NAAQS. Modeling for compliance with the NAAQS was conducted using all existing HWAD sources. Modeling results were compared to the associated National and Nevada AAQS.

1.2.1 MODEL SELECTION AND SETUP

The *Guideline on Air Quality Models (Revised)* (EPA 2005) recommends that the AMS/EPA Regulatory Model (AERMOD) be used for source-specific analysis emission sources for a wide range of regulatory application in all types of terrain (EPA 2005). The AERMOD model is a steady-state Gaussian plume model that is appropriate for estimating pollutant concentrations in flat or complex terrain at distances to 50 kilometers, and for averaging times from one hour to one year. Because of the elevated terrain from the Wassuk mountain range to the west and south of HWAD, a model's ability to address complex terrain features is important. The recommended applications of the AERMOD model are consistent with the needs of the HWAD impact analysis; therefore, the AERMOD model (Version 07026) was used to evaluate maximum pollutant concentrations in ambient air from HWAD emission sources for comparison with the NAAQS. AERMOD was run using all the AERMOD regulatory default options, including use of elevated terrain algorithms, stack-tip downwash, calms processing routines, and missing data processing routines.

1.2.2 SOURCE INPUT DATA

Emission inventories for CO, NO_x, PM_{10}, and SO_2 were obtained from HWAD. The HWAD emission sources modeled for the analysis include the Main Base sources, Old Bomb, PODS, BEDS, Hot Gas, RF-9, the SVE system, and a pallet heater. Figure 1-1 shows the locations of these emission sources. Discharges from some material handling sources are oriented in a horizontal direction. These sources are represented with discharge velocities of 0.001 meters per second (m/s). Table 1-2 shows the emission rate and stack parameters for each modeled source.

Annual average pollutant concentrations were modeled using proposed yearly emission rates, and short-term pollutant concentrations were modeled using proposed hourly emission rates.

FIGURE 1-1
HWAD EMISSION SOURCES

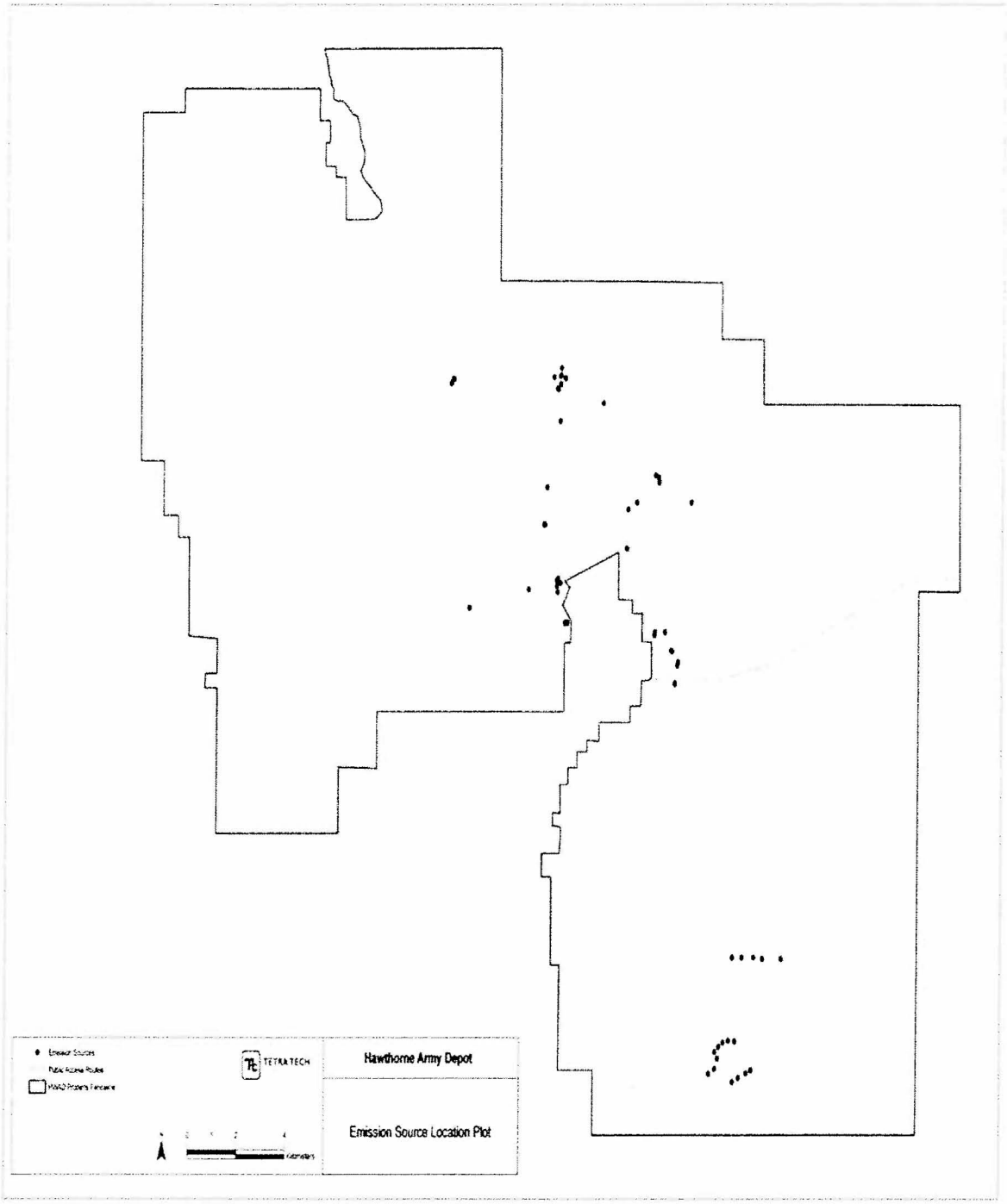


TABLE 1-2

POINT SOURCE EMISSION RATES AND STACK PARAMETERS

Source ID	Source UTM Location		Elevation	Annual Hours of Operation (hr/yr)	Stack/Release Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)	Long-Term Emission Rates (g/s)			Short-Term Emission Rates (g/s)		
	Easting (m)	Northing (m)	(m)						PM_{10}	SO_2	NOx	PM_{10}	SO_2	CO
BULK ENERGETICS DEMILITARIZATION SYSTEM (BEDS)														
BEDS	355963.0	4273050.0	1231.0	3120	18.29	446.5	34.44	0.66	0.0417	0.4618	1.8208	0.1172	1.2975	0.2293
RF.9														
RF.9	355972.0	4273287.0	1226.8	4660	13.72	449.8	25.60	0.51	0.0295	1.1440	3.1682	0.0554	2.1520	0.0958
PLASMA-ARC ORDNANCE DISPOSAL SYSTEM (PODS)														
S2.043	356147.0	4273205.0	1226.8	6240	15.77	604.8	4.65	0.30	0.0003	0.3139	0.5382	0.0004	0.4410	0.0335
HOT GAS DECONTAMINATION SYSTEM														
S2.044	355987.0	4273479.0	1226.2	6000	15.20	659.8	16.80	0.74	0.0279	0.0791	0.3708	0.0408	0.1157	0.0328
SOIL VAPOR EXTRACTION SYSTEM														
S2.045	359999.0	4270576.0	1265.0	8760	3.05	293.0	0.01	0.20	1.64E-04	1.64E-04	1.64E-03	1.64E-04	1.64E-04	4.16E-04
BOILERS														
S2.001	355879.0	4267905.0	1262.0	8760	10.67	533.2	14.02	0.63	0.0441	0.3173	0.4848	0.0441	0.3175	0.3307
S2.002	355879.0	4267905.0	1262.0	8760	10.67	533.2	14.02	0.63	0.0441	0.3173	0.4848	0.0441	0.3175	0.3307
S2.003	355879.0	4267905.0	1262.0	8760	12.19	533.2	14.02	0.63	0.0441	0.3173	0.4848	0.0441	0.3175	0.3307
S2.004	359106.0	4269916.0	1260.0	8760	12.19	533.2	14.02	0.63	0.0441	0.3173	0.4848	0.0441	0.3175	0.3307
S2.011	356150.0	4273210.0	1226.0	8760	16.76	533.2	11.06	0.73	0.0332	0.2393	0.3657	0.0333	0.2395	0.2495
S2.014	356150.0	4273210.0	1226.0	8760	16.76	533.2	11.03	0.62	0.0332	0.2393	0.3657	0.0333	0.2395	0.2495
ENERGETIC MATERIAL RECOVERY PROCESSES														
S2.015	355676.0	4373240.0	1222.0	8760	20.73	366.5	13.53	0.36	0.0101	0	0	0.0101	0	0
S2.016	355830.0	4272940.0	1225.0	8760	20.73	369.3	13.53	0.36	0.2015	0	0	0.2016	0	0
S2.017	355850.0	4272920.0	1225.0	6024	20.73	294.0	11.03	0.66	0.0487	0	0	0.0709	0	0
S2.018	355860.0	4272920.0	1225.0	6024	20.73	355.4	13.53	0.36	0.0520	0	0	0.0756	0	0

TABLE 1-2 (Continued)

POINT SOURCE EMISSION RATES AND STACK PARAMETERS

Source ID	Source UTM Location		Elevation	Annual Hours of Operation (hr/yr)	Stack/Release Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)	Long-Term Emission Rates (g/s)			Short-Term Emission Rates (g/s)		
	Easting (m)	Northing (m)	(m)						PM_{10}	SO_2	NOx	PM_{10}	SO_2	CO
ROCK CRUSHING AND SCREENING DEVICES														
PF.1.001	355290.0	4269340.0	1247.0	1080	10.67	294.0	0.01	3.05	0.0013	0	0	0.0106	0	0
PF.1.002	355290.0	4269330.0	1247.0	1080	10.67	294.0	0.01	0.01	0.0013	0	0	0.0106	0	0
PF.1.003	355310.0	4269330.0	1246.0	1080	3.05	294.0	0.01	0.01	0.0013	0	0	0.0106	0	0
PF.1.004	355315.0	4269330.0	1246.0	1080	3.05	294.0	0.01	0.01	0.0140	0	0	0.1134	0	0
PF.1.008	351490.0	4273200.0	1254.0	1296	3.05	294.0	0.01	0.01	2.8E-05	0	0	0.0002	0	0
PF.1.009	351495.0	4273195.0	1254.0	1296	3.05	294.0	0.01	0.01	0.0007	0	0	0.0049	0	0
PF.1.010	351500.0	4273190.0	1253.0	1296	3.05	294.0	0.01	0.01	0.0007	0	0	0.0049	0	0
PF.1.011	351505.0	4273188.0	1253.0	1296	3.05	294.0	0.01	0.01	0.0078	0	0	0.0527	0	0
PF.1.012	351510.0	4273185.0	1253.0	1296	3.05	294.0	0.01	0.01	0.0007	0	0	0.0049	0	0
PF.1.013	351515.0	4273185.0	1252.0	1296	3.05	294.0	0.01	0.01	0.0012	0	0	0.0084	0	0
PF.1.014	351520.0	4273185.0	1251.0	1296	3.05	294.0	0.01	0.01	0.0007	0	0	0.0049	0	0
PF.1.015	351525.0	4273185.0	1251.0	1296	3.05	294.0	0.01	0.01	0.0007	0	0	0.0049	0	0
STACKERS														
PF.1.016	355944.0	4272075.0	1229.0	1296	3.05	294.0	0.01	0.01	0.0032	0	0	0.0219	0	0
PF.1.017	355950.0	4272077.0	1229.0	1296	3.05	294.0	0.01	0.01	0.0024	0	0	0.0164	0	0
PF.1.018	355953.0	4272079.0	1229.0	1296	3.05	294.0	0.01	0.01	0.0024	0	0	0.0164	0	0
PF.1.019	355958.0	4272081.0	1229.0	1296	3.05	294.0	0.01	0.01	0.0024	0	0	0.0164	0	0
ABRASIVE BLASTERS														
S.2.034	359849.0	4266416.0	1299.0	1200	3.96	294.0	13.72	0.608	0.0383	0	0	0.2796	0	0

TABLE 1-2 (Continued)

POINT SOURCE EMISSION RATES AND STACK PARAMETERS

Source ID	Source UTM Location		Elevation	Annual Hours of Operation (hr/yr)	Stack/Release Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)	Long-Term Emission Rates (g/s)			Short-Term Emission Rates (g/s)		
	Easting (m)	Northing (m)	(m)						PM_{10}	SO_2	NOx	PM_{10}	SO_2	CO
SURFACE COATING BOOTHS														
S.2.037	358750.0	4269740.0	1258.0	8760	6.40	294.0	7.19	0.46	0.0007	0	0	0.0007	0	0
S.2.038	355859.0	4267539.0	1268.0	8760	4.57	294.0	7.19	0.46	6.6E-05	0	0	0.0001	0	0
S.2.039	355859.0	4267539.0	1558.0	8760	4.57	294.0	7.19	0.46	6.6E-05	0	0	0.0001	0	0
S.2.040	359846.0	4266422.0	1554.0	8760	4.57	294.0	7.19	0.46	2.68E-04	0	0	0.0003	0	0
S.2.041	360576.0	4265983.0	1554.0	8760	4.57	294.0	7.19	0.46	2.33E-04	0	0	0.0002	0	0
S.2.042	360783.0	4265607.0	1575.0	8760	4.57	294.0	7.19	0.46	1.19E-04	0	0	0.0001	0	0
FACILITY WIDE PROPANE COMBUSTION/GASOLINE DISPENSING CAPS														
IU-12 & 16	357570.0	4271142.0	1243.0	8760	9.14	533.2	12.94	0.30	0.0039	0.0013	0.1313	0.0039	0.0013	0.0223
EMERGENCY GENERATORS														
EG.001	354453.0	4267800.0	1283.0	500	3.05	450.0	4.50	2.50	0.0013	0.0012	0.0179	0.0220	0.0206	0.0674
EG.002	355980.0	4267800.0	1264.0	500	3.05	450.0	4.50	2.50	0.0004	0.0003	0.0052	0.0064	0.0060	0.0197
EG.003	355900.0	4267650.0	1266.0	500	3.05	450.0	4.50	2.50	0.0017	0.0016	0.0238	0.0293	0.0274	0.0899
EG.004	355900.0	4267500.0	1268.0	500	3.05	450.0	4.50	2.50	1.8E-05	1.3E-06	5.1E-04	3.2E-04	2.4E-05	0.0083
EG.005	360690.0	4265120.0	1319.0	500	3.05	450.0	4.50	2.50	0.0002	0.0002	0.0030	0.0037	0.0034	0.0112
EG.006	360690.0	4265125.0	1319.0	500	3.05	450.0	4.50	2.50	3.4E-05	2.8E-05	0.0005	0.0006	0.0005	0.3708
INSIGNIFICANT COMBUSTION EMISSION UNITS														
ICEU.001	360012.0	4270480.0	1295.0	8760	6.40	477.6	11.55	0.3048	0.0017	0.0113	0.0315	0.0017	0.0113	0.0079
ICEU.002	360530.0	4266010.0	1316.0	8760	7.01	533.2	14.14	0.33	0.0017	0.0113	0.0315	0.0017	0.0113	0.0079
ICEU.004	358707.0	4268697.0	1316.0	8760	9.14	533.2	14.14	0.33	0.0012	0.0079	0.0219	0.0012	0.0079	0.0055
ICEU.005	358707.0	4268697.0	1316.0	8760	9.14	533.2	14.14	0.33	0.0012	0.0079	0.0219	0.0012	0.0079	0.0055
ICEU.006	355949.0	4273272.0	1225.0	8760	6.71	810.9	3.90	0.61	0.0035	0.0233	0.0647	0.0035	0.0233	0.0157
ICEU.008	360818.0	4265695.0	1316.0	8760	7.01	533.2	14.14	0.33	0.0024	0.0163	0.0453	0.0024	0.0163	0.0113

TABLE 1-2 (Continued)

POINT SOURCE EMISSION RATES AND STACK PARAMETERS

Source ID	Source UTM Location		Elevation	Annual Hours of Operation (hr/yr)	Stack/Release Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)	Long-Term Emission Rates (g/s)			Short-Term Emission Rates (g/s)		
	Easting (m)	Northing (m)	(m)						PM_{10}	SO_2	NOx	PM_{10}	SO_2	CO
ICEU.009	360818.0	4265695.0	1316.0	8760	7.01	533.2	14.14	0.33	0.0037	0.0245	0.0680	0.0037	0.0245	0.0170
MISCELLANEOUS INSIGNIFICANT SOURCES														
PODSCTWR	356154.0	4273212.0	1226.8	6240	15.75	294.0	3.00	3.00	0.0012	0	0	0.0017	0	0
PKILN1	357718.0	4272552.0	1237.8	8760	3.66	355.4	0.001	0.67	0.00025	$5x10^{-5}$	0.0124	0.00025	$5x10^{-5}$	0.0124
PKILN2	357718.0	4272549.0	1237.8	8760	3.66	355.4	0.001	0.67	0.00025	$5x10^{-5}$	0.0124	0.00025	$5x10^{-5}$	0.0124

1.3 BUILDING DOWNWASH

The modeling analysis includes evaluation of building dimensions at HWAD to assess the potential downwash effects on stack emissions from nearby structures. EPA's Building Profile Input Program PRIME (BPIPPRM) software was used to produce building dimension data that were incorporated into AERMOD input files. The direction-specific downwash parameters were calculated using facility plot-plan maps, and BPIPPRM software, which is the building downwash program associated with the AERMOD model.

Table 1-3 provides a list of building dimensions used for the modeling wake affects in AERMOD.

1.4 BACKGROUND CONCENTRATIONS

Ambient background concentrations represent the contribution of pollutant sources not included in the modeling analysis, including naturally occurring sources. The background concentration for each criteria pollutant is added to the maximum modeled concentration to calculate the total estimated pollutant concentration. The ambient background concentrations generally recommended by NDEP for relatively pristine areas were used for this modeling analysis. The background concentrations recommended by NDEP for PM_{10}, measured at the Lehman Caves monitoring site, are 10.2 micrograms per cubic meter ($\mu g/m^3$) 24-hour average, and 9.0 $\mu g/m^3$ annual average. Because HWAD is located in a generally remote area, gaseous pollutant background concentrations were assumed to be negligible.

TABLE 1-3

BUILDING DIMENSIONS

Building Name	Building Height (meters)	Building Corner Coordinates UTM meters Easting and Northing
Bldg13	7.62	355864.6 4267914.8; 355884.6 4267921.7; 355893.8 4267897.5; 355875.1 4267889.3
Bldg13	7.62	355903.8 4267871.7; 355915.1 4267876.5; 355919.0 4267865.8; 355908.8 4267861.2
Bldg5	6.096	355811.5 4267707.8; 355830.9 4267715.3; 355838.7 4267698.7; 355818.8 4267690.1
Bldg26	4.572	355832.7 4267543.3; 355864.4 4267555.3; 355872.5 4267533.9; 355842.6 4267522.0
103_6	9.144	359106.4 4269932.2; 359120.7 4269910.2; 359102.6 4269898.8; 359087.7 4269921.0
103_16	12.192	358742.1 4269765.8; 358774.6 4269729.7; 358743.6 4269696.6; 358708.1 4269734.8
117_2	16.764	356193.9 4273244.6; 356210.1 4273228.0; 356172.5 4273196.8; 356156.3 4273214.4
117_16	10.668	355968.0 4273489.1; 355984.8 4273482.9; 355988.6 4273493.6; 355998.2 4273490.4; 355995.0 4273480.8; 356017.9 4273473.9; 356015.0; 355964.0 4273476.0 4273459.7
RF_9	9.144	355994.9 4273288.8; 356019.8 4273272.3; 355981.7 4273239.7; 355961.9 4273260.8
RF_9BldgtoSW	7.62	355933.7 4273256.2; 355947.8 4273242.1; 355909.3 4273203.4; 355895.6 4273217.5
117_5	19.812	355666.5 4273263.5; 355682.5 4273243.7; 355669.1 4273232.7; 355652.8 4273248.7
117_6N	21.336	355801.6 4272947.1; 355817.4 4272959.4; 355841.7 4272937.4; 355823.9 4272921.6
117_6S	21.336	355828.2 4272911.8; 355847.6 4272928.6; 355860.4 4272914.3; 355843.3 4272898.4
117_6_square_bldgtoNW	12.192	355770.0 4272912.6; 355778.7 4272921.0; 355787.9 4272910.7; 355778.9 4272903.0
117_6_rectangle_bldgtoW	12.192	355791.0 4272913.5; 355800.4 4272920.8; 355816.5 4272903.3; 355807.3 4272894.1

TABLE 8-3 (Continued)

BUILDING DIMENSIONS

Building Name	Building Height (meters)	Building Corner Coordinates UTM meters Easting and Northing
117_6_round_bldgtoW	7.62	355793.4 4272894.6; 355798.2 4272895.9; 355803.2 4272892.8; 355803.8 4272886.8; 355801.1 4272883.4; 355795.6 4272883.4; 355792.6 4272886.6; 355792.2 4272892.1
117_6_square_bldgtoSW	6.096	355813.5 4272895.6; 355821.6 4272904.8; 355833.7 4272893.8; 355823.8 4272884.0
BEDS	13.716	355948.3 4273049.1; 355962.7 4273061.9; 355977.6 4273046.5; 355961.0 4273035.0
117_1	7.62	356113.8 4273113.4; 356137.8 4273133.8; 356156.9 4273109.4; 356134.2 4273090.3
102-52	6.096	359939.4 4270537.0; 360059.1 4270477.6; 360051.3 4270463.8; 359933.3 4270524.0
102_52bldgtoS	4.572	359915.0 4270510.6; 360053.4 4270443.0; 360048.5 4270435.7; 359910.5 4270502.0
Bldg94	9.144	359872.7 4270655.9; 359851.1 4270633.1; 359862.1 4270658.3; 359861.7 4270627.4
103-31	4.572	358693.0 4268694.6; 358716.4 4268707.4; 358721.7 4268700.5; 358697.8 4268686.0
49_31	7.62	359844.2 4266506.6; 359862.2 4266514.5; 359872.3 4266488.6; 359856.5 4266480.2
49_9bldgtoN	10.668	359770.4 4266556.2; 359785.8 4266562.8; 359812.6 4266507.9; 359798.1 4266500.9
49_9	10.668	359823.1 4266446.0; 359838.5 4266452.6; 359866.2 4266396.3; 359851.3 4266390.6
104_9	4.572	360249.5 4266501.0; 360303.0 4266517.0; 360309.9 4266496.4; 360254.9 4266479.6
104_3	12.192	360510.8 4266034.2; 360494.8 4266008.2; 360528.4 4265989.8; 360546.0 4266013.5
104_2	6.096	360570.4 4265992.1; 360566.6 4265985.3; 360584.2 4265973.8; 360586.5 4265979.2
104_4	6.096	360812.6 4265704.9; 360830.2 4265699.5; 360823.3 4265679.7; 360807.3 4265688.8

1.5 METEOROLOGICAL DATA

NDEP provided meteorological data to be used for the dispersion modeling. The data are from Desert Rock, Nevada (National Weather Service [NWS] station number 03160) during the period 1988 to 1992. Because the meteorological data files were not created by Tetra Tech, variable-specific data completeness measurements were not available. However, AERMOD results show that each of the five years had fewer than 1% missing hours. The percentage of calm hours ranged from 4.6 to 6.3% of the total hours for the year.

The meteorological data were processed into model-ready format using the AERMET software. AERMET processed the HWAD data into the proper format using a three-stage process. The first stage extracts the data and administers several data quality checks. The second stage merges the data, and the third stage estimates required boundary layer parameters.

1.6 AERMOD MODEL RECEPTORS

The modeling was completed using many receptor locations to ensure that the maximum estimated impacts are identified. The receptors were previously developed based on discussions between Tetra Tech and NDEP. Receptors included in the modeling analysis consist of a dense receptor grid outside the HWAD fenceline, receptors located along the HWAD fenceline, and receptors positioned at all areas inside HWAD that are accessible to the public. The dense receptor grid outside the facility fenceline includes receptors located from the edge of HWAD extending out at least 500 meters in 100-meter increments. The fenceline receptors are located at 100-meter intervals around the entire HWAD perimeter. In addition, any areas within the HWAD boundary that are accessible to the public were included in the modeling as receptor points. These areas include all public roads and highways that run through HWAD. Road receptors were located at 100-meter intervals along the center of the road.

Because HWAD encompasses an extremely large area, many receptors are required for the modeling analysis. A total of 10,352 receptors are used, including 1,826 fenceline receptors, 7,913 grid receptors, and 613 special receptors. Figure 1-2 shows a plot of the HWAD model receptors, along with the HWAD property fenceline.

Because the receptors are located close together, receptor points in Figure 1-2 may appear as shading rather than as individual points. Model receptors are presented in the Universal Transverse Mercator (UTM) coordinate system using meters and the North American Datum of 1983 (NAD83).

