

# 13th AEC AIR CLEANING CONFERENCE

## SESSION X

### FIRE AND EXPLOSION

Thursday, August 15, 1974

CHAIRMAN: John Dempsey

#### INCINERATION PROCESS FIRE AND EXPLOSION PROTECTION

D.L. Ziegler

#### OPENING REMARKS OF SESSION CHAIRMAN:

I am pleased to be associated with this particular session because, first of all, I know the author first hand and secondly, the paper pertains to waste management. Donald Ziegler is primarily interested in waste management and, necessarily, is interested in air cleaning. I am with the Division of Waste Management in Washington, and we are interested in all things you air cleaning people are doing. We are at the end of the line where you deliver your used products. We see them and we know there must be better ways of handling them. Those hundreds of thousands of tons of used air clean-up materials that you are going to be delivering to waste represents an inefficiency from our point of view and we are directing our research programs to find better ways. I think we have seen a few better ways already this week. The title of this session is billed as Fire and Explosion, but a primary interest of Mr. Ziegler is waste volume reduction. I think that starting in 1976 we will see many more papers directed to this goal and we won't have any more one-paper sessions in this area. This topic will gradually grow to be a significant part of this conference. I can say that with some assurance. Being in the position I am, I see tremendous problems from a million to 10 million 55 gallon drums of waste produced by the end of this century. The problems are bearing down on us.

INCINERATION PROCESS FIRE AND EXPLOSION PROTECTION

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I. Abstract

Two incinerators will be installed in the plutonium recovery facility under construction at the Rocky Flats Plant. The fire and explosion protection features designed into the incineration facility are discussed as well as the nuclear safety and radioactive material containment features. Even though the incinerator system will be tied into an emergency power generation system, a potential hazard is associated with a 60-second delay in obtaining emergency power from a gas turbine driven generator. This hazard is eliminated by the use of steam jet ejectors to provide normal gas flow through the incinerator system during the 60-second power interruption.

II. Introduction

In the plutonium processing facility under construction at the Rocky Flats Plant, a rotary kiln incinerator will be used to burn materials which are contaminated with significant concentrations of plutonium. The ash from this unit will be processed for recovery of the plutonium. A second incinerator will be used to burn the low specific activity (LSA) type materials or materials which contain only trace concentrations of radioactive contamination. This will be a single hearth unit with a rabble arm which continually mixes the waste during combustion.

The objective of the incineration process is to convert combustible materials to an ash and flue gas in a safe and economical manner. The primary safety concern with an incineration process is the potential of explosion due to accumulation of flammable vapors. A second area of concern is the possibility of fire, primarily in combustion of radioactive waste, the containment of the radioactive material and the requirement for nuclear criticality control are of vital safety concern and they further necessitate the need for minimization of fire and explosion potential.

### III. Discussion

#### Process Description.

A flow diagram of the incineration process is presented in Fig. 1. The incinerator used to burn materials containing recoverable concentration of plutonium will be referred to as the H.S.A. unit and the other one will be referred to as the L.S.A. unit. All of the material which comes to the incinerator area will have been assayed for plutonium content and segregated as either HSA feed or LSA feed. The solid waste from other process buildings on the Rocky Flats Plant will be packaged in 55-gallon drums except for used High Efficiency Particulate Air (HEPA) filters which will be received in cardboard boxes. Waste generated in the recovery building will be transferred to the incinerator area by the retriever system and a pneumatic conveyor as well as by drums transferred externally to the glovebox system. The drummed waste and boxed waste will be introduced in the feed preparation area of both incinerators by an air lock glovebox through guillotine-type doors. In the feed preparation area, the 55-gallon drum liners or the boxes will be manually opened and the individual packages placed in the feeder for the incinerator.

In addition to the solids waste, liquid waste such as used oils, solvents, and lab solutions will be burned in the HSA incinerator. Used ion exchange resin will be slurried and fed with the liquid waste which will be pneumatically atomized into the unit. No liquid wastes are fed to the LSA incinerator.

