DISPOSAL OF WASTE OR EXCESS HIGH EXPLOSIVES

MASON & HANGER - SILAS MASON CO., INC.

PANTEX ERDA PLANT

DEVELOPMENT DIVISION

*PROGRESS REPORT
APRIL - JUNE 1975*

MASTER

For

*U.S. Energy Research and Development Administration
Albuquerque Operations Office
Albuquerque, New Mexico*

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Progress Report
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ABSTRACT

Evaluation of the full-scale test incinerator (closed-pit, batch-type) at the ERDA Pantex Plant continued.

Air and I-beam temperature levels during combustion were acceptable. Surface temperatures within the incinerator created by radiated heat are high, resulting in a high temperature gradient both in the I-beams and the concrete walls. The I-beams deflected elastically as much as 2.5 cm.

Venting (the release of flames above the sand filter bed) was observed only for burn rates in excess of 36 kg/sec with 5.1 cm of sand.

With the aid of the blowers the I-beams were cooled to within 10 degrees of ambient two hours after the burn.

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I. INTRODUCTION

The present research and development effort for the disposal of high explosives (HE) is being conducted for ERDA/ALO by the Mason & Hanger - Silas Mason Co., Inc. The project began January 1971. The objectives of this effort have been: (1) to assess the magnitude of the problem which will exist at ERDA facilities in meeting the new environmental regulations, (2) to determine methods for disposal and (3) to select the best methods and develop pilot-scale processes. This effort has been conducted at the Burlington and Pantex ERDA Plants.

Previous progress reports(1,2) have summarized the quantities and types of waste HE generated at ERDA facilities. Disposal methods—including open burning, detonation, incineration, deep-well injection, ocean dumping, biochemical decomposition and chemical recovery—were surveyed(2). Detonation and combustion products of HE were also measured and results have been presented in previous reports(2,3,4,5,6,7,8). These investigations indicated low concentration levels of primary air pollutants.

Further progress in developing new disposal methods and measuring air pollutants from burning HE have been reported in nine progress reports (3,4,5,6,7,8,9,10,11). After reviewing all methods, incineration has been selected as the best presently known method of disposal and biodegradation was selected as the most feasible long-range recycle method. Development is continuing at Pantex on a closed-pit, batch-type incinerator. A final report has been issued on the Burlington investigation of a rotary incinerator(15).

II. CLOSED-PIT, BATCH-TYPE, FULL-SCALE TEST INCINERATOR

The full-scale test (FST) facility, Fig. 1, was completed in July 1974. The facility is, in essence, an enclosure in which HE can be burned. The present closed-pit incinerator concept is shown in Fig. 2. The facility is located in a remote area (Zone 5) at the Pantex Plant and uses Firing Site No. 21 as the remote control point.

The purpose of the facility is to provide sufficient data for the design of a large incinerator complex to be built at Pantex. This incinerator complex must be capable of processing as much as 250,000 kg (1/2-million lbs) of HE and HE-contaminated material per year. The waste material will consist of a variety of sizes, shapes and types of explosives.

The closed-pit incinerator developmental program has been divided into four phases. The definition of each phase and the respective time schedule is shown in Fig. 3. Most of the important design criteria for the incinerator complex will be determined by the end of Phase II. It can be seen from Fig. 3 that the program is in the later part of Phase II and it is this portion of the effort discussed in this report.

Fig. 1. Full-Scale Test Facility

Closed-Pit, Batch-Type Incinerator Concept

Fig. 2

FY 75				FY 76			
Quarters				Quarters			
1st	2nd	3rd	4th	1st	2nd	3rd	4th
I							
II							
III							
IV							

PHASE I Determine feasibility of burning a large quantity of explosive in a closed pit-incinerator.

PHASE II Establish basic design information for the incinerator structure, maximum number of burns per day, and limitation of burn conditions.

PHASE III Define pollution conditions and establish abatement requirements.

PHASE IV Develop burning procedures and safety requirements for the incinerator complex.

Fig. 3. Planned Development Schedule for the Closed-Pit, Batch-Type Incinerator Project

Phase II is the study of temperature and pressure effects caused by large mass flow-rates developed during burning. The temperature and pressure will also depend on the thickness of sand used in the overhead filter. Phase II is a systematic variation of both mass flow-rate of HE gases and thickness of sand. The important design criteria to be realized from Phase II are air temperatures and pressures, overhead I-beam temperatures, air flow requirements, flame containment, wall temperature and possible I-beam deflection. The data are obtained using thermocouples, temperature sensitive pellets(12) and pressure transducers (Validyne Engineering Corp., Model No. DP15TL). The location of the thermocouples is shown in Fig. 4. Flame containment is evaluated from 16 mm film records. Gas sampling and particulate sampling will be added to the list of diagnostics later in Phase II.

