LA-9445-PNTX-G

1

nal Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

Supplementary Documentation for an Environmental Impact Statement Regarding the Pantex Plant

Estimated Releases and Downwind Concentrations of Air Pollutants from Waste Organic Solvent Evaporation, Waste High-Explosive Burning, and High-Explosive Test Shots

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

This report was prepared by Kathy Derouin, Lois Schneider, and Mary Lou Keigher, Group H-8.

LA-9445-PNTX-G

Issued: December 1982

Supplementary Documentation for an Environmental Impact Statement Regarding the Pantex Plant

Estimated Releases and Downwind Concentrations of Air Pollutants from Waste Organic Solvent Evaporation, Waste High-Explosive Burning, and High-Explosive Test Shots

(Daniel G.) D. G. Macdonell
(Jean M.) J. M. Dewart

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

CONTENTS

TABLES

SUPPLEMENTARY DOCUMENTATION FOR AN ENVIRONMENTAL IMPACT STATEMENT REGARDING THE PANTEX PLANT:

ESTIMATED RELEASES AND DOWNWIND CONCENTRATIONS OF AIR POLLUTANTS FROM WASTE ORGANIC SOLVENT EVAPORATION, WASTE HIGH-EXPLOSIVE BURNING, AND HIGH-EXPLOSIVE TEST SHOTS

by

D. G. Macdonell and J. M. Dewart

ABSTRACT

This report documents work performed in support of preparation of an Environmental Impact Statement (EIS) regarding the Department of Energy's (DOE) Pantex Plant near Amarillo, Texas. Specifically, this report discusses the following operations at the Pantex Plant that routinely emit air pollutants: evaporation of waste organic solvents contaminated with high explosives, burning of waste high explosives, and high-explosive test shots. Available experimental data and published emission factors were used to estimate the amounts of pollutants released into the atmosphere from each source. Pollutant concentrations were calculated at the main plant area and at the site boundary under both typical and unfavorable meteorological dispersion assumptions using Gaussian plume and puff models. These concentration estimates were then compared to existing air quality standards, occupational exposure limits, and, where no standards exist, to toxicological data.

I. INTRODUCTION

This report documents work performed in support of preparation of an Environmental Impact Statement (EIS) regarding the Department of Energy's (DOE) Pantex Plant near Amarillo, Texas. That EIS addresses continuing nuclear weapons operations at Pantex and the construction of additional facilities to house those operations. The EIS was prepared in accordance with current regulations under the National Environmental Policy Act. Regulations of the Council on Environmental Quality (40 CFR 1500) require agencies to prepare concise EISs with fewer than 300 pages for complex projects. This report was prepared by Los Alamos National Laboratory to document details of work performed and supplementary information considered during preparation of the draft EIS.

Air quality at the Pantex Plant is affected by a variety of sources of air pollutants such as evaporation of waste organic solvents, burning of waste high explosives, high-explosive test detonations, and plant exhaust stack emissions. Because nonradioactive air sampling data are not available to verify the air quality impact of these sources, Pantex operations and material use records were reviewed to determine which sources were of potential concern.

Because of the relatively large quantities involved and the types of emissions that result, waste organic solvent evaporation, waste high-explosive burning, and high-explosive test shots are believed to create the greatest potential for air pollution or adverse health effects. With no ambient air-sampling data available, types and quantities of emissions from these operations were estimated from experimental data and published emission factors. Air concentrations under unfavorable and typical meteorological dispersion conditions were then calculated using Gaussian dispersion equations.

Potentially toxic materials such as beryllium, mercury, 4,4'-methylenebis-(2-chloroaniline) (MOCA), and various acids are used and, in some cases, released to the atmosphere through plant exhaust stacks. A review of the material usage and a site evaluation of emission control procedures indicated that the small amounts of these materials being used are adequately controlled through the use of air scrubbers or air filtering systems. Emissions that are not collected by control equipment are considered to be small and are rapidly diluted and widely dispersed by the prevailing winds. Based on this evaluation, emissions from existing plant exhaust stacks are not considered to cause an air quality problem and will not be discussed in this report. Air pollution from the natural gas-fired power plant has been previously addressed (USERDA 1976A).

II. DESCRIPTION OF PLANT OPERATIONS

Both high-explosives burning and waste organic solvent evaporation are performed at the burning ground. High-explosives test firing takes place at several different sites around the plant.

The burning ground consists of burning pads, evaporation tanks, storage buildings, and a control building. The burning ground is approximately 800 m from the nearest site boundary and 4300 m from the main operations area. The closest test firing site to any of the site boundaries is approximately 700 m from the site boundary. The testing site nearest to the main operations is approximately 3000 m distant.

A. Waste Organic Solvent Disposal

Waste organic solvents, usually contaminated with high explosives and water, are received at the burning ground for disposal through natural evaporation to the atmosphere. The waste solvent is placed in one of two open-topped circular tanks, 2.4 m (8 ft) in diameter and 0.6 m (2 ft) deep. The rate at which a solvent evaporates varies, depending on the weather conditions and characteristics of the particular solvent. When the organic solvent has evaporated, the residual waste high explosive in the tank is burned. The total amount of waste organic solvent disposed of at the burning ground in 1981 was approximately 69 750 ℓ (18 426 gal). Table I lists the various organic solvents and the quantities of each (Laseter 1982A).

B. Waste High-Explosive Disposal

Waste high explosives are disposed of by burning. Generally, the explosive is spread on one of 18 open-burn pads, with no more than 682 kg (1500 lb) per pad (Laseter 1982B). Often, two pads are used simultaneously, and occasionally, as many as four pads may be used. The thickness of the explosive is limited to about 7.6 cm (3 in.) to allow for a rapid burn and to reduce the potential for accidental detonation. The burn is remotely ignited by the operator from the control building. Most of the explosive is burned in 2 to 5 minutes, but smoke may last for 15 to 30 minutes.

Two high explosives burned at the Pantex Plant during 1981 are Baratol and Boracitol; they do not burn completely during normal burning operations (Laseter 1982C). The explosives remaining from the first burn are piled on old railroad ties, and the ties are set afire. The ties burn for 2 to 3 hours, and the Baratol or Boracitol burns and/or smolders for several days.

TABLE I

WASTE ORGANIC SOLVENT DISPOSAL FOR 1981

Solvent	Amount Gallons	Liters
Acetone	6 940	26 270
Butyl acetate	15	57
Dimethylformamide (DMF)	3 410	12 908
Ethyl acetate	450	1 703
Isobutyl acetate	10	38
Methanol	727	2 752
Methyl ethyl ketone (MEK)	550	2 082
Methyl isobutyl ketone (MIBK)	50	189
Tetrahydrofuran (THF)	1 320	4 997
Toluene	4 954	18 752
TOTAL	18 426	69 748

Approximately 69 000 kg (151 800 lb) of high explosives were burned at the Pantex Plant in 1981 (Laseter 1982A). Most of the high explosives burned in a single burn in the past several years was estimated to be 1818 kg (4000 lb) (Laseter 1982C). Most of the high explosive burned was one of five types: LX-10, PBX-9502, Baratol, Comp B, or Cyclotol. Cyclotol, Comp B, and Baratol are primarily from weapons teardown; LX-10 and PBX-9502 are from high-explosive machining waste. Thus, Cyclotol, Comp B, and Baratol could be burned in large quantities in a single burn, whereas PBX-9502 and LX-10 are probably present in most of the burns in small quantities. Small quantities of many other types of explosives were also burned (Table II). Only emissions from the five high explosives comprising the bulk of explosives burned at the Pantex Plant are discussed in this report.

