ADDITION OF LIQUID WASTE INCINERATION CAPABILITY

TO THE INEL's LOW-LEVEL WASTE INCINERATOR

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ABSTRACT

A liquid waste system has recently been installed in the Waste Experimental Reduction Facility (WERF) incinerator at the Idaho National Engineering Laboratory (INEL). In this paper, aspects of the incineration system such as the components, operations, capabilities, capital cost, EPA permit requirements, and future plans are discussed. The principal objective of the liquid incineration system is to provide the capability to process hazardous, radioactively contaminated, non-halogenated liquid wastes. The system consists primarily of a waste feed system, instrumentation and controls, and a liquid burner, which were procured at a capital cost of $115,000.

INTRODUCTION

At the Idaho National Engineering Laboratory (INEL) and elsewhere within U.S. Department of Energy (DOE) facilities, radioactively contaminated waste liquids have been generated which, because of certain characteristics (e.g., ignitability), have not been processed and disposed. Some have been in storage for many years awaiting suitable processing methods. Many could be disposed of in an incinerator capable of processing solid low-level radioactive waste (LLW) if a suitable liquid waste burner and supporting incineration control equipment were installed.

The disposal problems presented by radioactively contaminated and frequently hazardous liquids, i.e., mixed wastes, are not unique to DOE, but are common throughout the nuclear industry. Even so, no incinerators exist in the United States that presently have the capability and the necessary Environmental Protection Agency (EPA) permit to process liquid mixed wastes.

At the INEL, the LLW incinerator at the Waste Experimental Reduction Facility (WERF) has recently been modified by the addition of a liquid waste incineration system. Preparations are now being made to conduct EPA trial burns with this system. Progress in bringing this system to full operational status and using it on a production basis to process low-level radioactive mixed liquid waste should generate information of considerable value in support of nuclear waste treatment.

In this paper, the liquid system installed in the WERF incinerator is described. Aspects of the incineration system such as the components, operations, capabilities, capital cost, EPA permit requirements, and future plans are discussed.

WERF INCINERATION SYSTEM

The WERF incinerator (Fig. 1) was developed for the incineration of combustible low-level wastes. The purpose of the facility is to a) reduce the volume of low-level combustible waste being disposed at the INEL's radioactive waste disposal site and thereby prolong the site's useful life, and b) develop waste processing technology by providing a facility where full size processes and equipment can be tested, modified as necessary, and proven for contaminated waste processing applications during production scale operations.

Since the composition of radioactive waste being buried at the INEL disposal site is more than 80% by volume lightly contaminated waste (less than 10 mrem/h at near contact), the incineration facility was designed to process this level of waste, which would allow contact handling. The facility includes systems to characterize and convey the waste to the incinerator, incinerate the waste, cool and drum the resulting ash, and condition and filter the off-gas.

The incinerator is a commercially available, dual chambered, controlled air incinerator capable of burning combustible material at a rate of 1400 kW (4.8×10^6 BTU/h). Although initially intended to incinerate only solid combustible low-level wastes, the incinerator was designed to accommodate liquid waste with the addition of the necessary hardware. The incinerator was designed for compatibility with pathologic and other hazardous wastes. It incorporates a leak-tight feed system and a secondary combustion chamber which provides a 2-second residence time at 2100°F (at rated capacity). The incinerator operates at a subatmospheric pressure to prevent the release of radioactively contaminated materials.

The ash handling system provides for removal of the incinerator ash. An ash ram in the primary combustion chamber periodically pushes the ash across the hearth to a drop chute where it falls into a hopper for storage and cooling (see Fig. 1). When cooled sufficiently, the ash is allowed to drop through a sliding gate valve into drums positioned below.