Gas generation rates vary widely for the variety of explosive waste anticipated for the disposal program. The effects of this variation will become apparent as Phase II progresses in that burn times will differ markedly between burns that consume the same total HE weight but contain pieces of different shapes and sizes. Burn rates also depend on the moisture content of the HE.

Gas generation rates, to be varied in Phase II, may be categorized as follows: large billet type pieces exhibiting a low exposed surface-area, e.g. 25 kg hemispheres; high-surface-area machining waste with varying moisture content; and a medium-area waste such as pressed pieces a few centimeters in size. Dry machining waste will generate the highest mass flow-rate whereas damp machining waste will produce the lowest rate. The large billets and small pieces develop intermediate flow rates.

A. PHASE II: PARTIAL RESULTS

The last quarterly report(16) gave the results for the first part of Phase II (results for Burn Nos. 9 - 14). This report gives additional results (results for Burn Nos. 15 - 23) and the next quarterly report will present the complete data for Phase II. The results for Burn Nos. 9 - 20 are for the case with 5.1 cm of sand as a porous-flow filter atop the incinerator. Tables I and II list these results (temperatures, pressures, etc.) and preliminary results for the case of a 10.2 cm thickness of sand.

As already mentioned the burn rate can be varied using HE with different exposed surface area and/or moisture content. This is demonstrated by examining the burn times in Table II. However, Burn Nos. 16 and 19 exhibit a factor of almost 7 in the burn time for the same amount of dry machining waste. For Burn No. 19, machined flakes of LX-04 were used and for Burn No. 16, machined powder of PBX 9404 was used. Flakes of LX-04 burn much faster than PBX 9404 machining waste (powder) and considerable variation of results between the burns is evident.

Thermocouple Legend:

- Location of I-Beam Deflection Measurement
- A1-A6 - Air Thermocouples (~ 20 cm below ceiling)
- ⊗ I1-I2 - I-Beam Thermocouples
- × Floor Thermocouples
- △ W1, W2 --- Wall Thermocouples (1/2, 1 cm deep, respectively)

Fig. 4. Instrumentation Layout

Table I. Results for Burn Nos. 9 - 23

Burn No.	Greatest Pellet Temperature (K)		Temperature from Thermocouples (K)							
	I-Beam	Air	Air						I-Beam	
			A1	A2	A3	A4	A5	A6	I-1	I-2
9	<477	590	680	720	620	720	780	600	390	370
10	<477	700	900	880	820	950	850	800	Lost	Lost
11	<477 >477, <590	810		1050	990	1180	1070	920	560	560
12	None	None	1220	1080	960	1230	1210	980	410	370
13	↓	↓	1140	1110	1000	1200	1080	910	660	590
14			← L O S T →							
15			980	1250	1040	1250	1230	1110	350	350
16			1120	1270	1380	1200	1270	1230	540	540
17			1030	980	920	1150	1140	840	-	-
18			1160	1100	970	1210	1080	1000	710	680
19			1350	-	1510	1370	-	1280	520	Lost
20			1470	-	1080	1430	-	1270	740	630
21			780	760	690	770	-	720	480	460
22			1280	-	930	1130	-	950	Lost	610
23			1250	-	1110	1400	-	1140	580	630

Table II. Results for Burn Nos. 9 - 23

Burn No.	Amount of HE (kg)	Thickness of Gravel (cm)	Pressure (Pa)		Burn Time (s)	Flame Propagation Time (s)	Avg. Burn Rate (kg/s)	Air Flow Setting	Remarks
			Blower	Max					
9	182	5.1	70	130	200	36	0.9	4	Billet Type Pieces
10	363		70	110	180	45	2.0		Billet Type Pieces
11	454		70	100	160	55	2.8		Billet Type Pieces
12	227		70	980	20	13	11.0		Dry Machining Waste
13	454		L O S T		130	59	3.6		Billet Type Pieces
14	240		← L O S T →						Dry Machining Waste
15	232		70	1050	16	20	14.0		Dry Machining Waste
16	459		70	1050	90	13	5.0		Dry Machining Waste
17	136		70	840	9	14	16.0		Dry Machining Waste
18	454		70	100	134	40	3.4		Billet Type Pieces
19	465		70	1960	13	13	36.0		Dry Machining Waste
20	455		70	220	26	36	18.0		Wet Machining Waste
21	272	10.2	120	240	180	190	1.5		Billet Type Pieces
22	454		120	230	150	90	3.0		Billet Type Pieces
23	463		120	570	100	30	4.7		Molding Granules

