THE INCINERATION OF ABSORBED LIQUID WASTES IN THE INEL'S WERF INCINERATOR[a] (1)

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ABSTRACT

The concept of burning absorbed flammable liquids in boxes in the WERF incinerator was evaluated as a waste treatment method. The safety and feasibility of this procedure were evaluated in a series of tests. In the testing, the effect on incinerator operations of burning various quantities of absorbed flammable liquids was measured and compared to normal operations conducted on low-level radioactive waste (LLW). The test results indicated that the proposed procedure is safe and practical for use on a wide variety of solvents with quantities as high as one liter per box. No adverse or unacceptable operating conditions resulted from burning any of the solvents tested. Incineration of the solvents in this fashion was no different than burning LLW during normal incineration.

INTRODUCTION

The purpose of the Idaho National Engineering Laboratory's (INEL) Waste Experimental Reduction Facility (WERF) is to (a) reduce the volume of the INEL's low-level beta/gamma-contaminated solid waste, and (b) develop waste processing technology. The WERF incinerator was developed for the volume reduction of low-level beta/gamma-contaminated combustible wastes. A RCRA Part B Trial Burn was recently conducted on the incinerator in support of permitting the facility to also burn hazardous and low-level radioactive mixed (i.e., radioactive waste also containing hazardous constituents) wastes. The WERF incinerator is now routinely processing INEL-generated combustible low-level waste (LLW).

The incinerator (Fig. 1) is a commercially available, dual chambered, controlled-air incinerator capable of burning 181 kg/hr of 27,900 kJ/kg (400 lb/hr of 12,000-BTU/lbm) combustible solid waste. The incinerator was designed for compatibility with pathologic and other hazardous wastes. It incorporates a batch feed system (for solids) and a secondary combustion chamber which provides a 2-second residence time at 1150°C (2100°F) (at rated capacity). The incinerator operates below atmospheric pressure to prevent the release of radioactively contaminated particles (2).

The incinerator is also equipped with a liquid incineration system. The principal objective of the liquid incineration system is to process hazardous, radioactively contaminated, nonhalogenated liquid wastes.

Some combustible liquid wastes generated at the INEL cannot be processed through the WERF liquid waste incineration system due to their small quantities or physical properties, such as solids content or viscosity. It was proposed that these wastes be burned by feeding them through the solid feed system. The batch feeding of free flammable or combustible liquids to an incinerator presents safety considerations, due to the possibility of pressurizing the incinerator chambers from rapid combustion or explosion. Simple combustion calculations indicate that the instantaneous combustion of as little as 10 mL of hexone, for example, could cause a pressure spike of 3.7 kPa (15 in.H_2O) in the WERF incinerator lower chamber. However, these phenomena can be controlled by limiting the amount of liquid feed per batch and by absorbing the liquid in solid material. Absorption into solid material limits the evaporation rate of the liquid, thereby limiting the combustion rate. Limiting the amount of liquid per batch limits the explosive potential.

A literature search on burning absorbed liquids was conducted to gain insight into determining a safe limit on liquid addition per batch charge. The search yielded no relevant information on the subject. Therefore, a test program was conducted to determine safe limits and guidelines and a safe in-box incineration procedure.

The results, conclusions, and insight gained from the in-box testing are presented in this paper, along with recommendations for other incinerator operators who may be interested in using this waste treatment method. The procedure will be used at the INEL to treat limited quantities of miscellaneous hazardous and radioactive mixed wastes and to treat wastes which already contain absorbed hazardous liquids, such as cleaning rags, liquid filters, and