C. High-Explosive Testing

High-explosive test firings at the Quality Test Fire sites are performed for quality assurance testing of weapons explosives and components. Each site is surrounded by a bunker approximately 4.6 m (15 ft) high. The types and

TABLE II

WASTE HIGH EXPLOSIVE BURNED IN 1981

Major Types of High Explosives	Per Cent of Total*
LX-10	2.5
PBX-9502	7.5
Baratol	9.0
Comp B-3	13.5
Cyclotol	67.5

Other High Explosives Burned

- Boracitol
- LX-04
- LX-09
- LX-17
- PBX-9010
- PBX-9011
- PBX-9404
- PBX-9501

---

*A total of 69 000 kg was burned in 1981.

TABLE III

HIGH-EXPLOSIVES TEST FIRED IN 1981
(Quality Test Fire Site)

Type	Weight (g)
PBX-9404	4 118
PBX-9407	7 038
PBX-9501	101
PBX-9502	56 513
LX-04	310 559
LX-09	567
LX-10	24 164
LX-13	5 782
LX-14	7 361
XTX	221
Comp B	12 024
Cyclotol	82 220
TOTAL	510 669 (1124 lb)

amounts of high explosives tested at these sites are presented in Table III. There were 1378 test shots in 1981 involving 511 kg (1124 lb) of high explosives. Less than one per cent of all tests conducted involved depleted uranium. The radiological impacts of these tests are discussed in another Pantex report (Buhl 1982).

High-explosive skid tests occur in the High-Explosives Development Test Fire Area. In 1981, these tests involved 636 kg (1400 lb) of explosives of which 586 kg (1290 lb) actually detonated. These tests are performed to evaluate new explosive compounds. The types of explosives tested in 1981 were PBX-9404, PBX-9501, and LX-10, but the amount of each was unavailable.

III. CRITERIA FOR ESTIMATING AIR CONCENTRATIONS

Estimates of atmospheric concentrations of emissions from the previously discussed operations were made by determining the emission rates of pollutants from each operation. These emission rates were then used in a dispersion analysis. Two separate meteorological dispersion conditions are used in the analysis: an unfavorable dispersion condition from which the highest concentrations are expected, and a typical dispersion condition that provides a more realistic estimate of what air concentrations would normally be expected.

Concentration estimates for each operation also were made for two locations, at the nearest site boundary and at the main operations area. Concentrations at the site boundary were compared to Environmental Protection Agency (EPA) ambient air standards. Concentrations at the main operations area were compared to DOE-adopted occupational exposure limits to assess potential worker exposures.

A. Waste Organic Solvent Evaporation

1. Solvent Evaporation Emissions. Organic solvent vapor emission rates (g/s) were calculated from solvent evaporation rates (g/s-cm^2) and the evaporation tank size (cm^2). The evaporation rates, presented in Table IV, were derived from laboratory data (Mellan 1950, Doolittle 1954). The calculated emission rates (Table IV) were found to be a conservative estimate (i.e., overestimate) of the emission rate measured for a mixture of solvents at the Pantex Plant. This measured emission rate was 0.2 g/s for a 24-hour period with cloudless skies and temperatures ranging from 10° to 27°C.

A literature search for a convenient physical constant or formula that could be used to calculate relative evaporation rates for the variety of conditions found at the Pantex Plant was unsuccessful. Various methods of

TABLE IV

WASTE ORGANIC SOLVENT EVAPORATION AND EMISSION RATES

Solvent	Evaporation Rate*,** (g/cm^2/h)	Emission Rate*** (g/s)
Acetone	11.80	3.0
Butyl acetate	0.87	0.3
DMF	0.20	<0.1
Ethyl acetate	5.03	1.6
Isobutyl acetate	1.45	0.5
Methanol	5.03	1.6
MEK	4.80	1.5
MIBK	1.51	0.4
THF	10.24	2.1
Toluene	2.04	0.6

*Mellan (1950) and Doolittle (1954).
**Measured at 25°C and atmospheric pressure.
***Emission rate = evaporation rate x tank size x 2 tanks.

calculating evaporation rates were found in the literature [(Doolittle 1954), (Gardner 1940), (Gray 1974), (Mellan 1950), (Perry 1956), and (Scheflan 1953)]. The estimates of evaporation that could be obtained from these methods were not considered to be better than the experimental data [(Mellan 1950) and (Doolittle 1954)].

2. Solvent Vapor Dispersion. Downwind air concentrations of evaporated solvents were estimated using a centerline Gaussian plume dispersion equation. For a ground-level source, the equation is (Turner 1970)

$$\chi = \frac{Q}{\pi \sigma_z \sigma_y u} ,$$

where

χ is the ground-level, centerline concentration (g/m^3),
Q is the source emission rate (g/s),
u is the wind speed (m/s), and
σ_y and σ_z are the horizontal and vertical dispersion coefficients (m).

The meteorological parameters selected for the two dispersion cases are presented in Table V. The unfavorable case represents nighttime conditions--low wind speeds and a stable atmosphere. The typical case represents day or nighttime conditions--moderate wind speeds and neutral atmospheric stability.

TABLE V

METEOROLOGICAL DATA FOR SOLVENT DISPERSION

Unfavorable Case	Typical Case
F stability (stable)	D stability (neutral)
$u = 2$ m/s	$u = 6$ m/s
$\sigma_y = 27.5$ m at 800 m	$\sigma_y = 56$ m at 800 m
$\sigma_z = 12.0$ m at 800 m	$\sigma_z = 26.5$ m at 800 m
$\sigma_y = 130$ m at 4300 m	$\sigma_y = 260$ m at 4300 m
$\sigma_z = 32$ m at 4300 m	$\sigma_z = 81$ m at 4300 m

Note: σ_y and σ_z values from Turner (1970).

B. Waste High-Explosive Burning

1. High-Explosive Burning Emissions. Experimental data characterizing the combustion products of Comp B-3 (MHSM 1971B) and PBX-9502* were used in this study. Emission data for the other high explosives burned at the Pantex Plant during 1981 were not available. However, experimental combustion data for a number of high explosives not currently burned at Pantex were found in a series of Atomic Energy Commission (AEC) studies performed in the early 1970s (MHSM 1971A, 1971B, 1972, 1973). These studies involved burning a small sample of high explosive in an expandable closed chamber followed by chemical analysis of the gases evolved from the burn. The emissions from high-explosive burning at the Pantex Plant have been estimated from these experimental data.