Burn No. 20 was the first attempt to produce a long burn (> few minutes) by burning wet machining waste. Samples from the burning ground were taken to estimate the effect of moisture on burn rate for machining waste. It was determined that machining waste (LX-04) with moisture content less than 11% by weight burns unhindered, whereas a moisture content greater than 37% will not support combustion. Water was added to dry machining waste for Burn No. 20. The moisture content was $17 \pm 8\%$ and the burn time was increased only a factor of 2. A burn time of 10 - 20 minutes may require a moisture content of 25%.

Molding granules (Burn No. 23) are large-grain molding powder of LX-04 which are produced in the formulation process. The long burn time (compared to Burn No. 19) may be due to the fact that the exposed surface of the granules is coated with the inert binder, unlike the surface condition after the machining process in which explosive is exposed.

The billet-type pieces mentioned in Tables I and II are approximately 23 kg hemispheres. Fig. 5 is a graph of the air temperature in the incinerator (A1 - A6) for high burn rates (dry machining waste) and for medium burn rates (billet-type pieces) as a function of the amount of HE present. It is seen that the higher the burn rate the higher the air temperature for a given amount of HE and the greater the amount of HE the higher the temperature.

Fig. 6 shows the temperature of an I-beam (I-1) as a function of the amount of HE burned for two different burn rates. The larger the amount of HE that is burned the higher the temperature of the I-beam and for a given amount of HE the slower the burn the higher the temperature. For these two burn conditions the I-beams stay well below the maximum allowable temperature even at full incinerator capacity (454 kg). However, Fig. 6 suggests the existence of possible I-beam damage (temperature greater than 800 K) due to a relatively slow burn not yet performed. It is because of this possibility that the incinerator should be subjected to slower burn conditions.

The air temperatures in Table I indicate the existence of fairly uniform temperatures throughout the incinerator. This result reduces the need for using the temperature sensitive pellets. Their main purpose was to detect severe hot spots on the I-beams. The I-beam thermocouples (I-1, I-2) indicate an average temperature and provide data on the rate of cooling of the I-beam.

In Table II the following definitions have been used: the time it takes for the air temperature to reach a maximum is called the flame propagation time. The burn time is defined as the time from which the air reaches one-half maximum to the time the air begins to cool and the "air flow setting No. 4" is the louvre position on the blower duct for which both air velocity and air flow are maximum (85 mph and 10,000 CFM per blower, respectively).

Fig. 5: Air Temperature in the Incinerator as a Function of Total HE Weight

Fig. 6. I-Beam Temperature (I-1) versus amount of HE Burned for two different burn rates

The blower pressure-rise and the maximum pressure-rise during the burn are also listed in Table II. Venting pressure (14) for 5.1 cm of sand is approximately 980 Pa. The maximum pressure developed when burning at a medium rate (billet-type pieces) are much less than this value whereas burning at a faster rate (dry machining waste) invariably produces venting. However, 16 mm film records show flame leakage only for Burn No. 19 which displayed an extremely fast burn rate of 36 kg. It is hoped that 10.2 cm or 15.3 cm of sand will contain the flames for even this high burn rate.

Repeated exposure of the thermocouple signal cables to moisture and elevated temperatures resulted in increasingly erratic behavior due to induced noise on the signal cables. The incinerator was rewired to protect the cables from exposure to heat and moisture. A protective conduit, made from an asbestos substitute (Thermo-12, pipe insulation, Johns-Manville), was constructed as shown in Fig. 7.

The layout of the conduit on top of the sand filter is shown in Fig. 8. Fig. 9 shows thermocouples A4, A5 and A6 protruding into the incinerator. Duxseal was used to seal the conduit and to protect all signal cables protruding from the conduit. Fig. 10 shows the location of the reference junctions for the thermocouples. Fig. 11 shows the individual pre-amplifiers for each thermocouple circuit. It is anticipated that this arrangement will provide the capability of conducting a long, uninterrupted series of burns in the future.

B. WALL TEMPERATURES

The two burn pads within the incinerator are near two of the four concrete walls, as shown in Fig. 12. The temperature of the south wall was measured at two depths (W1 - 5 mm deep and W2 - 10 mm deep) by imbedding two thermocouples into the wall with high temperature mortar (Fire bond HS-879, Kaiser Refractory, Oakland, California). These two thermocouple locations are shown in Fig. 12.