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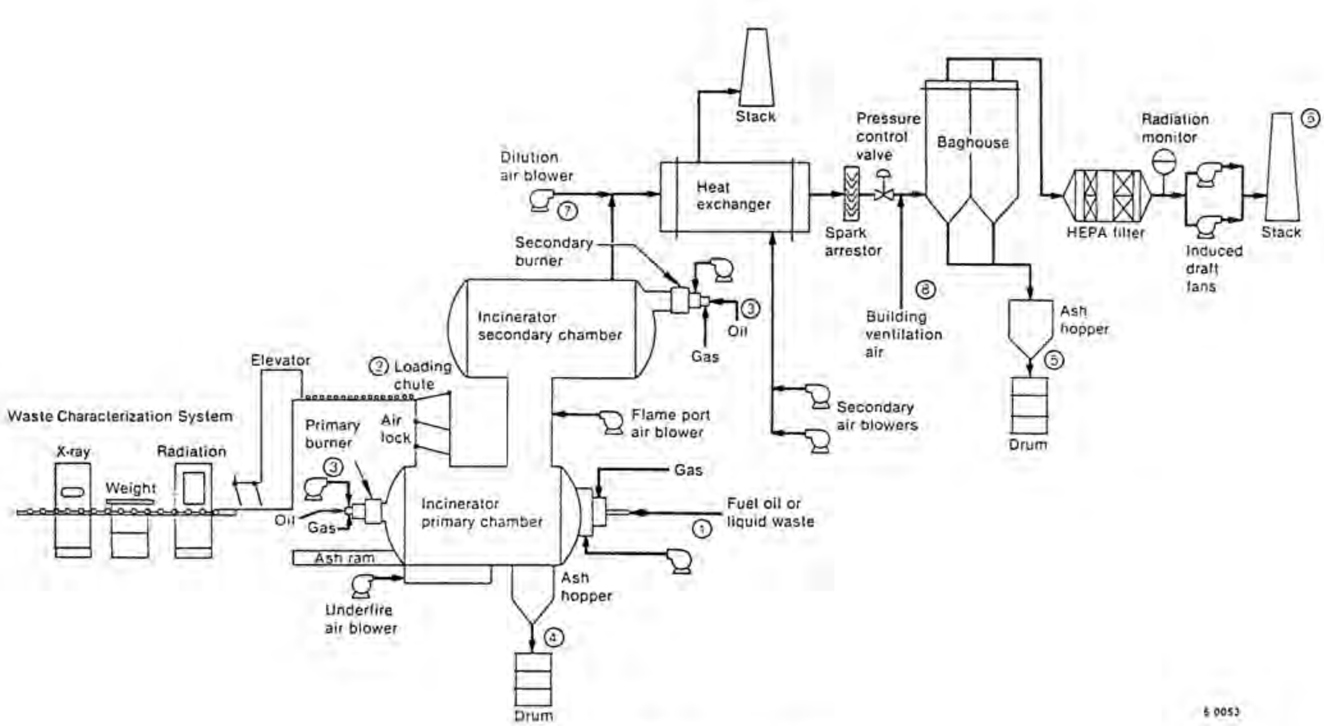


Fig. 1. WERF incinerator.

absorbents used in spill cleanup. It was also used in a RCRA Part B Trial Burn to demonstrate destruction efficiency on hazardous solid waste.

TESTING PROGRAM

In order to establish a safe operating procedure for incinerating waste in this manner, a test program was conducted. As stated earlier, the incinerator is normally operated below atmospheric pressure to control the release of contaminated particles; however, there were concerns that the high combustion rate of volatile liquid wastes fed to the incinerator could pressurize the incinerator chamber. The purposes of the test program were: (a) to define suitable absorbents, (b) to define a safe limit on the quantity of liquid that can be incinerated per box, and (c) to operationally evaluate the proposed procedure.

In the test program, various quantities of several solvents were absorbed in several types of absorbent materials, sealed in plastic bags, placed in waste boxes, and incinerated. Incinerator operating conditions (pressure, temperature, oxygen content, etc.) were monitored for each box to determine the effect on operations. The absorbents tested were dehydrated corncobs, activated carbon, and spill-control pillows (shredded polypropylene in polypropylene pillow). Solvents used in the testing were typical of the types of waste expected to be incinerated, including hexone, acetone, toluene, Stoddard solvent, and mineral spirits in varying quantities up to 1 L per box. The Flammability Index (as defined in Reference 3) and the Flammability Hazard Classes (as defined in Reference 4) were used as guidelines for choosing solvents. It was determined that materials with a Flammability Index of 4 or a Hazard Class of IA would be specifically excluded from treatment by this method. These types of materials are very volatile (boiling point $< 37.8°C$) and very flammable (flash point $< 22.8°C$) and therefore, present considerable risk.

Prior to testing with absorbed liquids, the magnitude and duration of pressure excursions normally encountered when burning LLW boxes were measured. Limits on chamber pressure, which were determined from the incinerator pressure data, were imposed on all of the testing.

In addition to determining the effect of the in-box incineration of absorbed liquids on incinerator operations, the test was also designed to determine the quantity of absorbed hexone (up to 1 L) that could be safely added to the incinerator. Universal spill-control pillows (with an absorbent capacity of about 1 L per pillow) were chosen as the combustible absorbent for the test. Solvent addition began at 10 mL and was increased by 25 mL for each subsequent box, up to a limit of 1 L. This scheme was followed as a conservative method to determine if up to 1 L of hexone could be incinerated safely.