The off-gas system is a dry filtered system which cools the incinerator combustion gases by means of both air dilution and passage through a shell and tube, gas-to-air heat exchanger. The cooled gases are passed through a fabric filter baghouse and then through high efficiency particulate air (HEPA) filters prior to discharge to the atmosphere. The off-gas is continuously monitored for radioactivity and for acid

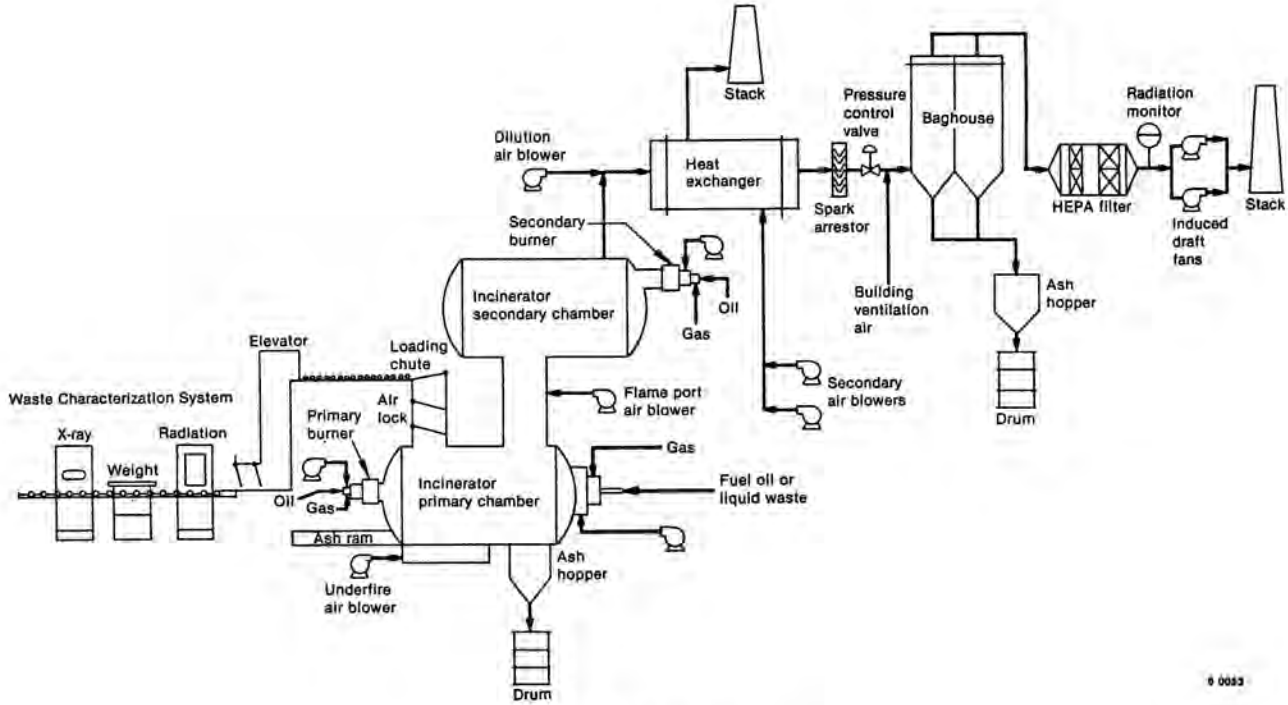

Fig. 1. WERF Incinerator.

content. Waste generators are required to segregate materials which may generate large quantities of acid-forming compounds.

The first burn of contaminated solid waste took place in September 1984. The WERF incinerator is now routinely processing INEL-generated combustible waste.

LIQUID INCINERATION SYSTEM

Functional Requirements

The principal objective of the liquid incineration system is to provide the incinerator at WERF with the capability to process hazardous, radioactively contaminated, nonhalogenated liquid wastes. The specific functional requirements for the liquid incineration system were as follows:

1. The system will be compatible with the existing incinerator, controls, and operating procedures.
2. The system will be flexible enough to process a wide variety of liquid wastes with varying physical properties.
3. The burner will have a thermal capacity of at least 290 kW (1.0×10^6 BTU/h).
4. The system will meet all EPA Part B Permit requirements.
5. The system will operate in a safe manner and meet or exceed all applicable codes and standards.