The high explosives for which combustion product data were available and the high explosives currently burned at Pantex are presented in Table VI. A comparison of the composition by explosive component and binder (Table VI) shows that the explosives burned at the Pantex Plant are similar to those for which combustion products data are available. The per cent composition by weight of these explosives (Table VII) indicates that the major difference between the explosives is the amount of fluorine, chlorine, or, for Baratol, barium present.

How the emissions for each of the high explosives burned were obtained is presented next.

Emissions from the burning of Cyclotol were estimated to be the same as the emissions measured for Comp B-3. The emissions from LX-10 were estimated to be the same as the measured emissions from LX-07 with the exception of hydrogen fluoride (HF). Because the fluorine composition of LX-10 is one-half the fluorine composition of LX-07, the HF emission rate of LX-07 was estimated to be one-half the LX-10 emission rate.

The emissions from PBX-9502 were estimated from data collected during an experimental open burn. The analysis of gases from the open burn provided data on the principal combustion products (CO, CO_2, NO_2), but not other combustion products that would be expected (HCl, HF). Emissions of HCl were conservatively estimated by assuming that all of the chlorine present in PBX-9502 was converted to HCl.

The HF emissions from PBX-9502 were estimated as a ratio of the LX-07 emission rate. Because PBX-9502 contains only 34% as much fluorine as LX-07, the HF emission rate was estimated at 34% of the LX-07 emission rate.

---

*These data were supplied by T. E. Larson, Dynamic Testing Division (M Division), Los Alamos National Laboratory, May 1982.

TABLE VI

COMPARISON OF HIGH EXPLOSIVES

High Explosives--Combustion Product Data Available (Dobratz 1981)		High Explosives Burned at Pantex--1981	
HE	Explosive Component/Binder (Atomic Composition)	HE	Explosive Component/Binder (Atomic Composition)
TNT	TNT $(C_7 H_5 N_3 O_6)$	Baratol	24% TNT, 76% Ba $(NO_3)_2$ $(C_{9.46} H_{5.01} N_{8.51} O_{22.51} Ba_{2.74})$
PBX-9502	95% TATB/5% Kel-F 800 $(C_{1.40} H_{1.36} N_{1.35} O_{1.35} Cl_{0.08})$	PBX-9502	95% TATB/5% Kel-F 800 $(C_{1.40} H_{1.36} N_{1.35} O_{1.35} Cl_{0.02} F_{0.08})$
LX-07	90% HMX/10% Viton A $(C_{1.48} H_{2.62} N_{2.43} O_{2.43} F_{0.35})$	LX-10	95% HMX/5% Viton A $(C_{1.48} H_{2.77} N_{2.68} O_{2.68} F_{0.18})$
Comp B-3	60% RDX, 40% TNT $(C_{2.05} H_{2.51} N_{2.15} O_{2.67})$	Comp B-3	60% RDX, 40% TNT $(C_{2.05} H_{2.51} N_{2.15} O_{2.67})$
		Cyclotol	75% RDX, 25% TNT $(C_{2.05} H_{3.03} N_{2.80} O_{3.15})$

TABLE VII

HIGH EXPLOSIVES--PER CENT COMPOSITION BY WEIGHT

High Explosive	Composition by Weight (%)	High Explosive	Composition by Weight (%)
TNT	37 C	Baratol	12 C
	2 H		1 H
	19 N		12 N
	42 O		37 O
			39 Ba
PBX-9502	28 C		
	2 H		
	31 N		
	36 O		
	1 Cl		
	2 F		
LX-07	18 C	LX-10	17 C
	3 H		3 H
	34 N		36 N
	39 O		41 O
	7 F		3 F
Comp B-3	25 C	Comp B	24 C
	3 H		3 H
	30 N		30 N
	43 O		43 O
		Cyclotol	21 C
			3 H
			33 N
			43 O

Note: C - Carbon
H - Hydrogen
N - Nitrogen
O - Oxygen
Ba - Barium
Cl - Chlorine
F - Fluorine

Unfortunately, the PBX-9502 test data indicate two problems with the test: not all of the mass of the PBX-9502 burned was accounted for by the emissions data, and the burn was oxygen deficient. Thus, some gases (composed of carbon, hydrogen, nitrogen, and oxygen) emitted from burning PBX-9502 were not measured, and the emission estimates for CO and hydrogen cyanide (HCN) are higher than would be expected under conditions of more complete combustion.

The emissions from burning Baratol were estimated in part from experimental data. Baratol is 24% TNT, for which emission data were available, and 76% barium nitrate, for which emission data were calculated. All of the nitrate in the barium nitrate was conservatively assumed to be released as nitrogen dioxide. Ten per cent of the barium oxide produced from the combustion of Baratol was assumed to be aerosolized and released during the burn. No information was available concerning emission products from the combustion of railroad ties containing creosote, used for burning Baratol. Therefore, no downwind air concentrations were estimated for the railroad ties.

To calculate downwind air concentrations of high-explosive combustion products, 1818 kg (4000 lb) of one single type of high explosive were assumed to be burned, with the burn lasting 3.5 minutes. These values represent the maximum amount of high explosives burned at one time at the Pantex Plant (Laseter 1982C) and an average burn time.

2. Combustion Products Dispersion. Downwind air concentrations of combustion products were estimated using a centerline Gaussian dispersion equation for an elevated source (Turner 1970)

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z u} \exp \left[\frac{-H^2}{2\sigma_z{}^2} \right] ,$$

where

H is the release height (m). All other symbols are as previously defined. The effect of the release height must also be included because of the buoyancy of the hot gases.

High-explosive burning takes place only during the daytime, so the meteorological parameters selected for evaluating dispersion represent daytime conditions (Table VIII). The most unfavorable dispersion conditions are those for which the plume does not rise vertically but flows along the

TABLE VIII

METEOROLOGICAL PARAMETERS FOR HIGH-EXPLOSIVES BURNING DISPERSION

Unfavorable Case	Typical Case
D stability (neutral)	C stability (unstable)
$u = 6$ m/s	$u = 3$ m/s
$H = 5$ m	$H = 25$ m
$\sigma_y = 56$ m at 800 m	$\sigma_y = 85$ m at 800 m
$\sigma_z = 26.5$ m at 800 m	$\sigma_z = 49.5$ m at 800 m
$\sigma_y = 260$ m at 4300 m	$\sigma_y = 390$ m at 4300 m
$\sigma_z = 81$ m at 4300 m	$\sigma_z = 230$ m at 4300 m

ground horizontally. This corresponds to relatively strong winds and neutral atmospheric stability. Although this was the typical condition for solvent dispersion, the limitation of burning only during the daytime and the minimization of plume rise makes this the most unfavorable dispersion condition for high-explosives burning. Another daytime condition was chosen for the typical case--unstable atmosphere stability and moderate wind speeds. The height of the release was estimated for both cases.

C. High-Explosive Test Shots

Estimates of air concentrations of air pollutants from high-explosive test shots were made using theoretically derived detonation products and a Gaussian puff dispersion equation. Calculations were not made for each explosive type. There is generally only a small amount of explosive involved in each shot (several grams to 20 kg), and the primary detonation products are similar for all explosives (Ornellas 1982). Thus, only a few of the high explosives were selected for calculation of detonation products and downwind air concentrations.