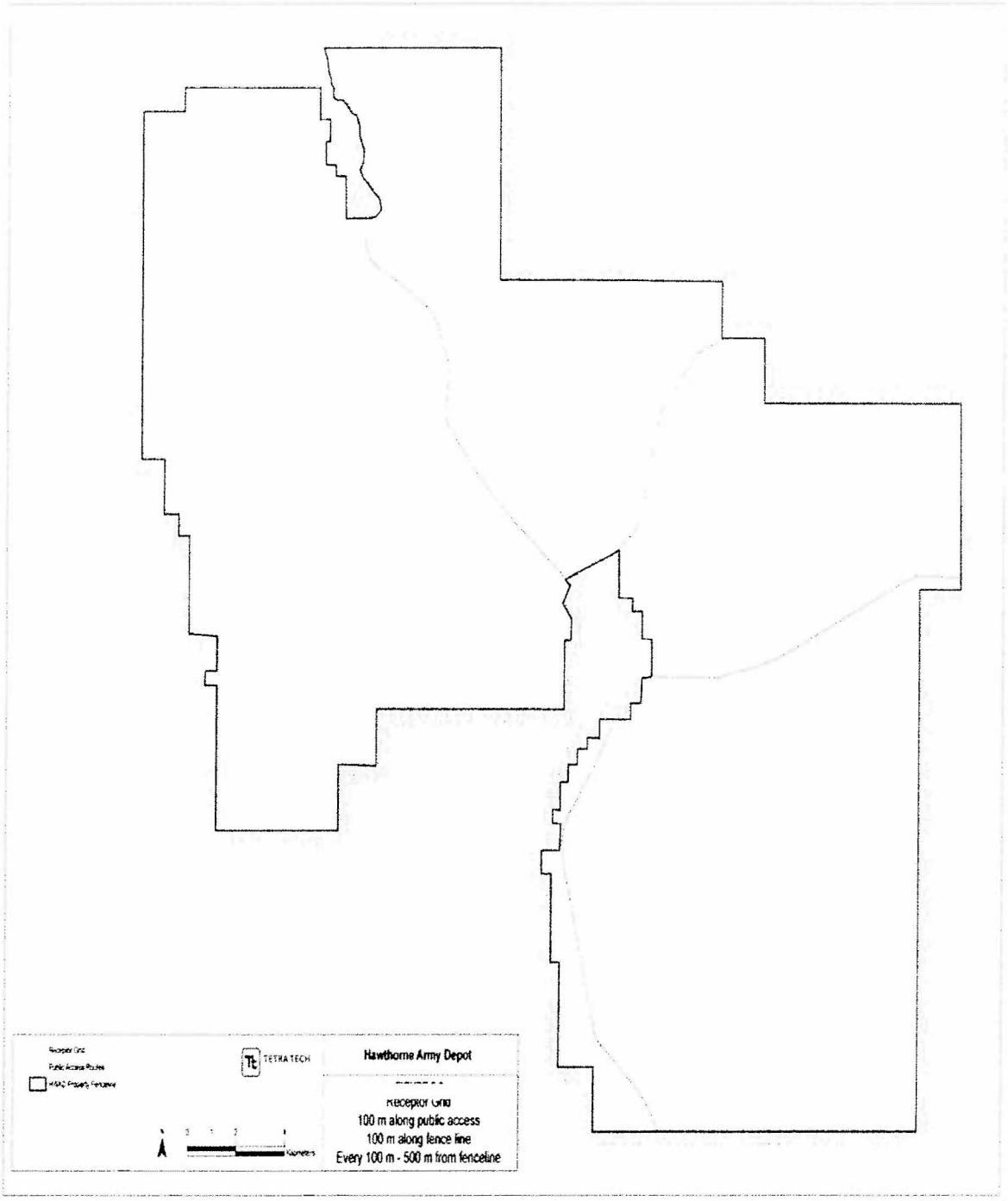
Receptor terrain parameters were characterized using AERMET software (Version 06341). U.S. Geological Survey (USGS) 7.5-minute series digital elevation model (DEM) data were used in AERMET to assign terrain elevations to the receptors.

1.7 OLD BOMB MODELING

Modeling for the old bomb facility has previously been completed using the OBODM model. Maximum modeled OBODM output was added to the maximum AERMOD output to provide a worst-case estimate of total ambient impacts at HWAD. This section discusses the methodology that was used for the Old Bomb modeling.

A separate dispersion model is necessary for evaluating open burn/open detonation (OB/OD) emissions because of the unique dispersion characteristics associated with OB/OD operations. The OBODM model was developed specifically for modeling OB/OD emission sources and characterizes emissions from these sources in a more realistic way than straight-line Gaussian models like AERMOD.

FIGURE 1-2
MODEL RECEPTORS



OBODM is intended for modeling emissions from OB/OD of obsolete munitions and solid propellants at DOD and Department of Energy (DOE) facilities (Bjorklund and others, 1998). OBODM is divided into two components: a Gaussian puff model for OD applications, and an integrated-puff and plume model for OB applications. The main features of OBODM are described as, "(1) a continuous treatment of dispersion as the release condition varies from instantaneous to continuous, (2) cloud and plume rise obtained from appropriate entrainment models, (3) cloud and plume penetration of elevated inversions, (4) relative (puff) and total dispersion based on modern scaling concepts for the planetary boundary layer (PBL), and (5) a capability for the use of onsite profiles of wind, temperature, and turbulence from a mobile meteorological platform" (Weil and others 1996).

EPA recommends OBODM for OB/OD modeling applications. OBODM was designed specifically for the types of emission sources at the Old Bomb area and therefore is selected as the model best suited for the Old Bomb modeling analysis.

1.7.1 OBODM MODEL SETUP OPTIONS

OBODM can be run to calculate peak concentration, time-averaged concentration, dosage, or particulate deposition. For this modeling analysis, time-averaged concentrations will be calculated for each of the applicable averaging periods for a given pollutant.

OB operations at Old Bomb are limited to daylight hours when wind speeds are greater than 3 miles per hour (mph) and less than 15 mph. To accommodate these operational limitations, the model was configured to eliminate model calculations during atmospheric conditions outside these boundaries. First, the OBODM option for limiting OB operations to daylight hours was activated. Second, all hours when the wind speed is outside the acceptable range were eliminated from the modeling analysis by modifying the meteorological dataset. Every wind speed that is less than 3 mph or greater than 15 mph was changed to 0 mph, thus invoking the model's calm processing routine which eliminates those hours from the calculations. A total of 1,356 hours in the dataset have wind speeds that are outside the acceptable wind speed range.

OBODM was run two times for each pollutant. The first run estimated maximum 1-hour concentrations assuming OB operations occur during all daylight hours when the wind speed requirements are met. The second run estimated maximum concentrations for averaging times greater than one hour. Because daily burn operations last less than one hour, the worst-case hour was determined from the first model run and assumed to be the hour that OB operations take place for the second run. In most cases, the worst-case hour was early in the morning.

1.7.2 OBODM EMISSION SOURCES

The Old Bomb facility includes four burn pads oriented 150 feet apart in a square pattern. Each pad has five carbon-steel burn pans. Pan dimensions are 6 feet wide by 16 feet long by 1 foot deep. The pans are located approximately 1 foot above the ground. Burning operations last approximately 7.5 minutes per pad. A total of 20,000 pounds of propellant are burned daily (1,000 pounds per pan), and 3,900,000 pounds per year.

The modeling was conducted assuming each burn pad is one emission source. A total of four volume sources were modeled, representing the four pads. Each source has dimensions of 1.8 meters wide and 24.4 meters long to account for the five burn pans on each pad. All four sources were input as quasi-continuous sources. Source dimensions to be used for modeling are given in Table 1-4. The pollutants modeled included PM_{10}, NO_2, SO_2, CO.

Because PM_{10} is a particulate species, the PM_{10} model requires particle size distribution data. The OBODM feature that calculates a particle size distribution was activated for PM_{10}. The PM_{10} particle sizes were distributed between 0 and 10 microns. The PM_{10} model was run in flat terrain mode to take advantage of the OBODM particle depletion algorithms.

1.7.3 OBODM MODEL RECEPTORS

Model receptors were placed around the HWAD boundary on the southeast section of the facility. Receptors were also placed at 500-meter intervals along Highway 95, running east of the City of Hawthorne, and surround the Old Bomb area. In addition, another row of model receptors with 1,000-meter spacing were added along the portion of the HWAD property boundary where maximum concentrations were expected.

TABLE 1-4

OLD BOMB EMISSION SOURCE RELEASE PARAMETERS

Source	UTM Location X/Y (m)	Source Length (m)	Source Width (m)	Source Depth (m)	Source Angle (Degrees)	Mass of Material Burned (grams)	Fuel Material Heat Content (C/g)	Fuel Material Burn Rate (g/s)
Pad1	363321 / 4255987	25	1.8	0.3	100	2,268,000	1020	5040
Pad2	363309 / 4255922	25	1.8	0.3	100	2,268,000	1020	5040
Pad3	363396 / 4255960	25	1.8	0.3	100	2,268,000	1020	5040
Pad4	363372 / 4255895	25	1.8	0.3	100	2,268,000	1020	5040

Notes: m = meters
C/g = Calories per gram
g/s = grams per second

The total number of model receptors allowed in OBODM is limited to 100 discrete receptors and one receptor grid. To maximize the number of receptors in the modeling, both a receptor grid and discrete receptors were included in the modeling. A receptor grid was located along the east boundary since it runs directly north-south and is the longest portion of the HWAD boundary. All other model receptors were discrete locations. Receptor elevations were determined using USGS DEM data. Figure 1-3 presents the model receptors that were used in the Old Bomb analysis.

1.7.4 METEOROLOGICAL DATA

The dispersion modeling for Old Bomb was accomplished using one full year of available surface meteorological data (1998) collected from HWAD, and twice-daily mixing height values from the Reno, Nevada, NWS station. All wind speeds that were less than 3 mph or greater than 15 mph were changed to 0 mph, thus invoking the model's calm processing routine which eliminates those hours from the calculations. This was done because OB/OD operations do not take place when wind speeds are outside this range. A total of 1,356 hours in the dataset have wind speeds that are outside the acceptable wind speed range.

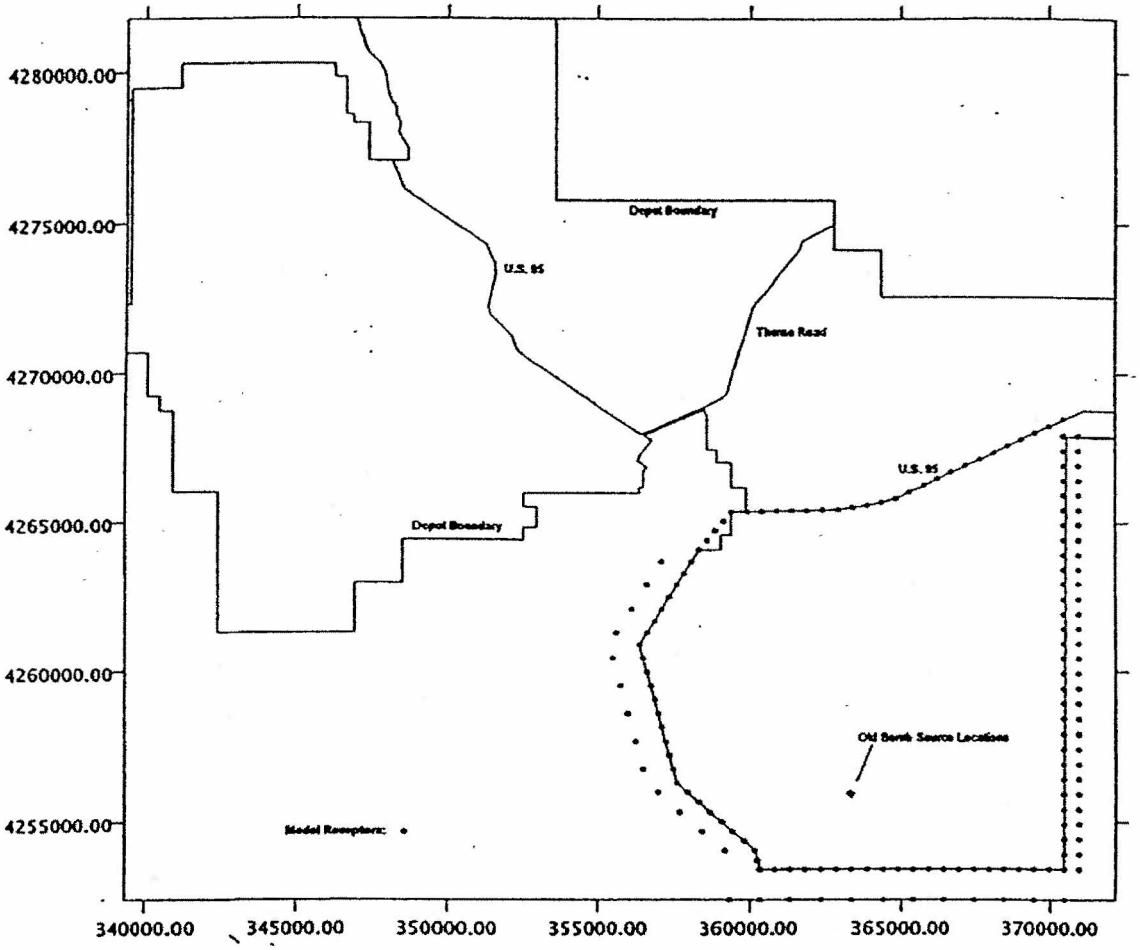
1.7.5 OBODM MODEL RESULTS

The analysis of maximum impacts from the Old Bomb facility have been added to the maximum AERMOD impacts to estimate worst-case total HWAD impacts. These results are discussed in Section 1.8.

FIGURE 1-3

OLD BOMB MODEL RECEPTORS

Hawthorne Army Depot
OBODM Model Receptors,
Facility Fence Line, and Old Bomb Source Locations



1.8 SUMMARY OF MODEL RESULTS

The maximum modeled pollutant concentrations, background concentrations, and total concentrations are listed in Table 1-5. Criteria pollutant dispersion modeling analyses completed for operations at Main Base, PODS, BEDS, Hot Gas, RF-9, the SVE system, and a pallet heater were added to the previously modeled concentrations from Old Bomb operations. These cumulative concentrations (including ambient background concentrations) were evaluated for compliance with criteria pollutant ambient air quality standards. The maximum modeled criteria pollutant concentrations for Old Bomb, Main Base and associated operations, background concentrations, and resulting total concentrations are listed in Table 1-5. The total concentration for each pollutant is compared with the National and Nevada ambient air quality standards for each applicable averaging time in Table 1-5.

Modeled concentrations of CO, NO_2, SO_2 and PM_{10} demonstrate that HWAD sources comply with the AAQS. The highest 1-hour and 8-hour cumulative CO impacts are 168.28 $\mu g/m^3$ and 74.45 $\mu g/m^3$, respectively. These values are well below the AAQS values of 40,000 $\mu g/m^3$ and 10,000 $\mu g/m^3$. The maximum cumulative NO_2 concentration of 17.25 $\mu g/m^3$ is well below the AAQS value of 100 $\mu g/m^3$. The highest 3-hour, 24-hour and annual cumulative SO_2 impacts are 69.81 $\mu g/m^3$, 32.16 $\mu g/m^3$ and 7.75 $\mu g/m^3$, respectively. These values are below the AAQS values of 1300 $\mu g/m^3$, 365 $\mu g/m^3$ and 80 $\mu g/m^3$. The highest 24-hour and annual cumulative PM_{10} impacts are 45.09 $\mu g/m^3$ and 10.67 $\mu g/m^3$, respectively. These values are well below the AAQS values of 150 $\mu g/m^3$. Table 1-5 shows the AAQS modeling results.

An analysis of maximum impacts from emission sources at HWAD, including Old Bomb, demonstrates that operation of all HWAD emission sources at the proposed maximum operating conditions will not cause or contribute to a violation of any air quality standards.

All modeling electronic files are included on compact disk in Attachment A.

TABLE 1-5

MAIN BASE, OLD BOMB & TOTAL DISPERSION MODELING RESULTS

Pollutant	Averaging Period	Old Bomb Maximum Modeled Concentration ($\mu g/m^3$)	Main Base Modeled Concentration ($\mu g/m^3$)	Background Concentration ($\mu g/m^3$)	Total Concentration ($\mu g/m^3$)	National Ambient Air Quality Standard ($\mu g/m^3$)	Nevada Ambient Air Quality Standard ($\mu g/m^3$)
Nitrogen Dioxide	Annual	0.006	17.24	0	17.25	100	100
Sulfur Dioxide	Annual	0.005	7.74	0	7.75	80	80
	24-hour	0.377	31.78	0	32.16	365[a]	365
	3-hour	3.019	66.79	0	69.81	1,300[a]	1,300
Carbon Monoxide	8-hour	0.653	73.80	0	74.45	10,000[a]	10,000[b]
	1-hour	5.221	163.06	0	168.28	40,000[a]	40,000
PM_{10}	Annual	0.098	1.58	9.0	10.67	50	50
	24-hour	6.951	27.94	10.2	45.09	150[a]	150

Notes:

$\mu g/m^3$ = micrograms per cubic meter
PM_{10} = Particulate matter with aerodynamic diameter less than or equal to 10 microns
a Not to be exceeded more than once per calendar year
b 7,000 $\mu g/m^3$ at areas equal to or greater than 5,000 feet above Mean Sea Level

Appendix T - US Army ARCOM Regulation 385-5

Department of the Army ARCOM Regulation 385-5
"Contamination, Decontamination, and Disposal"

*ARR

DEPARTMENT OF THE ARMY
HEADQUARTERS, UNITED STATES ARMY ARMAMENT MATERIEL READINESS COMMAND
Rock Island, Illinois 61299

RECEIVED 1978 DEC 19 U.S.

ARRCOM REGULATION
No. 385-5

26 October

Safety

CONTAMINATION, DECONTAMINATION, AND DISPOSAL

Issue of supplements to this regulation by subordinate commanders is permitted. One copy will be sent to Commander, ARRCOM, ATTN: DRSAR-SF.

Para

Purpose----------
Scope----------
Definitions----------
Policies----------
Responsibilities----------
References----------
Appendix A. Decontamination Procedures
B. Record of Operations

1. Purpose. This regulation prescribes policies, responsibilities, and procedures relating to decontamination and disposal of contaminated items (facilities, land, tooling, materiel, material and equipment).

2. Scope. This regulation applies to:

a. Headquarters, US Army Armament Materiel Readiness Command (HQ, ARRCOM), and subordi installations and activities having contaminated items that are being placed in standby, tr from one location to another for any reason, or being disposed of to other Government agenc to the general public.

b. Contaminated items shut down for maintenance, repairs, alteration, or modification, regard of who performs the work, i.e., set-up personnel, facilities personnel, contractors (service and construction), and "do-it-yourselfers".

c. Materiel which by nature of its use or intended use could be contaminated or contain a contaminant.

3. Definitions. The following definitions apply for purpose of this regulation:

a. Contaminant: Includes any reactive material (i.e., explosives, propellants, pyrotechnics) radioactive materials, acid or corrosive materials, toxic substances, chemical agents/munitions or their by-products.

b. Contaminated: Status of an item which has been in contact with or exposed to a contaminant

c. Contaminant area: The area within which the contaminant is contained. It may be limited t the inside compartments of a laboratory glove box; single room within a building; an entire buildin or group of buildings with associated services (drains, sumps, exhaust units, ramps, narrow gauge R etc.); open terrain, such as test and demolition areas; a vehicle; etc.

d. Decontamination: The partial or complete removal or neutralization of a contaminant. The words "decontamination" and "decontaminated" should be used with other words, such as "degree of", "partial" or "partially", "complete" or "completely", to assure that the person receiving informati does not assume contaminant has been completely removed when it may have been only partially remove

e. Degree of decontamination:

(1) "X" - A single "X" indicates item has been partially decontaminated. Further dec tion processes are required before item is moved or any maintenance, repair, etc., is perfor

*This regulation supersedes ARRCOMR 385-5, 15 December 1974.

degree would generally be applied to item as it stands in place after being used and subjected only to routine cleaning after use.

(2) "XXX" - Three "X's" indicate that an item has been examined and cleaned by approved procedures and no contamination can be detected by appropriate instrumentation, test solutions, or by visual inspection on easily accessible surfaces in concealed housings, etc., and is considered safe for intended use only.

(3) "XXXXX" - Five "X's" indicate equipment has been completely decontaminated and may be released for general use or sold to the general public.

(4) "0" - A single "0" (zero) indicates the item, although located in a contaminant area, was never exposed to the contaminant and may be released for general use. Examples: Equipment in motor-equipment rooms, offices isolated from the contaminant within a contaminant area, a building which contains no contaminants and is located within a contaminant area, such as an inert building within a contaminated test or production area.

4. Policies. a. Detailed procedures for decontamination or clean-up applicable to specific items will be prepared for each location or project where decontamination or clean-up is to be accomplished. All procedures and instructions covering decontamination will be in writing. See Appendix A.

b. When work is performed in a contaminant area or on a contaminated item, such work will be overseen by persons knowledgeable of the item and contaminant involved, in addition to the supervision by the supervisor of the work crew(s).

c. A complete record of decontamination and clean-up actions that have been performed in each contaminant area and on each piece of equipment and tooling, will be prepared whenever operations in a contaminant area are discontinued for the purposes of putting item in standby, dismantling, demolition, alteration, conversion, repair or maintenance. This record is to acquaint those involved in working in the area as to what hazards may exist in order for them to institute proper precautions. See Appendix B.

d. Standing Operating Procedures (SOP) will be prepared in advance to cover those operations in a contaminant area of a routine recurring nature, such as preventive maintenance involving oiling and greasing equipment, changing light bulbs and fuses, changing dies and punches on presses, replacing broken keys in presses, repairing or replacing belts or adjusting presses, set-up, etc. SOP's will be reviewed and approved by the commander or designated agent. SOP's will be reviewed, updated, and approved annually. See paragraph 4-3i, DARCOM Suppl to AR 310-2, for preparation of SOP's.

e. All standby contaminated items that will remain in place or in storage at the installation/activity will be cleaned of hazardous contaminants to a minimum of XXX degree to make them safe for maintenance by experienced personnel.

f. All contaminated items that will be used for the same purpose, and which are relocated or transferred to another knowledgeable segment within the installation/activity, transferred to a knowledgeable Government installation/activity, or furnished to a knowledgeable contractor will be cleaned of hazardous contaminants to a minimum of XXX degree before moving, to make them safe for handling and use by experienced personnel. "Knowledgeable" is used as a qualifying condition to restrict locations to which an item can be sent and refers to the ability of the receiver to handle the contaminant(s) involved. These items will not be transferred to above locations/areas outside of contaminant area, into station supply and stock control departments, or Defense Property Disposal Offices, without written approval of the commander or designated agent.

g. All contaminated items planned for release to the general public will be decontaminated to a XXXXX degree before transfer to Defense Property Disposal Offices.

h. Contaminated material or materiel generated as a result of producing a commodity will be handled in accordance with approved procedures. Material/materiel includes rags, cartons, packing materials, reject materiel, unused products, boxes, uniforms, papers, munitions and subcomponents, etc. exposed to contaminants.

i. Reactive materials and contaminated items will not be buried. When underground pipe or ground area (including existing burial sites) contains a contaminant, such locations will be indicated on plot plans, as well as on the ground by signs and appropriate fencing. These sites will remain posted and fenced until they are cleaned completely of contaminant(s).

j. Installations/activities will prepare plot plans delineating non-contaminant and cont. areas, operating lines with specific buildings or structures, grounds, surface and underground process lines. The plot plans will be annotated to indicate the types of contaminant(s) that present in these facilities or areas. Plans will be kept current and reviewed annually. Thes plans will be used as a guide in determining whether an item should be considered as coming fr contaminant area. In the absence of any indication on the plot plan that an area is a non-con area, it will be considered as a contaminant area and items within it treated accordingly. Al compartments, rooms, buildings or test/demolition areas in which a contaminant is present will posted conspicuously with a sign - "CAUTION - CONTAMINANT AREA (Insert name of contaminant)". color and size will be in accordance with AR 385-30. Signs will be posted at all points of en into the contaminant area.

k. A contaminated item which would lose its usefulness if subjected to procedures for com decontamination may be worked on in accordance with an approved SOP established for each situa as it arises.

l. Not used.

m. Materiel which by nature of its use or intended use could be contaminated or contains a contaminant and which is to be transferred to or from laboratories, to offices, to shops, to or from storage, to disposal or remains in place for testing, modification, use in displays or mod will either be decontaminated or handled in accordance with specific handling instructions deve for the materiel involved. Examples of materiel involved are:

(1) Commodity containers/tanks used for flammable or toxic materials.

(2) Munitions and associated subcomponents.

(3) Radioactive components.

(4) Test fixtures.

n. Material/materiel which is a commodity in production will be handled in accordance wi approved SOP which provide for alternate controls of these materials/materiels, such as inspe and certification by product/quality assurance personnel.

o. Items in storage of one degree of decontamination will be kept segregated from items of different degree of decontamination.

p. Items decontaminated to a XXX degree may be transported in Government vehicles or vehicl under Government control.

q. Items decontaminated to a XXX degree will not be worked on with open flame, high tempera heating devices or devices which when used generate heat, due to friction or rubbing or cutting (examples - hand or power drills and saws, lathe operations, powered wire brushing) without speci written approved SOP.

r. Items moved to or from a contaminant area will be identified and documented as follows:

(1) Items placed in stand-by or transferred to another location will be marked with cons yellow painted "X's" or "O" as appropriate. Exception: material/materiel outlined in d, h, and above; items being serviced, tooled-up or repaired in place; and items in or from a non-contamina area will not be marked.

(2) Items placed in standby, dismantled, demolished, altered, repaired, disposed of or transferred will be tagged with a Decontamination Tag, DA Form 3303, indicating methods, type and degree of decontamination, and restrictions on handling. Exception: material/materiel outlined in h and n above and items covered by SOP's which provide for alternate means of identification of decontamination status will not be tagged. Items in or from a non-contaminant area do not require tags.