Major Components

The liquid incineration system consists primarily of a waste feed system, instrumentation and controls, and a liquid burner. In the interest of economy, off-the-shelf, previously-proven equipment was used in this system. The major components of the system are described briefly below.

1. Liquid Waste Burner: The burner is a Trane Thermal Model LV-1 vortex burner (see Fig. 2). It is capable of firing a variety of liquids with a minimum heating value of 10,500 KJ/kg (4500 BTU/lbm) (air atomized). It has a thermal capacity of 380 kW (1.3×10^6 BTU/h) at high fire with a turndown ratio of 3.5 to 1 at 5% excess air. The burner has a combustion chamber lined with 85% alumina refractory brick. The burner is equipped with a propane pilot system used for startup. The burner is also equipped with flame view ports and an ultraviolet flame scanner for flame supervision.

   The burner design provides for extreme turbulence in the combustion chamber by introducing combustion air tangentially into the windbox. Swirl vanes in the windbox intensify the mixing process in the combustion chamber. The result is highly efficient combustion ensuring complete destruction of the waste and a very short flame length (20 - 33 cm or 8 - 13 in.).

2. Combustion Air Blower: The combustion air blower is a North American Model 2320. The air blower provides 0.12 m^3/s (260 scfm) at 8600 Pa (20 osi) above system back pressure. It is equipped with a silencer for noise reduction and an inlet filter. The filter is used both for filtering the inlet air and providing additional safety against blowback of contamination due to positive chamber pressure. The blower is driven by a 2.24 KW (3 HP) electric motor.

3. Waste Feed System: The liquid waste pump is capable of delivering a nominal 10.5 cm^3/s (10 gph) at 170 KPa (25 psig). It is a vane

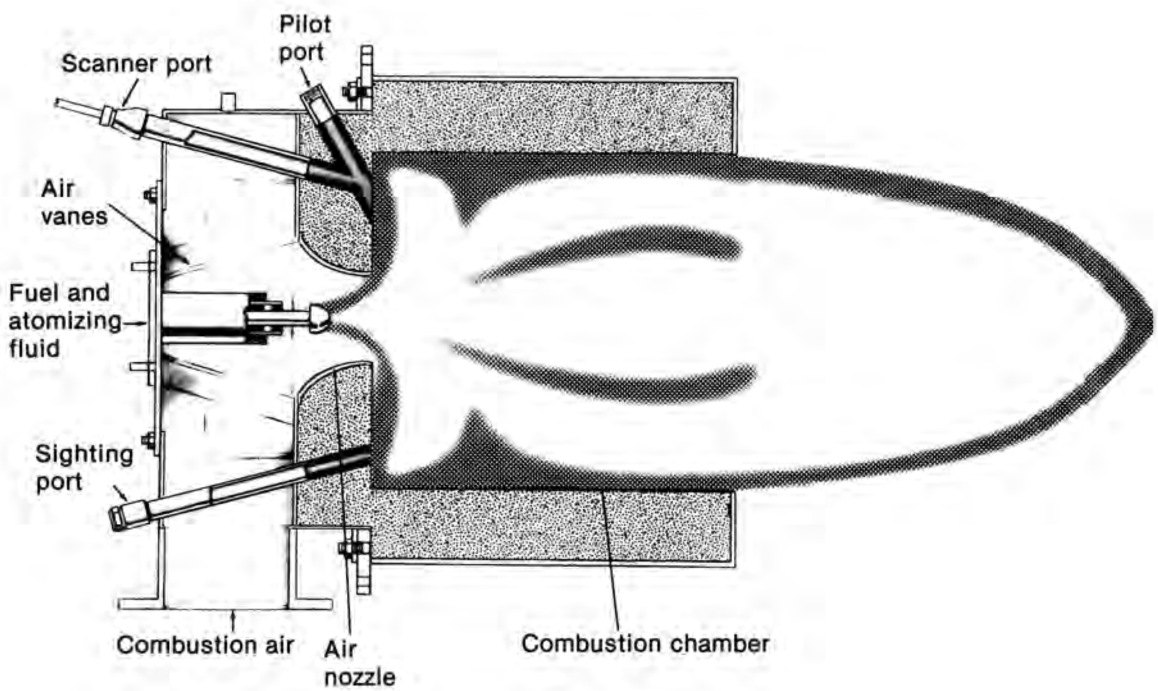

Fig. 2. Vortex Burner.

pump with graphite vanes and 316 stainless steel wetted parts. It is magnetically coupled to a one-third horsepower, explosion-proof electric motor.