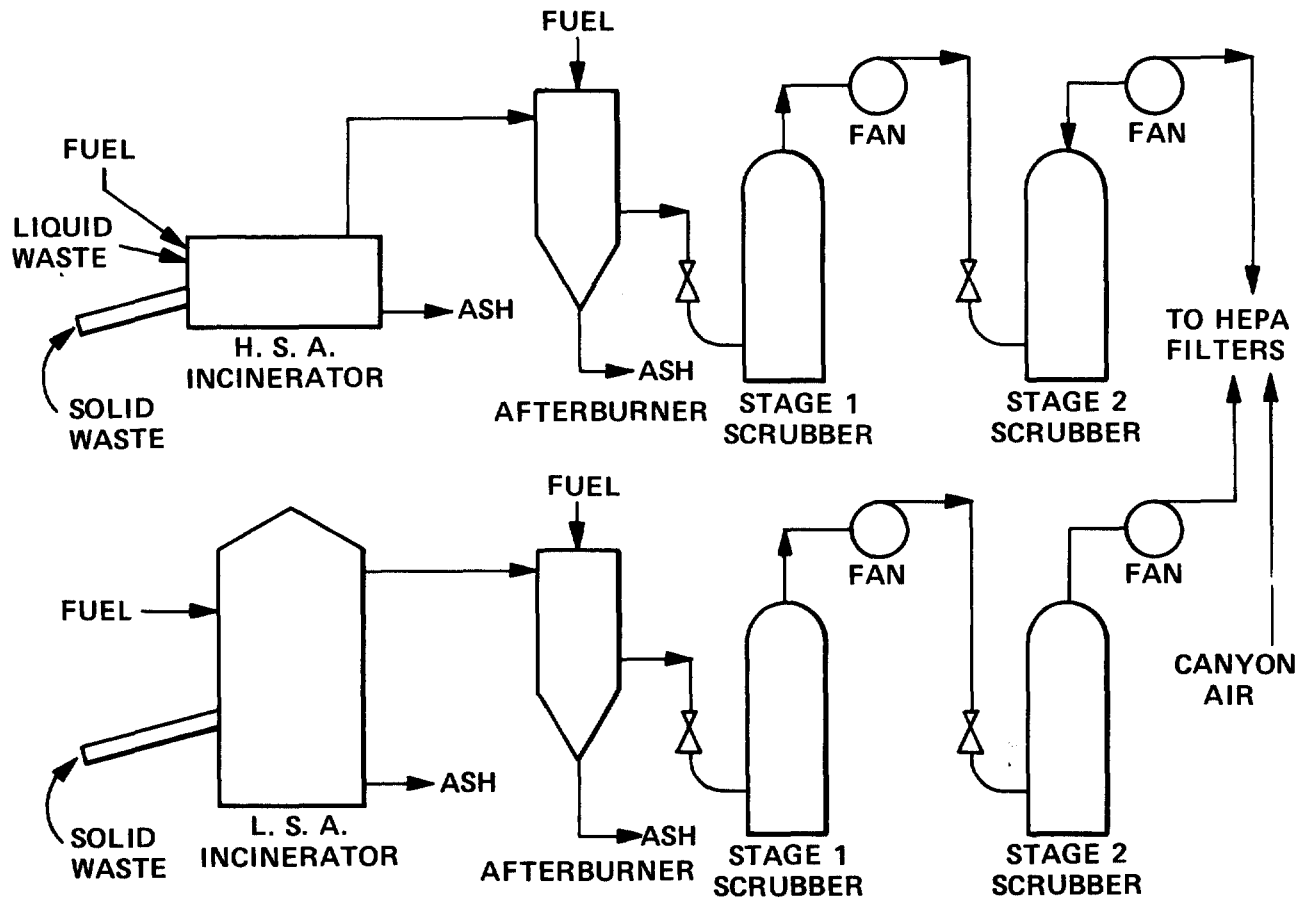
Normal operating temperature for each incinerator is 800°C in the primary combustion chamber and 1000°C in the afterburner. Each incinerator and afterburner will be supplied with diesel oil as supplemental fuel to maintain the desired operating temperature. The HSA unit will burn some materials such as rubber gloves, and HEPA filters which will form a low melting point ash. These materials will be burned at temperatures of 600 to 700°C.

The flue gas from each unit passes through two stages of high energy venturi scrubbing. The gas is then introduced into the filter plenum where it passes through four stages of HEPA filtration. Fans downstream of each scrubber provide the draft through the incinerator and scrubbing system. Fans downstream of the filters move the flue gas and room exhaust through the filter plenum.

#### Equipment.

Presented in Table I is a list of the waste materials which will be burned in the HSA incinerator. A list of the liquid waste feed is presented in Table II. The incinerator is sized to burn 90 lbs/hr of the mixed solid waste (polyethylene, polyvinyl chloride, paper, etc.).