The test plan for the Phase II Test is presented in Table I. The purpose of the Phase II testing was to demonstrate the safety and feasibility of incinerating a variety of combustible and flammable liquids. Four solvents, in addition to hexone, were chosen for the test, including paint thinner (mineral spirits), acetone, Stoddard solvent, and a mixture of toluene and carbon tetrachloride (CCl_4). The solvents were chosen to represent a wide range of properties (see Table II) and to represent the types of wastes expected to be incinerated by this procedure in the future. The toluene/CCl_4 mixture was chosen because this mixture was to be burned by the in-box method in the RCRA Part B trial burn to demonstrate the destruction efficiency of incinerating solid hazardous waste.

The Phase II test was also intended to demonstrate the use of dehydrated corncob pellets and activated carbon for comparison with spill-control pillows. Absorption capacity and the effect on incinerator operating conditions were to be evaluated and compared. The relative ease of working with each absorbent in test box preparation was also evaluated.

TABLE I

Phase II In-Box Test Plan

Run No. 1 (1 L Hexone Per Box)		Run No. 2 (2 Pillows per Box)		
Box No.	Absorbent[a]	Box No.	Solvent	Quantity (mL)
1	Pellets	4[b]	Hexone	1000
2	Carbon	6[b]	Hexone	1000
3	Pellets	7	Hexone	750
4[c]	Pillows	8	Hexone	750
5	Carbon	9	Toluene/CCl_4	750
6[c]	Pillows	10	Toluene/CCl_4	750
		11	Toluene/CCl_4	1000
		12	Toluene/CCl_4	1000
		13	Mineral Spirits	750
		14	Mineral Spirits	750
		15	Mineral Spirits	1000
		16	Mineral Spirits	1000
		17	Acetone	500
		18	Acetone	500
		19	Acetone	750
		20	Acetone	750
		21	Acetone	1000
		22	Acetone	1000
		23	Stoddard Solvent	750
		24	Stoddard Solvent	750
		25	Stoddard Solvent	1000
		26	Stoddard Solvent	1000
		27	NONE	NA[d]
		28	NONE	NA

a. Pellets are dehydrated corncob; carbon is activated carbon; pillows are 2 spill-control pillows.

b. Part of Run No. 1 also.

c. Part of Run No. 2 also.

d. Not applicable.

TABLE II

Properties of Solvents Used in the Test Program

Solvent	Molecular Weight	Boiling Point (°C)	Specific Gravity	Vapor Pressure (kPa at 66°C)	Heating Value (kJ/kg)	Flash Point (°C)	Lower-Upper Flamm. Limits (vol%)	Health-Flamm.-React. Index[a]	Autoignition Temperature (°C)	Vapor Density (Air=1)	Flammability Hazard Class[b]
Hexone	100	117	.801	19	37,900	23	1.4-7.5	2-3-0	459	3.5	IB
Toluene	92	111	.867	23	42,600	4	1.4-6.7	2-3-0	479	3.1	IB
CCl_4	154	78	1.60	76	1,000	--	--	3-0-0	--	5.3	--
Acetone	58	56	.790	138	30,700	-21	2.6-13.	1-3-0	465	2.0	IB
Stoddard solvent	127	104	1.00	NA[d]	44,000	38	1.1-6.0	0-2-0	232	NA	II
Paint Thinner	109	149	.800	NA	--[c]	40	0.8-6.0	0-2-0	245	NA	II

a. See Reference 3.

b. See Reference 4.

c. Estimated at 19600 (see Reference 6).

d. Not available.

The toluene/CCl_4 mixture, paint thinner, and Stoddard solvent burned in Run No. 2, were initiated at the 750-mL level (75% of maximum level demonstrated on hexone) before going to the 1-L level. This was done as a precaution, since it was the first time solvents other than hexone had been purposely incinerated at WERF. As an added precaution, an extra, lower treatment level (500 mL) was run on acetone, because acetone is more volatile than the other liquids.

RESULTS AND DISCUSSION

Pressure Monitoring during LLW Operation

In order to establish safe operating limits and a baseline with which to compare the results of subsequent tests, and before any testing was conducted, incinerator chamber pressure data were obtained while processing normal LLW. The lower chamber pressure data when processing LLW indicated that a pressure spike above the incinerator pressure setpoint -0.4 kPa (-1.5 in.w.g.) is associated with each box that is dropped into the incinerator (see Fig. 2). However, the spike is apparently not caused by rapid combustion, but rather by a surge of air drawn into the incinerator each time the lower doors of the loading chute open to drop a box, and by the displacement of air volume by the 0.23-m^3 (8-ft^3) boxes. These spikes ranged from 0.5 to 1.4 kPa (2.0 to 5.8 in.w.g.) in magnitude, averaged 0.8 kPa (3.2 in.w.g.), and lingered for less than 1 second. A similar spike, although of less magnitude (<0.4 kPa) is associated with the opening of the top hatch to the loading chute.

