DISPOSAL OF WASTE OR EXCESS HIGH EXPLOSIVES

MASON & HANGER - SILAS MASON CO., INC.
PANTEX ERDA PLANT

DEVELOPMENT DIVISION

PROGRESS REPORT
JANUARY - MARCH 1976

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

MASTER

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ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
under
U. S. GOVERNMENT Contract DA-11-173-AMC-487(A)

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ABSTRACT

The evaluation of the closed-pit, batch-type, full scale test incinerator at the ERDA Pantex Plant is continuing. Preliminary gas sampling data are reported. For a full capacity burn (454 kg) of LX-09 or LX-04, concentrations of NO_x and CO inside the incinerator are exceptionally high. Nitrous oxide is the dominant component of NO_x . Determination and reduction of the emissions from the incinerator are discussed as future work.

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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 of 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 measured and preliminary 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. A development effort 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(12).

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

A. GENERAL DISCUSSION

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 control-point.

The purpose of the facility is to provide design data for the proposed construction of an incinerator complex 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. In the present plans, construction of the incinerator complex is scheduled to begin in December 1978.

The closed-pit incinerator developmental program consists of four phases. The definition of each phase and the respective time schedule are shown in Fig. 3.

Fig. 1. Full-Scale Test Facility

Fig. 2. Closed-Pit, Batch-Type Incinerator Concept

	FY 75				FY 76				FY 76A
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	Quarter 1st
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 was a study of temperature and pressure effects caused by large mass flow-rates developed during burning. The temperature and pressure also depend on the thickness of sand used in the overhead filter. In Phase II a systematic variation of both mass flow-rate of HE gases and thickness of sand was conducted. The important design data obtained from Phase II were air temperatures and pressures, overhead I-beam temperatures, air flow requirements, flame containment, wall temperature and I-beam deflection. The data were obtained using thermocouples, temperature sensitive pellets(13) and pressure transducers(14). The location of each thermocouple is shown in Fig. 4. Flame containment was evaluated from 16 mm film records.

The information obtained from Phase II was presented in a previous report(15). Essentially, these findings show that the closed-pit, batch-type incinerator concept is feasible and that the present design, with minor modification, can meet the requirements of the proposed HE waste disposal program at the Pantex Plant.

B. PHASE III - POLLUTION ABATEMENT STUDY (CONTINUED)

Phase III began in the second quarter of FY 1976. The primary objectives of Phase III are: (1) to determine what concentration of pollutants are produced and to what degree the production of these concentrations can be minimized, and (2) to study the effectiveness of the overhead filter in reducing the effluents (NO, NO₂, CO and particulates) produced. To accomplish these, stringent, controlled conditions must be maintained.

The last quarterly report(16) presented the study plan for Phase III in detail. Essentially, 20 burns are required to evaluate production parameters and filter effectiveness. Phase III is scheduled for completion in June 1976.

A single explosive type and size will be used in the study to establish control of burn-products and burn-rate. LX-09 granules were originally chosen as the control; however, a second HE (LX-04 granules) has been selected due to a reduced availability of LX-09.

Also contained in the last quarterly report were a detailed description of the NO_x, CO and particulate sampling systems, some CO-sampling difficulties encountered and the general procedures to be used for the data reduction. Results for particulate sampling were given showing that these emissions were below the minimum required by the state of Texas. The interaction of the gases with the sampling system was also discussed. No additional particulate emissions data have been obtained during this quarter due to high winds.

This report presents preliminary data on the gases generated within the incinerator for a full-capacity burn (454 kg). LX-09 and LX-04 are the two explosives used. (It is emphasized that Phase III began using LX-09, but at a later time LX-04 was substituted in place of LX-09.) In addition, an interpretation of the sampling data is given followed by a discussion of the sampling of gases above the filter.

Instrumentation 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)
- Gas Sampling Ports (Inside the Incinerator)

Fig. 4. Instrumentation Layout

1. Gas Generation Within the Incinerator

Fig. 5 shows typical gas-sampling data for NO_x and CO. The high levels of CO (6500 ppm max) show clearly the difficulties encountered using an analyzer with a capability of measuring concentrations less than 1000 ppm. This difficulty was overcome by diluting the incinerator gas with a known amount of fresh air prior to analysis in the CO-analyzer.