The pump draws suction directly from 0.21 m^3 (55 gal) drums containing waste. The waste containment area is a stainless steel pan capable of holding the volume of two 0.21 m^3 (55 gal) drums. All liquid waste piping between the drums and burner is 316 stainless steel.

4. Flame Safeguard System: The flame safeguard system senses burner flame with an ultraviolet detector. The ultraviolet flame detector cannot be "fooled" by infrared radiation emitted by hot refractory, but will detect flame only. The system will safely shut down fuel and/or waste feed in the event of flame extinguishment.

5. Mass Flow Meter: Waste flow is measured with a Micro Motion Model D12 mass flow meter. The meter measures mass flow unobtrusively to within 0.4%. Mass and total flows are displayed digitally in the incinerator remote control room.

6. Instrumentation and Controls: The control of fuel, waste, and air-flows is accomplished from the incinerator remote control room through two Barber-Coleman (Model 560 series) controllers operated as manual loading stations. These controllers operate four air-actuated control valves located in the waste, fuel oil, and combustion air lines. Mass flow is monitored with the readout from the mass flow meter output and controlled with one of the two Barber-Colemans. Pressure switches are provided to automatically shut down burner feed in the event of:

   a) low fuel oil pressure

   b) low atomization pressure

   c) low waste feed pressure

   d) high waste feed pressure

   e) low combustion air pressure.

7. Waste Gun: The waste gun atomizes the liquid waste or fuel and injects it into the combustion chamber of the burner. It is constructed of concentric tubing for separate delivery of the atomization medium and fuel. The wetted parts are constructed of 316 stainless steel except for the nozzle tip which is Hastelloy. The nozzle has an external atomizing tip for firing liquids in a viscosity range of 0.0005 - 0.0035 Pa·s (0.5 to 3.5 cp). Other fuels and wastes with different physical properties can be accommodated by changing the atomizing tip.

Normal Operations

The liquid waste system is shown in Fig. 3. The nomenclature used in Fig. 3 is explained in Table I. All of the streams, switches, indicators, and valves are labeled and numbered for the liquid waste system to facilitate the description of normal operations that follows.

Prior to injection of liquid waste into the liquid waste burner, the incinerator chambers are preheated to operating temperature with the primary and secondary oil burners. When operating temperature has been established, the underfire air blower is shut off. The secondary chamber burner and the flameport air blower continue operating. Temperature control in the secondary chamber is accomplished by modulating the secondary burner and flameport air damper.

Common safety interlocks for the liquid and solid systems include pressure and temperature set points in the combustion chambers. Specifically, the