The events described above occurred consistently throughout a LLW burn, seemingly independent of effects which might be expected to cause variation in the pressure response, including box weight, box contents, etc. It was expected that boxes containing significant quantities of polyethylene (which is volatile) would cause a temporary increase in chamber pressure soon after being dropped into the incinerator. Other incinerator operators have reported problems with pressure spikes when burning large quantities of polyethylene (5). This problem was not observed in this test.

Phase I Test

The parameter of primary interest in the Phase I test was lower chamber pressure. This operating condition was continuously monitored on a strip chart recorder during the test. Other parameters of interest were lower chamber temperature and off-gas oxygen content. The lower chamber temperature was verified to be betweeen 980 and 1090°C (1800 and 2000°F) before each test box was dropped.

At no time during the test were the imposed pressure limits exceeded. In fact, the incinerator pressure never went positive other than the positive excursions that normally occur when a box is loaded.

For each of the 44 test boxes, and for each of nine randomly chosen normal LLW boxes, the minimum and maximum pressures were determined from the pressure tracings for two time intervals, as illustrated in Fig. 3. Interval 1 represents the time between the lower loading chute doors beginning to open until they were completely closed; interval 2 represents the time after the lower doors completely closed until the pressure returned to the controller setpoint. The maximum and minimum pressure levels for intervals 1 and 2 will be called MAX1, MAX2, MIN1, and MIN2.

Interval 1 data were examined to determine if rapid combustion occurring as soon as the box drops into the incinerator has an effect on the maximum pressure spike that normally occurs when the box drops. Interval 2 data were examined to determine if addition of solvent causes an increase in pressure after the lower doors close. Minimum pressures were examined because they affect the magnitude of the maximum pressure through the pressure controller.

Statistical analyses were run on the data to determine if addition of solvent had an effect on incinerator pressure and if there was a significant difference between burning absorbed hexone and normal LLW. Statistical analyses on the data showed no effect due to increasing solvent on any incinerator operating condition, except for the MAX2 pressure data. It was determined, however, that the significant effect on MAX2 pressure was not solvent addition, but feed rate. A change in feed rate from a box every 3.5 minutes to a box every 2.5 minutes for temperature control caused a significant increase in the MAX2 pressure.

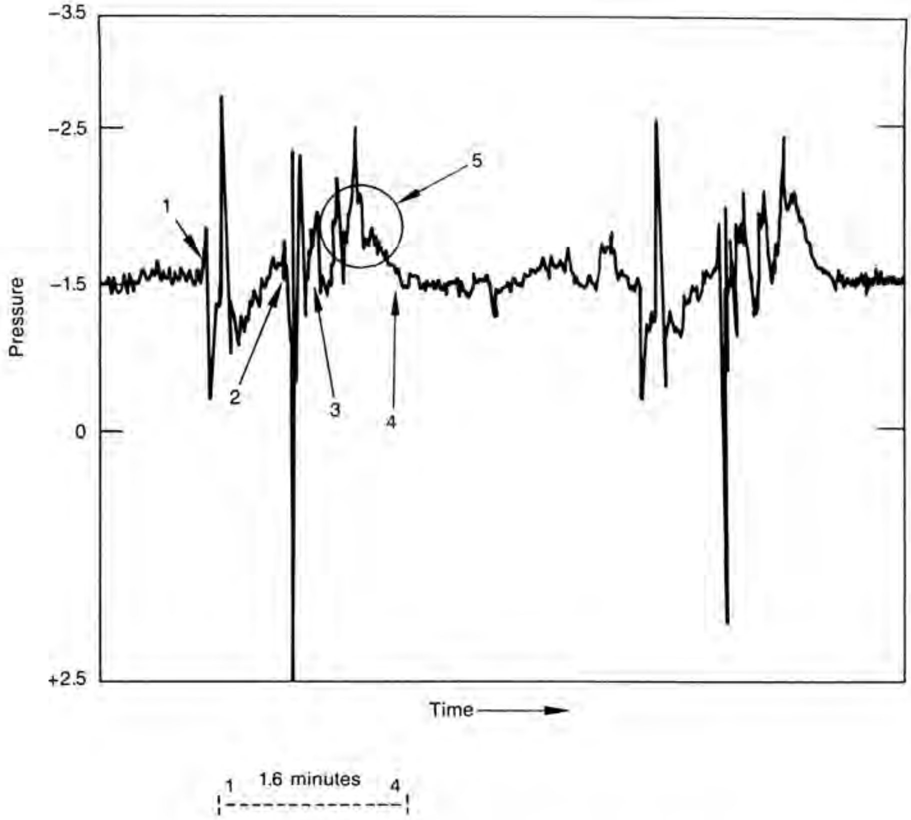
Since solvent addition was not a significant effect, the data from test boxes could be compared with the data from LLW boxes. Student's T-tests were run on the data; a summary of the results is presented in Fig. 4. The test indicated that normal LLW boxes exhibited a significantly higher pressure spike associated with loading a box (MAX1) than did the test boxes. The test comparing the LLW and test box MAX2 means, isolating the effect of feed rate, showed no significant difference between these means (see Table III). The mean minimum pressures of LLW and test boxes for each of the two intervals were not significantly different, which indicates that differences in the maximums are not due to the controller on pressure.