(3) All transfer documents, work orders, etc., concerning an item, whether it comes from contaminant or non-contaminant area, will be annotated with the degree of decontamination (using X XXX, or XXXXX) or the statement that the item has never been exposed to contaminants, whichever is appropriate.

s. When degree of decontamination is changed, the old tag will be replaced with new tag in accordance with instructions on tag and markings changed to reflect the latest status of item. Accordingly, all documents will be changed to correspond.

t. When an item is to be placed in service, the tag will be removed, in accordance with instructions on tag, and the yellow markings obliterated prior to use.

u. Access to areas containing contaminated items will be controlled. Jurisdiction will always be under the direction of persons knowledgeable with the item and contaminant involved.

5. Responsibilities. a. Commanders of ARRCOM installations and activities will:

(1) Assure that adequate written procedures for decontamination of items are prepared and approved (by the commander or designated representative) prior to initiating request for disposal, shipment, transfer, accomplishment of maintenance, or repairs.

(2) Assure that a safety representative certifies to the degree of decontamination.

(3) Assure that personnel (drivers, supervisors, warehousemen, repairmen, toolroom attendants, etc.) transporting, receiving, relocating or performing work (set-up, maintenance, repairs, alterations, modifications) are aware of the restrictions on handling, are thoroughly acquainted with the hazards involved and the operational procedures (SOP) and know how to verify that the item is properly decontaminated.

(4) Issue written procedures to insure that all reject or obsolete materials, equipment, facilities, and generated waste are disposed of on a timely basis by an approved method.

(5) Maintain appropriate records of contaminant areas, equipment and facilities containing information outlined in Appendix B.

(6) Assure that all contaminated equipment or material which is to be transferred between installations or from one area of an installation to another is tagged and marked, and documents properly annotated as to degree of decontamination.

(7) Assure that installation safety concurrence is obtained prior to the submission of a request for disposal approval or funding projects for disposal.

(8) Submit request to Commander, ARRCOM, ATTN: DRSAR-SF, for approval of the method of decontamination for disposal of any contaminated land and/or facilities. Request will include as a minimum:

(a) Description of facility, land involved, type and degree of contamination, method of decontamination, method of dismantling and disposal action. Note: Items for disposal to non-Government agencies will include decontamination to a XXXXX degree.

(b) SOP applicable to the job. Generalized procedures are not adequate.

(9) Submit Request for Approval of Disposal of Buildings and Improvements (DA Form 337) to Commander, ARRCOM, ATTN: DRSAR-IS. Request will contain the following statements:

(a) Type of contamination.

(b) Degree of decontamination.

(c) Date of ARRCOM Safety concurrence.

b. The Chief, Safety Office, HQ, ARRCOM, will review and evaluate all requests, procedures, and instructions for method of disposal of contaminated facilities and/or land.

6. References. a. AR 405-90.

b. AR 746-1.

c. TB 700-4.

d. AMCR 385-100.

e. ARRCOMR 385-6.

Appendix A

DECONTAMINATION PROCEDURES

Section	
I	GENERAL SAFETY PROCEDURES
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III	TNT MANUFACTURE
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Section I - GENERAL SAFETY PROCEDURES

1. GENERAL. This section on decontamination comprises general information for all facilities. sections follow which apply distinctly to acids; TNT; DNT; tetryl; nitrocellulose; single, doubl triple base smokeless powder; pentolite; sodium and lead azide; nitroglycerin; RDX and RDX compo ammunition loading, including small arms ammunition; radioactive materials and toxic substances; technic compositions; foreign ammunition; experimental or degraded reactive materials; and chemic agents/munitions.

2. EXPLOSIVES HAZARDS. a. Heat and Impact. During the decontamination or clean-up of an plant, high temperature and rough handling must be avoided to prevent explosive accidents. cutting devices such as oxyacetylene torches, electric welders, and blow torches must not be use before or during decontamination, due to the possibility of explosive material remaining in a con space. Striking explosive material with hammers must be avoided. Frictional heat must also be a As an example, before attempting to loosen nuts (in disassembling a conveyor) penetrating oil mus be applied to the contacting surfaces. Sufficient time must be allowed for the oil to penetrate within the threads before attempting to separate the parts. This procedure is mandatory prior to removing nuts or bolts whenever contamination exists. Two applications of penetrating oil are recommended.

b. All fire prevention regulations in effect during operations must remain in effect during decontamination or clean-up and dismantling. Explosives must not be exposed to strong alkali or other chemicals in such manner that local heating may cause decomposition, ignition or explosion. Soda ash in solution and of proper concentration is considered safe as recommended herein.

c. The responsibility for executing decontamination or clean-up procedures and inspection wil be given to explosives supervisors, preferably those who are familiar with the particular plant, equipment, or areas involved. Such supervisors are familiar with the extent of contamination to be expected at each location.

d. Non-contaminated equipment will not be stored with equipment which has been contaminated.

3. EQUIPMENT CONTAMINATED WITH ACID ONLY. All equipment such as tanks, pipes, valves, and fitting which have contained acid, but no explosives material, will be drained thoroughly by opening pipes at flanges in low sections of piping where liquid may settle; valves will be disassembled and packi removed. This equipment will then be washed, first with water followed by a wash with soda ash sol tion. Only soda ash will be employed in solution. After neutralizing, a solution of 5 percent sod ash should be retained in the pipe or equipment for approximately 24 hours. Since the action of ac on metal may generate explosive gas mixtures, flame and spark must be avoided. Brick lined tanks a equipment will be excluded from neutralizing procedures when equipment is to be placed in stanchy s Equipment that presents the greatest possible hazard are sulfuric acid concentrators, precipit cooling tubs, weak acid return tanks and any brick lined tank or vessel used in acid service. wash followed by a wash with soda ash solution should precede dismantling of this kind of equ Caution should be exercised to avoid use of flame or spark producing tools until it has been that equipment is free of acid and the consequent danger of hydrogen being generated and form explosive gaseous mixture.

Appendix A-Continued

4. EQUIPMENT CONTAMINATED WITH ACID AND EXPLOSIVES. a. All large pieces of equipment which have contained explosive material, such as nitrators, centrifuges, and metal wash tanks will be washed and then steamed. Equipment to be sold as scrap must be flashed (subjected to a hot fire to destroy explosive material). Flashing is considered the most effective method for destroying explosives material, but the equipment will be scrap thereafter. Solvent, steaming, and swabbing methods are considered effective only when complete inspection can be given all surfaces of equipment to assure that decontamination is complete. If, however, the equipment is to be placed in standby condition for possible subsequent use in explosives operation, such as a nitrator in the manufacture of high explosive material, flashing in addition to thorough inspection is not required. When any equipment or material which has been used in explosives manufacturing or loading operations, and which may be contaminated, is to be relocated or transferred to another knowledgeable segment within the installation/activity, or furnished to a knowledgeable/qualified contractor, it will first be inspected, cleaned to a XXX condition, properly marked, and tagged before forwarding. Movements of contaminated equipment will be transported in approved Government vehicles only, accompanied by a shipping/receipt document containing a statement certifying decontamination to XXX condition.

b. Acid tanks which have contained nitrocellulose will be flusehd with water and treated with a 15 percent solution of sodium hydroxide to desensitize the nitrocellulose. Acid tanks which are not contaminated with explosives material will be drained and flushed clean with water. All lines entering and leaving the tanks must be disconnected. Protection must be afforded workmen against acid splash and acid fumes (air supply of self-contained breathing apparatus). Two men must always be present when a man enters an acid tank and the man going into the tank must wear safety harness with a rope attached. Goggles, rubber boots, rubber aprons and masks for protection against oxides of nitrogen must be worn when washing sludge from acid tanks with water since oxides of nitrogen may be generated. The drain will be closed, tank filled with water and soda ash added until tank contents are alkaline. The tank will then be flushed with clear water, drained and dried thoroughly.

5. EQUIPMENT CONTAMINATED WITH SOLVENT AND EXPLOSIVES. Piping, valves, tanks, etc., which have contained ether and other flammable liquies will be drained thoroughly, washed with water and steamed. Weak alcohol and other lines which may contain nitrocellulose will, in addition, be dismantled and flashed if to be sold. Weak alcohol storage tanks that may have been contaminated with nitrocellulose will be treated with 15 percent alkali solution (sodium hydroxide) and flushed with water. Tanks which have contained flammable liquids only, will be tagged to indicate that the steaming operation will be repeated immediately prior to use of flame producing devices on such tanks.

6. EQUIPMENT CONTAMINATED WITH AMMONIA. Tanks which contained anhydrous ammonia will be degassed to 3 pounds per square inch pressure and then vented to the atmosphere. Air must be blown through the tank until all ammonia is dissipated, and rupture disks and other connections must then be blanked off. Tanks which contained aqua ammonia will be drained for protection against ammonia fumes. Tanks placed in standby will be degassed to 3 pounds per square inch pressure and retain heel.

7. WOODEN EQUIPMENT. Pipe lines, hods, benches, tables, hoods, vent stacks, catch boxes, etc., which have been in contact with explosive material will be burned after the bulk of the hazardous material has been removed. Hardware after flashing may be treated with slushing compound and salvaged. Wood drowning tubs will be kept filled with water. Extreme care must be used in disposing of wood catch tanks and wood waste water disposal lines due to the danger of ignition and possible explosion. Wood pipe used to carry off TNT waste becomes extremely dangerous when removed and allowed to dry out. Waste disposal lines should be flushed with water before removal because of possible deposits of contaminants. Metal transite or vitrified clay waste water lines must be handled with the same care during removal.

8. MISCELLANEOUS EQUIPMENT. Miscellaneous equipment such as electric motors, switches, conduit, steam traps, indicating and recording instruments, scales, reducing gear housing, bearings, flexible couplings, belts, hoists, conveyors, and elevators will be inspected for contamination. Such items will be thoroughly cleaned and disassembled if necessary to thoroughly decontaminate. Careful inspection will be given equipment to detect hollow spaces wherein explosives material might lodge such as hollow agitator columns, handles, wheels on hods, sparger tubes, steam jackets, radiators, machine and equipment pedestals.

9. PUMPS. Pumps which contained acid only will be drained, flushed with water, and neutralized with soda ash solution. Cleaning of pumps will include removal of packing, washing of threaded fittings with soda ash solution, drying and oiling. This may be done in connection with washing and neutralization of acid pipe lines. However, pumps which have handled spent acids, nitrocellulose or explosives slurry, or which may be contaminated with explosives, will be disassembled and all parts which have come into contact with explosives will be cleaned. The bed plates and floor coverings beneath explosive-contaminated pumps will be raised and surfaces thoroughly cleaned by hosing, swabbing with rags or other suitable means.

10. NITRATOR COILS. Nitrator coils will be washed, steamed and flashed if the metal is to b to dealers as metal scrap. If coils are to remain in standby condition, they will be washed steamed only. Coils so treated will be thoroughly inspected and marked to show the extent of Nitrator coils will be tested for leaks by applying 30 pounds per square inch air pressure whi mersed in water. If leaks are found, the coils must be flashed and sold as scrap.

11. UNDERGROUND PIPE. a. Underground pipe lines which may contain contaminants will be flus free them of contaminants. The soil surrounding the pipe line may contain explosive material. Underground pipe lines which contain hazardous materials will be removed or a determination ma uncovering the pipe, separating sections in accordance with paragraphs 12 and 13, and examinin pipe at practical intervals to assure that no such material remains within or outside the pipe Surface or shallow pipe lines that cannot be flushed free of explosives will be removed and fl

b. If, in special cases, underground pipe or adjacent ground contains explosive material cannot be entirely removed or decontaminated, such location will be indicated on the plans, as as on the grounds by signs and appropriate fencing.

12. PIPES AND FITTINGS. Pipes, fittings, and valves which have contained explosive material, including wash water containing nitrobody and white water, and pipes where hazardous material infiltrate (such as sparger pipes and service water lines connecting to white water lines), wil be decontaminated. The decontamination of valves may be accomplished by disassembling, boiling in soda ash solution and thorough cleaning with steam or other methods or materials authorized in SOP. Soda ash tanks and pipe lines will be flushed with hot water to remove the crystallize soda ash. If evidence of explosive contamination is found, the equipment will be considered an treated as contaminated and appropriate decontamination or clean-up procedures will be followed eliminate the hazard. Service water, steam, air, fume, sewer, and sprinkler system piping may usually be assumed to contain no explosive material, but such systems will be examined for pres of nitrocellulose slurry, white water, and other explosive contamination if pipe systems are interconnected at mains, sparger tubs, and drains. Contaminated packing, lagging, and gaskets will be burned. Acid pipe which has been subject to corrosion will be pressure-tested befor Pipe used for combustible gas will be blown with compressed air. Putty will be removed pro from dismantled equipment. Pipes and fittings which have contained explosive material will disconnected or separated at flanged connections. While threaded pipe and fittings are prohi for use in process lines used for explosives, it is possible they will be encountered, particula in older facilities. In such cases the threaded part will not be unthreaded without providing personnel protection (shields or remote control) from an explosion. In lieu of unthreading pipe or fittings, pipes may be cut the same as welded pipe (para 13).

13. PIPE CUTTING. If pipe lines which contain explosive material have been welded at the joint cutting of the pipe can be approved after explosive material has been flushed out, using high pressure water through both ends and all branches. The pipe will then be filled with water and using a roller type cutter, keeping the pipe full of water and playing a water hose over the outs of the pipe at cutting location. Such a pipe must not be hammered or subjected to heat of a torc nor sawn by hand or power saw.

14. PIPE LAGGING. Lagging on pipes which have been subject to overflow of slurry water, white w or other explosives material, or which may contain explosive material which has leaked from withi be removed to the burning ground and destroyed. The insulation will be thoroughly wetted before removal.

15. BUILDINGS. Structures contamined with explosives material may be cleaned by the use of stea or hot water. When steam or hot water is employed for cleaning walls and floors, efforts will be made to avoid washing the molten or dissolved explosive into cracks of the building and the adjace areas. Contaminated combustible buildings and combustible portions of such buildings will be burn when declared excess to the requirements of the Government. Foundations, concrete floors, and flo drains found to be contamined should be removed and the site cleaned up where the value of the lan warrants such action; otherwise, it will be restricted to surface use only.

16. DRY HOUSE. Buildings used for the purpose of drying Tetryl, propellants, Pentolite, black powder, Mercury Fulminate, lead azide, etc., will be thoroughly cleaned of all visible signs of contaminant prior to layaway or performance of necessary maintenance.

Appendix A-Continued

17. FLASHING PROCEDURES. Controlled temperature method using approved decontamination ovens may be used in decontamination of equipment that is to be reassembled for production or standby purposes. Other contaminated materials and equipment to be sold for scrap must be subjected to high temperature flashing to assure complete decontamination. Standing operating procedures will be followed. No metal scrap which has been contaminated with explosives or harmful chemicals will be sold unless flashed and certified to be free of contamination.

18. BURNING GROUNDS. Decontamination of burning grounds should be accomplished by subjecting ground to a sustained fire of reasonable duration using available scrap lumber and other combustible materials and soaking with fuel oil. After burning, a visual inspection should be made and samples taken to determine the extent of decontamination. The burning operation should be repeated until reasonable assurance can be made that the ground is safe for surface use only.

19. DEMOLITION GROUNDS. A search of the demolition grounds should be made and all visible foreign objects and scrap metal removed to a suitable location for storage pending disposal. Scrap metal may be disposed of by sale after flashing.

20. GROUND CONTAMINATION. The ground within 50 feet of buildings where an explosive material was handled will be carefully inspected. If the ground is contaminated with explosives material to such an extent that a fire or explosive hazard exists, the layem containing the explosive material will be removed in accordance with SOP and the hazardous material disposed of by burning at the burning ground. If acid contamination is suspected around building foundations, the ground will be thoroughly neutralized. The soda ash solutions from neutralizing acid tanks may be used for this purpose.

21. ORGANICS AND INORGANICS. Tanks which contain organic or inorganic materials should be thoroughly cleaned before dismantling because of the possibility of toxic materials and explosive or flammable gases. Thorough washing with water should be sufficient in most instances.

Section II - ACID WORKS

22. GENERAL. This section applies to the decontamination and dismantling of those parts of the acid area where explosive material has not contacted the buildings and equipment. The hazards of explosive material plus acid are covered in sections pertaining distinctly to each explosive manufacturing area.

a. The decontamination of steel tanks, pipe, valves, pumps, blow cases, etc., will be accomplished by flushing with generous quantities of water, followed immediately by soda ash solution. Corrosion may result from action of weak acid which remains from water washing only. The soda ash solution will remain in contact with the steel parts for sufficient time to neutralize the acid which may remain in crevices of pipe and tanks. Final washing with water and blowing with compressed air may be appropriate to prevent corrosion.

b. In dismantling absorption towers, large quantities of water will be applied to the partition rings and packing.

23. ACID STORAGE TANKS. Appreciable deposits of sulphates will be removed prior to flushing with water to avert possible violent chemical reaction. The acid will be drained and the tank flushed with water. A solution of 7 percent soda ash will be blown or pumped into the tank. Water may be added to overflowing, keeping the soda ash concentration to not less than 3 percent. Interconnecting acid lines, scale tanks, and tanks will then be decontaminated by pumping this solution throughout the system, making certain that alkalinity remains for effective neutralization. This procedure is intended only for acid decontamination, and the solution will not be allowed to enter pipe or tanks contaminated by explosives. The wash will be allowed to remain in each tank until neutralization is complete. The overflow will be allowed to remain on the floors of buildings for sufficient time to neutralize acid which may have been spilled. The neutralizing solution will be forced through pipe lines several times. Tests of the effluent will be made with litmus paper to insure thorough neutralization.

24. AMMONIA OXIDATION PLANT. a. The catalyst will be removed from the converter and a complete platinum recovery made from the converter, heat exchangers, and recovery filter assembly. The assembly will be blown completely free of nitrous gases, acid, etc., and dried. The entire mixer-converter-heat exchanger-platinum recovery assembly will be reassembled and open ends blanked off. Platinum recovery will be extended to include the cooler condenser and ammonia oxidation plant storage tanks.

b. Absorption towers will be washed thoroughly with water to displace the nitric acid on tower plates. After the acid is displaced with water, and the exit line from the tower remov steam at approximately 5 pounds per square inch gauge pressure, will be applied to the water to put steam on each coil. The exit header will be left open to drain condensate. With stea the coils, a small flow of air will be put through the tower until the plates are dry. The co will be blown dry with air. After drying with air the connection between water supply servic manifold cooling coils will be broken to prevent leakage and subsequent coil freezing.

25. SULFURIC ACID CONCENTRATION. Acid vessels in standby status which are brick lined will n decontaminated by the use of steam, hot water, boiling soda ash or other neutralizing solution which accelerates the deterioration of mortar and brick. It is desired that these facilities in an acid condition. Following the removal of any sludge all openings will be cleaned. Roof be provided for open top vessels that are exposed to the elements. The following general proc will be used when it is necessary to decontaminate and/or neutralize equipment prior to making repairs, modifications, and/or alterations.

a. Disconnect the steam traps and supply headers of concentrator units, blanking off open of these lines. The distributor and separator tank covers will be removed and the units thorou washed with water. Packing will be removed from steam jackets. Valves will be dismantled, cle and preserved. Steam lines will be disconnected from vacuum jets and openings plugged.

b. Acid will be drained from the charring unit tubes and tubes cleaned out. The retention will be drained, neutralized and cleaned. Connections will be blanked off, the fume stack disc and its top covered. Any accumulated nitrobodies will be steamed out of the fume system.

c. Sump tanks will be drained, washed, neutralized and disconnected. The hazard of hydroge gas being present where acid reacts with steel will be avoided in locations where acid may be pr especially inside tanks and equipment.

d. Chemical putty will be removed promptly from all equipment, pipe, and fittings, and dest at the burning ground in all instances.

26. NITRIC ACID CONCENTRATOR. a. The preheater will be drained and the unit allowed to coo completely before proceeding. The unit will first be thoroughly flushed with hot water. The in the dams on each boiler tube will then be loosened to allow drainage of the pool in each tube. After drainage the flange will be tightened again. The residual traps, flash concentrator feed t and residual tubs will be drained completely. Then water will be put through the preheater to th unit from the concentrating mix feed header which previously has been blown out and washed. This water can be passed through the residual tubs to the sewer by breaking a flange at the residual pumps. The tee cover on the dehydrating tower will be removed for washing out the hot fume line the bleacher column.

b. The S-bend condensers will be thoroughly washed by disconnecting a flange at the top and passing the water out through the bleacher as before.

c. After washout, all preheater and boiler tube gaskets will be removed. All putty and packi will be removed from the bleacher, dehydrating tower, boiler tube return bands, and the condensers The entire unit will be left loosely assembled and new gaskets will be installed only when necessa to protect flange faces.

d. All acid lines, acid coolers, residual lines, feed lines, etc., will be drained, blown out with air, washed first with water and then with soda ash solution, drained, and disconnected. Line likely to contain sulphate deposits will be exposed to a circulating soda ash solution for several hours. Lead spools will be removed from residual lines. The flash concentrator assembly will be washed thoroughly with water and then given a soda ash solution treatment which includes the feed tanks, feed lines, make tank and line, separator and fume line. The soda ash solution will remain in contact for several hours. After draining, the concentrator will be reassembled and blanks installed at open ends. The acid in the tower will be flushed out with water as completely as possible. Steam at 5 pounds per square inch maximum gauge pressure will be applied to the water inlet header on the tower coils, with the outlet header open to drain the condensate. Air will then be drawn through the system by suction, from the steam jet. This air flow will be continued until the tower plates are essentially dry. The cooling coils on the trays will be blown out thoroughly after disconnecting the steam source and then blanked off. Sample valves will be repacke and nipples replaced with plugs. The water headers will be disconnected, blown free of water blanked off.

27. CATALYST. The catalyst should be removed from converters when oleum plants are placed in standby. Care should be taken to keep catalyst dry, then seal catalyst in drums and store in a weather tight building.

Section III - TNT MANUFACTURE

28. GENERAL. a. All tanks and nitrators will have the acids removed. The pipe lines will then be opened at low points for draining and reconnected for the washing process. The same basic procedures will be followed when decontaminating TNT lines.

b. With the fortifier drain line disconnected, the mono-mix lines may be blown back and drained through the fortifier.

c. Soda ash solution, 7 percent, will be prepared in each of the mono- and bi-nitrators to within a few inches of the top and heated to not above 180°F. While this is being done, the bi-house and tri-house drowning lines will be steamed out. When the bi-nitrator solution reaches 130°F, it will be pumped through the bi-oil tank, reheated, and pumped to the "B" tri-nitrator. Both "A" and "B" nitrator charges of solution will be checked with litmus paper for alkalinity (should be blue; if not, soda ash should be added in small amounts until litmus paper turns blue), reheated with agitation and then run into the bi-nitrator and on into the fortifier. Before receiving this wash solution the drip pan will be washed free of any accumulation of acid. From the fortifier the wash solution will be pumped into the mono-mix tank, dripped to the mono-nitrator and drowned. This comprises the first rough wash in the nitrator area.

d. The sludge deposited in the nitrators will be flushed out with water. A second and third soda ash wash will be given as above, except these may be at boiling temperature. The tanks and nitrators will be washed so that the solution overflows and runs from the top tank nozzles and openings. A part of each wash solution will run through each drowning line. In the mono-house, the mono-mix will be filled until the wash water overflows through the disconnected vent line outlets to the tailings tank and to the mono-oil scale tank. All nitrator covers will be lifted 3/4 inch and blocked in this position and all gasket material removed so that the top of the nitrator and entire underside of cover may be thoroughly washed with soda ash solution and subsequently with sellite solution.

e. A final wash through the nitration system will be made, using a mixture of sellite and soda ash solutions.

f. This solution will be boiled in each nitrator for 4 hours minimum and a small quantity of the boiling solution will be allowed to run over the lids and upon the contaminated parts of the floor. This procedure will follow closely the procedure on previous washes in that all tanks will be overfilled and the boiling solution pumped at least twice through every process line. The boiling solution will be sent to the wash house through the tri-oil line from each nitrator. On the second trip through the tri-house viz the bi- and mono-houses, another solution will be put through each tri-drowning line. A soda ash and sellite solution will be used to flush over the mono-waste line to the recovery house. At each stage the solution will be boiling. Upon completion of final sellite wash, all drowning tubs will be drained and residual nitrobody removed and tubs refilled with water.

29. MONO-HOUSE DECONTAMINATION. a. After the washings with soda ash and sellite are completed, all oil and acid lines will be taken apart and gaskets removed. The acid and oil lines, together with all fittings, etc., will be steamed and boiled.

b. All valves will be taken apart and parts thoroughly steamed, preserved, and reassembled. New packing on valves will not be reinserted if scheduled for layaway.

c. All pumps will be taken apart and the parts thoroughly steamed, preserved, and reassembled. New packing glands will not be reinserted if scheduled for layaway.

d. Sight boxes will be removed, steamed and boiled.

e. Nitrator valves will be steamed and flushed.

f. Pump lines will be taken down; the gaskets removed; and the sections steamed, and boiled, and inspected.