The shape of the NO_x - curve seems reasonable, for the most part, and an explanation of the strange shape of the CO-curve is attempted later in this report. Fig. 6 shows that the NO_x signal is primarily that of NO . (Neither NO_2 nor N_2O is present in any appreciable amounts).

Table I summarizes the gas data measured within the incinerator on combustion of 454 kg of LX-09 granules. The location of the sampling ports is shown in Fig. 4. The burn-time and average air temperature were measured by thermocouples also shown in Fig. 4. Averages have been calculated and are shown at the bottom of the table. The values in the table show that sampling data for NO_x are considerably more reproducible than data for CO. Figs. 7 and 8 show this in graphical form. (Values for $\overline{C\Delta t}$ were calculated(16) and are proportional to the integral under the curve.)

Gas production within the incinerator in burning LX-09 is well above EPA maximum emission levels for nitrous oxide but comparable in the case of carbon monoxide.

Table II gives the results for burning 454 kg of LX-04 granules. The conclusions are different from those for LX-09. Both NO_x and CO gas production levels inside the incinerator are well above the maximum allowable values for emission and again, the dominant oxide of nitrogen is nitrous oxide.

2. An Interpretation of the Gas-Sampling Data

Considerable skepticism was felt in relation to the carbon monoxide analysis. This was based upon the strange shape of the concentration versus time curve shown in Fig. 5 and the poor reproducibility under seemingly identical conditions (see Fig. 8). At times, for example, the first "hump" in Fig. 5 was unexplainably missing. To obtain a satisfactory explanation, burn No. 49 was carefully analyzed.

The sampling system was described in the last quarterly report(16). Nine sampling ports supply gases within the incinerator to a manifold. The manifold is then independently sampled by two sampling tubes, each supplying samples to the analyzers. The NO_x levels within the incinerator were low enough that samples from the manifold could be directly introduced into the NO_x analyzer. However, the CO-concentrations were much too high (Fig. 5) and hence dilution was necessary (as much as 50/1 for burn No. 49). Thus, the flow rate from the manifold to the CO-analyzer was low (20-30 cc/min in comparison to 1200 cc/min for the NO_x sampling line). This produced a delay time in the sampling system of approximately 10 sec for the NO_x system and 100 sec for the CO-system.

Fig. 5. Gas - Sampling Data within the Incinerator as a Function of Time for 454 kg of LX-09 Granules (Burn No. 49)

Fig. 6. NO_x and NO-Concentration as a Function of Time for 454 kg of LX-09 Granules

Table I. Gas Production Within the Incinerator (454 kg LX-09 Granules)

Burn No.	Burn Time (min)	Air Temp. (K)	NO _x Analysis				NO Analysis				CO Analysis			
			Max. (ppm)	Integral (ppm-min)	Wt. % (g/g)	24 Hrs Average ^a (ppm)	Max. (ppm)	Integral (ppm-min)	Wt. % (g/g)	24 Hrs Average ^a (ppm)	Max. (ppm)	Integral (ppm-min)	Wt. % (g/g)	8 Hrs Average ^b (ppm)
49	1.41	1280	460	1130	0.19	0.79					6500	13200	1.9	28
50	1.21	1300	475	1120	0.19	0.78					2600	4700	0.7	10
51	1.47	1290	428	1070	0.18	0.74					4500	7800	1.1	16
52	1.11	1310	476	1190	0.20	0.83					3900	6860	1.0	14
53	1.19	1300					442	1110	0.15	0.77	6500	8970	1.3	19
54	1.30	1300					535	1180	0.16	0.82	7800	12900	1.8	27
55	1.19	1320	485	1080	0.18	0.75					7100	12400	1.8	26
56	-	-	605	1240	0.21	0.86					10400	16100	2.3	33
57	-	-	----- L O S T -----								----- L O S T -----			
58	-	-	510	1120	0.19	0.78					15600	24300	3.5	51
59	-	-	400	930	0.16	0.65					22400	41500	6.0	87
Avg.	1.27	1300	480	1110	0.19	0.77	488	1140	0.16	0.80	8730	14800	2.1	31
% Dev.	±16	±1.5	±26	±16	±15	±16	±10	±7	±3	±3	+160 - 70	+180 - 70	+180 - 70	+180 - 70

^aEPA maximum allowable value is 0.05 ppm(16).^bEPA maximum allowable value is 35 ppm(16).