The significant difference between the MAX1 means of LLW versus test boxes was expected because the LLW boxes were 0.23 m^3 (8 ft^3) while the test boxes were 0.13 m^3 (4.6 ft^3). The LLW boxes would displace more air upon dropping into the incinerator, thus causing a higher pressure spike. The fact that this difference was detectable and statistically significant provides evidence that pressure differences due to even small effects can be detected.

While statistically significant effects on incinerator pressure were identified in the Phase I in-box test, these effects were incidental to incinerator operation and not due to solvent addition. Statistical analyses on the data, with the incidental effects isolated, showed there to be no significant difference in incinerator operations when burning absorbed hexone in quantities less than, or equal to, 1 L and burning normal LLW. There also was no significant trend in the data associated with increasing solvent level, which further supports the conclusion that burning 1 L or less of absorbed hexone causes no incinerator operating problems.

Phase II Test

The Phase II test was organized into two runs. The first was designed to test and compare corncob pellets and activated carbon to the spill-control pillows used in the Phase I testing. The objective



Legend:

1. Hatch opens, box drops into chute, and hatch closes. (see Fig. 2)
2. Lower doors open and box drops into incinerator.
3. Lower doors close.
4. Pressure returns to setpoint.
5. Extra safety margin for containing pressure spikes.

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Fig. 2. Pressure tracing from WERF incinerator lower chamber.

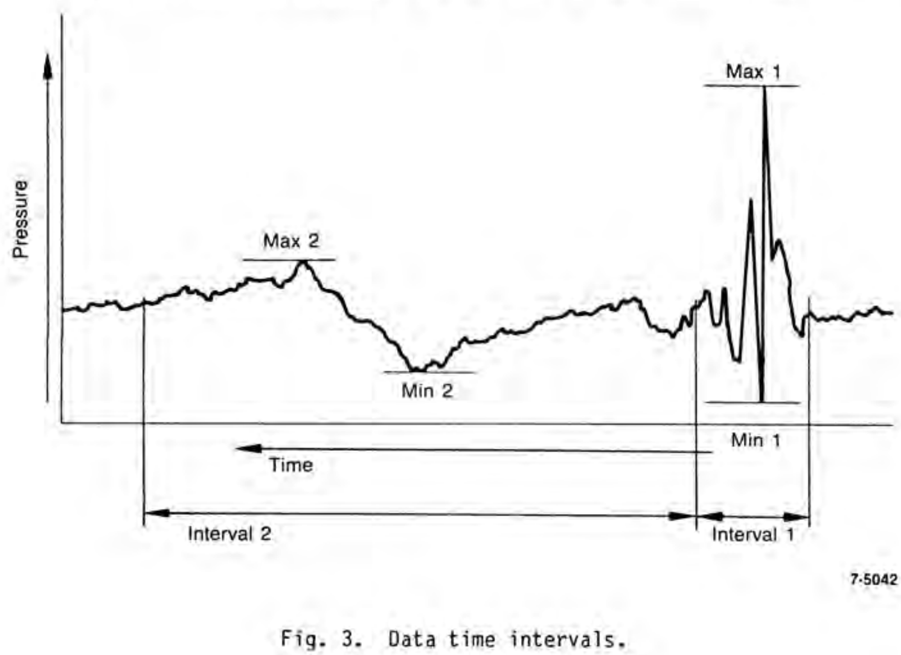

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Fig. 3. Data time intervals.