FIGURE 1  
INCINERATION PROCESS FLOW DIAGRAM



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TABLE I

## H.S.A. INCINERATOR SOLID FEED

MIXED WASTE		LEADED DRY BOX GLOVES
PVC	50%	
POLYETHYLENE	12%	HEPA FILTERS
POLYPROPYLENE	12%	
PAPER	26%	GRAPHITE

TABLE II

## H.S.A. INCINERATOR LIQUID FEED

	<u>%</u>
CARBON TETRACHLORIDE	32.6
TRICHLOROETHANE	36.1
CUTTING OIL	12.9
LAB WASTES	2.7
ION EXCHANGE RESIN	7.1
WATER	8.6

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This corresponds to a heat release rate of 1.5 million BTU/hr. The HEPA filters and the rubber gloves will be campaigned through the incinerator because these materials have to be burned below 700°C to prevent slag formation and minimize refractory damage from melt formation. The graphite will be ground to about 8 mesh (US) size particles and burned at 1000°C. The liquid waste and used resin will be campaigned through the incinerator separately or can be burned at a reduced rate with the mixed solid waste.

A rotary kiln was selected for the HSA incinerator because it provided for automatic continuous removal of ash and minimal hold up of ash in the unit. This is required because of the need to campaign low melting ash materials through the unit and because it minimizes the hold up of fissionable materials which enhances the nuclear criticality safety of the unit. A sketch of the rotary kiln is presented in Fig. 2. The kiln will be six feet internal diameter (ID) by fifteen feet long. The solid waste, supplemental fuel, and combustion air are introduced at one end of the unit. The unit can be cleaned of ash by allowing it to rotate for a short period of time after the feed to the unit has stopped. This is a desirable feature for the nuclear materials inventory.

A list of the materials to be burned in the LSA unit is given in Table III. This unit is sized to burn about 150 lbs/hr of waste which corresponds to a heat release rate of 1.5 million BTU/hr.

TABLE III

L.S.A. INCINERATOR FEED

	<u>%</u>		<u>%</u>
RUBBER	25.0	LEATHER	0.5
PAPER	46.5	WOOD	7.0
PVC	1.0	WATER	5.0
POLYETHYLENE	5.0	TRAMP METAL	5.0
CLOTH	6.0		

A single hearth stationary incinerator was selected for the LSA application. A sketch of the unit is presented in Fig. 3. It is about 8 ft. 8 in. in diameter by about 15 ft. tall. This unit will be operated in a cyclic manner as follows:

1. Feed Cycle - waste will be charged on a frequency of about 5 lbs. every two minutes for a period of about five hours. During this period the rabble arm will continually mix the burning waste and the ash generated will accumulate in the unit.