Appendix A-Continued

g. Scales will be cleaned, preserved, and raised off the knife edges. Openings in tanks w remain open and be screened against wildlife and foreign matter.

h. Wood drowning tubs will be maintained in operating condition by keeping filled with wat

i. Nitrator coils will be disconnected and each coil blown out separately with air. Cap immediately to prevent moisture from entering coils.

j. The floors and walls of the buildings will then be thoroughly washed.

k. The toluene system will be drained and flushed thoroughly with water.

30. BI-HOUSE DECONTAMINATION. a. After the washings with soda ash and sellite are completed, oil and acid lines will be taken apart and the gaskets removed. The acid and oil lines together all fittings, etc., will be steamed and boiled.

b. All valves, pumps, and fume lines will be taken apart and the parts thoroughly cleaned.

c. Sight boxes will be removed and cleaned.

d. Scales will be cleaned and preserved.

e. Nitrator coils will be disconnected and each coil blown out separately with air.

f. The floors and walls will then be thoroughly steamed and washed.

31. TRI-HOUSE DECONTAMINATION. a. After the washings with soda ash and sellite are completed, oil and acid lines will be taken apart and the gaskets removed. The acid and oil lines together with all fittings, etc., will be steamed and boiled.

b. All valves, pumps, and fume lines will be taken apart and the parts thoroughly cleaned.

NOTE: Tetranitromethane has been found in fume lines and in fume recovery equipment. Washing thoroughly with sellite solution will remove the tetranitromethane.

c. Sight boxes will be removed and cleaned.

d. Scales will be cleaned and preserved.

e. Nitrator coils will be disconnected and each coil blown out separately with air.

f. The floors and walls will then be thoroughly steamed and washed.

32. ACID FUME RECOVERY BUILDINGS. a. Wash building interior thoroughly. Soda ash solution may be used if necessary.

b. Absorption towers - acid - chemical ware: Drain acid from towers and flush tower, pulsomet and equalizer pots with water until free of acid.

c. Absorption towers - acid - stainless steel: Drain acid from tower to storage tank. Dilute remaining acid with water and drain manifold and coils.

d. Blast gates: Remove from line and clean with water.

e. Gas cooler: Neutralize tubes with soda ash solution and flush with sellite solution. Steam interior followed by a water wash and dry. Disconnect water line and drain jacket.

f. Oil separator: Disconnect acid lines, remove cover from separator and steam interior.

g. Oxidizing tank: Disconnect fume lines, neutralize with soda ash solution and clean with sellite solution. Flush with steam followed by a water wash and dry using approved method.

h. Storage tanks: Remove material from tanks and clean by approved method described in 1 C

Appendix A-Continued

i. Bleacher: Disconnect acid inlet line and steam interior of bleacher. Neutralize contents of bleacher with soda ash and drain to nitric storage tank.

j. Denitrating towers: Drain acid from towers. Neutralize the denitrating towers and preheater with soda ash solution. After flushing with water, blow out with air until system is dry.

k. Ejector - fume - stainless steel: Flush with soda ash solution followed by a water wash and dry with forced air.

33. WASH HOUSE DECONTAMINATION. a. Contaminated insulation will be removed from pipes and process equipment. The contaminated insulation will be sent to the burning ground and burned.

b. Pipes, valves, and fittings which have come in contact with TNT will be dismantled. Iron and steel pipe, valves, and fittings will be steamed and cleaned. Stainless steel valves will be taken apart, steamed, and washed with boiling water and toluene.

c. Stainless steel pipe and stacks will be steamed and boiled.

d. Wooden catch boxes will be dismantled, sent to the burning ground, and burned.

e. Slurry screens and hoppers will be steamed, washed and boiled. As stated heretofore, all bolts and nuts will be thoroughly saturated with penetrating oil prior to removal.

f. Slurry pumps will be disassembled and parts steamed and washed.

g. Wash tubs will be cleaned by removing the tri-oil line, the waste water drain line, and the fume stack. After removing bolts, the top of the tub will be raised about 1/2 inch by driving wedges between the flanges, and washers placed between flanges at intervals to keep them separated. TNT will be scraped from the inside of the top of the tub, using non-sparking tools. The tub will then be washed with steam and hot water until all traces of TNT are removed. The tub will then be wiped with cloths soaked in a mixture of turpentine and kerosene. The mixture will be applied to inside and outside of tub, the gear box, and motor.

h. The slurry tank will be cleaned in like manner. The flanges at the top will be wedged apart after the bolts have been removed. TNT will be scraped from the interior of the tank, using non-sparking tools. A steam hose will be inserted and the tank heated for 1 hour. While the tank remains hot, it will be cleaned with steam and hot water which should clean the tank of all TNT. The tank will be thoroughly inspected and if any TNT remains, the cleaning process will be repeated.

i. The filter tank and wringer assembly will have feed lines from wash tank and red water discharge pipes removed.

j. Brake band assemblies will be dismounted and cleaned.

k. Bolts will be removed from wringer tops.

l. Not used.

m. The wringer casing cover will be suspended above wringers with rope, so that inside of wringer basket and casing can be cleaned.

n. The plate on back of wringer casing will be removed.

o. TNT will be pushed out of holes in wringer basket, using non-sparking tools. Scrape TNT from sides and bottom of baskets and casings.

p. Wringers will then be washed with steam and hot water until free of TNT.

q. After application of penetrating oil, bolts will be removed from bottoms of casings and casings raised from concrete supports. All TNT will then be cleaned from beneath the wringers.

r. TNT will be cleaned from elevators, elevator shafts, and pits.

Appendix A-Continued

s. All TNT will be washed from ceilings, walls and floors with steam and hot water. Inspe will be made to determine presence of explosives behind transite walls and beneath floors so th thorough job of decontamination can be performed by subsequent removal.

t. Slurry pits will be steamed out and cleaned.

u. Ground around the wash house will be inspected and hazardous contamination will be coll: and removed to the burning grounds.

34. DECONTAMINATION OF MELTING AND FLAKING OPERATION. a. Melt tank covers will be raised, an: covers and melt tank thoroughly steamed and washed with hot water to remove all traces of TNT. shaft and agitator will receive the same thorough treatment. Particular attention will be paid the underside of the drier lid for sublimated TNT.

b. A soda ash and sellite solution will be boiled in the melt tank to remove the last trace of TNT.

c. Exhaust stacks from the melt tank and driers will be removed and boiled.

d. Driers will be completely dismantled and the covers boiled. Spargers will not be repair but will be flashed and sold as scrap.

e. The driers will be filled with soda ash and sellite solution, and boiled.

f. Piping and valves to the flaker will be removed, thoroughly steamed, and boiled. Compre: air will be used to dry the internal part of the flaker drum.

g. The covers of the flakers will be removed, steamed, and boiled. The water will be draine from the drums and the driers thoroughly steamed and cleaned.

h. The pan under the flaker must be steamed and washed. Additionally, all areas, around and adjacent to flaker pan and top of chute must be steamed and washed as necessary.

i. The chute leading from the flaker to the scales will be removed and boiled.

j. The shaker will be washed and cleaned with kerosene and turpentine or other suitable mate

k. Conveyors will be thoroughly steamed and cleaned, disassembled if necessary. Damaged woo rollers will be sent to the burning ground and burned.

l. Not used.

m. All insultation will be removed from piping and burned.

n. All TNT piping and drain lines will be boiled or thoroughly cleaned.

o. The dust exhaust system will be dismantled and all parts boiled. The sump will be inspect and cleaned.

35. NAIL HOUSE DECONTAMINATION. a. The nail house will be thoroughly steamed and washed with ho

b. Conveyors will be steam cleaned.

Section IV - WASTE WATER DISPOSAL SYSTEM

36. EVAPORATOR AND INCINERATOR BUILDINGS. a. Waste water will be evaporated as low as possible from all wooden surge tanks (raw storage tanks), equalization tanks (settling tanks), and all store tanks.

b. All storage thick liquor will be evaporated to the lowest possible level.

c. All lines will be flushed with hot water through preheater feed pumps to all preheaters deaerators, feed tanks, long and short tube evaporators, lines running to thick liquor tanks, l running to thick liquor tank pumps, lines running to constant level thick liquor feed tanks, a feed lines to weir boxes of all incinerators. Lines will be drained thoroughly and, if necess for cleaning, dismantled.

Appendix A-Continued

d. Manhole covers will be removed from evaporators and the tubes will be inspected for explosive dust and cleaned where necessary. If tubes are in bad shape, a 48-hour boiling period is recommended Boiling has been found to be much more effective than drilling, but the latter should never be perfor prior to boiling and flushing.

e. The constant level thick liquor feed tanks will be filled with hot water, agitated to clean solids from agitators and float valves, and drained completely into kiln.

f. Flanges at pumps on all preheater feed tanks will be broken, flushed, and all lines drained thoroughly.

g. All preheaters and all vapor line valves will be drained and left in cracked position.

h. All liquor in kiln will be burned to an ash before shutting off the gas flow into furnace. As much ash and scaling as possible will be scraped loose from the inner walls of the kiln and allowed to work down into the conveyor system. Condensate water should be used to wash ashes into drainage pit.

i. All sump pits, steam traps (leave plugs out), vapor legs, drip lines, unit heater, etc., will be drained and blown.

j. Valves will be treated as described elsewhere in this appendix.

k. Sodium hydroxide solution will be removed from storage tanks. Storage tanks will be flushed with hot water and drained thoroughly.

l. Not used.

m. Equalization tanks and all storage tanks will be thoroughly flushed and drained to the open ditch.

n. Wooden surge or raw waste storage tank will be thoroughly flushed to reservoir. Surge tank will be opened (bottom valve or manhole) and reflushed.

o. The pond will be drained into ditch.

p. All wooden lines and lines carrying combination of raw red and yellow water must be handled with extreme care, as residual on these lines will flash with a minimum of friction. All wooden lines will be burned and all metal lines flushed. The lines requiring caution will be from areas settling basins to waste water surge tank and from tank to building. The line from waste water buildings to pond should be flushed with hot water. The pond will be flashed after draining.

q. Raw sludge taken from lines and surge tank will be removed to burning ground. The tank will be dismantled and burned.

r. The ground, in ditches, in ponds and surrounding buildings or equipment, which may be contaminated with explosive material will be carefully inspected. Hazardous contaminated ground will be removed and burned.

Note 1. The "whiskers" formed on outside surfaces of catch tanks, etc., are more sensitive to impact and friction than ordinary TNT. Ignitions of the dry material have occurred upon contact by personnel. Red and yellow wash waters contain highly sensitive material. Dried residues from such wash waters must be carefully handled.

Note 2. The roofs of catch tanks will be burned.

Note 3. Water flowing in ditches carries only a small part of the TNT by entrainment, leaving the bulk of the material. Burning the ditches after several weeks of dry hot weather is recommended. Waste explosives and contaminated ground when redried, remains sensitive after all kinds of weather conditions.

Note 4. Light fixtures, conduits, switch boxes, etc., will be inspected.

Appendix A-Continued

Note 5. Wood troughs, tank staves, etc., must be removed and burned.

Note 6. Wood pipe clogged with explosive waste must be removed and burned.

Note 7. Waste pipe to catch tanks, etc., will be flushed with sellite solution to remove sedim

Note 8. Putty in locations contacted by acid will be considered hazardous. The putty will be w and removed, using non-sparking tools.

Section V - TETRYL WORKS

37. GENERAL. This section covers the decontamination of a plant which has manufactured tetryl the dimethylaniline process. Decontamination of equipment contacted by acid only (no explosive) covered in Section II.

a. Cleaning Agent. See paragraph 40, NOTE.

b. The dimethylaniline storage and scale tanks and connecting pipe will be drained, flushed water, and washed with soda ash solution.

c. The sulphator will be washed thoroughly with water, followed by neutralization with soda solution.

d. Pumps, pipe lines, and valves which have handled dimethylaniline and dimethylaniline solut will be flushed thoroughly with water, neutralized with soda ash solution, and disassembled if necessary for thorough cleaning.

38. ACID FUME RECOVERY BUILDING. a. Cooler - cascade - acid - steel. Drain water lines and flu cooler with water. Neutralize with soda ash solution and reflush with water.

b. Cooler - trombone - acid - HCl and duriron. Drain coolers and flush with water. Dis cooler and boil sections in soda ash solution.

c. Cooler pan. Drain cooler pan and neutralize with soda ash solution.

d. Constant head tank - acid - steel. Remove tetryl from tank, neutralize with soda ash solut Drain tank to waste acid storage.

e. Decomposition unit. The entire unit should be flushed with water and neutralized with soda ash solution. Disassembly where necessary will be accomplished using approved installation procedu

f. Fume condenser - stainless steel. Drain condenser and neutralize with soda ash solution.

g. Weir pots - acid - stainless steel. Remove tetryl from weir pot by flushing with water and/ scraping with a non-sparking tool. Neutralize with soda ash solution and flush with water.

h. Surge pot. Flush with water and neutralize.

All acid storage tanks, service tanks and dimethylaniline tanks will be cleaned in an approved manne

39. NITRATORS. a. The cover and gaskets will be removed from the nitrator. The nitrator and adja pieces of equipment such as emergency drowning tank, acid nutsche, wash tanks, kidney pans and final nutsche, including connecting pipe lines, will be washed with cold water followed by scrubbing with sellite solution. The cover, agitator blades, baffles, and adapter lines will be removed. Nuts and bolts will be treated with penetrating oil before an attempt is made to remove these parts. The part from the nitrator will be thoroughly inspected and cleaned.

b. The fume lines will be washed with water.

40. ACID NUTSCHE. a. Remove screens and wash with cleansing agent, followed by water wash. Remove backing screen grid and ring and wash parts and nutsche with cleansing agent, followed by water wash.

NOTE: When a cleansing agent is referred to, acetone or hot sellite solution may be used. Ac is the better solution for treating tetryl, but the flammable and toxic nature of acetone makes it undesirable for use in confined places or in large quantities.

b. Remove, clean, and wash nutsche fume stack as was done with nitrator fume stack.

c. Kidney pans will be removed, cleaned with cleansing agent, and flashed.

41. FINAL NUTSCHE. a. Remove cloths, wash, and send to burning ground for destruction.

b. Remove heavy backing plate, and clean. Clean nutsche with cleansing agent, followed by water wash.

42. EMERGENCY DROWNING TUB. Wash thoroughly with water. Remove sparger tubes, clean with cleansing agent. Tub will be sent to burning ground and burned, if wood, of flashed if metal.

43. WASH WATER CATCH TRAY. Remove tops and wash with cleansing agent followed by water wash.

44. STEAM EJECTORS. Remove lines from nutsches to catch boxes, including ejectors; clean lines and ejectors.

45. VACUUM TANK. Wash inside of vacuum tank with cleansing agents, followed by water wash. Remove all lines from the nutsche to the vacuum tank, from the vacuum tank to the acid nutsche ejector, and the lines from the vacuum tank to the waste acid settling tank. Clean tank and lines.

46. WASTE ACID SETTLING TANKS. Remove tank covers and clean with cleansing agent. Wash tank with cleansing agent, followed by water wash.

47. NEUTRALIZING TUB. a. Lift the top and clean thoroughly with cleansing agent. Remove sparger and valve assembly and clean by boiling in sellite solution.

b. Wash tank with sellite solution cleansing agent, followed by a water wash.

c. Remove lines and fittings, and clean.

d. Waste acid lines will be removed up to and including check valves in the waste acid line to the acid recovery building.

e. Clean waste acid lines.

f. Lead floor drains will be removed, cleaned with cleansing agent, and flashed. Clean the drain wells with cleansing agent.

48. REFINERY. Run two acetone charges to remove as much tetryl as possible from the lines and equipment. Recover acetone and store in drums. Fill the system completely with water and thoroughly flush.

49. DISSOLVER. a. Remove the dissolver and clean with sellite solution.

b. Remove the grind and back-up screen and clean with sellite solution.

c. Scrub inside thoroughly with water. Clean the basket with cleansing agent, followed by water wash.

50. MIXING KETTLE. a. Remove jets and steam lines from jets to reducer on first floor and flash.

b. Remove agitator blades and clean with sellite solution.

c. Remove dump valve, disassemble, and clean.

d. Clean mixing kettle with cleansing agent, followed by thorough water flush.

e. Remove blanks from extra jet openings and clean thoroughly.

51. CONDENSER. Remove the heads from the top and bottom of the condenser, applying penetrating oil to prevent ignition of dust beneath bolts and nuts. Clean tubes with sellite solution, followed by water wash. Wet shaker screen will be disassembled and cleaned.

52. PROCESS LINES. Remove and clean the following:

a. Line from dissolver to drain.

b. Line from dissolver to still.

c. Line from condenser to dissolver.

d. Line from condenser to measuring tank.

e. Line from top of condenser to vapor trap.

f. Line from measuring tank to still.

g. Lead floor drains from second and third floors.

53. DRY HOUSE. Remove tetryl by sweeping and using non-sparking dust pans. Remove blower ducts metal frames, washing tetryl from surfaces with water, and using penetrating oil on nuts and bolt when disassembling equipment. Interior walls and floors will be washed with sellite solution and flushed. Remove metal equipment and clean. Equipment in blower house is assumed to be uncontami If contaminated, it should be cleaned in the same manner.

54. PACKING HOUSE. a. Clean walls and floors thoroughly with water.

b. Remove hopper hood and clean.

c. Clean, preserve, and block up scales.

d. Clean the nailing machines, oil with kerosene.

e. Drain and clean outside catch box.

f. Disassemble, clean, and preserve water circulater pump.

g. Remove and clean ejector and circulating lines.

h. Elevator pit and shaft will be thoroughly cleaned with water.

55. LAG HOUSE. Remove all visible tetryl using non-sparking dust pans or tools, and wash interior of building with water. Unit heater should be thoroughly inspected for tetryl contamination in accordance with procedure outlined in paragraph 8.

Section VI - NITROCELLULOSE WORKS

56. GENERAL. a. This section covers the decontamination and dismantling of a plant which has manufactured nitrocellulose, starting with cotton or wood pulp at the point where water-wet purified nitrocellulose is delivered to the smokeless powder manufacturing area. Care must be given to nitrocellulose that may become dry, especially in a confined location such as beneath floor boards, in threads or pipe joints, within walls, beneath bolt heads, etc. Nitrocellulose may be handled water-wet with safety. Buildings and equipment (electrical equipment excepted) will be maintained wet while the decontamination work is in progress. Dry nitrocellulose is more sensitive to heat, impact, and friction than most of the materials encountered in decontamination of military explosive plants.

b. The buildings and equipment where raw cotton and wood pulp have been stored and handled will be given general cleaning treatment consisting of water washings. Inspections must be made of interiors of hollow walls, the space above ceilings, and beneath floors, and if cellulose dust is found, it must be washed out.

57. NITRATING HOUSE. a. The building must be washed thoroughly with water. If loose flooring is found, the floor surfacing material will be removed and surfaces cleaned. When wooden sections have been exposed to slurry water, wash thoroughly to remove the nitrocellulose lodged in the crevi All wood exposed to nitrocellulose slurry must be removed while wet to the burning ground, an

b. Sump pits, floor drains, and traps must be flushed with water and sediment transported while wet to the burning ground.

58. BOILING TUB, PULPING, POACHER, BLENDING, AND WRINGER HOUSES. a. - Wash the buildings thoroughly with water (except electrical equipment), removing nitrocellulose from all of the slurry lines, especially at flanges and valves. The surfaces of beams and piping beneath floors must be inspected and any nitrocellulose lodged beneath will be removed by washing. All wooden tubs will be kept filled with water. Slurry troughs, etc., which have contained slurry, must be washed with water and dismantled while wet. Metal parts must be flashed and wood removed to the burning ground to be destroyed by burning.

b. Acid tanks will be cleaned with soda ash solution beginning with storage tanks, then run through mix and weight tanks, warming tanks, and nitrating units to spent acid filters, then to spent storage and finally to sewer. Test soda ash solution at intervals and keep strength at 3 percent. With caustic solution, start flow at mix and weigh tanks and follow same flow. The weak nitric tank will be flushed with water and treated with boiling caustic soda solution for 2 hours, drained, and flushed again. The surge tanks and the settling tank will also be boiled with caustic soda solution.

c. Nitrating wringers will be rotated while boiling caustic solution is run through the pipe lines, wringer basket, etc. While wet with water, any nitrocellulose adhering to the holes in the wringer basket will be punched out. Drain, flush, and fill wringers with water to overflowing.

d. Fume recovery systems must be washed thoroughly with water before being dismantled. Penetrating oil will be applied to seams of flange bolts before dismantling, and the duct maintain wet while dismantling.

e. Jordan engines must have all piping disconnected and flushed. The wooden separators will be removed from the plug and shell knives and sent to the burning ground. Gland packing must be sent to the burning ground and burned. Metal parts exposed to nitrocellulose must be flashed. All small tanks in this building will be removed while wet and flashed. The large tanks must be boiled with 15 percent caustic soda solution and filled with water.

f. The packet screen must be dismantled completely and brass screen cleaned with caustic soda solution. Other metal parts will be cleaned with caustic. Separate wood at joints and clean thoroughly. If equipment is not to be used for a nitrocellulose packet screen, metal parts should be flashed and wood destroyed by burning.

g. Final wringers will be disassembled, including driving head, plough mechanism and brake drum, and all parts thoroughly cleaned. Flash basket and unloading chute.

h. Boil tub save-alls or settling tank of wood construction must be cleaned of visible signs of nitrocellulose, filled with water, and maintained in this condition. Steel, concrete, and acid resistant brick lined tanks will be drained and all visible nitrocellulose removed. The tanks will be flushed with water, drained, and remain empty. The same procedure will be used for submerged concrete and acid brick lined tanks.

Section VII - SMOKELESS POWDER WORKS

59. GENERAL. The hazards of dry nitrocellulose as outlined in Section VI apply to the location where smokeless powder is manufactured. Even though nitrocellulose is handled in a water-wet or alcohol-wet condition until a colloid is formed in the mixing operation, wet nitrocellulose becomes dry quite readily and such a possibility should be guarded against in dismantling the plant. Smokeless powder dust in a dry state must be considered an explosion hazard the same as dry nitrocellulose.

60. DEHYDRATING PRESSES. Dehydrating presses must be thoroughly flushed with water and the pipe lines emptied, drained, and flashed. Auxiliary solvent lines, tanks and accumulators will be drained, disassembled, or dismantled. Pipe lines will be flushed with caustic soda solution. Leathers and gaskets must be burned at the burning ground. Wet nitrocellulose transfer cars will be washed.

6. MIXERS. Mixers must be scraped with non-sparking tools while the surfaces of bowl, blades, and shafts are maintained wet with water. Parts will be disassembled and cleaned. The packing must be removed from the mixers, then burned.

62. MACARONI, BLOCKING, AND GRAINING PRESSES. Macaroni, blocking, and graining presses will have screens, plates, manifolds, etc., removed and parts swabbed with acetone when necessary to remove colloid. Powder end of press ram will be scraped while water-wet with a non-sparking tool, then swabbed with acetone. All metal must be flashed before being released for use in non-explosive wor or for scrap.

63. POWDER TRANSFER, SOLVENT RECOVERY AND AIR-DRY CARS. Powder transfer cars, solvent recovery cars, and air dry cars will be flushed clean with water. Solvent recovery tanks and auxiliary equipment will be drained thoroughly, flushed with water, and disassembled while water-wet.

64. PIPE LINES. The pipe lines will be disconnected from water-dry tanks, inspected, and thorough washed. Pumps and other auxiliary equipment will be thoroughly cleaned.

65. AIR DRY EQUIPMENT. The air-dry equipment must be thoroughly flushed with water inside and out, protecting the electrical parts of such equipment. When dismantling duct systems, surfaces will be wet and penetrating oil will be supplied to joints before separating parts which have been exposed to smokeless powder dust.

66. BLENDER. The blender elevator car pit and shaft must be washed thoroughly at the same time the buildings and bins are decontaminated. The pack house and equipment will be cleaned by flushing wit water, followed by thorough inspection to assure that decontamination is complete.

Section VIII - SODIUM AND LEAD AZIDE WORKS

67. GENERAL. This section covers the decontamination and dismantling of lead azide manufacturing plants. The treatment recommended for cleaning ammonia storage tanks and lines and acid equipment is given in Section II of this appendix. The formula for "Killing Solution" as referred to hereafte is contained in paragraph 74.

68. SODIUM AZIDE BUILDING. a. All metallic sodium will be removed from equipment.

(1) Screens will be removed from melt pots and cleaned.

(2) Metallic sodium lines and nozzles will be cleaned thoroughly.

b. After autoclaves have been thoroughly cleaned and steamed, the system must be flushed with ammonia from the ammonia scale tanks. This ammonia will be drowned. All ammonia valves and the ammonia feed vent line must be left open and the autoclave thoroughly steamed again. The ammonia scale tank must then be vented further through lines to the storage tank.

c. All nitrous oxide cylinders will be disconnected and vented further through lines to the storage tank.

d. After all azide has been destroyed (see para 74 for azide test), sodium nitrate solution must be drained from the storage tank to the killing tank and the storage tank flushed several times with water, allowing the water to drain into the killing tank.

e. After washing and steaming autoclave, hot water will be blown to the drowning tank and pumped through the crude scale tank to the ammonia evaporator where the water will be boiled for 1/2 hour before draining to the killing tank. Vent lines will be flushed into autoclaves from roof. Wash water plus an appropriate amount of killing solution will be added to the autoclave through the blank flange opening and agitated for 1/2 hour. The solution will then be blown to the drowning tank and pumped through the crude scale tank to the ammonia evaporator to the drain. The system will then be flushed with water. Killing solution and wash water will again be added to the autoclave and the pro repeated until the effluent gives a negative test for azide. Should the azide-free effluent be acid soda ash solution must be flushed through the system until neutralized.

f. The clear liquor tank will be flushed with hot water from the clean ammonia evaporator. Killing solution will be added, followed by another water flush until effluent gives a negative test for azide. The manhole cover will be similarly cleaned.

g. Evaporators, condensers, condensate receivers, wringer, and catch tank.