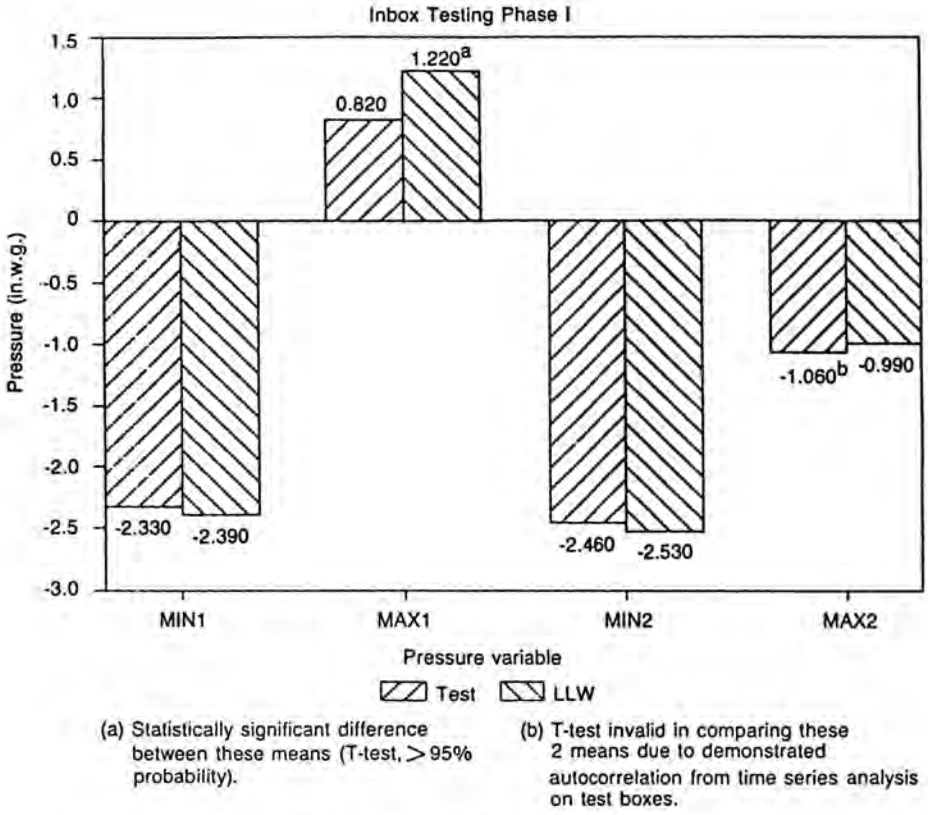

Fig. 4. Lower chamber pressure extremes.

TABLE III

MAX2 Pressure Results

	MAX2 (in. w.g.)	
	Mean	St. Dev
Timer at 2.5 minutes		
Test Boxes	-0.96	0.03
Normal LLW	-0.96	0.03
Timer at 3.5 minutes		
Test Boxes	-1.18	0.04
Normal LLW Boxes	-1.10	0.01
Test Boxes		
2.5 minutes	-0.96[a]	0.03
3.5 minutes	-1.18[a]	0.04
Normal LLW Boxes		
2.5 minutes	-0.96	0.03
3.5 minutes	-1.10	0.01

a. Statistically significant difference between these means (T-test, >95% probability).

was to evaluate the absorptive capacity and applicability of these two new absorbents to in-box incineration.

It was found that corncob pellets were quite compatible with the process, absorbing approximately 0.22 mL of hexone per mL of pellets. Activated carbon, however, heated up significantly when hexone was added. The temperature rise was deemed unacceptable and activated carbon was determined to be incompatible with the process. The absorptive capacity of this absorbent was not successfully measured.

Statistical analyses on the pressure data from the Phase II test showed no identifiable treatment effects due to the type or amount of solvent (see Fig. 5). This indicates that burning the amounts of the solvents used in the test resulted in incinerator conditions that were within the incinerator's control envelope, resulting in no adverse operating effects.

Since there were no treatment effects due to solvent type or amount, normal LLW and test boxes could be compared directly. As seen in Fig. 6, the MAX1 pressure levels for normal LLW were consistently greater than the levels for test boxes. This difference was statistically significant and was again due to the difference in the size of the normal LLW and test boxes (0.23 m^3 versus 0.13 m^3). The larger LLW boxes displace a greater volume when they are dropped into the lower chamber, which results in a higher MAX1 pressure. This effect was also seen in the Phase I testing.

There was no significant difference between LLW and test boxes seen in MAX2 levels. The individual data points shown in Fig. 7 show a random pattern.