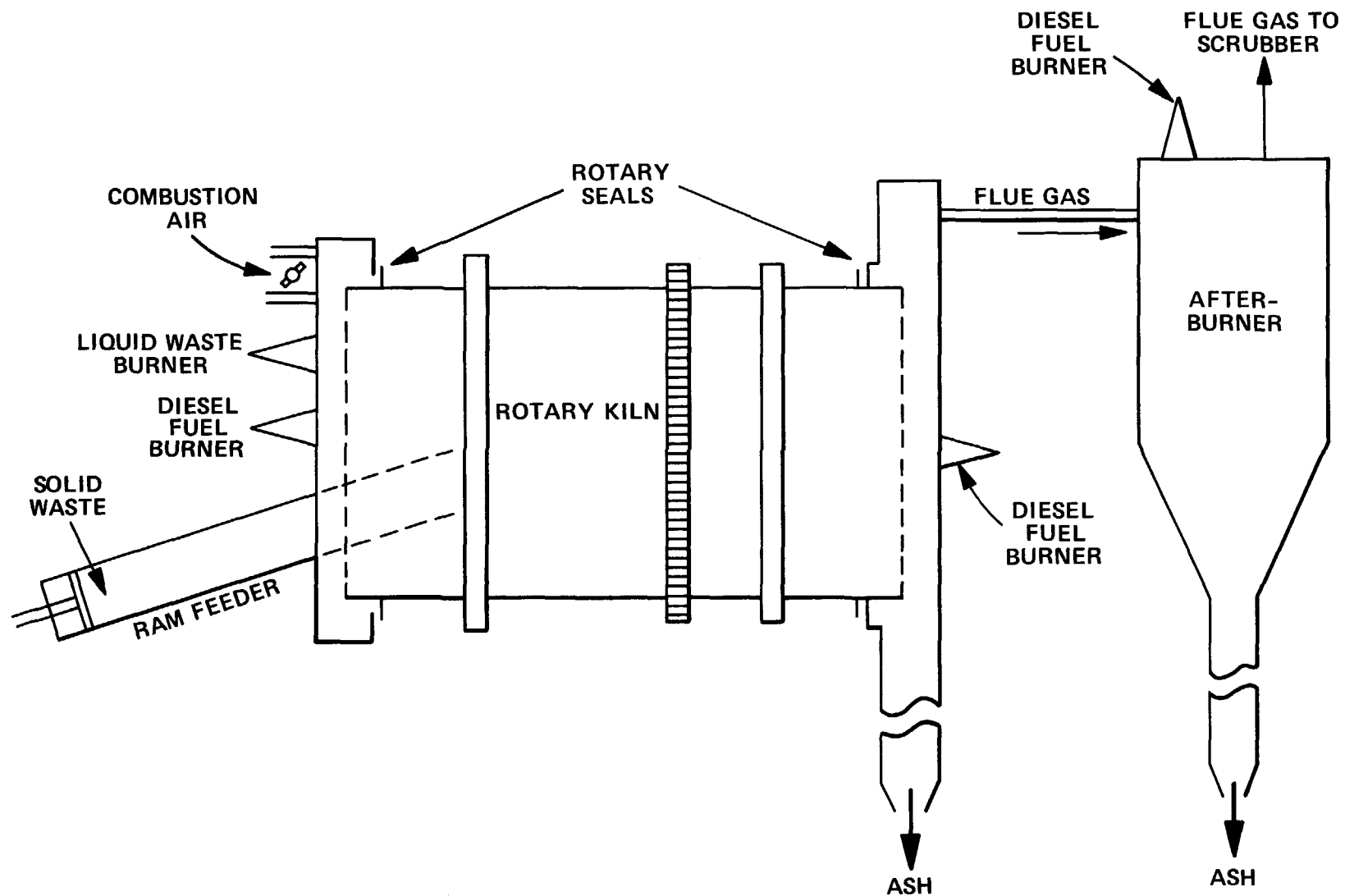


FIGURE 2  
H. S. A. WASTE INCINERATOR

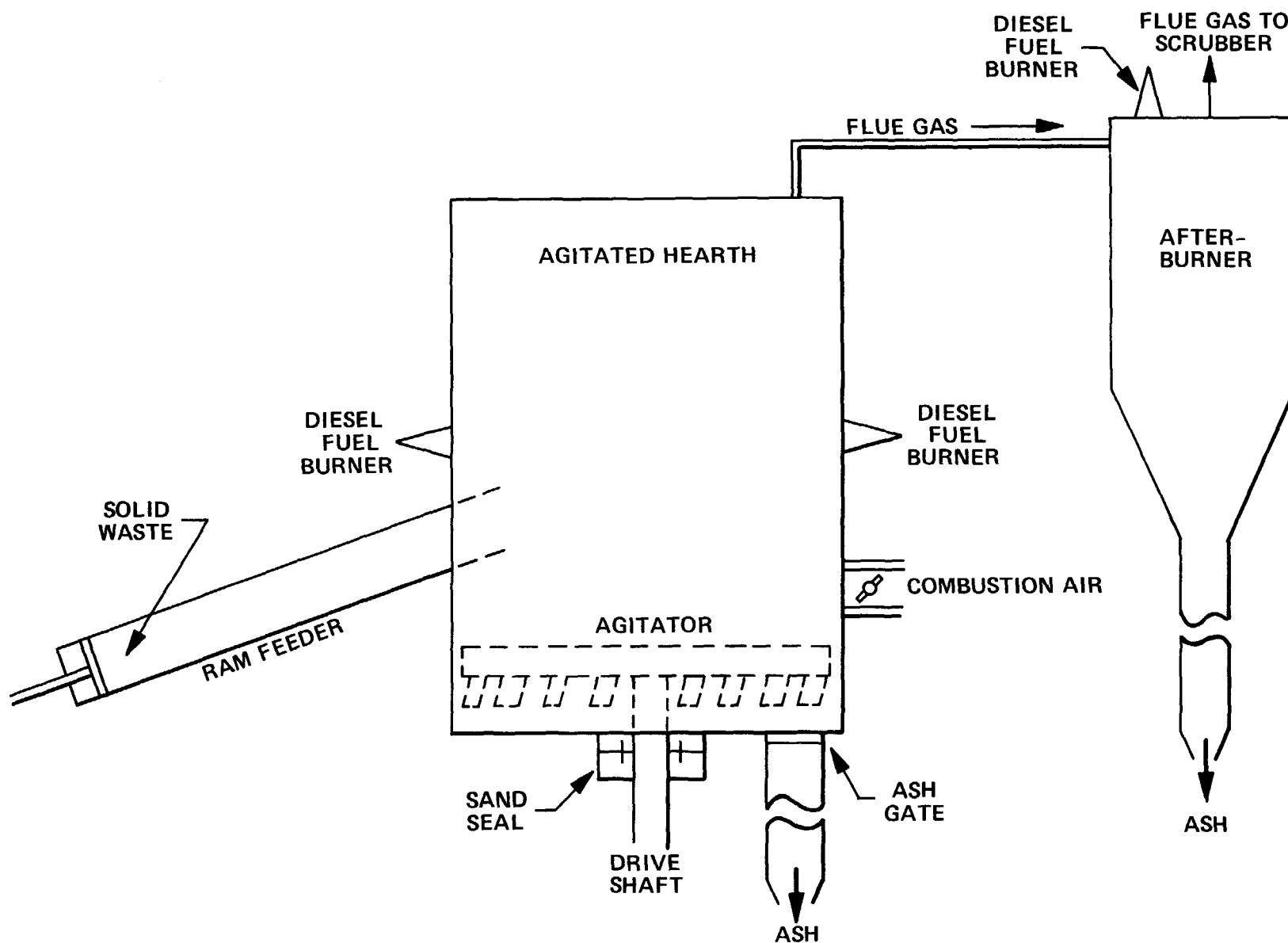


FIGURE 3  
L. S. A. WASTE INCINERATOR



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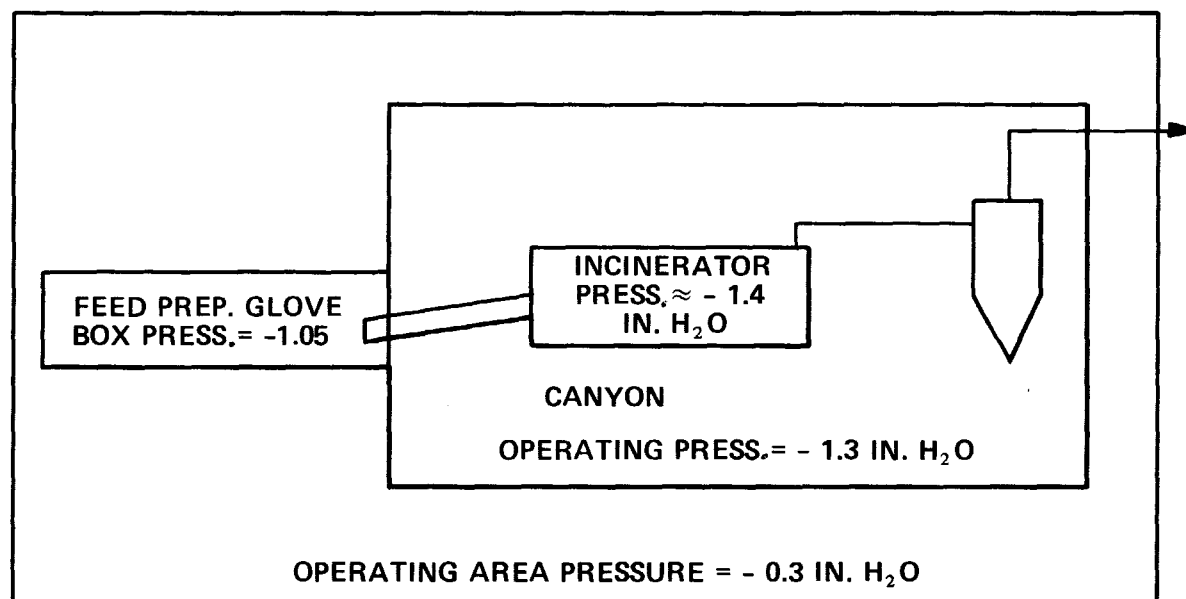
2. Burn-out Cycle - waste feeding will stop and the unit will be held at the operating temperature by combustion of supplemental fuel for about an hour to allow complete burn-out of the solid waste.
3. Ash Discharge Cycle - the ash discharge door will be opened and the ash raked out by the rotation of the rabble arm over a one-half hour cycle period. After the ash discharge the unit can be returned to the feed cycle.

The single hearth unit was selected for the LSA application primarily for its automatic ash removal system and with the hope that extended refractory life will be obtained with a stationary unit.