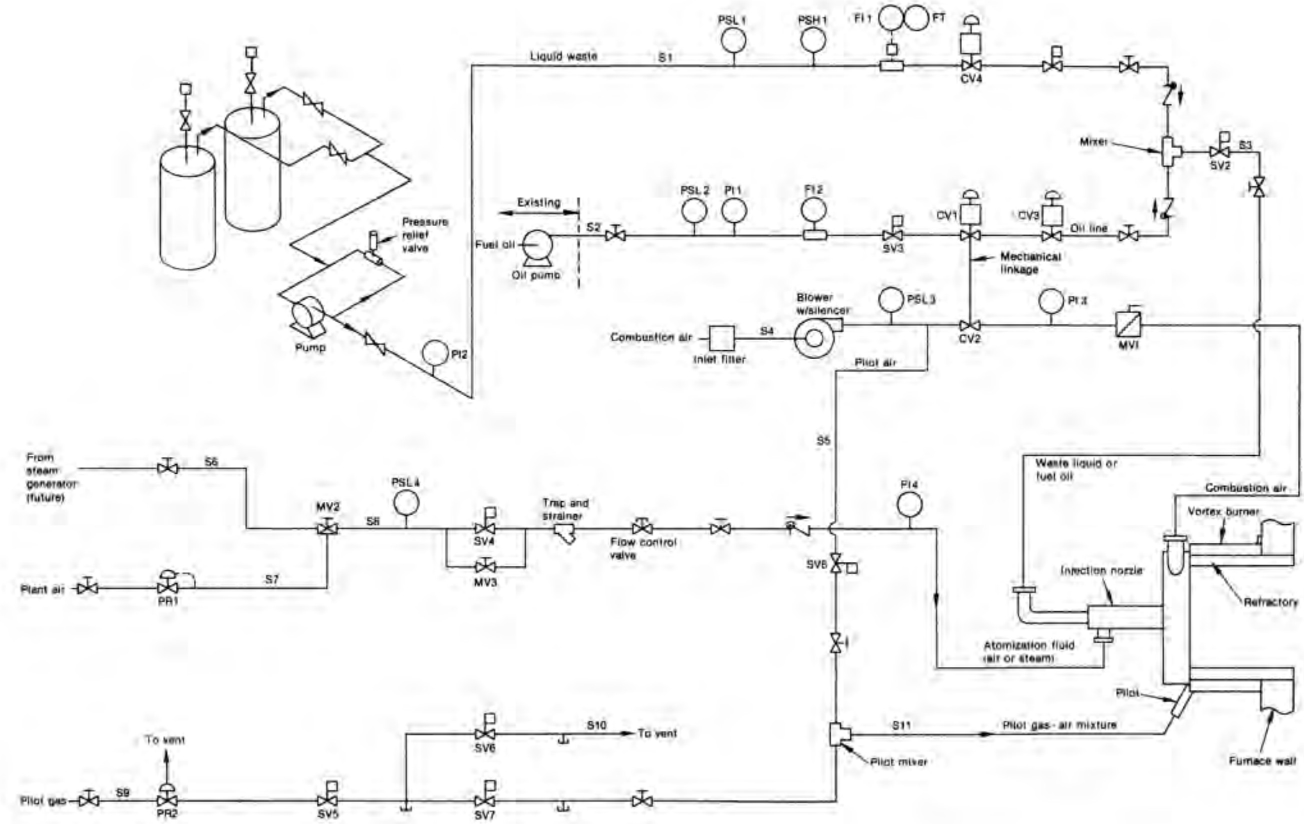

Fig. 3. WERF Liquid Waste System.

temperature and pressure set points for the primary and secondary chambers are interfaced with the liquid waste burner flame safeguard system to shut the burner down in the event one of these set points is exceeded. In addition, the incinerator's emergency stop buttons will shut down the liquid waste burner, combustion air blower and liquid waste pump.

After operating conditions have been established in the incinerator chambers, the combustion air blower for the liquid waste burner is started (pressure confirmed by low pressure switch PSL2). The operator then starts the burner automatic ignition cycle. The following sequence of events occurs automatically if all incinerator operating condition set points are proven (including PSL2, PSL3, and PSL4):

1. The pilot gas (SV5 and SV7) and air (SV8) valves open, the pilot vent valve (SV6) closes, and the pilot gas-air mixture is spark ignited. The pilot must be proven by the ultraviolet (UV) flame detector within 10 seconds.

2. If the pilot flame has been established, the fuel oil valve (SV3) and atomization medium valve (SV4) open and the main flame must be ignited by the pilot within 10 seconds.

3. At the end of this 10-second interval, the pilot gas and air valves (SV5, SV7, and SV8) close and the vent valve (SV6) opens.