Appendix A-Continued

(1) The evaporators will be filled with water boiled for 2 hours under vacuum, thereby flushing the condensers through to the condensate receiver.

(2) The condensate receiver will be drained to the killing tank.

(3) After the filter cloth has been removed from the wringer and burned, hot water will be dropped through the wringer to the catch tank. The water will be pumped to the first and second mother liquor tanks and to the lime treatment tank.

(4) The evaporators will be refilled with water to the level of the upper sight glass. An appropriate amount of killing solution will be added through the sampling device. The solution will be agitated for approximately 1 hour, then water will be added until the evaporator overflows through the condenser to the condensate receiver. This treatment will be continued until the effluent gives a negative test for azide.

(5) The remaining solution in the evaporators will be dropped through the wringer to the catch tank and pumped to the mother liquor tanks.

h. Mother Liquor Tanks. The hot water pumped from the catch tanks, as described above, will be drained and washed to the killing tank sump. The tanks will also be drained of the killing solution and flushed to the sump. The tanks will then be hosed from the top and flushed thoroughly until the effluent gives a negative test for azide.

i. Lime Treatment Tank, Nutsche, and Second Clear Liquor Tank.

(1) The hot water will be dropped and flushed through the nutsche to the second clear liquor tank and drained to the sump. The same procedure will be followed with the killing solution flush.

(2) The nutsche cloth must be washed and burned.

(3) The lime treatment tank will be filled with water and boiled for 1 hour, using a steam coil. The water will then be dropped to the second clear liquor tank and tested for azide. The procedure will be repeated until azide test gives negative results.

j. Refined scale and storage tanks.

(1) The refined scale tank will be flushed through with water and drained to the killing tank.

(2) The catch tank will be filled with water, killing solution added, and the solution pumped through to the refined scale tank until the latter overflows. The solution will be allowed to stand for 2 hours. The solution will then be dropped to the refined storage tank and tested for removal of azide. The procedure will be repeated until the azide has been destroyed.

(3) The refined storage tank will be filled nearly full of water and killing solution added through the sampling valve. The solution will be circulated for 16 hours, sampled, and tested for azide. If azide is present, more killing solution will be added and the process repeated until all azide has been destroyed. The solution will then be pumped to the feed tank in the lead nitrate preparation building.

k. Killing Tank Sump. The sump must be flushed several times with water, after which the caustic mud will be removed from the sump and burned. Care must be taken as the mud is strongly caustic. The killing tank and sump will be left empty.

l. Not used.

m. General Building Clean-up.

(1) The screen cleaning, sodium storage, and cylinder rooms will be cleaned thoroughly and all waste sodium burned. The screen cleaning room will be flushed and drained repeatedly.

(2) Walls, tanks, and floors will be washed thoroughly. The room will be inspected and washed if necessary.

6D. PREPARATION BUILDING. a. Raw Material Disposal.

(1) The killing solution from the refined storage tank in the sodium azide building will be pumped through the sodium azide tank system and to the measuring tanks in precipitation buildir

(2) The feed tank, dilution tank, nutsche, and settling tanks will be flushed with water. The wash water will be tested for azide, and, if present, killing solution must be employed to cle the system. When azide has been destroyed, the system will be flushed with a 1 percent soda ash solution, followed by another water flush.

(3) The nutsche basket and settling tank lids must be removed and any settlings will be hosed out. The nutsche cloths must be soaked in killing solution, washed, dried, and burned.

(4) Lead nitrate tanks will be filled with water containing 2 percent nitric acid. The nutsche cloths must be dried and burned. The lead nitrate preparation and storage system will be flushed with this nitric solution until a negative test for lead is obtained. This solution may b dropped to the precipitator measuring tanks. The nutsche, nutsche basket, and settling tank lids will be treated as described in (3) above.

b. General building clean-up. All walls, tanks, and floors must be washed thoroughly.

70. PRECIPITATION BUILDING. a. Raw Materials Disposal.

(1) Lead nitrate measuring tanks and delivery lines must be treated as described in paragr 69a(4) until effluent gives negative test for lead. The tanks will be drained through the bottom nipple, removing valve completely.

(2) Sodium azide measuring tanks and delivery lines must be flushed with water and killing solution until all azide has been decomposed. Final water flushes will be made and drained through bottom nipple, removing valve completely. All rotometers will be removed from delivery lines and cleaned together with monel screens, in killing solution.

b. Lead Azide Disposal.

(1) Kettles and cells must be cleaned with killing solution of high concentration. T entire cell must be hosed down several times.

(2) To remove all azide from floors, the cell doorways will be dammed to height above the mastic covering, the drain to the hot water sump tank blanked off, and overflow drains covered. Mastic at the cover will be pulled away from the walls as far as necessary to insure complete remova and killing of azide that has collected at these points. The cell floors will then be flooded to a depth of 10 to 12 inches. Killing solution will be added in quantity and the floors kept flooded for 48 hours after which more killing solution will be added at intervals, agitating the flooded portion each time killing solution is added, until all azide is destroyed.

(3) All splash guards, precipitator frames, and metal supports must be washed down with killing solution.

(4) The solution will be syphoned from the killing tank after first adding soda ash solutior The syphoning will be continued from sump to killing tank until cell and killing tank have been emptied.

(5) The entire cell must be hosed down thoroughly and the water syphoned to the ditch.

71. FINISHING BUILDING. Lead azide disposal:

a. All cloths, sponges, and paddles must be soaked in killing solution for 24 hours, washed, dried, and burned.

b. All trays and buckets must be cleaned with killing solution. Killing solution will be poured around the base of the scale and flushed.

c. Killing solution must be poured on tables and in all cracks around tables, walls, and floors. The solution must be allowed to stand 4 hours, then equipment will be flushed with water. Wooden guard rails, the platform, and supports must be removed, soaked again in killing solution, wash dried, and burned.

d. The nutsche basket must be soaked in killing solution. The wash tray and nutsche must be washed down with killing solution. The equipment should then be flushed thoroughly with water and let dry.

e. The killing tank room must be cleaned out with killing solution and several water flushes.

f. The alcohol tank will be steam cleaned.

72. WASH WATERS. Wash waters and waste liquors from decontamination operations must be treated with killing solution in the killing tank, if necessary, until all azide has been destroyed.

73. WASTE AZIDE. Waste azide in sumps must be syphoned into a killing tank until the tank is approximately 1/3 full. The agitator will be started and steam will be opened to the blast nozzle in the stack. The liquid must be agitated and a sample withdrawn from the tank and analyzed so that the quantity of killing solution required for the destruction of azide can be calculated. The killing solution must then be added and a sample of the contents must be tested periodically for the presence of azide. When the destruction of azide is complete, the contents of the tank will be syphoned to the settling pond, continuing the agitation until the tank is empty.

74. KILLING SOLUTION. The killing solution and treatment recommended for destroying azide is 25-28% solution of nitric acid and 10% solution of sodium nitrite. Extreme care must be taken during the destruction of azide as poisonous and explosive gases may be liberated during the reaction. Personnel will not be permitted in rooms where azide is being destroyed, and possible sources of ignition of explosive gases must be removed. All liquors in which azide has been destroyed must give a negative test for the presence of azide before permitting release. A simple test consists of adding a small amount of 0.1N ferric chloride solution to a sample of the liquor. If the azide content has been destroyed, the solution will be colorless; and if it has not been destroyed the solution will turn red or will have a reddish cast. Liquors in which azide has been destroyed must be treated with soda ash solution to precipitate all lead and to neutralize any free acid before such liquors are dumped into streams or brooks. The chemical destruction methods recommended herein involve complicated chemical reactions which may vary in effectiveness, depending upon temperature, concentration of solutions, etc. It is therefore essential that none but fully trained personnel be permitted to judge the effectiveness of azide destruction.

Section IX - NITROGLYCERIN MANUFACTURE

75. GENERAL. This section applies to the decontamination of nitroglycerin manufacturing plants. Procedures for the proper cleaning of equipment which has come into contact with solvents for acids, except for the acid equipment specifically mentioned below, are described in Section II.

76. SPENT ACID ELEVATED STORAGE - NITROGLYCERIN RECOVERY. a. The tank will be drained and flushed with water. The tank will then be washed with soda ash solution to neutralize any residual acid, followed by a washing with soap and water, and completed by cleaning with nitroglycerin desensitizer. (Soda ash solution, 5 to 7 percent soda ash, will be employed to neutralize any residual acid.)

NOTE: For desensitizing solution see paragraph 95.

b. The air agitator coil will be washed with water and blown out with air. The coil will then be flashed.

c. All gaskets must be removed from acid lines and burned.

d. The acid lines will be washed out with water and any residual acid will be neutralized with soda ash solution and nitroglycerin desensitizer must be run through the lines.

e. The wash tank will be neutralized with soda ash solution and washed with soap and water, followed by nitroglycerin desensitizer.

77. SPENT ACID RECOVERY. a. All lead acid lines will be washed with water and neutralized with soda ash solution.

b. Lead residual cooling coils will be disconnected, washed out with water, and neutralized with soda ash solution.

Appendix A-Continued

c. The denitrated sulfuric storage tank will be washed out with water and neutralized with ash solution.

d. The bleacher pot will be washed out with water and soda ash solution.

78. SPENT ACID STORAGE. a. Storage tanks will be drained and neutralized with soda ash solut follwed by cleaning with soap and water and nitroglycerin desensitizer.

b. Gaskets must be removed from acid lines and burned. Acid lines will be neutralized wit soda ash solution, flushed with water, washed with soap and water, and flushed with nitroglycer desensitizer.

c. Soda ash solution and nitroglycerin desensitizer must be poured down vent pipes. The ve pipes will be removed and be sent to the burning ground for flashing.

d. Wash tanks must be washed with soap and water, neutralized with soda ash solution, and cleaned with nitroglycerin desensitizer.

e. The catch box must be drained and washed first with soda ash solution then with soap and water, and cleaned with nitroglycerin desensitizer.

f. Wooden drop plug sticks must be destroyed by burning.

g. Block cocks must be removed, dismantled, and cleaned, first with soda ash solution and th with soap and water and nitroglycerin desensitizer. Due to porosity, chemical ware must be subme in nitroglycerin desensitizer for several hours.

h. Ceramic valves must be removed and treated as described in g above.

i. Rubber hose must be removed and burned.

79. NITRATOR. a. The nitrator must be filled to within a few inches of the top with a 3 to soda ash solution. Agitation will be provided during the neutralization, and it is important that the inside top of the nitrator is thoroughly laved with soda ash solution. When neutralization is complete, the cover and top of the nitrator will be removed and cleaned. Wash waters from cleanin the nitrator and from subsequent pieces of equipment will be allowed to flow through the normal operating stages to the catch boxes at the neutralizing and store houses.

b. The lead air coil must be removed and sent to the burning ground to be flashed.

c. The walls and inside top of the nitrator must be washed with soap and water, followed by a thorough application of a nitroglycerin desensitizer.

d. The Woulff bottle must be removed and neutralized with soda ash solution and nitroglycerin desensitizer.

e. Condensate lines and vent lines will be similarly treated where possible. The pipes must b sent to the burning ground and flashed.

80. SEPARATOR. a. The separator must be scrubbed out with soap and water, followed by cleaning wi nitroglycerin desensitizer.

b. The air agitator coil must be removed and sent to the burning ground to be flashed.

81. PREWASH TANK. a. The tank must be washed with soap and water, followed by treatment with a nitroglycerin desensitizer. The paint, while being kept wet will be scraped from the interior of the tank and treatment given prior to removal of the paint should be repeated on the bare interior of the tank.

b. Prewash and sour water tank drop plugs must be removed and sent to the burning grounds, together with all hose clamps, and burned.

c. Hard rubber parts of agitators on prewash and sour water tanks must be sent to the bu ground to be flashed. The lead parts of these agitators must be sent to the burning ground t flashed. The pliable rubber tubing used on the outlets of the prewash tanks, after washing wi soda ash solution, must be removed to the burning ground to be burned.

Appendix A-Continued

82. DROWNING TANK. a. The drowning tank must be scrubbed with soap and water, then cleaned with nitroglycerin desensitizer.

b. The lead air agitator pipe must be removed and sent to the burning ground to be flashed.

83. NEUTRALIZING AND STORE HOUSES. a. Nitroglycerin slums must be cleaned from tanks and catch boxes by absorbing it in sawdust. The sawdust must be burned.

b. Nitroglycerin storage tanks must be washed with soap and water and cleaned thoroughly with nitroglycerin desensitizer.

c. Drop plugs and sticks must be burned.

d. Combustible lids of tanks must be burned.

e. All rubber tubing used in the neutralizing and store houses must be washed with soda ash solution and then be sent to the burning ground and burned.

84. NITROGLYCERIN LEAD TANKS. Tanks and connecting lines must be drained, flushed with soda ash solution, washed with water, and cleaned with nitroglycerin-desensitizer. This treatment should be followed by neutralization with 5 to 7 percent soda ash solution, after which the tanks should be washed again with soap and water.

85. NITROGLYCERIN SLUM HOUSE. a. All nitroglycerin slums must be absorbed in sawdust and burned.

b. The slum filter must be washed out with soap and water, cleaned with nitroglycerin desensitizer, and burned.

86. NITROGLYCERIN CATCH BOXES. a. All metal catch boxes must be washed with soap and water and cleaned with nitroglycerin desensitizer prior to removal of paint. Paint will be scraped while wet. After paint has been removed, the catch boxes will be retreated with soap and water and nitroglycerin desensitizer. Wooden catch boxes which may be contaminated with nitroglycerin will be washed with water, dismantled while wet, and burned.

b. Drop plugs and sticks must be removed to the burning ground and burned.

87. NITROGLYCERIN GUTTERS AND ADAPTERS. a. Rubber lined gutters.

(1) If plant is to be placed in "standby" condition, the rubber lining will be washed with soap and water, then sponged with nitroglycerin desensitizer. Otherwise, the lining must be removed and burned.

NOTE: For desensitizing solution see paragraph 95.

(2) Lids will be washed with soap and water, followed by nitroglycerin desensitizer, if plant is to be placed in "standby" condition. Otherwise, lids must be removed and burned, salvaging metal parts after exposure to flame.

b. Waste water gutters

(1) Tar paper lining will be removed and burned at the burning ground.

(2) Gutters and lids will be treated as described in a above.

c. Lead gutters and adapters. Lead gutters and adapters must be washed thoroughly with soap and water, then cleaned with nitroglycerin desensitizer. See paragraph 95. They must then be removed to the burning ground and flashed.

88. NITROGLYCERIN BUGGIES. a. Copper tanks must be removed from the chassis and cleaned with soap and water and nitroglycerin desensitizer.

b. The chassis also must be washed with soap and water, followed by cleaning with nitroglycerin desensitizer.

c. Buggy covers must be soaked overnight in nitroglycerin desensitizer, then flushed.

89. NITROGLYCERIN BLOCK COCKS. Block cocks will be taken apart and all parts cleaned with so: water and nitroglycerin desensitizer. Care should be taken to see that all drains in the cores cocks are cleaned.

90. CHEMICAL WARE CERAMIC VALVES. a. Valves of this type must be dismantled, and the parts w with soap and water and nitroglycerin desensitizer.

b. All drains in the core will be cleaned thoroughly. Cocks may then be reassembled.

NOTE: Nitroglycerin block cocks, chemical ware, and ceramic valves will be submerged in nitrog desensitizer for several hours due to priority of the material.

91. RUBBER HOSE. All rubber hose through which nitroglycerin has passed must be removed from e and burned.

92. WHEELING WALKS. When a plant is to be placed in "standby" status, walks will be inspected, rotten planks removed, and loose boards nailed securely. Any portion of the walk ways that has involved in a nitroglycerin spill must be dismantled, removed to the burning ground, and burned after treatment with desensitizer.

93. VENTS. Vents and vent lines over nitroglycerin equipment will be washed with soap and wate: soda ash solution, and nitroglycerin desensitizer poured down vent lines. The pipes must be sent to the burning ground and flashed.

94. BUILDINGS. All buildings in which nitroglycerin has been processed must be washed down thor Lead and conductive flooring covers and walls must be cleaned also with nitroglycerin desensitize

95. NITROGLYCERIN DESENSITIZER. Nitroglycerin desensitizer is commercially available and may be used if the material effectively decomposes nitroglycerin. A desensitizing solution which can be made readily at the facility consists of:

1/2 gallon water
1/2 gallon wood (methyl) alcohol
2 pounds sodium or potassium sulfite
(Larger amounts may be prepared in the sampe proportion.)

Where desensitizing solution is used on large quantities of nitroglycerin, a rapid reaction may oc at one point, causing local heating and possible subsequent detonation of the nitroglycerin. When possible, wash equipment first with soap and water before using desensitizer. After desensitizer has been used, the equipment must be flushed with water to remove all decomposition products.

96. FLASHING. Personnel should be adequately protected by barricades or distance from a possible detonation during flashing operations. Special care must be taken in flashing spargers and hollow piping where quantities of nitroglycerin may be present.

NOTE: The same general procedures will be followed when decontaminating a plant employing the BIAZ process.

Section X - RDX OPERATIONS

97. GENERAL PRACTICES AND PRECAUTIONS. Basic Plan. In general, the same basic plan of decontamin will be followed in each operating building where the presence of RDX or any other type explosive, acid, or toxic material is known or suspected, as follows:

a. All explosives and other ingredients remaining in a building will be removed and disposed of according to established SOP.

b. The building will be thoroughly washed down and cleaned until all visible traces of explosiv are removed.

c. Acid lines will be flushed with fresh water until all traces of acid have been removed as determined by litmus paper test.

d. All processing lines, vessels, kettles, tanks, etc., will be empty and reasonably clea any dismantling operation is begun in connection with decontamination or cleaning. Instruction to use of penetrating oil (see para 2b) are applicable.

e. Catch boxes will be cleaned and all waste explosives sent to the burning ground for destructio

98. METHODS OF DECONTAMINATION AND CLEANING. Decontamination will be accomplished by one or a combination of several of the following methods:

a. Flush with water. This method will be employed initially in all cases.

b. Cleaning with mixture of steam and water. Steam not to exceed 5 pounds per square inch pressure.

c. Dissolving and removing RDX contamination by use of acetone as a solvent. This solvent is highly flammable and toxic. Proper safety precautions must be used in handling it.

d. Decomposition by submerging the item in a mixture of potassium hydroxide and carbitol, and agitating the mixture until the RDX has disintegrated. Removal of RDX may be accomplished by the use of a non-metallic brush and/or non-ferrous or wooden paddles.

e. Burning or detonation of explosive by flashing. Decontamination by this method must be kept at a minimum and employed only when absolute decontamination is required since the excessive heat causes warping and distortion, and if detonation occurs severe damage to the item usually results.

f. Non-sparking plastic or wooden scrapers, brushes, sponges, cleaning cloths, etc., will be employed when decontamination is accomplished by flushing, steam cleaning, and the use of acetone.

g. See paragraph 113 for desensitizing solution for RDX.

h. Acid.

(1) Flush copiously with water.

(2) Neutralize by use of alkali.

99. HEXAMINE HOUSE. Thoroughly wash down all ceilings, walks, floors, and equipment with water.

100. NITRATING HOUSES. a. Clean all visible explosives from the building.

b. Flush the hexamine hoppers, processing vessels, pumps, and process lines thoroughly with water. CAUTION: All nuts and bolts must be thoroughly soaked with penetrating oil before loosening and maintained wet while being loosened.

c. Hexamine Feed Room.

(1) Thoroughly clean the elevator and elevator pit.

(2) Dismantle the hexamine granulator, chutes, and hoppers and clean thoroughly with water. Clean the granulator and hexamine feed motors and drives.

(3) Wash the aspirator thoroughly with water.

(4) Flush the 98% nitric and head tank and flow lines with water.

(5) Dismantle the condensate water head tank flow lines.

d. Nitrating Level.

(1) Water wash the rotameters, thermometers, and instruments.

(2) Thoroughly wash the nitrators, cooling coils, agitator arms, nitrator tops, and overflow lines. Wash the nitrator shells, motors, PIV's, gear boxes, and the drain lines. Thoroughly flush the fume stack.

(3) Wash the stabilizer shells with water without removing them from position. Wash the agitator shafts, blades, and wiper arms, the cooling drums, all covers for openings on the stabilizer top, the overflow trough, the steam spargers, the thermometer wells and the drain lines with water.

Flush the fume ducts, dampers, and surge chambers, motor uprights, and the stabilizer drain valve Clean and flush between the vacuum receiver tanks and the inlet opening to stabilizer. Special equipment, such as valves, rotameters, etc., will be cleaned but not flashed.

CAUTION: Carefully inspect the cooling water catch pans and drain lines and remove all RDX found

(4) Flush the coolers, cooler tops, surge chamber tops, agitator arms, cooling coils, overflow troughs, and thermometer wells. Clean the agitator motors, post indicator valves, gear boxes, and drain valves, and thoroughly wash the drum cooling coils.

c. Wash Level.

(1) Flush the accumulators, accumulator tops, agitators drain lines, cooling coils, and the valve stems, with water. Examine the motor and drive for contamination and remove same by approved procedures. Remove heavily contaminated lagging to burning ground and burn.

(2) Wash filter tank, grids, and screens with water. CAUTION: All tie bolts and nuts above screen level will be removed under 2 inches of water. Wash the slurry and acid lines.

(3) Flush the vacuum receiver tanks, processing lines, pumps, and holding tanks thoroughl with water.

(4) Wash the slurry sending tanks, tank tops, tank bands, agitators, drain lines, and drai valve stems with water. Clean the agitator motors and drives.

(5) Dismantle and wash the condensate water holding tank and inspect carefully for RDX, which, if present, should be disposed of as outlined heretofore. Flush the wash water lines, the overflow line, and the drain line.

(6) Dismantle and wash the slurry sending pumps and the condensate water pump with water.

101. FUME RECOVERY HOUSES. a. Neutralize all towers, pumps, acid lines, fume ducts, and acid tan until they are acid free (effluent turns RED, litmus paper BLUE).

b. Dismantle and wash the fume duct with water. Dismantle and wash all acid lines from the vacuum receiver to the weak acid storage tanks with water.

c. Dismantle and wash the RDX trap and the flush-back line with water.

d. Remove the manhole covers on the towers and wash inside the base of the towers with water.

e. Remove the manhole covers from the tanks and flush with water.

102. BOILING HOUSES. a. Clean all visible explosive material from the building and flush the slurry lines and pumps thoroughly. CAUTION: Thoroughly soak all nuts and bolts with penetrating oil and water before loosening and drench under a stream of water while being loosened.

b. Flush the tanks, tank tops, agitator units, cooling coils, and steam spargers with water.

c. Flush all slurry lines and air blow steam tracer lines.

d. Dismantle and clean the pasting mills. Water may not remove all RDX, in which case acetone may be used.

e. Clean and flush the transfer and spending pumps and slurry lines with water.

f. Fill the cooling coils and the steam spargers with acetone and allow them to soak for 12 hours to dissolve any RDX caked on the inside of the coils. Flush with water, then decontaminate with sodium hydroxide solution, if necessary.

g. Send dangerously contaminated portable wooden "utensils" to the burning ground for disposal. Store serviceable ones in building after cleaning.

103. WAXING HOUSE. a. Clean all visible explosive material from the building and flush the slurry lines thoroughly. Clean all screw heads and threads with steam and solvent if necessary. CAUTION: Thoroughly soak all nuts and bolts with penetrating oil and wash with water before loosening. Drown all nuts and bolts under a stream of water while loosening.

Appendix A-Continued

b. Clean the tank tops, wax holding tanks, and agitator units as described above.

c. Process the steam spargers with acetone. Apply acetone for 12 hours to dissolve any RDX caked inside and subsequently flush them with water, inspect, and repeat decontamination if necessary. Flash these and other equipment only if unable to decontaminate.

d. Dissolve with acetone and/or wash as necessary the tank tops, agitator shafts, tank vents, and wax melting and slurry lines.

e. Clean the filter nutsche grids and coarse screens with steam and water.

f. Send portable building utensils which are contaminated and cannot be economically cleaned to the burning ground for proper disposal.

104. TRAY DRYERS. a. Clean all visible explosive material from the building using proper equipment. Clean all screw heads and threads with steam and solvent as necessary.

b. Clean powder chutes, dryer gratings, and mouldings with water as required.

c. Clean lead floors with acetone, water, and steam as necessary until explosive material is removed.

d. Clean the catch tubs and boxes. Send all portable utensils that are contaminated and cannot be economically cleaned to the burning ground for burning.

105. FILTER HOUSES. a. Clean the building and equipment of all visible explosive material. CAUTION: Thoroughly soak all nuts and bolts with penetrating oil and water before loosening.

b. Clean the receiving and sending tank tops and agitator units with water and/or acetone as necessary.

c. Remove the manifold slurry header and clean with water and/or acetone.

d. Maintain the filter in a wet condition and dismantle and clean the tubs, screens, and nutsches as required.

e. Send portable wooden building utensils which are dangerously deteriorated and cannot be economically cleaned to the burning ground for disposal by burning.

f. Appropriately tag any equipment listed above which must be flashed and sent to burning ground.