The afterburners and scrubbing equipment for each incinerator system will be quite similar except that the scrubbing equipment for the HSA unit will be dimensionally restricted to provide the desired nuclear safety features. Each system consists of two stages of scrubbing. For each stage, the gas passes through a high energy venturi and a cyclic separator incorporated as a part of an absorption column. A caustic solution will be used in both stages of the LSA system and in the second stage of HSA scrubbing. The primary stage of the HSA system will operate with a dilute hydrochloric acid solution. This acid system will be used because it extends the life of raschig rings used in the column and because a smaller volume of waste solution will be generated compared to that of a caustic system. Because of the high concentration of polyvinyl chloride in the solid waste and the chlorinated solvents in the liquid waste, a large amount of HCl will be generated in the HSA incinerator.

### Radioactive Material Containment.

The incinerators will be installed in a canyon. All major maintenance will be performed by personnel in pressure suits from inside the canyon. Operation of the incinerators will be performed by personnel from outside the canyon with the aid of remotely operated valves and mechanical devices. Fig. 4 shows the pressure levels of the equipment in relation to the building exterior pressure. Any air leakage should be from the operating area to the feed preparation glovebox or the canyon. The incinerator will be maintained negative to both the canyon or the feed preparation area. Pressure differential controllers will be used to maintain the desired pressure level in the operating area, glovebox, and the canyon. Each of these areas are equipped with independent exhaust ventilation systems. The desired negative pressure in the incinerator will be maintained by controlling the flue gas flow through the scrubbing system.



BUILDING EXTERIOR PRESSURE = 0.0 IN.  $H_2O$

FIGURE 4  
INCINERATION PROCESS OPERATING PRESSURE LEVELS

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The two stages of scrubbing are expected to remove greater than 99.95% of the fly ash contained in the flue gas. The flue gas will then pass through four stages of HEPA filtration for final decontamination prior to release to the atmosphere. The scrubber will be equipped with a bypass system such that either stage would be bypassed to maintain the desired pressure in the incinerator during a malfunction of a scrubber. Under these conditions, the incinerator would be put on stand-by operation. That is, all waste feeding would be stopped and only supplemental fuel would be used to maintain a suitable stand-by temperature until the malfunction could be corrected.

### Nuclear Safety Features.

An inventory of nuclear material will be maintained around the incinerator system. That is, all feed will be assayed and all ash, scrub solution, and HEPA filters exiting the system will be assayed for plutonium content. The main nuclear safety criteria relies on maintaining the materials in the incinerator in a dry non-reflected condition. To accomplish this objective, at least two independent sensing devices must be satisfied before liquids can be introduced into the incinerator. If either a flame failure should occur or the operating temperature of the unit should drop below 600°C, all liquid fed to the unit would be automatically locked out. The solid waste feed would also be locked out. The liquid feed referred to above includes the diesel oil feed as well as the liquid waste feed to the HSA unit. A gravity overflow system will be used to prevent any possibility of liquid scrub solution from flowing back to the incinerator. Before any solution could flow back to the incinerator from the scrubbing system, the malfunction would be sensed by several devices such as level indicators and pressure differential controllers. Because of the elevation difference between the incinerators and the scrubbing system, the scrubbers would become completely liquid filled and inoperable before the liquid could be forced back to the incinerators.

In both incinerators, the ash will be distributed in a thin layer during operation. On the rotary kiln, a torque measuring device will be used to sense any malfunction of the kiln rotation. This should sense any major bearing failure as well as any large accumulation of material in the incinerator. Remotely operated cameras will be used to physically observe the inside of the primary combustion chamber of the incinerators and the afterburners.

In the scrubbing system, multiple sensing devices, dimensional limitations and borosilicate rashig ring packing will be used to maintain the desired nuclear safety conditions. In the HSA scrubbing system multiple parallel venturies will be used to limit any void to less than six-inch diameter or a slab to less than two-inch thickness. Larger voids which could become filled with liquid are

protected with either borosilicate raschig ring packing or a gravity overflow system. Because of the trace quantities of plutonium in the LSA system, the dimensional limitations are somewhat less restrictive and multiple parallel venturies will not be required.