The liquid waste burner now fires on number two fuel oil at low fire and the automatic sequence is over. The primary chamber burner is shut off at this point but can be restarted to provide additional heat input if required. The burner is then manually brought to high fire on fuel oil by an electronic controller in the remote liquid waste control panel which modulates a mechanically linked fuel oil/combustion air control valve assembly (CV1 and CV2). If the temperatures in the combustion chambers are still within the acceptable operating range, the liquid waste pump is started from the control panel and the pressure proven (PSL1) followed by the opening of the liquid waste shutoff valve (SV1). The liquid waste control valve (CV4) is then gradually opened to allow waste to flow to the burner. At the same time, a control valve in the fuel oil line (CV3) is gradually closed. This continues until the burner is firing completely on liquid waste. The transition from fuel oil to liquid waste is accomplished manually via a single electronic controller in the remote control panel.

Once the burner is operating on waste at the prespecified flow rate, verifiable by the readout of the flow meter (FI1), the operator will make final adjustments on waste flow based on O_2 concentration in the primary chamber. This will be supplemented by information received from another operator stationed at the burner who will be observing the flame through the incinerator view port. Once this is accomplished, very little operator intervention is necessary. The only anticipated adjustments are trim on waste flow drift. In the future, automatic control of normal operations will be added.

The flame safeguard system, pressure switches, and incinerator temperature and pressure set points ensure safety during operations. The liquid waste burner will shut down (feed shut-off) in the event of any of the following conditions:

a) flame failure

b) low combustion air pressure

TABLE I

NOMENCLATURE FOR FIG. 3

Symbol	Definition
CV1	Oil control valve (mechanically linked with the combustion air control valve)
CV2	Combustion air control valve
CV3	Oil control valve for switching to waste
CV4	Waste control valve
FI1	Waste flow indicator, remote readout
FI2	Oil flow indicator, local readout
FT	Waste flow totalizer, remote readout
MV1	Manual control valve for combustion air
MV2	Three-way manual valve for selecting atomization medium
MV3	Manual control valve in atomization by-pass loop
PI1	Oil pressure indicator
PI2	Waste pressure indicator
PI3	Combustion air pressure indicator
PI4	Atomization medium pressure indicator
PR1	Atomization air pressure regulator
PR2	Pilot gas pressure regulator
PSH1	Waste high pressure switch
PSL1	Waste low pressure switch
PSL2	Oil low pressure switch
PSL3	Combustion air low pressure switch
PSL4	Atomization medium low pressure switch
S1	Liquid waste stream
S2	Fuel oil stream
S3	Common fuel oil and liquid waste stream
S4	Combustion air stream
S5	Pilot air stream
S6	Atomization steam stream
S7	Atomization air stream
S8	Atomization medium (air or steam) stream
S9	Pilot gas stream
S10	Pilot gas vent stream
S11	Pilot mixture (air and gas) stream
SV1	Waste solenoid shutoff valve
SV2	Solenoid shutoff valve in waste/oil common line
SV3	Oil solenoid shutoff valve
SV4	Atomization solenoid shutoff valve
SV5	Pilot gas solenoid shutoff valve
SV6	Pilot gas solenoid vent valve
SV7	Pilot gas solenoid shutoff valve
SV8	Pilot air solenoid shutoff valve

c) low fuel oil pressure

d) low atomization pressure

e) low liquid waste pressure

f) high liquid waste pressure

g) high primary or secondary chamber temperature

h) low primary or secondary chamber temperature

i) high primary chamber pressure

j) any emergency stop button pushed

k) high stack carbon monoxide content

l) high waste feed rate

m) high stack gas velocity.

Any attempt to restart the burner after an automatic shutdown has occurred must be preceded by a prepurge cycle.

At the end of the liquid waste burn, the burner is shut down by slowly closing control valve CV4 in the liquid waste line while slowly opening control valve CV3 in the fuel line. This returns the burner to high fire on fuel oil and purges the common lines and burner nozzle of liquid waste. When the purge is complete, the burner is turned off, which closes solenoid valves SV2 and SV3 and shuts off feed to the burner. The combustion air blower is left on temporarily to cool the burner refractory.