106. LAC STORAGE HOUSE. a. Clean the building of visible explosive material.

b. Remove contaminated transite walls and ceiling only where necessary.

c. Send all waste material to the burning ground for destruction.

d. Clean the sump pit catch box.

107. COMPOSITION A-3 PACKING HOUSE. a. Clean all visible explosive material from the building using approved equipment and procedure. Clean all screw heads and threads with steam. CAUTION: Thoroughly soak all bolts and nuts with penetrating oil and water before loosening. Submerge all nuts and bolts under a stream of water while loosening.

b. Dismantle and clean the dust exhaust system as necessary.

c. Dismantle and clean all parts of screen and hopper with steam and proper solvents as necessary.

d. Clean the conveyors and vibrator using steam and water as necessary.

e. Inspect and thoroughly clean elevator and pit.

f. Clean floors with steam and water and/or solvent.

g. Send portable utensils that are deteriorated and cannot be economically cleaned to the burning grounds for disposal.

108. RECRYSTALLIZATION. a. Clean all visible explosive material from the building.

b. Flush the entire system, processing vessels, tanks, pumps, and process lines with warm (130° - 135°F) water.

c. Dismantle, clean, drain, and reassemble the solvent metering assembly and store in buil but do not reinstall.

d. Clean solution tank tops and agitator units, tank heating coils and steam sparger with hot water, or acetone as deemed necessary.

e. Drain and flush the solvent service tank.

f. Clean, flush, and drain the vacuum receiver.

g. Clean, flush, and drain the filter nutsche. Remove filter cloth and send to laundry for processing.

109. ACETONE RECOVERY. a. Determine that all bulk acetone has been removed to storage and non in the tanks or equipment. Thoroughly flush tanks and pipe lines with water using a 2-1/2" fire where appropriate. Allow the water to circulate through the equipment for several hours. With strong acetone tank filled with water, complete cycling of water through the equipment until cle

b. Steam the acetone recovery tower and the solvent storage tanks. Flush with water and dra

c. Dispose of acetone as follows:

(1) Contaminated. Destroy in small quantities at burning ground.

(2) Non-contaminated. Excess through stores and ship to active using facilities.

110. EXTRUDER. a. Clean all visible explosive material from the building using approved equipm (non-sparking).

b. Clean fume exhaust system with steam and water or acetone as necessary.

c. Clean all external parts of the extruder with steam and hot water.

d. Clean all internal parts of the extruder with acetone.

e. Clean conveyor and gear reducer belts with hot water.

f. Clean scales with acetone.

g. Clean floor with PS-661 Solvent. Sparge with water and dry with clean rags.

h. Clean, neutralize with soda ash, and drain catch box.

i. Send portable wood and/or composition utensils and tools that are contaminated and cannot be economically salvaged to burning ground for disposal.

111. INCORPORATOR HOUSE. a. Clean all visible explosive material from the building and equipment.

b. Clean the agitator units, the kettle uprights, the gear boxes, and incorporator shells (Dopp Dettles) with steam, hot water, or acetone as required.

c. Clean and inspect the lead floor, remove any entrapped explosives.

d. Clean the fume removal system and steam jets. Dismantle as necessary.

e. Send all unsalvageable utensils to the burning ground.

f. Clean and preserve the scales.

Appendix A-Continued

112. PACK HOUSE. a. Clean all visible explosive material from building.

b. Clean and preserve scales.

c. Clean all moulding and linoleum tops of tables, stands, and benches and send those which are contaminated and cannot be economically salvaged to the burning ground.

d. Remove all visible explosives from catch boxes.

113. PREPARATION AND USE OF 7% SODIUM HYDROXIDE (NAOH) SOLUTION. Mix 60 gallons of water with 47 pounds of sodium hydroxide. This ratio is considered safe in that it will desensitize RDX without too violent a reaction. A solution of sufficient quantity should be prepared to fill the nitrator and this solution can be circulated through the entire RDX area process equipment until the RDX is killed. It may be necessary to butt a solution to insure the proper strength.

Section XI - LOADING OPERATIONS

114. GENERAL. The installations applicable under the term "loading facilities" are intended to include high explosive melting and pouring, component loading, propellant charge loading, and wash out operations.

115. HEATING DEVICES. Heating devices, such as welding and flame cutting equipment, will not be used on equipment.

116. SOLVENTS. The following materials are recommended for swabbing equipment contaminated with explosives:

a. Hot water for removal of black powder and Explosive D.

b. Steam for TNT and mixtures of TNT with other explosives.

c. Acetone for tetryl. The use of acetone will be avoided in confined places when a high concentration of the vapors might cause asphyxiation.

d. Safety solvent with flash point above 100°F can be employed for swabbing but does not dissolve explosive material, merely acting to loosen or float particles.

e. Safety solvent may be used to swab equipment contaminated with tracer dust and incendiary dust.

117. HIGH EXPLOSIVE MELTING AND POURING. a. Receiving and storage magazines are to be swept clean of all explosive dust after which the entire building is to be hosed with water and mopped. Where magazines are equipped with ceilings, side walls or wainscoting, and wooden surfaces are contamined, the sections between the ceiling and rafters and sections between walls and studs are to be mopped free of explosive dusts after removing the ceilings and wall materials.

b. High explosive box opening and screening buildings are to be cleaned of explosives. The equipment used for screening explosives is to be disassembled and the interior of the box-like inclosure and the inlet, as well as the discharge ducts and screens, cleaned of all explosive contamination by steaming out with steam at not more than 5 pounds gauge pressure. In screening equipment provided with spherical balls as the medium for influencing the explosive travel, the balls will be removed from the screen and the explosive contamination removed by immersion in hot water heated with steam at not to exceed 5 pounds gauge pressure. The machine will be completely disassembled and all surfaces thoroughly cleaned.

c. Melt and pour buildings are to be thoroughly cleaned of explosives by steaming the floors, using steam at not more than 5 pounds gauge pressure. Temporary partitions are to be removed and explosive deposits removed, then steam-cleaned. Melt units and mixing kettles and other equipment will be cleaned with steam at not more than 5 pounds gauge pressure. Particular attention must be directed to cracks and joints to assure the removal of all explosives. Funnels and pouring tools used in the pouring of high explosives will be thoroughly cleaned.

d. Ducts and piping used for the transfer of explosives and loading from the melt unit to the mixing kettles must be disconnected and all joints and surfaces steam-cleaned of explosives, removed to the burning ground, and flashed.

Appendix A-Continued

e. Sumps at melting and pouring buildings are to be cleaned of all explosives by removing t residue when wet. The interior of the sump, if concrete, is to be steam-cleaned. Where sumps a wood construction, the deposited explosive on the surface is to be removed with steam; the wood are then to be disconnected from attached piping, using non-ferrous tools; and the wood sump dis while wet, for burning. Small wood receptacles must be burned.

(1) High explosives must be removed from the vacuum collectors and surfaces cleaned, usi steam of 5 pounds pressure or less for TNT and Explosive D, acetone for tetryl. The piping servi the collection tank will be flushed with water, under pressure, to remove as much of the explosiv as possible. While the interior of the pipe is wetted, penetrating oil will be applied to the jo bolts, or pipe fittings, and a sufficient time allowed for the oil to enter the threads, before n or pipe sections are separated.

(2) Dry type primary and secondary vacuum collectors are to be cleaned by removing the fabric socks and burning.

(3) The bottom collector bells of vacuum separator tanks will be removed and thoroughly cleaned of all encrusted explosives.

(4) Wet type vacuum collecting systems are to be drained of water and the interior of th tank and piping cleaned in the manner prescribed for dry type collectors and piping. Sludge tank and pumps forming a part of the wet collecting systems are to be cleaned of explosive deposits; joints in the equipment that were in contact with explosives, where secured by screws, bolts, or other type of fastenings, are to be carefully separated after lubricating the screw threads with penetrating oil.

f. Contaminated lagging should be wet down, removed and burned.

g. The wooden parts of hand trucks, tables, platforms and elevator doors in locations where explosives dust has contacted their surfaces must be destroyed by burning.

h. Electric motors, switches, and conduit which have been exposed to explosive dust will be carefully disassembled and cleaned.

118. COMPONENT LOADING LINES. a. Fuze loading lines must be carefully cleaned because of ease o ignition from sparks. Buildings must first be thoroughly soaked with water before decontaminatior of equipment is started.

b. Sump or drainage areas serving black powder operations are considered a nonexplosive hazar provided water has been run through to dissolve the explosive.

c. Loading presses, facing lathes, drilling machines, powder blenders, powder screens, and other processing equipment used in the operating lines producing fuzes are to be cleaned with wate Screens are to be dismantled in order to remove all explosives that may have collected on the inte and the blender trunion, as well as the pipe sleeves inclosing the connection between the blender its motive power, are to be inspected and all black powder deposits removed by use of copious amou of warm water (135°F).

d. Work tables used in the loading, facing, and drilling rooms are to be carefully inspected for cracks and abrasions that would permit powder to infiltrate between the table and the table covering. Where conditions are found indicating that powder deposits may be beneath the table covering, this covering will be removed and the table cleaned of explosive dust with water.

e. Detonator, relay, and fuze primer loading facilities, including the explosive preparation buildings, also present a hazardous problem in decontamination processes because of the relative sensitivity of the products being removed and the ease with which the mercury fulminate, lead azid and primer composition containing mixtures of these sensitive primary explosives with chlorates ca be initiated. Hammer blows and forces exerted by wrenches, screw drivers, and other tools must no be permitted until it is determined that the surfaces being contacted and their threaded sections free of explosive contamination.

f. Lead azide and mercury fulminate preparation buildings, including dry houses, before decont tion operations are started must be washed down with water, and while the floor is maintained in a wet state, the decontamination operations can be started, using desensitizing solutions (para 74) to reduce the hazard from explosive that may be present.

g. Dry houses for azide and fulminate are usually equipped with drying racks or cabinets. The surfaces and interior of these units must be washed thoroughly with the appropriate desensitizing solutions for the explosive involved. Door hinges and air-duct connections to the cabinets and into the room must be disconnected, after desensitizing solutions have been used, and again cleaned in the solution. Wooden trays and racks must be destroyed by burning at the burning ground. Interior of air-duct piping is to be carefully cleaned, after washing with water, by clean rags wet with desensitizing solution drawn through the pipe; the rags must be attached to rope lanyards when lengths of pipes are being cleaned. Wood or metal ram rods must not be used for this purpose.

h. Leather strap dry racks are to be washed with water and desensitizing solution, after which the leather straps are to be carefully removed and burned.

i. Sumps used to collect waste lead azide, mercury fulminate, or primer mixtures suspended in water are to be desensitized (para 74) and flushed with clean water.

j. Short runs of under ground piping leading to or from the mercury fulminate, lead azide, or primer mixture sumps, must be decontaminated by flushing with water and swabbing with rags saturated with appropriate desensitizing solution. Long runs of underground pipe, those that exceed 10 feet in length, are to be flushed with desensitizing solution and then dug up while wet and removed for disposal by burning.

k. Operating buildings containing consolidating presses are to be thoroughly washed with water and mopped down. All ledges above windows, doors, and at the wall plates must be thoroughly cleaned with wet mops.

l. Not used.

m. Equipment is to be freed of explosives by wiping with rags moistened with desensitizing solution (para 74) after which this equipment including press control levers and other devices, is to be oiled or greased to prevent rust. Scales consolidating presses, detonator loading and primer loading machines should be disassembled and surfaces thoroughly cleaned.

n. Table top coverings, when found cracked or otherwise damaged to permit infiltration of powder, are to be removed and burned in the usual manner, and the table carefully decontaminated with desensitizing solution. All other table top coverings are to be washed with water. Tables should be burned when decontamination cannot be complete.

o. Tracer, igniter, and incendiary processing buildings are peculiar in that the promiscuous use of water may develop a fire hazard; therefore, all excess explosives must first be removed by sweeping or by mopping with cloths dampened with safe solvent. Where tracer, igniter, and incendiary dusts are found within hollow walls and above ceilings, all surfaces will be kept wet during dismantling operations.

p. Press buildings where pellets of tracer, igniter, and incendiary mixtures are processed, including the screening buildings, rest house, and magazines, will be carefully inspected to determine that the hazardous mixtures are removed from corners, above ceilings, and interior side walls.

q. Tetryl pelleting and booster and fuze assembly buildings are to be washed down with water. The equipment is to be disassembled and thoroughly cleaned with acetone-dampened rags after which a light coating of oil or grease must be applied to the surfaces. Blending and screening buildings and equipment are to be cleaned in the same manner.

119. PROPELLANT CHARGE LOADING PLANTS. a. Since these plants load only smokeless powder and black powder, the decontamination process will consist of thoroughly washing and mopping the building with water. No heating devices such as welding torches, blow torches, oxyacetylene flame, etc., will be used in these buildings since explosives material may remain in cracks and crevices.

b. When no special hazard, other than that normally associated with black powder and smokeless powder, liberal use of water should be sufficient to remove all explosive contamination. Special care must be exercised in the removal of black powder drying cabinets and screening equipment, and the work must not be accomplished until the exterior and interior of that equipment is completely wetted with water. The equipment will then be disassembled and the explosives removed with water dampened rags.

120. HIGH EXPLOSIVE RECOVERY (WASHOUT PLANTS). The procedure for decontamination of these pl: and the equipment which is in common with a TNT wash house, will be that recommended for the m: loading building of high explosive loading plants.

Section XII - SMALL ARMS OPERATIONS

121. GENERAL. This section covers the decontamination of plants which have been employed for paration and loading of small arms primer, tracer, and incendiary materials, and the loading of smokeless powder.

122. STRUCTURES. In explosives operating buildings, where a dust hazard may exist, the spaces ceilings, under floors, or floor coverings, within hollow partitions, and surfaces on ledges an: joists, must be cleaned so as to remove accumulations of explosive dust. Precautions as noted i paragraphs 118 o and p above will be adhered to when decontaminating areas and equipment previou used in processing and loading 20MM high explosive incendiary projectiles.

123. EQUIPMENT. a. All wooden equipment, such as tables, benches, hoppers, refrigerator cabin hand truck frames, sinks, troughs, shelving, wooden tote boxes, etc., which are contaminated wit explosives must be destroyed by burning.

b. In rooms where tracer compositions are handled, the residue in the dust collecting equipm is difficult to remove because of the resinate constituent. Application of a penetrating oil wit flash point not less than 100°F, followed by a brushing with a fiber bristle brush, is approved. Crimped joints or inaccessible places may be flushed free of explosives by using safety solvent w flash point not less than 100°F. Air exhaust ducts within ceilings must be thoroughly washed and cleaned in this manner prior to dismantling. Exhaust duct caps will also be cleaned. Where poss. equipment will be dipped or washed in or with a killing solution. Precautions as noted in paragr: 118 o and p above will be adhered to when decontaminating areas and equipment previously used in processing and loading 20MM high explosive incendiary projectiles.

c. Pipe lagging which has been exposed to dusty atmosphere must be wet down, removed carefull and destroyed by burning.

d. All machinery that has been exposed to explosive will be completely dismantled and all par cleaned. Flame producing devices will not be used near this material until the contaminated machi is properly flashed by means of controlled temperature using suitable safe guards.

(1) Special attention will be given to possible explosive dust accumulation inside hollow pedestals of machinery. Machines will be moved cautiously from their original position to avoid ignition of dust which may have sifted beneath the base of the machine.

(2) Contaminated transmission belts which are in good condition will be carefully cleaned with soap and water, ethyl acetate or other solvents authorized by SOP. Belts found to be cracked or split must be destroyed by burning.

(3) Conveyor systems which have been subjected to explosives will be carefully dismantled and the parts cleaned of all dust accumulations.

(4) Smokeless powder loading funnels or stacks will be brushed thoroughly from the top down and hosed with water as a final cleaning.

e. Metal tote boxes used for ammunition handling will be thoroughly cleaned with solvent. Wooden tote boxes which are contaminated must be destroyed by burning. Pointed wooden sticks may be used to remove powder lodged around the edges of boxes. Maize pans, catch pans, and screens will be soaked in solvent to loosen powder accumulations. After soaking the pans, a stiff fiber brush, or, when necessary, a wooden paddle may be used to remove the accumulation. Pans and waste cans in poor state of repair or which contain explosives difficult to remove must be sent to the burning ground for disposal. Rubber buckets will be thoroughly cleaned with killing solution and, when judged necessary, burned.

124. MISCELLANEOUS. a. Drains and sumps must be thoroughly soaked with a killing solution before being flushed with water. While killing solution is active, special precautions are required to avoid breathing toxic fumes resulting from reaction.

Appendix A-Continued

b. Live primers which may be found during clean-up operations must be placed under water pending disposal at the burning ground. Personnel engaged in these operations will be advised that primers are hazardous even when under water and must be handled carefully.

Section XIII - RADIOACTIVE MATERIALS AND TOXIC SUBSTANCES

125. Due to the variety of radioactive materials/toxic substances used and the different decontamination procedures required for each, specific instructions are not included in this appendix. Decontamination procedures will be included in SOP for use of these items. Technical assistance is available from HQ, ARRCOM (DRSAR-SF) for development of the SOP.

Section XIV - PYROTECHNIC COMPOSITIONS

126. Special procedures must be prepared for decontamination of items contaminated with pyrotechnic compositions, taking into consideration the difficulty in removing reactive fuel components by the standard flame or heat flashing method. The relatively low temperature of 600°F at which the decontamination oven operates will not decompose fuels such as Boron.

Section XV - FOREIGN AMMUNITION AND EXPERIMENTAL OR DEGRADED REACTIVE MATERIALS

127. Special procedures must be prepared for each situation involved. Technical assistance is available from HQ, ARRCOM (DRSAR-SF).

Section XVI - CHEMICAL AGENTS/MUNITIONS/EQUIPMENT

128. Special procedures must be prepared for each situation involved. Technical assistance is available from HQ, ARRCOM (DRSAR-SF).

Appendix B

RECORD OF CONTAMINATED ITEMS

1. Identification of the item/complex involved.

2. Office of Record (that segment having responsibility for facility/equipment).

3. Subjects to be included in record of facilities and equipment which have been contaminated are, as a minimum:

a. Previous use (include type of contaminant involved)

b. Decontamination procedure used

c. Decontamination status degree

d. Special instructions

e. Restrictions

f. Identification of critical points of operation

g. List of personnel knowledgeable about facility

h. Transfer lines, drains, sumps, etc., involved

i. Identity of equipment

j. Site plans

k. Signatures of personnel preparing and approving record

l. Not used

m. Dates of various actions

4. A Decontamination Tag (DA Form 3803) will be used when item is a single piece of equipment.

TB 700-4

DEPARTMENT OF THE ARMY TECHNICAL BULLETIN

DECONTAMINATION OF FACILITIES AND EQUIPMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY

OCTOBER 1978

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DECONTAMINATION OF FACILITIES AND EQUIPMENT

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CHAPTER 1

INTRODUCTION

1-1. Purpose. *a.* This bulletin provides general policies, responsibilities and procedures to all Army commands and activities for decontamination of facilities and equipment exposed to potential ammunition, explosive/explosive residue contamination. This includes facilities and equipment used in manufacture, maintenance, renovation, demilitarization, preservation, packing and packaging, or storage of ammunition or explosives.

b. Specialized decontamination procedures are required for radioactive materials, toxic substances, chemical agents/munitions/equipment, pyrotechnic compositions, foreign ammunition, experimental materials, and degraded reactive materials. Specific procedures contained in applicable publications for these items take precedence over this bulletin.

c. Supplementation of this bulletin by Army major and subordinate commands and activities is permitted. An information copy of each supplement should be provided to: Director, DARCOM Ammunition Center, ATTN: SARAC-AV, Savanna, Illinois 61074.

1-2. Scope. This bulletin is applicable to all Army activities having facilities or equipment that by nature of their use, intended use, or exposure to explosive operations may contain or be contaminated with explosives/explosive residue, or the associated chemicals used in their production. This bulletin is applicable whenever potentially contaminated facilities or equipment are being placed in standl transferred from one location to another for a reason, disposed of to other government agenci qualified users in industry, or to the general publ or, shutdown for maintenance, repairs, alteratio or modification, regardless of who performs t work.

1-3. Environmental Aspects. The environment consequences of any proposed decontamination pr cedure will be considered during the planning pro ess and will be evaluated for compliance with Occ pational Safety and Health Administration (OSH and Environmental Protection Agency (EP Standards along with the technical and operation factors in the decision making process.

1-4. Errors and Omissions. The Director for Mate rial Management, US Army Materiel Developmen and Readiness Command, is the proponent of thi bulletin. Errors and omissions or other propose changes will be reported on DA Form 2028 (Recom mended Changes to Publications and Blank Forms) to Commander, US Army Materiel Development and Readiness Command, ATTN: DRCMM-ST, 5001 Eisenhower Avenue, Alexandria, VA 22333. Information copy of each DA Form 2028 will be furnished: Director, DARCOM Ammunition Center, ATTN: SARAC-AV, Savanna, IL 61074.

CHAPTER 2

DECONTAMINATION OF FACILITIES AND EQUIPMENT

2-1. General. This chapter contains definitions, policies, responsibilities, objectives, and general safety requirements associated with decontamination operations.

2-2. Definitions. The following definitions apply to this bulletin:

a. Contamination. The presence of explosives/explosive residue in, on, or about equipment, facilities, and real estate that have been used in or exposed to explosives operations.

b. Decontamination. The partial or complete removal, neutralization, or destruction of explosives/explosive residue by flashing, steaming, neutralization, or other approved desensitizing methods. Sensitive analytical equipment can be decontaminated by chemical decomposition when small quantities (28 grams or less) of contaminants are involved and the decontamination process is performed by trained personnel.

c. Degrees of decontamination will be designated as follows:

(1) X—A single X indicates the facilities or equipment have been partially decontaminated. Further decontamination processes are required before facilities or equipment are moved or any maintenance, repair, etc. is performed. This degree would generally be applied to facilities or equipment that have been subjected to routine decontamination performed by an operator on a piece of equipment, room, bay, or building at the close of the workday.

(2) XXX—Three Xs indicate the equipment or facilities have been examined and decontaminated by approved procedures and no contamination can be detected by appropriate instrumentation, test solutions or by visual inspection on easily accessible surfaces or in concealed housings, etc. and are considered safe for the intended use. Items decontaminated to this degree can not be furnished to qualified DOD or Industry users or be subjected directly to open flame (cutting, welding, high temperature heating devices), or operations which generate extreme heat, such as drilling and machining unless the following two conditions are met:

(*a*) It is determined that decontamination to the XXXXX level will destroy the usefulness of the item; and,

(*b*) Decontamination to a degree less th XXXXX in combination with administrative a technical safeguards will eliminate risk of injury. A a minimum, an approved SOP (setting forth the sp cific operational limitations, precautions to b observed, and monitoring necessary to assure saf ty) will be available and decontamination will b performed under the direction of the Certifying O ficial (see para 2-3*f*).

(3) XXXXX—Five X's indicate the equipmen or facilities have been completely decontaminated are free of hazard and may be released for gener use or to the general public.

(4) Ø—AØ (Zero) indicates the item, althoug located in a contaminated area, was never directl exposed to contamination.