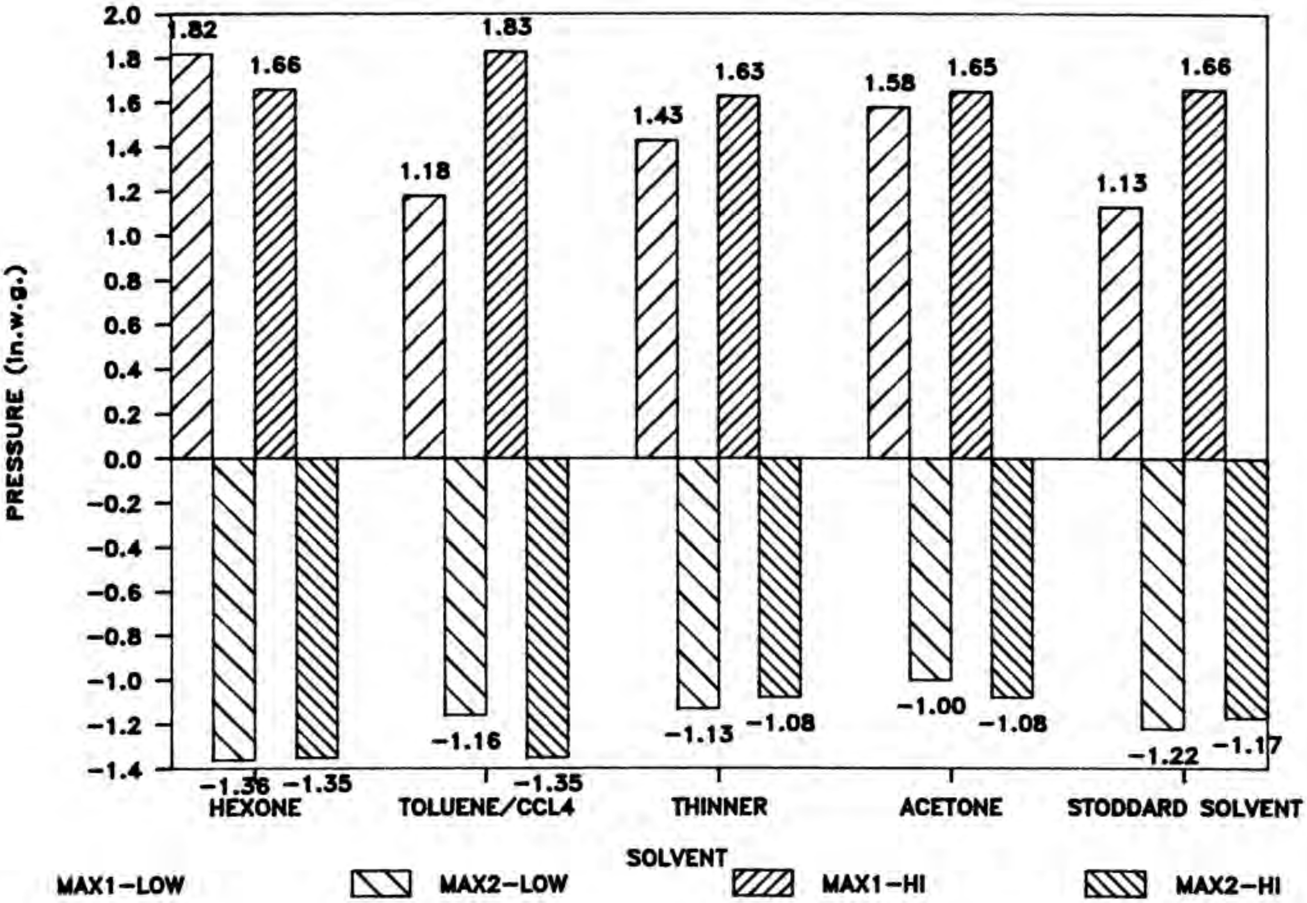

Fig. 5. Statistical analyses of pressure data.