1. Detonation Products. The detonation products for Cyclotol, Comp B, and LX-04 were theoretically derived (Mader 1963, 1982A, 1982B) and presented in Tables IX, X, and XI. The primary detonation products are water vapor, carbon dioxide, nitrogen gas, and solid carbon (particulate). Of these, only particulates are regulated under EPA ambient air quality standards. Air concentrations of the other primary products will not be evaluated.

Air concentrations were calculated for an 11.4-kg (25-lb) high-explosive test shot. This is an average size for skid testing; most of the quality assurance test shots are less than 10 lb.

TABLE IX

DETONATION PRODUCTS--CYCLOTOL
75% RDX/25% TNT, $C_{2.05} H_{3.03} N_{2.80} O_{3.15}$

Detonation Products Mole/Mole HE		Molecular Weight	Emissions (g/100 g HE)
H_2O	3.73	18	23.3
H_2	8.16×10^{-9}	2	--*
O_2	3.10×10^{-3}	32	0.034
CO_2	2.01	44	30.7
CO	1.61×10^{-3}	28	0.016
NH_3	8.46×10^{-8}	17	--
H^+	3.44×10^{-10}	1	--
NO	2.96×10^{-3}	30	0.031
N_2	3.44	28	33.4
OH^-	1.63×10^{-10}	17	--
CH_4	1.48×10^{-11}	16	--
Solid carbon	3.04	12	12.6

---

*Emissions less than 0.001 g/100 g HE.

TABLE X

DETONATION PRODUCTS--COMPOSITION B
64% RDX/36% TNT, $C_{2.05} H_{3.03} N_{2.80} O_{3.15}$

Detonation Products Mole/Mole HE		Molecular Weight	Emissions (g/100 g HE)
H_2O	4.38	18	22.7
H_2	6.32×10^{-10}	2	--*
O_2	3.40×10^{-3}	32	0.03
CO_2	2.46	44	31.2
CO	3.60×10^{-3}	28	0.03
NH_3	3.19×10^{-7}	17	--
H^+	2.47×10^{-10}	1	--
NO	4.14×10^{-3}	30	0.04
N_2	3.82	28	30.8
OH^-	1.92×10^{-10}	17	--
CH_4	7.95×10^{-11}	16	--
Solid carbon	4.39	12	15.2

---

*Emissions less than 0.001 g/100 g HE.

TABLE XI

DETONATION PRODUCTS--LX-04

85% HMX/15% VITON A, $C_{1.48}H_{2.46}N_{2.20}O_{2.2}F_{0.50}$

Detonation Products Mole/Mole HE	Molecular Weight	Emissions (g/100 g HE)
HF	20	--*
CF_4	88	11.0
F_2	38	0.01
H_2O	18	23.8
H_2	2	--
O_2	32	0.003
CO_2	44	21.3
CO	28	--
NH_3	17	--
H^+	1	--
NO	30	0.002
N_2	28	32.1
OH^-	17	--
CH_4	16	--
COF_2	66	--
Solid carbon	12	11.5

---

*Emissions less than 0.001 g/100 g HE.

2. Detonation Products Dispersion. The detonation products were assumed to be released as an instantaneous puff release. The peak concentration for a puff release assuming Gaussian dispersion is (Turner 1970)

$$X = \frac{0.127\, Q_t}{\sigma_x \sigma_y \sigma_z} \exp\left[\frac{-H^2}{2\sigma_z^{\,2}}\right] ,$$

where

Q_t is the total release (g),
σ_y and σ_z are horizontal and vertical puff dispersion coefficients (m),
σ_x is the downwind puff dispersion coefficient (m): $\sigma_x = \sigma_y$, and
H is the release height (m).

The height of the release was calculated as a function of the amount of high explosive involved in the test. The height of the cloud top is (Church 1969)

$$HC = 76\ (HE)^{.25}\ ,$$

where

HC is the height of the cloud top (m) and
HE is the amount of high explosive (lb).

The cloud center was estimated as one-half HC and this height was used as the release height in the puff dispersion equation. A virtual source distance was added to the downwind distances where air concentrations were calculated to account for the initial size of the detonation cloud. This virtual source distance is the distance where the initial σ_y is equal to HC/4.

Air concentrations were calculated for two sets of daytime meteorological conditions (Table XII). Because of the effect of release height, unstable atmospheric conditions were again chosen for the typical dispersion case and neutral stability conditions were chosen for the unfavorable case.

IV. RESULTS

Downwind air concentrations at the site boundary and at the main operations area are presented for organic solvent evaporation (Tables XIII and XIV), waste high-explosive burning (Tables XV and XVI), and high-explosive test shots (Tables XVII and XVIII). For comparison, the applicable EPA and state ambient air quality standards, and DOE-adopted occupational exposure limits, are presented in the corresponding tables.

TABLE XII

METEOROLOGICAL DATA FOR HIGH-EXPLOSIVE TEST SHOT DISPERSION

Unfavorable Case	Typical Case
Neutral stability	Unstable stability
$H = 85$ m	$H = 85$ m
$\sigma_y = 0.06\ x^{0.92}$	$\sigma_y = 0.14\ x^{0.90}$
$\sigma_z = 0.15\ x^{0.70}$	$\sigma_z = 0.53\ x^{0.73}$
$\sigma_x = \sigma_y$	$\sigma_x = \sigma_y$
Virtual source (y) distance = 1250 m	Virtual source (y) distance = 500 m
Virtual source (z) distance = 3185 m	Virtual source (z) distance = 405 m

---

Note: Puff dispersion coefficients from Slade (1968).
x is downwind distance (m).

TABLE XIII

ESTIMATED OFFSITE SOLVENT VAPOR CONCENTRATIONS

Solvent	Offsite Concentrations* (ppm) Unfavorable Case	Offsite Concentrations* (ppm) Typical Case
Ethyl acetate	0.21	0.02
Acetone	0.61	0.05
MEK	0.24	0.02
Toluene	0.08	0.01
Methanol	0.59	0.04
Butyl acetate	0.03	--**
MIBK	0.05	--
DMF	0.01	--
THF	0.34	0.03
Isobutyl acetate	0.05	--

*There are no applicable EPA or Texas ambient air standards for these solvents.

**Concentrations less than 0.005 ppm.

V. DISCUSSION AND CONCLUSIONS

Air concentrations of the various pollutants emitted at the Pantex Plant have been estimated for both offsite and onsite locations and compared to the appropriate standard or limit (Tables XIII through XVIII). Available toxicological information was also reviewed and compared to the estimated concentrations (Table XIX).

A. Waste Organic Solvent Evaporation

Results from dispersion modeling (Table XIII) indicate that concentrations of waste organic solvent vapor do not exceed 1 ppm offsite under any of the meteorological conditions assumed. No adverse health effects would be expected from exposure to these low concentrations. There are no applicable EPA or Texas ambient air standards for these solvents.