2-3. Policies. *a.* Standing Operating Procedure (SOP) will be prepared locally for each specifi decontamination operation. Decontamination pro cedures contained in chapter 3 of this bulletin ar intended to provide general guidance and do no negate the requirement for a locally developed SOP.

b. All standby contaminated items that will re main in place or in storage at the installation/activity will be decontaminated to a minimum of XXX degree to make them safe for maintenance by experienced personnel.

c. All contaminated items that will be used for the same or similar purpose, and which are relocated or transferred to another segment within the installation/activity, transferred to a qualified government installation/activity, or furnished to a qualified user within industry will be cleaned of hazardous contaminants to a minimum of XXX degree before moving, to make them safe for handling, transport and use by experienced personnel. "Qualified" is used as a condition to restrict locations to which an item can be transferred and attests to the awareness by the recipient of the potential hazards represented by the contaminant(s) involved. These items will not be transferred to locations/areas outside the contaminated area, i.e. into the station supply, stock control and storage departments, etc. or the Defense Property Disposal Office without the written approval of the commander or his designated agent.

d. All contaminated items planned for release to the general public will be decontaminated to the

e. Items in storage of one degree of decontamination will be kept segregated from items of another degree of decontamination.

f. Equipment placed in standby, dismantled, demolished, altered, repaired, disposed of or transferred will be tagged with DA Form 3803, Decontamination Tag, indicating method, type and degree of decontamination and restrictions on handling. Decontamination Tags (DA Form 3803) may be obtained through normal publication channels. Items in or from a non-contaminated area do not require a decontamination tag. The installation commander will designate in writing qualified individual(s) [e.g. Quality Assurance Specialist (Ammunition) or Safety Office Representative] as Certifying Official(s) responsible for certifying on DA Form 3803 the degree of decontamination or that the item has never been exposed to contamination.

g. All transfer documents, work orders, etc. concerning items of ammunition/explosive equipment, whether it comes from a contaminated or non-contaminated area will be annotated with the degree of decontamination (e.g. XXX) or the statement that the item has never been exposed to contamination, whichever is appropriate.

h. Prior to shipment, item(s) must be properly marked and a DA Form 3803 (Decontamination Tag), executed in accordance with *f* above, must be affixed to the item. Shipping papers, supply documents, etc., will be annotated to indicate that the designated certifying official has certified the degree of decontamination or that the item was never exposed to contamination.

i. Whenever the degree of decontamination is changed, old decontamination tags will be replaced with a new decontamination tag and markings changed to reflect the latest status of the item. Other records will be revised accordingly.

j. The decontamination tag will be removed and the degree of decontamination marking will be obliterated prior to use.

k. Access to areas containing contaminated items will be controlled. Jurisdiction will always be under direction of persons knowledgeable in the item and contaminant involved.

l. When work is performed in a contaminated area or on a contaminated item, such work will be overseen by persons knowledgeable of the item and contaminant involved, in addition to the supervision by the supervisor of the work crew(s).

m. A complete and permanent record of decontamination and clean-up actions that have been performed in each contaminant area and on each piece of equipment and tooling, will be prepared whenever operations in a contaminant area are completed or discontinued for the purposes of putting item in standby, dismantling, demolition, alteration, conversion, repair or maintenance. This record is to ac-

what hazards may exist in order for them to
tute proper precautions. The installation inv
shall be the office of record.

n. Standing Operating Procedures (SOP) wi
prepared in advance to cover those operations
contaminated area of a routine recurring na
such as preventive maintenance involving oiling
greasing equipment, changing light bulbs and f
changing dies and punches on presses, repla
broken keys in presses, repairing or replacing b
or adjusting presses, set-up, etc. The SOP wil
reviewed and approved by the commander or de
nated agent. SOP's will be reviewed, updated, a
or approved annually.

o. Contaminated material or material genera
as a result of producing a commodity will be hand
in accordance with approved procedures. Mater
materiel includes rags, cartons, packing materi
reject materiel, unused products, boxes, unifor
papers, munitions and subcomponents, etc. expo
to contaminants.

p. Reactive materials and contaminated ite
will not be buried. In situations where undergrou
pipe or ground area (including existing burial sit
contain a contaminant, such locations will be in
cated on site plans, as well as on the ground by sig
and appropriate fencing. These sites will rema
posted and fenced until they are cleaned complete
of contaminant(s).

q. Installations/activities will prepare site pla
delineating noncontaminated and contaminate
areas, operating lines with specific buildings
structures, grounds, surface and undergroun
waste process lines. The site plans will be annotate
to indicate the types of contaminant(s) that may b
present in these facilities or areas. Plans will b
kept current and reviewed annually. These sit
plans will be used as a guide in determining whethe
an item should be considered as coming from a con
taminated area. In the absence of any indication o
the site plan, or decontamination record that an are
is noncontaminated or has been decontaminated, i
will be considered as a contaminated area and mus
be treated accordingly prior to disposal. All buildings or areas in which an explosive contaminant is present will be posted conspicuously at the entrance with a sign—"CAUTION—EXPLOSIVES AREA." Where only portions of a structure or area are contaminated, and the areas or rooms are readily identifiable, only appropriate positions or rooms need be posted at the entrance. Sign color and size will be in accordance with AR 385-30. Signs will be posted at all points of entry into the contaminated area.

r. For real property, a record of all known or suspected contamination by explosives, chemical or other hazardous materials will be provided the Office of the Chief of Engineers (DAEN-REM-C). This office maintains the central repository of records of contaminated real property. Decontamination of

this bulletin, DOD Directive 4156.6, and AR 405-90.

s. A contaminated item which would lose its usefulness if subjected to procedures for complete decontamination may be worked on in accordance with an approved SOP established for each situation as it arises.

t. Materiel which by nature of its use or intended use could be contaminated or contain a contaminant and which is to be transferred to or from laboratories, to offices, to shops, to or from storage, to disposal or which remains in place for testing, modification, use in displays or models, will either be decontaminated or handled in accordance with specific handling instructions developed for the materiel involved. Examples of materiel involved are:

(1) Commodity containers/tanks used for flammable or toxic materials.

(2) Munitions and associated subcomponents.

(3) Radioactive components.

(4) Test fixtures.

u. Material/materiel which is a commodity in production will be handled in accordance with approved SOP which provide for alternate controls of these materials/materiels, such as inspection and certification by product/quality assurance personnel.

v. Items decontaminated to a XXX degree may be transported in Government vehicles or vehicles under Government control. Items decontaminated to a X degree may be transported within the ammunition restricted area in government vehicles or vehicles under Government control only when it is necessary to move them to a location where a XXX level of decontamination can be achieved. This necessity to move and the movement precautions to be taken must be approved by the individual designated as Certifying Official in paragraph *f* above.

w. Items decontaminated to a XXX degree will not be worked on with open flame, high temperature heating devices or devices which when used generate heat, due to friction of rubbing or cutting (e.g. hand or power drills and saws, lathe operations, powered wire brushing) without specific written approved SOP.

x. Items placed in standby or transferred to another location will be marked with conspicuous yellow (black will be used on yellow surfaces) painted "X's" or "O" as appropriate. Exception: Material/materiel outlined in *n*, *o* and *v* above; items being serviced, tooled-up or repaired in place; and items in or from a noncomtaminated area will not be marked.

y. Items that have been decontaminated, inspected, and marked in accordance with criteria in effect prior to implementation of this bulletin will not be reinspected and remarked solely for compliance with this regulation. Item(s) being processed for shipment will be reinspected, remarked, and retagged in accordance with this bulletin.

tivities covered by this bulletin are responsibl compliance with all stated provisions and for pr ration of detailed decontamination SOP's as quired.

b. Director, DARCOM Ammunition Center, i sponsible for maintaining this bulletin and provi assistance in the implementation thereof.

2-5. Objectives. The primary objective of this letin is to promote the safeguarding of lives of sonnel and protection of property while conduc decontamination operations.

2-6. General Safety Requirements. *a.* All persor performing decontamination operations must thoroughly familiar with their duties and hazards involved.

b. Personnel performing decontamination ope tions must be under medical surveillance progra outlined in AR 40-5.

c. Personnel must be limited to the number tually required to perform the operations safe however, personnel involved in decontamination hazardous materials shall not work alone. At le one other person should be within voice communi tion distance.

d. Areas in which decontamination is in progr should be restricted to necessary traffic and equ ment.

e. Unauthorized flame-producing devices mu not be permitted in decontamination work areas.

f. Operators must be equipped with protecti clothing, gloves, goggles, face shields, respirato and boots as required.

g. Fire extinguishers and first aid kits must available in close proximity to operations.

h. Vehicles and radio/wire communicatio equipment must be available for immediate use operating personnel.

i. Adequate wash rooms and showers are to available for personnel. Eye lavage and delug showers are required in mixing rooms of acid base solutions and at washout sites.

j. Hand tools required must be of nonsparkin material.

k. Firefighting personnel shall be notified of th operations being conducted.

l. Only approved type vehicles and other pow ered equipment will be used in the decontaminatio area.

m. Flame producing devices such as oxyacetylin torches, electric welders and blow torches must no be used before decontamination due to the possibil ty of initiation of explosive material remaining in confined space.

n. High temperature and rough handling must b avoided to prevent explosive accidents.

o. Steam cleaning should be accomplished prio to applying penetrating oil to nuts and bolts. Fric

contacting surfaces. Sufficient time must be allowed for the oil to penetrate within the threads before at-

tion is recommended. This procedure is mand prior to removing nuts or bolts whenever con nation exists.

CHAPTER 3

DECONTAMINATION PROCEDURES

3-1. General. *a.* The procedures described herein are general in nature and require augmentation by an approved SOP for each specific decontamination operation. Exact requirements for each specific decontamination must be detailed in the SOP for the operation.

b. Specialized decontamination procedures are required for radioactive materials, toxic substances, chemical agents/munitions/equipment, pyrotechnic compositions, foreign ammunition, experimental materials and degraded reactive materials. SOP's for these items will be developed in accordance with applicable publications. Technical assistance in development of SOP's is available from the appropriate DARCOM materiel readiness commands.

3-2. Equipment Contaminated with Acid Only: *a.* All equipment such as tanks, pipes, valves, and fittings which have contained acid, but no explosives material, should be drained thoroughly, opening pipes at flanges where necessary; valves should be disassembled and packing removed. This equipment should then be washed first with water followed by a wash with 7% soda ash (sodium carbonate) solution. Soda ash will be employed in solution only. It is recommended that after neutralizing, a solution of three percent soda ash be retained in the pipe or equipment for approximately 24 hours. Since the action of acid on metal may generate explosive gas mixture, flame and spark must be avoided. Brick lined tanks and equipment will be excluded from neutralizing procedures when equipment is to be placed in standby status.

3-3. Equipment Contaminated with Acids and Explosives. *a.* All equipment which has contained explosives material should be thoroughly washed with hot water, then steam cleaned. Equipment to be sold for scrap must be flashed (subjected to a hot fire to destroy explosive material). Flashing is considered to be the most effective method for destroying explosive materials. Solvent, steaming, and swabbing methods are considered effective only when complete inspection can be given all surfaces of equipment to assure that decontamination is complete. If however, the equipment is to be placed in standby condition for possible subsequent use in explosives operation, flashing in addition to thorough inspection is not required. Equipment or material which has been used in explosive operation and may contaminated, will be inspected and decontaminat and properly marked and tagged before removal shipment. If contaminated equipment is shipp the bill of lading must contain a statement to t effect.

b. Acid tanks which have contained nitrocellulc will be flushed with waters and treated with a percent solution of sodium hydroxide to desensiti the nitrocellulose. Acid tanks which are not conta inated with explosives material will be drained a flushed clean with water. All lines entering a leaving the tanks must be disconnected. Protecti must be afforded workmen against acid splash a acid fumes (air supply of self-contained breathi apparatus). Two men must always be present wh a man enters an acid tank and the man going into t tank must wear a safety harness with a rope a tached. Goggles, rubber boots, rubber aprons an masks for protection against oxides of nitroge must be worn when washing sludge from acid tank with water since oxides of nitrogen may be gene ated. The drain will be closed, tank filled with wate and soda ash added until tank contents are alkaline The tank will then be flushed with clear water drained and dried thoroughly.

3-4. Equipment Contaminated with Solvents Equipment contaminated with flammable liquid should be washed with hot water, then stean cleaned.

3-5. Equipment Made of Wood. Wooden benches tables, warehouse platforms, walking platforms catch boxes, etc., which have contacted explosive material shall be burned after all the hazardous material that can be removed has been removed.

3-6. Miscellaneous Equipment. Miscellaneous equipment such as electric motors, switches, conduit, steam traps, indicating and recording instruments, scales, reducing gear housings, bearings, flexible couplings, belts, hoists, conveyors, and elevators should be inspected for contamination. Such items should be thoroughly cleaned and disassembled if necessary to thoroughly decontaminate. Careful inspection will be given equipment to detect hollow spaces wherein explosive materials might lodge. Such items must be flashed prior to sale as

scrap. These items may be decontaminated by steaming after complete disassembly if the item is to be placed in standby for future use.

3-7. Pumps. Pumps which contain acid only shall be drained, flushed with water, and neutralized immediately with 7% soda ash (sodium carbonate) solution. Cleaning of pumps should include removal of packing, washing of screw threads with 7% soda ash solution, drying and oiling. Pumps which may have been contaminated with explosives shall be disassembled and all parts that have come in contact with explosives should be cleaned. The bed plates and floor coverings beneath explosives contaminated pumps shall be raised and surfaces thoroughly cleaned by hosing with hot water and steam, swabbing with rags, or other suitable means.

3-8. Pipes and Piping. *a. Underground Pipe:*

(1) Consideration should be given to underground pipe lines which may contain explosive material. Such pipe lines shall be flushed to free them of explosive material. The soil surrounding the pipe line may contain explosive materiel. Underground pipe lines which have contained explosive material should be removed or determination made that no explosive material remains in appreciable quantity within or outside the pipe.

(2) If, in special cases, underground pipe or adjacent ground contains explosive materials which cannot be entirely removed or decontaminated, such location will be indicated on the depot site maps, as well as physically marking the sites with appropriate signs and fencing as required.

b. Pipes and Fittings. Pipes, fittings, and valves which have contained explosive materials shall be decontaminated. The decontamination of some types of valves may be accomplished by disassembling, boiling in soda ash (sodium carbonate) solution and thorough cleaning with steam or other acceptable methods or materials. Service water, steam, air, fumes, sewer and sprinkler system piping may usually be assumed to contain no explosive materials. Contaminated packing, lagging and gaskets should be burned.

c. Pipe Cutting. If pipe lines which contain explosive material have been welded at the joints, cutting of the pipe may be approved after explosive material has been flushed out using high pressure water through both ends and all branches. The pipe should then be filled with water and cut, using a roller type cutter, keeping the pipe full of water and playing a stream of water over the outside of the pipe. Such a pipe must not be hammered or subjected to heat.

d. Pipe Lagging. Lagging on pipes which has been subject to overflow of explosive materials, or which may have contained explosive materials which have leaked from within, shall be removed to the burning grounds and destroyed. The insulation shall be thoroughly wetted before removal, and maintained wet.

e. Flash Propagation through Empty Tubes (Pipelines.

(1) Throughout Army installations-there many "empty" lines which have processed materi such as RDX, TNT, NG, Comp-B, Black Powd which were thoroughly washed out at the end of p duction, currently remain intact, and may give false sense of safety from a propagation viewpoint

(2) "*Cleaned*" empty tubes or pipelines c necting explosives or hazardous material proce buildings or equipment may provide paths throu which a "Flash" may propagate. Several previo incidents of this nature have been reported; and, fact, a system has been developed to *cause* flame propagate through empty tubes.

(3) Past experience has proven that inacti explosives or hazardous material process lin which have been decontaminated to a XXX conc tion, contain sufficient contamination to suppo flame propagation. Even after a thorough rinsin with water or steam cleaning, a thin film or residu may still remain in the process lines in sufficier quantity to support propagation from one source t another. If reliance is being placed on the fact tha empty tubes or pipelines will preclude incident, thi false sense of security could cause an accident.

(4) Previous decontamination operation should be reviewed to insure provisions of this bul letin have been complied with. In addition, consid eration should be given to filling lines with water o other approved liquids during production period when materials are not being transferred, or during maintenance operations.

3-9. Buildings. Structures contaminated with ex plosive materials may be cleaned by the use o steam or hot water. When steam or hot water is employed for cleaning walls and floors, efforts should be made to avoid washing the explosives into cracks of the building and the area surrounding the building. At the conclusion of the decontamination by steam and water, the structure must be inspected and appropriate tests made to assure all hazardous materials have been removed.

3-10. Flashing Procedures. *a.* Controlled temperature method should be used in decontamination of equipment that is to be reassembled for production or standby purposes. Other contaminated materials and equipment to be sold for scrap must be subjected to high temperature flashing to assure complete decontamination. Approved Standing Operating Procedures developed by the installation shall be followed.

b. No metal scrap which has been contaminated with explosives or harmful chemicals shall be released for general use unless flashed and certified to be free of hazardous contamination.

3-11. Burning Grounds. Decontamination of burning grounds should be accomplished by subjecting the ground to a sustained fire of reasonable duration using available scrap lumber and other combustible materials and soaking with fuel oil. After burning, a visual inspection should be made and samples taken to determine the extent of decontamination. The burning operation should be repeated until reasonable assurance can be made that the ground is safe for surface use only.

3-12. Soil Contamination. The ground within 50 feet of buildings where an explosive material was handled should be carefully inspected. If the soil is contaminated with explosive materials to such a extent that a fire or explosive hazard exists, the layer containing the explosive material should be wetted and scraped, using nonsparking tools, and the hazardous material disposed of by burning on the burning ground. If acid contamination is suspected around building foundations, the soil should be excavated and thoroughly neutralized with 7% soda ash solution.

3-13. Security Regulations. Applicable Army security regulations should be followed while decontamination work is in progress.

APPENDIX A

RECORD OF CONTAMINATED ITEMS

A-1. Identification of the item/complex involved.

A-2. Office of Record (that segment having responsibility for facility/equipment).

A-3. Subjects to be included in record of facilities and equipment which have been contaminated are, as a minimum:

a. Previous use (include type of contaminant involved).

b. Decontamination procedure used.

c. Decontamination status degree.

d. Special instructions.

e. Restrictions.

f. Identification of critical points of operation.

g. List of personnel knowledgeable about facili

h. Transfer lines, drains, sumps, etc., involv

i. Identity of equipment.

j. Site plans.

k. Signatures of personnel preparing and appr ing record.

l. Dates of various actions.

A-4. A Decontamination Tag will be used wh item is a single piece of equipment.

By Order of the Secretary of the Army:

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General, United States Arm
Chief of Staff

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APPENDIX U

COMPREHENSIVE PERFORMANCE TEST PLAN FOR THE BULK ENERGETICS DEMILITARIZATION SYSTEM (BEDS)

The Comprehensive Performance Test Plan (CPTP) is being generated and will be supplied at a later date due to not being operational

Appendix V

Training Plan for the Bulk Energetics Demilitarization System (BEDS)

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APPENDIX QQ TRAINING PLAN FOR THE BEDS

QQ-1 PURPOSE

The purpose of this training plan is to identify specific training requirements for HWAD staff involved in operation and maintenance of BEDS. BEDS personnel are also required to meet the general training requirements given in Section O, "Personnel Training."

QQ-2 BEDS STAFF

QQ-2a BEDS Control-Room Operator

A highly proficient operator who mans the control room at all times unless relieved by another operator. He/she would be very knowledgeable of all BEDS safe operating procedures and systems.

QQ-2b BEDS Auxiliary Operator

The auxiliary control-room operator periodically walks the plant to check local indicators, equipment integrity, and look for signs of possible trouble (a combination of control-room operator and rover). This operator would be trained in general BEDS operation, maintenance, and safe operating procedures. He/she would have troubleshooting skills. In the case of system upsets, spills, numerous simultaneous alarms, or other signs of trouble, the auxiliary control-room operator would always be available and proficient at investigating and troubleshooting before plant problems became more serious. He/she would also be available to relieve the control-room operator, help coordinate inventory control data entry, and help in other areas as needed. This operator would be responsible for ensuring removal of waste stream barrels when full and placement of empty barrels at waste collection points.

QQ-2c BEDS Feeder Loader (Munitions Handler with BEDS Training)

The full-time feeder loader (minimum) will be fully trained in the BEDS slurry preparation and feed systems and in general plant operation and safety procedures.

QQ-2d BEDS Feeder Loader Assistant (Munitions Handler with BEDS Training)

The feeder loader assistant is trained to operate the fork lift to deliver bulk propellant to the feeder platform and perform waste stream barrel removal and replacement, as directed by the auxiliary operator. This assistant could also help with empty propellant drum removal and performing related tasks.

QQ-3 BEDS TRAINING PROGRAM

QQ-3a Classroom Training Requirements

Training Course Description	Frequency	Control Room Operator	Auxiliary Operator	Feeder Loader	Feeder Loader Assistant
BEDS Overview Theory of operation of the system and all major components.	Initially	X	X	X	X
Operation and Maintenance (O&M) Review of O&M Manuals so operators are aware of the location of information.	Annually	X	X	X (Areas of Responsibility)	X (Areas of Responsibility)

QQ-3b On the Job Training (OJT)

Training Description	Frequency	Control Room Operator	Auxiliary Operator	Feeder Loader	Feeder Loader Assistant
Walk Through System walk through identifying all important items.	Initially	X	X	X	X
Start-Up and Shut-Down Participation in start-up and shut-down.	Initially	X	X	X (Areas of Responsibility)	X (Areas of Responsibility)
Maintenance Demonstration and hands-on participation in selected maintenance functions, such as, location and replacement of a failed bag.	Annually	X	X	X (Areas of Responsibility)	X (Areas of Responsibility)
Instrumentation and Upset/Alarm Conditions Explanation of the importance of all instrument readings and demonstration of actions required during upset or alarm conditions	Annually	X	X	X (Areas of Responsibility)	X (Areas of Responsibility)

QQ-4 HAZARDOUS WASTE TRAINING DIRECTOR QUALIFICATIONS

Qualification requirements for the Director of Hazardous Waste Training are presented in Appendix GG, “Training Plan and Requirements for the PODS.”

QQ-5 CONTINUED TRAINING/REQUALIFICATION AND PROFICIENCY

This section contains information on continued training and requalification and proficiency.

QQ-5a Continued Training

All BEDS personnel, once qualified, will be required to participate in the continued training program. Failure to participate in continued training will result in removal from duties requiring that qualification, until the deficiency can be corrected. Continuing training shall be used to enhance knowledge and skills relating to BEDS, operations, and fundamentals; update personnel on new and improved equipment and procedures; update personnel on lessons learned by the industry; and correct knowledge and skill deficiencies as these are identified. BEDS operating management will review and evaluate the respective continuing training programs annually to revise and improve its effectiveness and efficiency. BEDS personnel will be promptly notified of changes to the continuing training schedule.

BEDS personnel will also be required to participate in the site continuing training program (see Section O), as required by SOC.

QQ-5b Requalification and Proficiency

BEDS personnel qualifications shall be for a period not to exceed two (2) years from the date of qualification. Other concerns, such as medical and security requirements, may affect the ability of personnel to fulfill qualified responsibilities. Additionally, failure of a requalification examination, or serious job performance deficiencies which indicate performance in an unsafe manner, shall require removal from related activities.
BEDS personnel absent from qualified duties for extended periods of time shall participate in selected retraining prior to resuming duties requiring qualification. This training may include

management interviews and evaluations, classroom training, seminars, OJT, examinations, or performance evaluations. Additionally, if the absence is twelve (12) months or greater, retraining must be completed prior to the employee resuming duties.

Appendix W - ASTM Wipe Sampling Method

Designation: D6661 – 10

Standard Practice for Field Collection of Organic Compounds from Surfaces Using Wipe Sampling[1]

This standard is issued under the fixed designation D6661; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice addresses sampling of organic compounds (i.e., PCBs, dioxins, many pesticides and similar compounds) from smooth nonporous surfaces using a solvent-wetted wipe sampling method. Samples are collected in a manner that permits the solvent extraction of the organic compound(s) of interest from the wipes and subsequent determination using a laboratory analysis technique such as gas chromatography with a suitable detector. This practice is, however, unsuitable for the collection of volatile organic compounds.

1.2 This practice should only be used to collect samples for the determination of organic compound(s) on a loading basis (e.g., mass per unit area). It cannot be used to collect samples for the determination of organic compounds on a concentration basis (e.g., mass per unit mass).

1.3 This wipe sampling practice is not recommended for collecting samples of organic compounds from rough or porous surfaces such as upholstery, carpeting, brick, rough concrete, ceiling tiles, and bare wood. It is also not intended for the collection of dust samples (see Practice E1278) or sampling to estimating human exposure to contaminated surfaces.

1.4 To ensure valid conclusions are reached, a sufficient number of samples must be obtained as directed by a sampling design (the number and location of samples including quality control samples) and a quality assurance/quality control plan. This practice does not address the sampling designs used to achieve the data quality objectives (see Practice D5792).

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4687 Guide for General Planning of Waste Sampling

D5681 Terminology for Waste and Waste Management

D5792 Practice for Generation of Environmental Data Related to Waste Management Activities: Development of Data Quality Objectives

E1278 Guide for Radioactive Pathway Methodology for Release of Sites Following Decommissioning[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology D5681.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *wipe, n*—sorbent material (e.g., cotton gauze) that is rubbed on a surface to collect a sample for chemical analysis.

4. Summary of Practice

4.1 A wipe sample is collected from a smooth nonporous surface with a solvent-wetted wipe following a specified pattern of wiping to ensure complete coverage of an area of specified dimensions. The wipe is then extracted and analyzed to detect and quantify (at least semiquantitatively) the presence of organic compounds on surfaces.

5. Significance and Use

5.1 Wipe sampling is typically used by persons involved in hazardous waste site investigations to characterize the areal extent and the level of contamination on walls, floors, equipment, etc. Wipe sampling is also used to determine compliance with regulations.

5.2 There are many factors that contribute to variation in sampling results during wipe sampling including, the use of different pressures applied to the wipe, different kinds of wipes, different wiping patterns, the texture of the surface being

[1] This practice is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.01.02 on Sampling Techniques.

Current edition approved Dec. 1, 2010. Published January 2011. Originally approved in 2001. Last previous edition approved in 2006 as D6661-01 (2006). DOI: 10.1520/D6661-10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

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TABLE 1 Contaminant Recovery Data Using Common Solvents and TLC Pads[3]

Compound	Solvent	Percent Recovery
Chlordane	Acetone	71
	Isooctane	54
Chlorpyrifos	Acetone	72
	Isooctane	56
Malathion	Dichloromethane	81
	Isooctane	80
Diazinon	Isooctane	70
Aroclor 1260	Isooctane	80
	Acetone	76
Bendiocarb	Acetone	85
	Isopropanol	84
Propoxur	Isopropanol	96
	Acetone	90

wiped, and perhaps even the duration of wiping. The significance of this practice is that it standardizes wiping procedures to reduce sampling variability in the collection of samples from smooth, nonporous surfaces such as metal, glass, painted or sealed surfaces, tile, etc., in and around buildings, and from pipes, tanks, decontaminated equipment, etc.

6. Sampling Equipment and Supplies

6.1 *Sample Containers*—Airtight amber glass sample containers with PTFE-lined caps such as 40-mL volatile organic analysis vials are recommended. Larger 125-mL wide mouth bottles may also be used which eliminate the need for forceps to place or remove wipes from the sample container. To minimize solvent handling in the field, wipes may be wetted with solvent in the laboratory and shipped to the field in the sample container.