## Fire and Explosion Protection.

The major potential for uncontrolled fire hazard would be in the feed preparation glovebox area. An obvious ignition source for the combustible material would be through the charging mechanism to the incinerator. To minimize this potential, a sealed charging device will be used. There will be a door at the incinerator and another at the glovebox. These doors are designed so that only one of these doors can be open at any given time. The door at the glovebox will be opened and a waste charge placed in the ram-type feeder. The door then must be closed before the ram feeder can be activated. As the ram approaches the incinerator wall the second door will open and the waste will be discharged into the combustion chamber. As the ram returns, the incinerator door will close as soon as the ram clears the door. It may be possible for some of the waste to stick to the ram face and return open flame in the feeder. The ram chamber is equipped with an inert gas purge system which will be used to extinguish flame in the chamber if this proves to be a problem. The glovebox will be equipped with a sprinkler system to extinguish fire that could occur in the feed preparation area. Because of Nuclear Safety considerations, a dedicated water supply for the sprinkler will be used to limit the volume of water used.

The major potential for explosion in the incinerator would result from accumulation of a flammable gas mixture in the system. This potential is prevalent during start-up conditions and periods of power interruption. The start-up procedure will be in accordance with Fire Insurance Association (FIA) safety practice. That is, the unit would go through an established purge cycle before ignition could be attempted. If ignition is not obtained within the specified time, the purge cycle would have to be repeated before a second attempt could be made. Once ignition has been obtained, heat-up would proceed with oil fuel combustion using a keylock override system until the incinerator reaches minimal temperature conditions. Once this condition has been obtained, the unit will be operated with the fire safety features on automatic. This means that either a flame-out or temperature falling below the minimal temperature conditions would lock out all liquid feed to the incinerator, including the fuel oil. If the fuel should be locked out because of either of the conditions, two methods of reignition would be available:

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1. The unit could be cooled down and purged prior to reignition.
2. The gas from the unit could be analyzed to determine that it is free from flammable concentrations of hydrocarbons. The unit could then be reignited by a keylock supervised override ignition procedure.

The units will be equipped with automatic gas sampling and analyzing systems for the primary combustion chamber and afterburner in both incinerator systems.

Once the units are operating, burning solid waste, it is desirable to continue operation and avoid shutdown while the primary combustion chamber contains solid waste. In an effort to provide the desired reliability, all the equipment in the incinerator process is tied into an emergency power generating system. In the event of a power failure, the emergency generator would be activated. The emergency generator will be powered by gas turbine which will require 60 seconds to restore power to the incinerators.

A 60-second power delay was evaluated to determine the process hazards which could result. From tests made on a pilot plant rotary kiln incinerator, it was determined that some waste burn or decompose quite rapidly at 800°C. By scaling the change rate and size from the production unit design conditions to the pilot unit, the tests indicated that polyvinyl chloride, latex surgeons gloves, and ion exchange resin burn or decompose about four times as fast as the paper waste. These data were used to determine the minimum gas flow required through the incinerator to avoid any pressurization. These data were also used to evaluate the rate of combustion of oxygen in the kiln during a 60-second power interruption. Using the kiln dimensions (72 inches ID x 15 feet long) and assuming that five pounds of latex gloves were charged just prior to flow stoppage, the oxygen in the kiln could be consumed in about 14 seconds. In another 15 seconds the pyrolyzing waste could fill the unit with hydrocarbon vapor which, when mixed with an equal volume of air, could produce a flammable mixture. Since calculations indicate that potentially hazardous conditions could exist in 30 seconds after interruption of flow, a one-minute power interruption was considered unacceptable.

Several alternatives were considered to alleviate this potential explosion hazard:

1. The unit could be sealed in and cooled down. Then the flammable hydrocarbons could be purged from the system through the scrubbers and the filter plenum. There are several disadvantages to this approach such as the rotary seals on the unit will leak, letting flammable vapor escape into the canyon and then as the unit cools, air could be

drawn in, producing flammable conditions. If a purge is used to prevent air in-leakage more vapors would be expelled into the canyon. Even if the seals were considered adequate and leakage acceptable, the flammable mixture would have to be purged through the scrubbing and HEPA filtration system which presents some associated hazards.

2. Pressurized air or oxygen enriched air could be fed to the unit to sustain combustion until power could be restored. The major problem would be that the incinerator would be pressurized and gross contamination would be expelled through the seals into the canyon and some consideration would have to be given to the possibility of pressurizing the canyon. This approach may alleviate the explosion hazard but would present major potential contamination concerns.
3. The normal flow through the incinerator could be maintained through the use of either flywheels on the fans or by an alternate motive force such as steam jet ejectors. This system would provide for combustion of the flammable vapors, eliminate pressurization of grossly contaminated equipment, and would eliminate the need for a time-consuming and costly shutdown of the equipment. Steam jet ejectors were selected as the best alternative and will be installed to provide motive force for gas flow through the incinerator system during the power interruption prior to activation of the emergency power system.