Organic solvent vapor concentrations estimated at the main operations area (Table XIV) would not exceed 0.05 ppm. No occupational exposure limits would be exceeded for workers. No adverse health effects would be expected from exposure to these low concentrations.

TABLE XIV

ESTIMATED SOLVENT VAPOR CONCENTRATIONS AT MAIN OPERATIONS AREA

Solvent	Estimated Concentrations (ppm)		Occupational Exposure Limits* (ppm)	
	Unfavorable Case	Typical Case	8 h	15 min
Ethyl acetate	0.02	--**	400	NS***
Acetone	0.05	--	750	1000
MEK	0.02	--	200	300
Toluene	0.01	--	100	150
Methanol	0.05	--	200	250
Butyl acetate	--	--	150	200
MIBK	--	--	50	75
DMF	--	--	10	20
THF	0.03	--	200	250
Isobutyl acetate	--	--	150	187

---

*ACGIH 1982.
**Concentrations less than 0.005 ppm.
***No standard.

B. Waste High-Explosive Burning

Results from the dispersion modeling of waste high-explosive burning indicate that concentrations of combustion products range from 0.01 to 60 ppm at the nearest site boundary (Table XV) and from less than 1 ppb to 5 ppm at the main operations area (Table XVI). These concentrations were calculated for a burn of 1818 kg (4000 lb) of one single type of explosive. The highest pollutant concentrations were calculated for carbon monoxide and hydrogen cyanide from PBX-9502 and for nitrogen dioxide from Baratol. However, the emissions for these pollutants were very conservatively estimated and so the resulting concentrations are higher than would realistically be expected.

EPA ambient air standards exist for only two of the combustion products: carbon monoxide and nitrogen dioxide. The nitrogen dioxide annual standard, the carbon monoxide 1-hour standard, and the carbon monoxide 8-hour standard would not be exceeded by the high-explosives burning alone. The air concentrations from other sources of these two pollutants at the Pantex

TABLE XV

AIR CONTAMINANTS FROM WASTE HIGH-EXPLOSIVE BURNING AT PANTEX ESTIMATED CONCENTRATIONS AT THE NEAREST SITE BOUNDARY (800 m)

High Explosive	Combustion Product	Unfavorable Case Dispersion Estimate* (ppm)	Typical Case Dispersion Estimate* (ppm)	EPA Standard (ppm)	Texas Standard (ppm)
Cyclotol	CO	0.3	0.1	35 (1 hour)**	35 (1 hour)
	NO_2	3.0	1.4	0.05 (annual)	0.05 (annual)
Comp B-3	CO	0.3	0.1	35 (1 hour)	35 (1 hour)
	NO_2	3.0	1.4	0.05 (annual)	0.05 (annual
Baratol	CO	1.9	0.9	35 (1 hour)	35 (1 hour)
	NO_2	46.2	21.8	0.05 (annual)	0.05 (annual)
	NH_3	1.3	0.6	NS***	NS
	HCN	0.3	0.1	NS	NS
	BaO	13.5 mg/m^3	6.4 mg/m^3	NS	NS
PBX-9502	CO	55.2	26.1	35 (1 hour)	35 (1 hour)
	NO_2	12.8	6.0	0.05 (annual)	0.05 (annual)
	HCN	32.5	15.4	NS	NS
	C_2N_2	11.9	5.6	NS	NS
	HCl	2.9	1.3	NS	NS
	HF	1.9	0.9	NS	0.006 (3 hour)
LX-10	CO	0.2	0.01	35 (1 hour)	35 (1 hour)
	NO_2	2.3	1.1	0.05 (annual)	0.05 (annual)
	HF	5.2	2.5	NS	0.006 (3 hour)
	CHF_3	0.03	0.02	NS	NS
	C_2HF_5	0.08	0.04	NS	NS

---

*Estimates represent a 3-1/2 minute concentration for the estimated duration of the burn. To estimate concentrations for other averaging times (1 hour, 8 hour, annual), assume one burn per hour, one burn per day, and 38 burn days per year (1818 kg/burn).

**CO 8-hour standard, 8.75 ppm.

***No standard.

TABLE XVI

AIR CONTAMINANTS FROM WASTE HIGH-EXPLOSIVE BURNING AT PANTEX ESTIMATED CONCENTRATIONS AT THE MAIN OPERATIONS AREA

High Explosive	Combustion Product	Unfavorable Case Dispersion Estimate* (ppm)	Typical Case Dispersion Estimate* (ppm)	Occupational Exposure Limits**	
				8 hour (ppm)	15 min*** (ppm)
Cyclotol	CO	0.02	0.01	50	400
	NO_2	0.2	0.1	3	5
Comp B-3	CO	0.02	0.01	50	400
	NO_2	0.2	0.1	3	5
Baratol	CO	0.1	0.05	50	400
	NO_2	3.3	1.2	3	5
	NH_3	0.1	0.03	25	35
	HCN	0.02	0.01	10[+]	NS
	BaO	1.0 mg/m^3	0.3 mg/m^3	0.5 mg/m^3	NS
PBX-9502	CO	4.0	1.4	50	400
	NO_2	0.9	0.3	3	5
	HCN	2.3	0.8	10[+]	NS
	C_2N_2	0.8	0.3	NS	NS
	HCl	0.2	0.07	5[+]	NS
	HF	0.1	0.005	3	6
LX-10	CO	0.01	0.005	50	400
	NO_2	0.2	0.1	3	5
	HF	0.4	0.1	3	6
	CHF_3	0.002	--	NS[++]	NS
	C_2HF_5	0.006	--	NS	NS

---

*Estimates represent a 3-1/2 minute concentration, the estimated duration of the burn. To estimate concentrations for 15 minutes and 8 hours, assume one burn per 15 minutes and one burn per 8 hours.

**ACGIH 1982.

***Short-term exposure limit.

[+] Ceiling value: the concentration that should not be exceeded even instantaneously.

[++] No standard.

TABLE XVII

HIGH-EXPLOSIVE TEST SHOT DETONATION PRODUCTS PEAK OFFSITE CONCENTRATIONS

Explosive	Detonation Product	Offsite Unfavorable Dispersion Case (ppm)	Offsite Typical Dispersion Case (ppm)	EPA Standard (ppm)
LX-04	CF_4	1.1×10^{-4}	8.4×10^{-5}	NS**
	F_2	2.7×10^{-7}	1.9×10^{-7}	NS
	NO	--*	--	0.05***
	Solid carbon	8.4×10^{-4}	5.9×10^{-4}	0.15+
Cyclotol	CO	4.9×10^{-7}	3.5×10^{-7}	35++
	NH_3	--	--	NS
	NO	9.0×10^{-7}	6.5×10^{-7}	0.05
	CH_4	--	--	NS
	Solid carbon	9.2×10^{-4}	6.5×10^{-4}	0.15
Comp B	CO	9.6×10^{-7}	6.6×10^{-7}	35
	NH_3	--	--	NS
	NO	1.1×10^{-6}	8.2×10^{-7}	0.05
	CH_4	--	--	NS
	Solid carbon	1.1×10^{-3}	7.8×10^{-4}	0.15

*Negligible concentration.
**No standard.
***NO_2 annual standard.
+TSP annual standard assuming all particulate is carbon.
++CO 1-hour standard, CO 8-hour standard, 8.75 ppm.