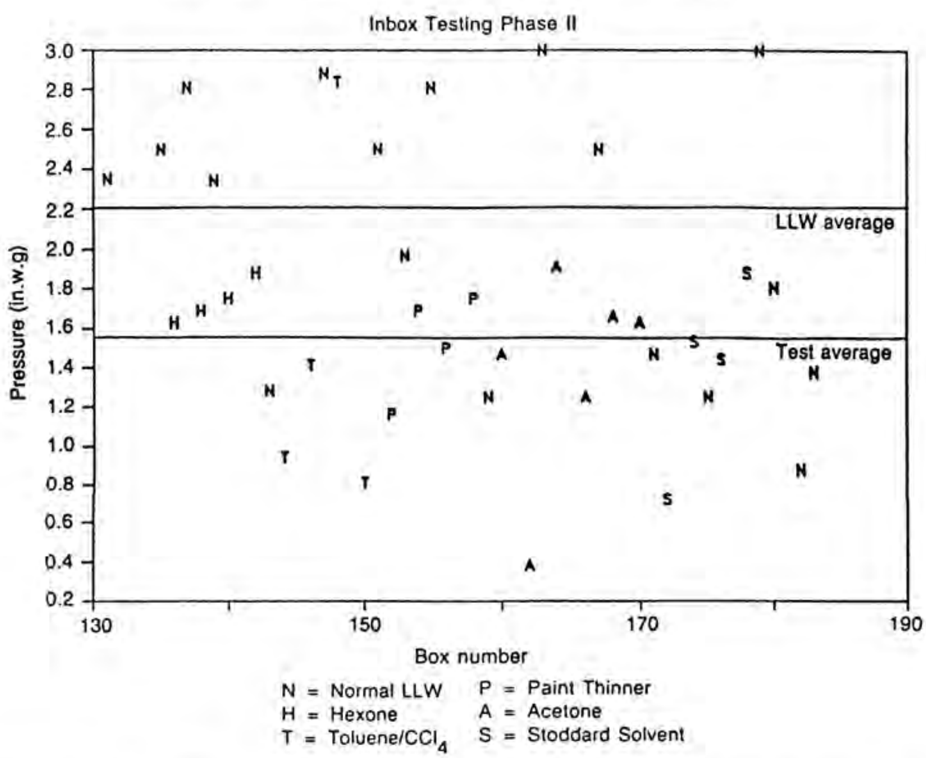

Fig. 6. Individual MAX1 pressure data points for normal LLW and test boxes.

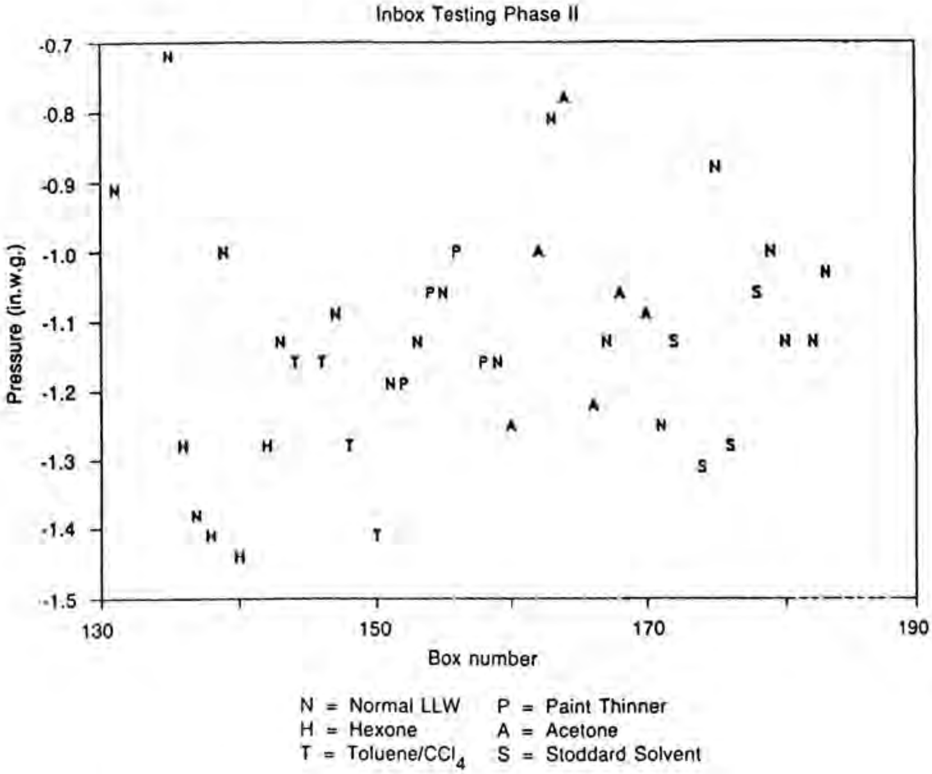

Fig. 7. Individual MAX2 pressure data points for normal LLW and test boxes.

CONCLUSIONS AND RECOMMENDATIONS

The In-Box Testing Program demonstrated that the incineration procedure is safe and practical on a wide variety of solvents in batch charges up to 1 L, the maximum amount tested in this study. No adverse or unacceptable operating conditions resulted from the burning of any of the solvents. The incineration of the solvents had no more effect on incinerator operations than the burning of LLW .

It can generally be concluded that liquids of Flammability Hazard Index 3 or less, and Flammability Class IB or less, are compatible with the in-box incineration method and the WERF system, when incinerated in quantities of 1 L or less. It is recommended, however, that a responsible party be designated to review candidate liquids prior to their incineration by this method. It is also recommended that liquids classified IA and/or having a Flammability Hazard Index of 4 be specifically excluded from this procedure, unless further testing on these materials demonstrates their safety. This would exclude liquids such as ethers, acetaldehyde, and propylene oxide from treatment by this method (liquids in this category are uncommon in significant quantities at the INEL). The reviewer should also assess the compatibility of the liquids with the materials involved (polyethylene, polypropylene) and should determine, in consultation with an industrial hygienist, any special handling and preparation precautions that should be exercised when processing Health Hazard Index 3 or 4 liquids.

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