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### DISCUSSION

BROOKS: This question may not be particularly relevant to the paper but I think it applies. Somewhere down the line in your project do you have as an objective reclamation of other materials?

ZIEGLER: At the present time we do not plan to recover any of the other nuclear materials involved. Certainly, in the long range it will pay to look at the materials that can be reused. I think in terms of decreasing the generation of waste as probably the most fruitful method of eliminating the amount of material that is contaminated.

FREEMAN: Are you using a refractory in either of these incinerators?

ZIEGLER: Yes, our incinerators are refractory lined.

FREEMAN: Another question: Could you give me an idea of the percentage of PVE?

ZIEGLER: 50 percent.

FREEMAN: In your facility, there are an awful lot of bag-outs between the glove boxes. In the new facilities, the amount of PVE generation should go down.

ZIEGLER: At the present time, that is where the majority is coming from, bagging from one glove box and introducing it into another.

FREEMAN: I understand that. Polypropylene plastic material will reduce your gaseous problems.

ZIEGLER: Yes, we are looking for other materials. We haven't found anything yet that gives us the required servicability.

FREEMAN: Why did you use a gas-driven generator instead of a Diesel which will start in 10 seconds?

ZIEGLER: Perhaps I will let Al Oliver or someone else in the audience answer that. I wasn't involved that much in selecting that equipment.

FREEMAN: As I understand it, the gas turbine was supposed to start as fast as the other equipment but I could be wrong.

BARLOW: In the event of an explosion in your combustion chamber, are you taking any steps to protect your HEPA filters or are you prepared to bypass to another set of filters?

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ZIEGLER: I don't believe we have a bypass system for HEPA filtration. We do have bypass capacity around the scrubbers. If a malfunction should occur in one scrubber, the gas can be bypassed to the other scrubber.

FREEMAN: You are going to lose the HEPA filters if an explosion occurs. There is no doubt about that.

ZIEGLER: There is a hatch that is going to release the pressure in the incinerators into the canyon itself.

FREEMAN: The shock wave is going to reach the HEPA filters before any protective measures can be instigated.

ZIEGLER: If that is true, the gases can be bypassed to other filters.

FREIBERG: In answer to the turbine generator question, after numerous tests between Diesel and gas turbine, we decided on the basis of public health and earthquake problems to go to the gas turbine. The studies generated a great deal of data that I could furnish to you. In answer to the question about HEPA filters, we tried to eliminate the possibility of an explosion by providing a system which will always provide ventilation to pull the vapors and gases out of the incinerator during the burning process. We don't feel there will be an explosion. If there is an explosion, as far as HEPA filtration is concerned, that system will be shut down. It will tear out the HEPA filters. I don't believe the explosion will be so great that a lot of that explosion is going to be ducted into the canyon area, which is quite large.

FIRST: I am interested in the design philosophy of the incinerator system you show and the air cleaning devices associated with it. You are getting your waste in about six different streams with this system, which strikes me as being a poor way to do it. It would seem to me, also, that you are not only generating a solid waste but also a liquid waste which is going to be difficult to handle. With a large amount of PVC being burned, plus chlorinated hydrocarbons, there will be a corrosive atmosphere that is difficult to cope with over long continuing operations. More particularly, when a system operates intermittently, corrosion takes place at a faster rate. It has been my impression that the principle to follow with this kind of system is to burn in the gas phase and route all solid residue to one or possibly two dry cleaning systems, thereby minimizing the number of waste streams and associated problems. I would be delighted to have your comments on this.

ZIEGLER: I agree with you. We have operated an incinerator for 14 years at this plant and short refractory life combined with the complexity of the system have all been disadvantages. We are presently involved in an incinerator development effort in which we will attempt to catch the residues in a sodium carbonate bed and collect the airborne particulates in a dry filtration system. We



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ZIEGLER (cont.): will also do the burning at a temperature low enough to maintain the refractory. In general, I agree with you, and development work is progressing along these lines. Unfortunately, at the time we had to prepare the design criteria for the new facilities, we weren't far enough along in our development. There are probably better ways of doing it.

DEMPSEY: A number of problems have been brought out by this discussion. It was announced this fall that it looks as though it is going to cost more to deliver the HEPA filter for waste disposal than it cost in the first place. One further point. The solid waste people are converting their waste to gaseous form whereas the gaseous waste people are converting their waste into solids. We give it to them in one state and they convert it to another in order to give it to someone else, but we are all in the same boat in the waste business.