Plant, automobile traffic (USERDA 1976) and the power plants (MHSM 1982), combined with air concentrations from waste high-explosive burning, are not expected to exceed the ambient air standards.

The State of Texas has adopted the EPA National Ambient Air Quality Standards (NAAQS) for sulfur dioxide, nitrogen dioxide, total suspended particulates, ozone, hydrocarbons, carbon monoxide, and lead. In addition, the State of Texas has adopted a hydrogen fluoride standard "directed to the protection of vegetation and animal life" (Texas 1981). Based on the assumptions used in this analysis, the 3-hour HF standard of 6.0 ppb could be

TABLE XVIII

HIGH-EXPLOSIVE TEST SHOT DETONATION PRODUCTS PEAK CONCENTRATIONS

		Main Operations Area		Occupational Exposure Limits (ppm)*	
Explosive	Detonation Product	Unfavorable Dispersion Case (ppm)	Typical Dispersion Case (ppm)	8-hour	15-minute
LX-04	CF_4	3.8×10^{-5}	6.7×10^{-6}	NS**	NS
	F_2	9.5×10^{-8}	1.7×10^{-8}	1	2
	NO	--***	--	3	5
	Solid carbon	2.9×1^{-4}	5.3×10^{-5}	NS	NS
Cyclotol	CO	1.7×10^{-7}	3.1×10^{-8}	50	400
	NH_3	--	--	25	35
	NO	3.2×10^{-7}	5.8×10^{-8}	3	5
	CH_4	--	--	NS	NS
	Solid carbon	3.2×10^{-4}	5.7×10^{-5}	NS	NS
Comp B	CO	3.3×10^{-7}	5.8×10^{-8}	50	400
	NH_3	--	--	25	35
	NO	4.1×10^{-7}	7.3×10^{-8}	3	5
	CH_4	--	--	NS	NS
	Solid carbon	3.9×10^{-4}	6.9×10^{-5}	NS	NS

---

*ACGIH 1982.

**No standard.

***Negligible concentration.

exceeded from the burning of LX-10 or PBX-9502. The 3.5-minute offsite concentrations of 5.2 and 2.5 ppm (Table XV) estimated under unfavorable and typical dispersion conditions from LX-10 are equivalent to 101 and 49 ppb, respectively, over 3 hours. However, it is unlikely that LX-10 and PBX-9502 are burned in quantities large enough [91 kg (200 lb)] in a single burn to cause a violation of the HF standard.

Through 1985, the total annual quantity of high explosives burned at the Pantex Plant is expected to be reduced by 30 to 50%. However, the amount of high explosives containing fluorine burned is expected to increase. Thus, to prevent a future violation of the Texas 3-hour HF standard, the amount of high explosives containing fluorine burned at one time will be limited, or the burning ground will be moved to a location farther from the site boundary (Owens 1982).

TABLE XIX

TOXICITY INFORMATION FOR HIGH-EXPLOSIVE EMISSION PRODUCTS

Carbon monoxide (CO):	Carbon monoxide (CO) combines with hemoglobin and reduces the oxygen-carrying capacity of the blood. It is reasoned that there is no dose of CO that is not without an effect on the body. Whether that effect is physiologic or harmful depends upon the dose of CO and the state of health of the exposed individual. It has been suggested that workers with heart disease or who work at high elevations, high temperatures, or at heavy labor should have a lower exposure limit (ACGIH 1980). Carbon monoxide at low levels may initiate or enhance deleterious myocardial alterations in individuals with restricted coronary artery blood flow and decreased myocardial lactate production (USDHEW 1977). Little is known about the effects of CO on vegetation, but levels necessary to cause injury are expected to be very high (APCA 1970).
Nitrogen dioxide (NO_2):	Daily animal exposures to 1, 5, and 25 ppm showed no chronic effect after 18 months. Transient, mild and acute effects were not noticeable at the end of a week's exposure. Because of an indication of a possible lung-tumor-accelerating capacity seen in a group of lung-tumor-susceptible mice, a ceiling occupational exposure limit of 5 ppm was set. Rats continually exposed to 0.8 ppm had elevated respiratory rates but showed no real ill effects. At 2 ppm, slight lung changes were observed but life spans were normal (ACGIH 1980). USDHEW (1976A) reports that a human subject was exposed to 62 ppm for 1 hour on three separate occasions. The subject noted laryngeal irritation and an increase in respiratory rate. There were no ill effects observed following this exposure. Patients suffering chronic bronchitis when exposed to 1.5 to 5.0 ppm experienced increased airway resistance, significant decrease in arterial oxygen tension, and significant increase of end-expiratory arterial pressure at 4-5 ppm. No effects were noted below 1.5 ppm.

TABLE XIX (cont)

Nitrogen dioxide (NO_2): (cont)	Plant species vary in susceptibility to NO_2 exposure. Sensitive species may be injured by a 2-hour exposure of 2.5 to 6 ppm NO_2 but the extent of injury is dependent on other climatic conditions. Other species are extremely resistant to NO_2 and are not injured at concentrations of 1000 ppm for 1 hour. The effects of NO_2 exposure can vary, but usually range from a nonspecific chlorosis, browning or bleaching, to conditions of water-soaked lesions and tissue collapse (APCA 1970). NO_2 is of greater significance in relation to photochemical smog than as a phytotoxin in itself.
Hydrogen fluoride (HF):	Repeated human exposure at concentrations as high as 4.7 ppm were tolerated without severe effects (ACGIH 1980). Human exposure of 2.6 to 4.8 ppm for periods up to 50 days resulted in slight nose, eye, and skin irritation, but there were no signs of pulmonary irritation (Proctor 1978). Mild irritation of the respiratory tract was found in repeated daily exposures of animals to 7 ppm. Exposures of 17 ppm resulted in damage to the lungs, liver, and kidney. No quantitative correlation that relates the degree of plant injury to the atmospheric concentration has been found. However, sensitive plant species may be injured by exposures below 1.0 ppb, while other species show no effects from exposure to several times this concentration. The injury may vary from necrosis and chlorosis to foliar lesions and defoliation. Fluoride injury to vegetation commonly results from gradual accumulation of fluoride in the plant tissue over a period of time. Another result of fluoride exposure is the accumulation of fluoride in the plant, which, when ingested by livestock and other herbivores, may cause dental or skeletal fluorosis (APCA 1970, Weinstein 1977).