In Table III measured temperatures at locations W1 and W2 are listed for six burns. The length of time to reach the maximum temperature, as well as the burn time are given for comparison. The time, t_{max} , is measured from the point the air begins to heat. Surface temperatures can be expected to be in excess of 725 K (850 F) and as in the case of the I-beams the walls get hotter for the more moderate burn rate than for faster rates of burn. Again this indicates a need to investigate conditions within the incinerator with a relatively slow burn rate. The data of Table III demonstrate the severe conditions the incinerator walls encounter. They must be able to dissipate large amounts of energy and withstand high surface temperatures and temperature shock.

Fig. 7. Section of Insulated Conduit for Thermocouple Signal Cables

Fig. 8. Protective Conduit Layout on Top of the Sand-Filter

Fig. 9. Location of Thermocouple Probes, A4, A5 and A6 Extending into the Incinerator

Fig. 10. Central Location of All Thermocouple
Reference Junctions (0 C)

Fig. 11. Individual Pre-Amplifiers for Each Thermocouple Circuit

Fig. 12. Location of the Thermocouples Imbedded in the South Wall

Table III. Concrete Wall Temperatures

Burn No.	Amount of HE (kg)	Burn Time	(W1 (5 mm Depth))		W2 (10 mm Depth)	
			Maximum Temperature (K)	tMAX	Maximum Temperature (K)	tMAX
15	232	16	544	42	388	230
16	459	90	669	88	475	220
17	136	9	467	52	352	180
18	454	134	724	180	507	350
19	465	13	551	36	374	190
20	455	26	687	67	422	220

C. I-BEAM COOLING CURVE

Thermocouples (I-1, I-2) were mounted on two I-beams on the center line of the incinerator (Fig. 4) to monitor the temperature of the I-beam over a long period of time. A preliminary cooling curve was given in the last quarterly progress report(16).

In Fig. 13 the I-beam temperature data are plotted on a semilog scale to show the existence of two exponential decay rates. Burning procedures require the blowers to be operating for 30 minutes after the air temperature begins to cool in order to provide ample oxygen for complete combustion and to assist in cooling the incinerator for re-entry. Fig. 13 shows the effect of the blowers in cooling the I-beams. The time required to reduce the temperature of the I-beam to within 10 K of ambient with the blowers on is only two hours, whereas it would take 22 hours with the blowers off. Fig. 14 is a linear plot of the data with the two exponential curves superimposed.

D. I-BEAM DEFLECTION

Fig. 15 shows the south wall of the incinerator after Burn No. 14 (240 kg of dry machining waste). The carbon deposits on the wall were created by airborne burning of machining waste. Considerable turbulence is created during a rapid burn.

Fig. 15 also shows that the concrete wall is flaking away underneath each I-beam. The I-beams are not attached to the wall but are allowed to slide on top of the wall as the beams expand and contract. If the I-beams were also sagging there would be an additional stress on the top corner of the wall where the I-beams slide. Fig. 15 suggests that the I-beams may be sagging.

Fig. 16 is a cut-away view of the bar used in measuring the sag of an I-beam. The bar is placed between the I-beam and the concrete floor (15 cm of dirt covers the concrete floor). The set screw is tightened and a scribe mark is made where the bar and pipe meet. The sagging I-beam compresses the bar-pipe combination. A new scribe mark is made and the set screw is released. The distance between the two scribe marks is the measurement of sag. The bar and pipe are insulated and a thermocouple monitors the temperature of the pipe for the purpose of correcting for the expansion of the bar and pipe.

Fig. 4 shows location of the I-beam deflection measurement. Fig. 17 shows the bar before the burn and Fig. 18 shows the bar after the burn.

The aluminum sheet melts and the insulation protects the bar from excessive heat. The temperature of the bar was less than 370 K (200 F).

Fig. 13. I-Beam Temperature (I-2) versus Time
Ambient Temperature, $T_A = 302$ K

Fig. 14: I-Beam Temperature versus Time

Fig. 15. South Wall - Flaking of Concrete Underneath Each I-Beam

Fig. 16. Cut-Away View of Bar for I-Beam Deflection Measurement

Fig. 17. I-Beam Deflection-Bar In Place Before the Burn

Fig. 18. I-Beam Deflection-Bar After the Burn

The maximum deflection observed for Burn No. 17 was 35 mm (1.4 inches). Static measurements between burns indicated that this sag was elastic. The origin of the sag is not due to the elevated temperature of the I-beams (I-1, I-2) since the strength of the beams at these temperatures is adequate(17). It is postulated that the sag is produced by a temperature differential, ΔT , created between the bottom and the top of the I-beam. Further static and dynamic measurements will be made to monitor for possible inelastic effects.