Fig. 7. NO_x-Concentration as a Function of Time
for Three "Identical" Burns

Fig. 8. CO-Concentration as a Function of Time for Three "Identical" Burns

Table II. Gas Production Within the Incinerator (454 kg LX-04 Granules)

Burn No.	Burn Time (min)	Air Temp. (K)	NO _x Analysis				NO Analysis				CO Analysis			
			Max. (ppm)	Integral (ppm-min)	Wt. % (g/g)	24 Hrs Average ^a (ppm)	Max. (ppm)	Integral (ppm-min)	Wt. % (g/g)	24 Hrs Average ^a (ppm)	Max. (ppm)	Integral (ppm-min)	Wt. % (g/g)	8 Hrs Average ^b (ppm)
60	1.3	1290	230	516	0.09	0.36					28600	40300	5.9	84
61	1.3	1310	185	410	0.07	0.29					32200	61400	8.8	130
62	1.4	1280	330	1000	0.17	0.70					12000	20900	3.0	44
63	1.4	1300					260	635	0.09	0.44	30000	68500	9.8	140
64	1.2	1330					230	520	0.07	0.36	16000	28200	4.0	59
65	1.5	1280					270	609	0.08	0.42	34800	65300	9.4	140
Avg.	1.4	1300	250	640	0.11	0.45	250	590	0.08	0.41	25500	47400	6.8	100
% Dev.	±10	±2	±30	+60 -40	+50 -20	+60 -40	±9	±12	±12	±11	+40 -50	+40 -60	+40 -60	+40 -60

^aEPA maximum allowable value is 0.05 ppm(16)

^bEPA maximum allowable value is 35 ppm(16)

Fig. 9 shows the NO_x concentration plotted on the same time scale as the average air temperature within the incinerator. An initial analysis of the two curves indicates that there is approximately a 30 second delay for the NO_x sampling system rather than 10 sec as calculated from the volume and the flow rate. To reconcile this, it is concluded that NO_x is not produced at the beginning of combustion. NO_x gases begin to form only after the air temperature increases to a threshold value. NO_x production then follows the average air temperature curve. The slightly larger width of the NO_x - curve is due to the finite time necessary to flush the incinerator with outside air.

Carbon monoxide has an autoignition temperature of 924 K. However, the average air temperature (as measured by a thermocouple) must be considerably above 924 K since thermocouples measure both convection and radiation temperatures. As has been previously determined(17), radiation comprises approximately one-third of the heat measured within the incinerator. Thus, the autoignition threshold will occur for average air temperatures in the neighborhood of 1200 K.

Fig. 10 is a plot of average air temperature and CO-concentration as a function of time. This graph shows that there is a small period of time at which the air temperature is above 1200 F. During this time the CO-signal can be expected to decrease ($\text{CO} \rightarrow \text{CO}_2$ via burning). There are time delays built into the sampling system and a careful analysis is necessary.

As has already been mentioned, the time delay in the CO-sampling system for a flow of 20 to 30 cc/min is approximately 100 sec. However, at the start of the burn the flame front spreads very rapidly producing a pressure spike. Thus, early in the burn the delay time is approximately 50 sec. (This was determined from the 16 mm film records of the flow meters in the CO-sampling system.)

Sketched in Fig. 10 (dash-line) is a "conceptual production" curve for CO if autoignition were not occurring. As a result of a decrease in the delay time, due to high pressure in the incinerator, CO begins to register at about 50 sec after combustion begins. The air temperature increases within the incinerator to the point where CO spontaneously converts to CO_2 reducing the CO-concentration. The pressure falls and the burn continues. However, the delay through the sampling system has increased, shifting the CO-concentration data to later times. Had there been no autoignition the production curve (dash-line of Fig. 10) would have reached a maximum 100 sec after the average air temperature was reached. As the burn progresses, the average air temperature soon drops below threshold for autoignition allowing CO-concentration levels to increase again. The CO concentration continues to increase until the HE is consumed and the incinerator is flushed with fresh outside air. Also, large variations in the carbon monoxide data (Tables I and II) can be expected, in that air flow patterns and temperature distributions within the incinerator cannot be duplicated exactly, and therefore the amount of CO consumed by autoignition will vary.