TABLE XIX (cont)

Hydrogen chloride (HCl):	Exposure of humans at 50-100 ppm for 1 hour was barely tolerable, 35 ppm caused irritation of the throat on short exposure, and 10 ppm was the maximum acceptable for prolonged exposure. Other authors reported 5 ppm as disagreeable and immediately irritating (ACGIH 1980, Proctor 1978). Hydrogen chloride is not considered to be of major phytotoxic concern. It will cause an acid-type necrotic lesion at concentrations of about 40 ppm for 1 hour. No chronic or growth effects have been reported for this pollutant (APCA 1970).
Ammonia (NH_3):	Ammonia levels of 100 ppm have been reported to cause irritation of the respiratory tract and conjunctiva, and 20 ppm reportedly caused complaints and discomfort in uninjured workers. It is reported that concentrations as low as 50 ppm are moderately irritating (ACGIH 1980). Ammonia injury to certain plant types was reported after a 1-hour exposure to 40 ppm and slight marginal injury after a 4-hour exposure to about 16 ppm. Levels required to produce injury were somewhat comparable to those reported for nitrogen dioxide and hydrochloric acid (APCA 1970). Ammonia in concentrations of 8 to 40 ppm caused injury to plants within a few minutes to a few hours, depending upon the concentration and length of exposure (Thornton 1940).
Barium oxide (BaO):	Dusts of barium oxide are considered to cause dermal and nasal irritation. Studies of the effects associated with various degrees of exposure were not available. The occupational exposure criteria were selected to cover all barium soluble compounds (ACGIH 1980). Information on barium toxicity to plants is scarce. One source reported that 23 mg Ba per gram of soil as $Ba(NO_3)_2$ would increase the levels of barium in bush bean leaves to 2% and in barley leaves to 1%, which resulted in decreased yields (Gough 1979).

TABLE XIX (cont)

Hydrogen cyanide (HCN):	Estimates of hydrogen cyanide (HCN) exposure that could be fatal are 270 ppm, immediately fatal; 181 ppm, fatal after 10 minutes; 135 ppm, fatal after 30 minutes; 110 to 135 ppm, fatal after 30 to 60 minutes. Workers exposed for 7 years to concentrations between 4 and 12 ppm were found to suffer only from subjective symptoms such as headache, weakness, changes in taste and smell, and irritation to the throat (ACGIH 1980). One report indicated the human exposure to concentrations of 20 ppm or more has produced adverse effects after several hours, whereas another report indicated that an exposure of 18 to 36 ppm resulted in minimum symptoms after several hours of exposure (USDHEW 1976B). Little information is available on the phytotoxicity of HCN. It is reported to have similar effects on tomato plants and soy bean plants as other pollutants such as ammonia (NH_3), where injury was observed at 8 ppm to 40 ppm. At higher concentrations, plants exposed to NH_3 would recover when removed from the NH_3 atmosphere but the plants exposed to HCN would continue to die after removal from the HCN atmosphere (Thornton 1940).

Available human, animal, and plant toxicity information was reviewed for those emissions for which no EPA or Texas ambient air standards exist (hydrogen cyanide, ammonia, barium oxide, and hydrogen chloride) as well as for those emissions that have ambient air standards (carbon monoxide, nitrogen dioxide, and hydrogen fluoride). Basic toxicity information is provided in Table XIX.

Human exposures to NO_2, HF, and HCl (Table XV) at the nearest boundary under unfavorable meteorological conditions could result in respiratory tract irritation to exposed individuals by forming highly irritating acids upon contact with moisture in the respiratory tract (USDHEW 1977). However, because of the relatively short duration of the high-explosive burn, more severe effects would be unlikely from any of these combustion products. No vegetation injury would be expected. Carbon monoxide exposures to humans and vegetation would not be expected to result in any observable effects. Acute toxicity to humans from HCN exposure is primarily a function of concentration and exposure time rather than just a function of concentration. Human exposures to 20 ppm or more have produced adverse effects in humans only after continuous exposures exceeding 1 hour (USDHEW 1976B). Therefore, the estimated 35 ppm HCN produced from burning PBX-9502 for about 3.5 minutes would not be expected to result in adverse health effects.

The information available to evaluate the potential effects of HCN on vegetation was too limited to predict the potential effects that could result. There is some evidence that potential HCN emissions from burning PBX-9502 could produce some plant damage; however, the exposure time would not likely be of a duration to cause any effects.

Based on the estimated concentrations of pollutants resulting at the main operations area (Table XVI) from high-explosives burning, employee exposures would not exceed occupational exposure limits.

C. High-Explosive Test Shots

Estimates of peak offsite airborne concentrations of detonation products from high-explosive test shots (Table XVII) indicate that no ambient air standards are exceeded. No occupational exposure limits would be exceeded for workers at the main operations area (Table XVIII).

D. Summary

Routine operations at Pantex involving weapons production and weapons retirement result in the need for disposal of fairly large quantities of waste organic solvents and waste high explosives. A routine program for quality assurance testing of high explosives is also conducted. These evaporation, burning, and testing operations employed at Pantex have the potential for release of large quantities of air pollutants. From the evaluation of these operations, no adverse health effects would be expected in healthy individuals. No ambient air standards would be violated because of air emissions from routine operations at Pantex. Predicting the health effects, either acute or chronic, that the exposure to these various emissions might have on an individual with a pre-existing health anomaly (such as heart or lung disorder) is not possible. However, the low population density of the area surrounding Pantex limits the number of such individuals who might be exposed. Thus, the routine air emissions from Pantex operations are not considered to be a hazard, either to the public or to employees at Pantex.

VI. RECOMMENDATIONS

Many uncertainties were encountered in the estimation of emissions from the burning of high explosives. These included:

no emission data for the burning of Cyclotol, Baratol, and LX-10;
incomplete analytical results for available experimental test data (not all combustion products were accounted for in each test); and
no emission data for the burning of Baratol and Boracitol with railroad ties.

Because of these uncertainties, emissions from high explosives may have been under- or overestimated in this study. In addition, some emissions were not considered. In particular, the combustion products from burning railroad ties with Baratol and Boracitol may result in a variety of potentially toxic or carcinogenic combustion products because of the presence of preservatives such as creosote in the ties. It was not possible to estimate the potential emissions.

Additional, more encompassing, experimental tests (similar to the AEC studies) are recommended to provide the emissions data needed to predict more accurately the impact of high-explosives burning.

ACKNOWLEDGMENTS

The authors would like to thank Bill Laseter, Tom Koger, Vicky Cornelius, and Walt Huddleston of Mason and Hanger, and Tom Larson of Los Alamos for their assistance in supplying data for this report. We also appreciate the technical advice provided by Don Rose and Roger Ferenbaugh of Los Alamos.

REFERENCES

ACGIH 1980: American Conference of Governmental Industrial Hygienists, Documentation of the Threshold Limit Values (4th ed., ACGIH Inc., 1980) pp. 16, 35, 72-73, 222-224, 305-306.

ACGIH 1982: American Conference of Governmental Industrial Hygienists, "Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1981," Cincinnati (1982).

APCA 1970: Air Pollution Control Association, "Recognition of Air Pollution Injury to Vegetation," Pittsburgh, Pennsylvania (1970).