6.2 *Wipes*—Cotton gauze pads 7.6-cm square are to be used. Sterile surgical gauze pads are typically used without precleaning however, samples of the pads should be analyzed or otherwise determined to be free of the target compounds and substances that could interfere with the analytical method. If necessary, pads should be precleaned by solvent extraction in a laboratory prior to field use.

6.3 *Solvent*—A high purity solvent (one which is free of contaminants that might interfere with analysis), capable of solublizing the target organic compound and compatible with the surface being wiped, should be used. For collecting PCBs and most pesticides (e.g., chlordane, chlorpyrifos and malathion) isooctane is an effective solvent. For carbamates or known polar pesticides, isopropanol is more effective. Some guidance on solvent selection (Table 1) was generated by EPA[4] using thin layer chromatography (TLC) saturation pads (essentially a heavy filter paper) which generally performs similarly to cotton gauze pads. Hexane is another commonly used solvent to consider for PCB sampling. Some effective solvents such as acetone are not the most desirable because interfering compounds from some surfaces can also be recovered.[4] The analytical laboratory should be able to assist in selecting a proper wiping solvent compatible with the surface to be sampled and with the analytical procedures.

6.4 *Disposable Gloves*—Powderless gloves which protect the sampler's hands from the solvent and do not contribute any possibly interfering contaminants should be used. A new pair of gloves should be used for each wipe.

6.5 *Sampling Template (Optional)*—Templates made of stainless steel, aluminum, disposable heavy-duty aluminum foil or other inert material can be used to expose a 10-cm by 10-cm surface area to be wiped.

6.6 *Other*—Standard field sampling supplies are discussed in Guide D4687 and may include a copy of the sampling plan, chain-of-custody forms, custody seals, logbook, camera, field data sheets, sample labels, forceps, noncontaminating marker (e.g., pencil, scribe), decontamination supplies, and solvent dispenser. Additional detailed equipment lists are included in EPA publications.[5, 6]

7. Procedure

7.1 Review the sampling plan and sampling procedures, assemble sampling equipment, ensure personnel are adequately trained for their tasks, arrange logistics, and ensure supplies will be available at the site when needed. Since sampling results can vary between operators sampling identical surfaces, the same person should collect all wipe samples at a given site[5] to minimize variability and enhance comparison of results from various locations.

7.2 Locate the sampling points as specified in, or according to the guidance of, the sampling plan.

7.3 Install the sample template or otherwise delineate the area to be sampled, normally a 10-cm by 10-cm area. This can be achieved by either taping a template in place (caution, tape used to secure a template should not be wiped since this may contaminate the sample), or by drawing the boundary of the area to be sampled with a noncontaminating marker. Although a 10-cm by 10-cm area is the standard-size template, the area does not have to be square as long as a 100-cm^2 area is being sampled. If contaminant levels are expected to be low, greater sensitivity may be achieved by sampling a larger area. In all cases, the location and dimensions (e.g., length, width, diameter) of the area sampled must be recorded and possibly photographed.

7.4 Don a new glove and obtain a clean wipe. If precleaned wipes were shipped in sample containers, forceps can be used to remove the wipe from the container.

7.5 If solvent-wetted wipes were not shipped to the field, dispense solvent (2 mL recommended although somewhat more may be desired if shipping solvent-wetted wipes to the field in 125-mL bottles) onto the cotton gauze pad. A repeating dispenser can be used for dispensing the same amount of solvent to each wipe. The EPA's PCB program specifies the use of a saturated, but not dripping, wipe (~5 mL of solvent),[5]

[4] Carr, B. L. and Hill, D. F., *Sampling of Common Pesticides and PCBs from Inert Surfaces*, EPA 330/1-90-001, National Enforcement Investigations Center, Denver, CO,1989.

[5] Smith, J. H., *Wipe Sampling and Double Wash/Rinse Cleanup as Recommended by the Environmental Protection Agency PCB Spill Cleanup Policy*, U.S. Environmental Protection Agency, Washington, DC,1991.

[6] U.S. Environmental Protection Agency, *Chip, Wipe and Sweep Sampling*, SOP#: 2011, Environmental Response Team, NJ,1994.

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which may slightly increase contaminant recovery, but research has shown more consistent results using 2 mL of solvent.[4]

7.6 Wipe the entire surface to be sampled using firm strokes by pressing with the fingertips. Wipe vertically and then horizontally to ensure there is complete coverage in both directions with minimal overlap of the previous stroke. The objective is to systematically, thoroughly, and consistently wipe the entire target area twice, each time from a different direction.[5] Excess wiping (e.g., more than single coverage in each direction) has been shown to reduce organic contaminant recovery.[4]

7.7 Fold the wipe with the sampled side inward, place it in the sample container, and cap the container. EPA's PCB program specifies air drying the saturated cotton gauze pad, either in the laboratory or the field. Field drying can be accomplished by placing wipes on clean aluminum foil or in the sample container with the lid off (ensure no liquid solvent is lost when placing wet wipes in the sample jar).

7.8 Label the sample container and complete standard documentation procedures.

7.9 Store the sample out of direct sunlight, cool to 4°C and ship or transport the sample(s) to the laboratory.

7.10 Quality control samples should be collected as specified in the sampling or quality assurance/quality control plan. The types of quality control samples may include blank, second wipe, duplicate, and spiked samples[5] as described below but may include other types as needed to achieve the objectives.

7.10.1 The first type of blank sample is a wipe in an unopened sample container (if provided to the field in this manner) or a clean wipe (with or without solvent) placed in a sample container. This type of blank is useful in determining whether the wipes and possibly the solvent are contaminated. The second type of blank is a wipe sample collected from a control area for each type of surface sampled. This type of blank is useful in determining whether contaminants may have been extracted from the surface sampled (e.g., target or interfering contaminants from painted, plastic, tile, etc. surfaces).

7.10.2 Two other types of quality control samples are second wipes and duplicate samples. A second wipe sample is collected from exactly the same area and immediately after the regular sample is collected. These sample results are used to estimate the residual contamination remaining after regular sampling. The data can be used to calculate an estimate of total surface contamination (this calculation is beyond the scope of this standard). This type of wipe is important for sampling relatively more porous surfaces such as vinyl tile. A duplicate sample is collected immediately adjacent to the regular sample and can be used to estimate sample collection precision (assuming the immediately adjacent area has the same level of contamination).

8. Keywords

8.1 sample collection; surface sample; wipe; wipe sample

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Designation: D6966 – 08

Standard Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Determination of Metals[1]

This standard is issued under the fixed designation D6966; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the collection of settled dust on surfaces using the wipe sampling method. These samples are collected in a manner that will permit subsequent extraction and determination of target metals in the wipes using laboratory analysis techniques such as atomic spectrometry.

1.2 This practice does not address the sampling design criteria (that is, sampling plan which includes the number and location of samples) that are used for clearance, hazard evaluation, risk assessment, and other purposes. To provide for valid conclusions, sufficient numbers of samples should be obtained as directed by a sampling plan.

1.3 This practice contains notes that are explanatory and are not part of the mandatory requirements of this practice.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D4840 Guide for Sample Chain-of-Custody Procedures

E1792 Specification for Wipe Sampling Materials for Lead in Surface Dust

3. Terminology

3.1 For definitions of terms not listed here, see Terminology D1356.

3.2 *Definitions:*

3.2.1 *batch, n*—a group of field or quality control (QC) samples that are collected or processed together at the same time using the same reagents and equipment.

3.2.2 *sampling location, n*—a specific area within a sampling site that is subjected to sample collection.

3.2.2.1 *Discussion*—Multiple sampling locations are commonly designated for a single sampling site (see 3.2.3).

3.2.3 *sampling site, n*—a local geographic area that contains the sampling locations (see 3.2.2).

3.2.3.1 *Discussion*—A sampling site is generally limited to an area that is easily covered by walking.

3.2.4 *wipe, n*—a disposable towellette that is moistened with a wetting agent. (E1792)

3.2.4.1 *Discussion*—These towellettes are used to collect samples of settled dust on surfaces for subsequent determination of metals content in the collected dust.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *field blank, n*—a wipe (see 3.2.4) that is exposed to the same handling as field samples except that no sample is collected (no surface is actually wiped).

3.3.1.1 *Discussion*—Analysis results from field blanks provide information on the analyte background level in the wipe, combined with the potential contamination experienced by samples collected within the batch (see 3.2.1) resulting from handling.

4. Summary of Practice

4.1 Wipe samples of settled dust are collected on surfaces from areas of known dimensions with wipes satisfying certain requirements, using a specified pattern of wiping.

[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.04 on Workplace Air Quality.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

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4.2 The collected wipes are then ready for subsequent sample preparation and analysis for the measurement of metals of interest.

5. Significance and Use

5.1 This practice is intended for the collection of settled dust samples for the subsequent measurement of target metals. The practice is meant for use in the collection of settled dust samples that are of interest in clearance, hazard evaluation, risk assessment, and other purposes.

5.2 This practice is recommended for the collection of settled dust samples from hard, relatively smooth nonporous surfaces. This practice is less effective for collecting settled dust samples from surfaces with substantial texture such as rough concrete, brickwork, textured ceilings, and soft fibrous surfaces such as upholstery and carpeting. Collection efficiency for metals such as lead from smooth, hard surfaces has been found to exceed 75 % (E1792).

6. Apparatus and Materials

6.1 *Sampling Templates*—One or more of the following: 10 cm by 10 cm (minimum dimensions) reusable or disposable aluminum or plastic template(s), or disposable cardboard templates, (full-square, rectangular, square "U-shaped," rectangular "U-shaped," or "L-shaped," or both); or templates of alternative areas having accurately known dimensions (see Note 1). Templates shall be capable of lying flat on a surface.

NOTE 1—For most surfaces, it is recommended to collect settled dust from a minimum surface area of 100 cm^2 to provide sufficient material for subsequent laboratory analysis. However, larger areas (for example, 30 cm by 30 cm) may be appropriate for surfaces having little or no visible settled dust, while a smaller sampling area (for example, 10 cm by 10 cm) may be appropriate for surfaces with high levels of visible settled dust. It is recommended to have a suite of templates with various sampling dimensions.

6.2 *Wipes*, for collection of settled dust samples from surfaces. Wipes shall be individually wrapped and fully wetted. The background metal(s) content of the wipes should be as low as possible. At a maximum, the background level of target metal(s) shall be no more than one-tenth the target concentration the metal(s) to be measured.

NOTE 2—Wipes meeting the requirements of Specification E1792 may be suitable.

NOTE 3—Wipes made of cellulosic materials in general produce fewer analysis problems than wipes made of synthetic polymeric materials.

6.3 *Sample Containers*, sealable, rigid-walled, 30-mL minimum volume.

NOTE 4—Screw-top plastic centrifuge tubes are an example of a suitable rigid-walled sample container.

NOTE 5—Use of a sealable plastic bag for holding and transporting the settled dust wipe sample is not recommended due to the potential loss of collected dust within the plastic bag during transportation and laboratory handling. Quantitative removal and processing of the settled dust wipe sample by the laboratory is significantly improved through the use of sealable rigid-walled containers.

6.4 *Measuring Tool*, tape or ruler, capable of measuring to the nearest ±0.1 cm.

6.5 *Plastic Gloves*, powderless.

6.6 *Cleaning Cloths*, for cleaning of templates and other equipment.

NOTE 6—Wipes used for dust sampling (6.2) can be used for cleaning templates and other sampling equipment, but other cleaning cloths or wipes not meeting the requirements described in (6.2) may be suitable for this purpose.

6.7 *Adhesive Tape*, suitable for securing the template(s) to the surface(s) to be sampled, and for demarcating sampling areas if templates are not used.

NOTE 7—Masking tape, for example, functions well for these purposes.

6.8 *Disposable Shoe Covers*, optional.

7. Procedure

7.1 Use one of the following two options when collecting settled dust samples from each sampling location. For wide, flat locations, it is recommended to use the template-assisted sampling procedure (see 7.1.1.2(a)). For small locations (for example, window sill, section of a piece of equipment, or portion of a vehicle interior), it will ordinarily be necessary to use the confined-area sampling procedure (see 7.1.1.2(b)).

NOTE 8—Metal contamination problems during field sampling can be severe and may affect subsequent wipe sample analysis results. Contamination can be minimized through frequent changing of gloves, use of shoe covers (see 6.8), and regular cleaning of sampling equipment with cleaning cloths (see 6.6). Use of disposable shoe covers between different locations, and removal of them prior to leaving the sampling site or entering vehicles, can be helpful in minimizing inadvertent transfer of contaminated dust from one location to another.

7.1.1 *Sampling Procedure*:

7.1.1.1 Don a pair of clean, powderless, plastic gloves (see 6.5 and Note 8).

7.1.1.2 Use either a template-assisted sampling procedure (a) or tape-defined sampling procedure (b):

(a.) Carefully place a clean template on the surface to be sampled in a manner that minimizes disturbance of settled dust at the sampling location. Tape the outside edge of the template to prevent the template from moving during sample collection.

(b.) Alternatively, mark the defined area to be sampled with adhesive tape (6.7) being careful not to disturb the settled dust, and measure the area to be sampled using the measuring tool (6.4).

7.1.1.3 Obtain a wipe (6.2) and, if there is a possibility for the package containing the wipe to be contaminated with dust, clean the outside of the package with a cleaning cloth (6.6).

7.1.1.4 Remove the wipe from its package, and inspect the wipe to ensure that it is fully wetted and not contaminated with dust or other material. Discard the wipe if it is found to be too dry or contaminated, or both.

7.1.1.5 Using an open flat hand with the fingers together, place the wipe on the surface to be sampled. Wipe the selected surface area, side to side, in an overlapping "S" or "Z" pattern while applying pressure to the fingertips (refer to Figs. 1 and 2). Wipe the surface so that the entire selected surface area is covered. Perform the wiping procedure using the fingers and not the palm of the hand.

7.1.1.6 Repeat 7.1.1.5 using a different brand of wipe (after selecting a different sampling location) if the wipe originally

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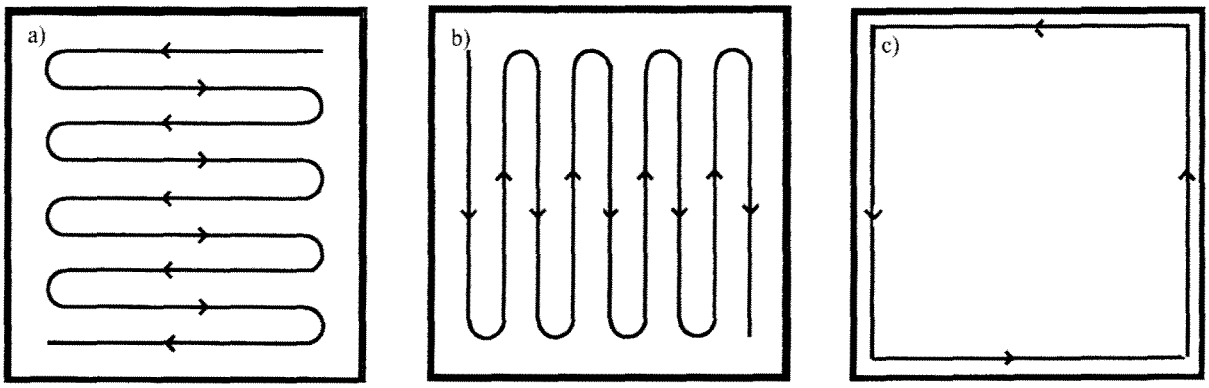
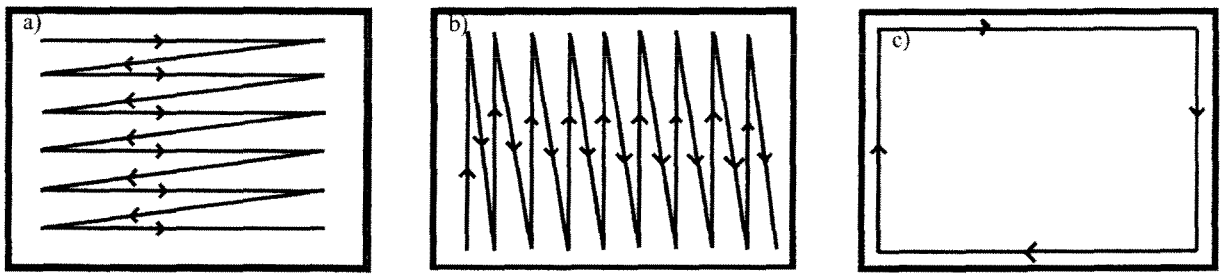


NOTE 1—Only the center of the wiping path is shown, not the entire wiping width. Fig. 1a) shows the first "S" wiping pattern over the surface area to be sampled; Fig 1b) demonstrates the second "S" wiping course over the surface; and Fig. 1c) shows the final wiping which is targeted toward edges and corners.

FIG. 1 Schematic of a Side-to-Side Overlapping "S" Wiping Pattern



NOTE 1—Only the center of the wiping path is shown, not the entire wiping width. Fig. 2a) shows the first "Z" wiping pattern over the surface area to be sampled; Fig 2b) demonstrates the second "Z" wiping course over the surface; and Fig. 2c) shows the final wiping which is targeted toward edges and corners.

FIG. 2 Schematic of a Side-to-Side Overlapping "Z" Wiping Pattern

used significantly changes shape (for example, rolls up by curling) or tears during the wiping process.

NOTE 9—Some surfaces (for example, rough surfaces) may cause certain wipes to curl up or otherwise significantly change shape during the wiping process. A type of wipe that maintains its integrity should be selected for each surface sampled.

7.1.1.7 Fold the wipe in half with the collected dust side folded inward and repeat the preceding wiping procedure (7.1.1.5) within the selected sampling area using an up and down overlapping "S" or "Z" pattern at right angles to the first wiping (see Figs. 1 and 2 and Note 10).

NOTE 10—Wipes are folded to envelop the collected dust within the wipe, to avoid loss of the collected dust, and to expose a clean wipe surface for further dust collection from the sampling location. For sample areas containing large amounts of settled dust, carefully wipe the area to ensure as much dust as possible within the wipe is captured.

7.1.1.8 Fold the wipe in half again with the collected dust side folded inward and repeat the wiping procedure one more time, concentrating on collecting settled dust from edges and corners within the selected surface area (see Figs. 1 and 2 and Note 10).

7.1.1.9 Fold the wipe again with the collected dust side folded inward and insert the wipe into a sample container (6.3).

7.1.1.10 Label the sample container with sufficient information to uniquely and indelibly identify the sample.

7.1.1.11 Record the dimensions (in square centimetres) of the selected sampling area (that is, the internal dimensions defined by the template or the taped area) or that the sample is a blank.

7.1.1.12 Discard the gloves.

7.2 Collect field blanks at a minimum frequency of 5 % (at least one field blank for every 20 wipe samples collected). The minimum number of field blanks to collect for each batch of wipe samples used shall be three. Place field blanks in sample containers and label these samples in the same fashion as the collected surface dust samples (see 7.1.1.10).

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7.3 Follow sampling chain of custody procedures to ensure sample traceability. Ensure that the documentation which accompanies the samples is suitable for a chain of custody to be established in accordance with Guide D4840.

8. Records

8.1 Field data related to sample collection shall be documented in a sample log form or field notebook (see Note 11). If field notebooks are used, then they shall be bound with pre-numbered pages. All entries on sample data forms and field notebooks shall be made using ink, with the signature and date of entry. Any entry errors shall be corrected by using only a single line through the incorrect entry (no scratch outs), accompanied by the initials of the person making the correction, and the date of the correction (see Note 12).

NOTE 11—Field notebooks are useful for recording field data even when preprinted sample data forms are used.

NOTE 12—These procedures are important to properly document and trace field data.

8.2 At a minimum, the following information shall be documented:

8.2.1 Project or client name, address, and city/state/country location.

8.2.2 General sampling site description.

8.2.3 Information as to the specific collection protocol used (for example, template-assisted; "Z"-wiping pattern, etc.).

8.2.4 Information as to the specific type or brand of wipes used, including manufacturer and lot number.

8.2.5 Information on quality control (QC) samples: which samples are associated with what group of field blanks.

8.2.6 For each sample collected (including field blanks): an individual and unique sample identifier and date of collection. This information shall be recorded on the sample container in addition to the field documentation.

8.2.7 For field samples (not including field blanks), record in field documentation (field notebook or sample log form) the dimensions of each area sampled (in square centimetres).

8.2.8 For each sample collected: name of person collecting the sample, and specific sampling location information from which the sample was removed.

9. Keywords

9.1 metals measurement; sample collection; settled dust; surfaces; wipe

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Appendix X

Final sample and analysis plan for PODS temporary closure

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APPENDIX QQ TRAINING PLAN FOR THE BEDS

QQ-1 PURPOSE

The purpose of this training plan is to identify specific training requirements for HWAD staff involved in operation and maintenance of BEDS. BEDS personnel are also required to meet the general training requirements given in Section O, "Personnel Training."

QQ-2 BEDS STAFF

QQ-2a BEDS Control-Room Operator

A highly proficient operator who mans the control room at all times unless relieved by another operator. He/she would be very knowledgeable of all BEDS safe operating procedures and systems.

QQ-2b BEDS Auxiliary Operator

The auxiliary control-room operator periodically walks the plant to check local indicators, equipment integrity, and look for signs of possible trouble (a combination of control-room operator and rover). This operator would be trained in general BEDS operation, maintenance, and safe operating procedures. He/she would have troubleshooting skills. In the case of system upsets, spills, numerous simultaneous alarms, or other signs of trouble, the auxiliary control-room operator would always be available and proficient at investigating and troubleshooting before plant problems became more serious. He/she would also be available to relieve the control-room operator, help coordinate inventory control data entry, and help in other areas as needed. This operator would be responsible for ensuring removal of waste stream barrels when full and placement of empty barrels at waste collection points.

QQ-2c BEDS Feeder Loader (Munitions Handler with BEDS Training)

The full-time feeder loader (minimum) will be fully trained in the BEDS slurry preparation and feed systems and in general plant operation and safety procedures.

QQ-2d BEDS Feeder Loader Assistant (Munitions Handler with BEDS Training)

The feeder loader assistant is trained to operate the fork lift to deliver bulk propellant to the feeder platform and perform waste stream barrel removal and replacement, as directed by the auxiliary operator. This assistant could also help with empty propellant drum removal and performing related tasks.

QQ-3 BEDS TRAINING PROGRAM

QQ-3a Classroom Training Requirements

Training Course Description	Frequency	Control Room Operator	Auxiliary Operator	Feeder Loader	Feeder Loader Assistant
BEDS Overview Theory of operation of the system and all major components.	Initially	X	X	X	X
Operation and Maintenance (O&M) Review of O&M Manuals so operators are aware of the location of information.	Annually	X	X	X (Areas of Responsibility)	X (Areas of Responsibility)

QQ-3b On the Job Training (OJT)

Training Description	Frequency	Control Room Operator	Auxiliary Operator	Feeder Loader	Feeder Loader Assistant
Walk Through System walk through identifying all important items.	Initially	X	X	X	X
Start-Up and Shut-Down Participation in start-up and shut-down.	Initially	X	X	X (Areas of Responsibility)	X (Areas of Responsibility)
Maintenance Demonstration and hands-on participation in selected maintenance functions, such as, location and replacement of a failed bag.	Annually	X	X	X (Areas of Responsibility)	X (Areas of Responsibility)
Instrumentation and Upset/Alarm Conditions Explanation of the importance of all instrument readings and demonstration of actions required during upset or alarm conditions	Annually	X	X	X (Areas of Responsibility)	X (Areas of Responsibility)

QQ-4 HAZARDOUS WASTE TRAINING DIRECTOR QUALIFICATIONS

Qualification requirements for the Director of Hazardous Waste Training are presented in Appendix GG, “Training Plan and Requirements for the PODS.”

QQ-5 CONTINUED TRAINING/REQUALIFICATION AND PROFICIENCY

This section contains information on continued training and requalification and proficiency.

QQ-5a Continued Training

All BEDS personnel, once qualified, will be required to participate in the continued training program. Failure to participate in continued training will result in removal from duties requiring that qualification, until the deficiency can be corrected. Continuing training shall be used to enhance knowledge and skills relating to BEDS, operations, and fundamentals; update personnel on new and improved equipment and procedures; update personnel on lessons learned by the industry; and correct knowledge and skill deficiencies as these are identified. BEDS operating management will review and evaluate the respective continuing training programs annually to revise and improve its effectiveness and efficiency. BEDS personnel will be promptly notified of changes to the continuing training schedule.

BEDS personnel will also be required to participate in the site continuing training program (see Section O), as required by SOC.

QQ-5b Requalification and Proficiency

BEDS personnel qualifications shall be for a period not to exceed two (2) years from the date of qualification. Other concerns, such as medical and security requirements, may affect the ability of personnel to fulfill qualified responsibilities. Additionally, failure of a requalification examination, or serious job performance deficiencies which indicate performance in an unsafe manner, shall require removal from related activities.
BEDS personnel absent from qualified duties for extended periods of time shall participate in selected retraining prior to resuming duties requiring qualification. This training may include

management interviews and evaluations, classroom training, seminars, OJT, examinations, or performance evaluations. Additionally, if the absence is twelve (12) months or greater, retraining must be completed prior to the employee resuming duties.