E. RADIATED HEAT CONSIDERATIONS

Radiated heat can give rise to an almost instantaneous deposition of heat compared with convection and conduction which are relatively slow processes. It has already been mentioned that a great deal of heat is deposited very rapidly on the concrete walls. It has also been suggested that a significant ΔT exists from the bottom to the top of the I-Beams. This ΔT would not normally be caused by air temperature alone since the air is flowing along the beams. In addition the temperatures of the hot gases have been estimated at ~ 1900 K and carbon dioxide and water vapor at these temperatures are good radiators(18).

To measure the radiated energy relative to that transported by convection two thermocouples were used: one exposed to both radiation and the hot gases and the other shielded from radiation but having ample exposure to the hot gases. Fig. 19 compares the two thermocouple readings. Radiation accounts for about one-third the energy developed. This heat will be deposited rapidly to the surroundings and the use of shields can be very effective.

Since the mathematical model for air temperature and pressure(19) does not consider radiation as a process of transporting heat, the results calculated from the model need correcting. Reference 18 contains a method for calculating the radiation from a hot volume of gases containing water vapor and carbon dioxide. This method can be used to calculate the energy radiated per second and then this energy can be subtracted from the total available energy per second. In this way a "corrected" air temperature can be calculated using the model presented in Reference 19. Table IV presents the results of the calculational model with radiation correction. The degree of agreement with measured values is not of great concern because of the many uncertainties involved in making the correction (see below). Regardless of the assumptions made the correction is large and, therefore, any calculational model for the prediction of temperatures and pressures must include radiation as a means of energy transport.

The assumptions used in the radiation calculation of Reference 18 are:

Fig. 19. Shielded and Unshielded Thermocouple Readings for Burn No. 19

Table IV. Radiation Correction to
Calculated Air Temperature

Burn No.	Average Air Temperature Rise (K)		
	Measured	Calculated	
		Without Correction	With Correction
9	370	870	480
10	520	1920	960
11	670	2680	790
13	700	3470	1200

1. Partial pressure of H_2O and CO_2 is one atmosphere.
2. An estimation of the volume of hot gases in the vicinity of each burn pad is necessary.
3. Only CO_2 and H_2O radiate.
4. The emissivity of concrete is 0.9.
5. The incinerator has six sides of concrete.
6. The temperature of the burning gases is 1900 K (3000 F).
7. The value for the burn rate was calculated from the burn data.

Any one or all of the above assumptions may contain considerable error which will effect the corrected temperatures. However, these assumptions form a reasonable set and indicate that a large correction to the "nonradiation model" is necessary. The experimental values in Fig. 19 are also in agreement with this conclusion.

III. SUMMARY AND FUTURE WORK

"The disposal of waste or excess high explosive" project is continuing with the main effort concentrated on obtaining data for the design of a closed-pit incinerator. The major portion of this design data will be obtained in Phase II (see page 5), and Phase II is nearing completion. A full-scale test incinerator, located at the ERDA Pantex Plant, is being evaluated for a variety of burn-conditions.

The air temperature within the incinerator does not, as yet, appear to be structurally damaging due to the short burn time (less than several minutes) and to its relatively low value (approximately 1200 K for 454 kg of HE). The internal pressure does not produce serious venting, except for burn rates greater than 36 kg/s using 5.1 cm of sand as the overhead filter. The I-beam temperature remains low enough, so far, to maintain sufficient strength (less than 810 K).

Heat radiation from the fire-ball within the incinerator has been observed and measured. This energy, about one third the total, is transmitted almost instantaneously to the walls, etc., and has produced very high concrete surface temperatures, i.e. above 700 K (800 F). A temperature gradient is also being produced from the bottom to the top of the I-Beams causing an elastic sag of more than 25 mm. This behavior will be monitored to detect any inelastic effects.

The I-beams can be cooled to within 10 K of ambient in two hours by leaving the blowers on. With the blowers off the required time is 22 hours.

This information has been gathered mainly for the case with 5.1 cm of sand as the overhead filter. Some data have been obtained for the case of 10.2 cm of sand. This case will be completed along with that of 15.3 cm of sand, and this will provide the major portion of the design data for the proposed incinerator complex. Pollution and pollution abatement efforts will be evaluated during Phase III.

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