Preliminary Testing

A complete component checkout and system operational test were completed in October 1985. All individual safety systems, major control components, and common interlocks with the existing incinerator safety systems were tested both with the burner off and ignited on fuel oil. Following component checkout, approximately 0.19 m^3 (50 gal) of technical grade hexone (methyl isobutyl ketone) was incinerated to test the system as a complete unit. The test was successful and required minimal operator intervention after the transition was made from fuel oil to hexone as the fuel source.

During the test burn, the fuel-to-air ratio was varied to observe combustion performance of the burner. The burner appeared to perform well in both fuel rich and lean conditions with no change in the combustibles level in the incinerator off-gas. A CO monitor was not installed for the test burn but performance tests with a CO monitor are planned for Fiscal Year 1986.

Capital Cost

The purchased cost of the system, including all of the necessary piping, wiring, vendor service, and valves was approximately $115,000. The system was assembled from off-the-shelf items for ease of replacement and cost reduction.

Permitting

The INEL received notification in April 1985 that a Part B Permit would be required for all hazardous waste activities as defined by the Resource Conservation and Recovery Act (RCRA). The incineration of hazardous organic wastes in the WERF incinerator was one of these activities. Accordingly, an incinerator section was included in the INEL permit application, which was filed in October 1985. Hazardous wastes cannot be incinerated at WERF until EPA approval is granted. Incineration of nonhazardous (radioactive only) combustible solid waste is continuing as an unregulated activity.

The EPA hazardous waste regulations require the addition of some controls and interlocks to the incinerator to ensure that waste can be fed to the system only when proper incineration conditions exist. The most significant additional equipment requirement is a carbon monoxide stack monitor.

The EPA permit will be granted based on the demonstration of successful performance of the system during a "trial burn". Very careful attention was given to the INEL trial burn plan to allow maximum permitted capability of the incinerator. The WERF incinerator does not have a well defined large volume of waste for destruction on a routine basis. Instead, small volumes of solid and liquid wastes of widely varying compositions are expected.

The trial burn plan was, therefore, developed to demonstrate system capability on difficult-to-destroy materials. According to EPA procedures, demonstration of acceptable destruction efficiency on a difficult-to-destroy material allows incineration of easier-to-destroy wastes at similar feed rates. Carbon tetrachloride is the most difficult-to-destroy compound expected in INEL wastes based on the EPA's heat of combustion ranking. The WERF incinerator's dry off-gas cleanup system is not capable of capturing acidic combustion products which result from burning chlorinated organics. The allowable feed rate of carbon tetrachloride is, therefore, limited to restrict acid gas stack emissions and avoid corrosion in the system by acid gas condensation.

These considerations limit the feed rate of carbon tetrachloride to less then 0.5 g/s (4 lb/h) far below the thermal capacity of the system. To perform the trial burn at the capacity of the system, the carbon tetrachloride will be mixed with the common nonchlorinated waste solvent, hexone.

Solid hazardous waste is another possible feed to the incinerator. In order to demonstrate the system capability on wastes of this nature, carbon tetrachloride will be absorbed on a combustible absorbent and fed to the unit using the regular solid waste feed system.

The incinerator conditions used during the trial burn were defined by a review of documented incinerator performance data and Trane Thermal recommendations. The acceptability of these conditions will be evaluated during pre-trial burn operation as allowed by the EPA rules. The trial burn is tentatively scheduled for the first quarter of FY-87. No other permits or licenses are anticipated.

Planned Upgrades and Activities

Improvements in capability will be made in the areas of control and capacity in the near future, if necessary. The current manual control system will be upgraded to automatic control from a process signal such as temperature, primary chamber oxygen content, or waste flow rate. An increase in capacity to 1259 kW (4.3×10^6 Btu/h) can be accomplished with the addition of a second burner to the incinerator.

A series of mini-burns in preparation for the EPA trial burn is planned for the summer of 1986. These tests will be used to prove destruction efficiencies and operational stability. Normal operation on INEL-generated liquid hazardous and radioactive mixed liquid wastes is anticipated to begin in the winter of 1987.

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