Fig. 9. Average Air Temperature and NO_x -Concentration as a Function of Time for Burn No. 49

Fig. 10. Air Temperature and CO-Concentration as a Function of Time For Burn No. 49

The investigation of the gas-production-parameters will constitute a large portion of Phase III and the above interpretation of the data will play an important role.

3. Gas-Sampling Above the Filter

A slight change of plans for Phase III has been instigated. Prior to studying gas-production-parameters as originally planned, a preliminary gas analysis will be conducted above the sand-filter. With the data already obtained (inside the incinerator), an estimate of the filter effectiveness can be obtained and would prove useful while studying the production parameters. If there are trade-offs among the production parameters, then these can be made in view of the effectiveness of the filter.

Work has begun to change from "inside" to "outside" sampling and measurements will begin immediately.

III. SUMMARY AND FUTURE WORK

The HE waste disposal project at the ERDA Pantex Plant has evolved over the past few years into an in-depth investigation of disposal-by-incineration. An incinerator concept (Fig. 2) and a full-scale test facility (Fig. 1) have evolved and test data have been gathered for the past two years. The data are being channeled into an "incinerator complex" design. The construction of this project is planned to begin in December, 1978.

The findings, thus far, are that this incinerator concept and the full-scale test facility can adequately form the basis of the proposed incinerator complex at Pantex, and in so doing, Pantex will comply with the requirements by the state of Texas for enclosed burning. In addition, the data indicate that particulate emissions will be within maximum allowable levels.

Initial concentration levels of NO_x and CO within the incinerator are appreciably above the maximum allowable emission levels established by the EPA. Concentration levels above the sand-filter, however, have not been measured and neither filter effectiveness nor gas-production-control have been investigated as yet.

NO_x and CO pollution emission from the incinerator (above the sand) will be measured next quarter. In addition, work will begin on filter effectiveness and gas-production-control.

IV. REFERENCES

- 1. F. I. Honea and Jane Wichmann, Disposal of Waste or Excess High Explosives, Mason & Hanger - Silas Mason Co., Inc., Report MHSMP-71-27, January - March 1971.
- 2. Jane Wichmann, F. I. Honea, W. A. Bullerdiel and T. K. Mehrhoff, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-71-55, April - August 1971.
- 3. Jane Wichmann and F. I. Honea, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-72-12, September - December 1971.
- 4. F. I. Honea, Jane Wichmann and W. A. Bullerdiel, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-72-30, January - March 1972.
- 5. F. I. Honea, Jane Wichmann and T. K. Mehrhoff, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-72-47, April - June 1972.
- 6. F. I. Honea and Jane Wichmann, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-72-73, July - September 1972.
- 7. Jane Wichmann, F. I. Honea, E. E. Leake and T. K. Mehrhoff, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-73-1, October - December 1972.
- 8. F. I. Honea, J. L. Barnard, W. A. Bullerdiel and T. K. Mehrhoff, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-73-11, January - March 1973.
- 9. F. I. Honea, W. A. Bullerdiel, Jane Wichmann and T. K. Mehrhoff, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-73-29, April - June 1973.
- 10. F. I. Honea and W. A. Bullerdiel, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-73-40, July - September 1973.
- 11. F. I. Honea and T. K. Mehrhoff, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-74-2, October - December 1973.
- 12. Disposal of Waste or Excess High Explosives, Mason & Hanger Burlington ERDA Plant Final Report MHSMP-75-14, April 1975.
- 13. R. D. Worley, Disposal of Waste or Excess High Explosives, Mason & Hanger Report MHSMP-74-39, July - September 1974.

- ✓ 14. Disposal of Waste or Excess High Explosives, Mason & Hanger Report
MHSMP-75-15, January - March 1975.
- 15. Disposal of Waste or Excess High Explosives, Mason & Hanger Report
MHSMP-75-52, July - September 1975.
- 16. Disposal of Waste or Excess High Explosives, Mason & Hanger Report,
MHSMP-76-6, October - December 1975.
- 17. Disposal of Waste or Excess High Explosives, Mason & Hanger Report,
MHSMP-75-29, April - June 1975.

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