Buhl 1982: T. Buhl, J. Dewart, T. Gunderson, D. Talley, J. Wenzel, R. Romero, J. Salazar, and D. Van Etten, "Supplementary Documentation for an Environmental Impact Statement Regarding the Pantex Plant: Radiation Monitoring and Radiological Assessment of Routine Releases," Los Alamos National Laboratory report LA-9445-PNTX-C (1982).

Church 1969: H. W. Church, "Cloud Rise from High Explosive Detonations," Sandia Laboratories report SC-RR-68-903 (May 1969).

Dobratz 1981: B. M. Dobratz (Ed.), "LLNL Explosives Handbook," Lawrence Livermore Laboratory report UCRL-52997 (March 1981).

Doolittle 1954: A. K. Doolittle, The Technology of Solvents and Plasticizers (John Wiley & Sons, New York, 1954), pp. 24-80, 354-356, 380-417.

Gardner 1940: G. S. Gardner, "Evaporative Index," Ind. Eng. Chem. 32, 226-232 (1940).

Gough 1979: L. P. Gough, H. T. Shacklette, and A. A. Case, Element Concentrations Toxic to Plants, Animals, and Man (US Government Printing Office, Washington, DC, 1979), p. 59.

Gray 1974: D. C. Gray, "Solvent Evaporation Rates," Am. J. Ind. Hyg. 35, 695-710 (1974).

Laseter 1982A: W. A. Laseter to K. H. Rea, Mason & Hanger-Silas Mason Co., Inc., letter on "Waste Solvent Disposal at Pantex," April 27, 1982.

Laseter 1982B: W. A. Laseter to K. H. Rea, Mason & Hanger-Silas Mason Co., Inc., letter on "Waste High Explosives Burning Procedures at Pantex," August 3, 1982.

Laseter 1982C: W. A. Laseter to K. H. Rea, Mason & Hanger-Silas Mason Co., Inc., letter on "Burning Ground Operations," August 26, 1982.

Mader 1963: C. L. Mader, "Detonation Properties of Condensed Explosives Computed Using the Becker-Kistiakowsky-Wilson Equation of State," Los Alamos Scientific Laboratory report LA-2900 (July 1963).

Mader 1982A: C. L. Mader to J. M. Dewart, Los Alamos National Laboratory, letter on "Detonation Products of Cyclotol and LX-17," April 7, 1982.

Mader 1982B: C. L. Mader to J. M. Dewart, Los Alamos National Laboratory, letter on "Detonation Products of LX-04," July 7, 1982.

Mellan 1950: I. Mellan, Industrial Solvents (Reinhold Publishing Corp., New York, 1950), pp. 46-89.

MHSM 1971A: J. Wichmann, F. I. Honea, W. A. Bullerdick, and T. K. Mehrhoff, "Disposal of Waste or Excess High Explosives," Mason & Hanger-Silas Mason Co., Inc., report MHSMP-71-55 (April-August 1971).

MHSM 1971B: J. Wichmann and F. I. Honea, "Disposal of Waste or Excess High Explosives," Mason & Hanger-Silas Mason Co., Inc., report MHSMP-72-12 (September-December 1971).

MHSM 1972: F. I. Honea, J. Wichmann, and T. K. Mehrhoff, "Disposal of Waste or Excess High Explosives," Mason & Hanger-Silas Mason Co., Inc., report MHSMP-72-47 (April-June 1972).

MHSM 1973: F. I. Honea, J. L. Barnard, W. A. Bullerdick, and T. K. Mehrhoff, "Disposal of Waste or Excess High Explosives," Mason & Hanger-Silas Mason Co., Inc., report MHSMP-73-11 (January-March 1973).

MHSM 1982: W. A. Laseter, "Environmental Monitoring Report for Pantex Plant Covering 1981," Mason & Hanger-Silas Mason Co., Inc., report MHSMP-82-14 (April 1982).

Ornellas 1982: D. L. Ornellas to J. M. Dewart, Lawrence Livermore National Laboratory, letter on "Products of Detonation and Burning of Explosives in Air" (May 6, 1982).

Owens 1982: J. W. Owens to A. K. Stoker, Department of Energy-Amarillo Area Office, letter on "Limitations on the Burning of Fluorine-Containing High Explosives," October 7, 1982.

Perry 1956: J. H. Perry (Ed.), Chemical Engineer's Handbook (McGraw-Hill Book Co. Inc., New York, 1956), pp. 545.

Proctor 1978: N. H. Proctor and J. P. Hughes, Chemical Hazards of the Workplace (J. B. Lippincott Co., Philadelphia, 1978), pp. 286, 290.

Scheflan 1953: L. Scheflan and M. B. Jacobs, The Handbook of Solvents (Krieger Publishing Co., New York, 1953), pp. 39-46.

Slade 1968: D. H. Slade (Ed.), "Meteorology and Atomic Energy," USAEC report TID-24190 (July 1968).

Texas 1981: Texas Air Control Board, "Texas Regulation III: Control of Air Pollution from Toxic Materials," April 30, 1981.

Thornton 1940: N. C. Thornton and C. Sutterstrom, "Toxicity of Ammonia, Chlorine, Hydrogen Cyanide, Hydrogen Sulfide, and Sulfur Dioxide Gases," Boyce Thompson Institute for Plant Research, Inc., Vol. II, pp. 352 (1940).

Turner 1970: D. B. Turner, "Workbook of Atmospheric Dispersion Estimates," USEPA report AP-26 (1970).

USDHEW 1976A: Department of Health, Education, and Welfare, "Criteria for a Recommended Standard, Occupational Exposure to Oxides of Nitrogen (Nitrogen Dioxide and Nitric Oxide)," Washington, DC, pp. 29, 39 (March 1976).

USDHEW 1976B: Department of Health, Education, and Welfare, "Criteria for a Recommended Standard Occupational Exposure to Hydrogen Cyanide and Cyanide Salts," (Washington, DC, October 1976), pp. 86-88.

USDHEW 1977: Department of Health, Education, and Welfare, "Occupational Diseases, A Guide to Their Recognition," (Washington, DC, June 1977), pp. 203-205, 418-419.

USERDA 1976: United States Energy Research and Development Administration, "Environmental Assessment, Pantex Plant, Amarillo, Texas," (Washington, DC, June 1976).

Weinstein 1977: L. H. Weinstein, "Fluoride and Plant Life," J. Occup. Med. <u>19</u>, No. 1, 49-78 (January 1977).

Printed in the United States of America
Available from
National Technical Information Service
US Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Microfiche (A01)

Page Range	NTIS Price Code	Page Range	NTIS Price Code	Page Range	NTIS Price Code	Page Range	NTIS Price Code
001-025	A02	151-175	A08	301-325	A14	451-475	A20
026-050	A03	176-200	A09	326-350	A15	476-500	A21
051-075	A04	201-225	A10	351-375	A16	501-525	A22
076-100	A05	226-250	A11	376-400	A17	526-550	A23
101-125	A06	251-275	A12	401-425	A18	551-575	A24
126-150	A07	276-300	A13	426-450	A19	576-600	A25
						601-up*	A99

*Contact NTIS for a price quote.

Los Alamos