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THE CONTINUOUS INCINERATION OF
PLUTONIUM-BEARING SCRAP

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MASTERTHE CONTINUOUS INCINERATION OF PLUTONIUM-BEARING SCRAP

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Richland, Washington, U.S.A.INTRODUCTION

The Atlantic Richfield Hanford Company at Richland, Washington, has a contract to operate the chemical processing facilities for the Atomic Energy Commission. Irradiated fuels and target materials are dissolved and elements of interest are separated and purified by the Purex process. Much of the plutonium nitrate solution produced is processed further to oxides or metal. Plutonium-bearing scrap, much of which is bulky and incinerable, is a normal by-product of the processing, and the quantities of plutonium are often economically attractive to recover. A Contaminated Waste Recovery Facility, which included both incineration and leaching equipment, was built in 1961 to recover plutonium from these scrap materials. During eight years of operation, a considerable amount of practical experience has been gained and used to improve the performance of the unit.

DESCRIPTION OF PROCESS

The incinerator was designed for continuous operation, with emphasis on (a) reducing the size of the unit to glove box proportions, (b) minimizing the problems of contamination control while charging feed, and (c) using geometric limitations wherever possible to assure criticality prevention.

A flow diagram of the process is shown in the first slide. Waste-filled cartons are introduced through an airlock into a sorting hood. Sorting is manual. Leachables are fed to a leach hood. Some waste, tools, sharp objects, etc., are discarded after the absence of economically recoverable plutonium has been confirmed by gamma or neutron counting. Smooth metal objects, for instance, may be wiped with rags and discarded. The rags are then incinerated.

Most all of the plastic and rubber materials, including gloves, are treated as noncombustibles because of the large amount of soot formed in burning and because of the corrosion resulting from chloride release. The noncombustibles are leached in nitric acid in trays or in steam-heated pots. The leached scrap is discarded after evaluation of plutonium content.

Combustibles are shredded in the chopper and conveyed on a belt to the incinerator, where a second belt carries them through the primary combustion chambers. The off-gas passes through a secondary combustion chamber and then through two cyclone separators in series. Ash from the cyclones and combustion chamber is collected in small iron cans and transferred to dissolution and reprocessing facilities elsewhere. The off-gas is treated by scrubbing with a counter-current spray of sodium hydroxide to neutralize acidic gases. Small amounts of urea are used to neutralize hypochlorite, which is generated when burning some plastics. Cooling is effected in the scrubber by circulating the sodium hydroxide through water-cooled heat exchangers. When the scrubber solution is spent, the plutonium content associated with the fine solids in it approximate 0.05 to 0.1 gram per liter. Provisions were made for filtration of the plutonium-bearing fines in the leach hood.

The cooled off-gas from the scrubber is heated above its dew point by an electric heater to prevent condensation of moisture on the high-efficiency filters. The blower, pulling a slight vacuum on the entire system, discharges to the main building stack via two more high-efficiency filters in series.

DESCRIPTION OF EQUIPMENT AND CONTROLS

A cutaway of the Contaminated Waste Recovery Facility in the next slide shows the principal features of the incinerator, the leach hoods, and the off-gas system. The chopper is a rotating drum with blades set in the periphery, parallel to the axis. The chopper has given excellent service on rags, papers, plastic, wood, and asbestos filter elements.

The feed conveyer is a conventional cleated rubber conveyer belt with a variable speed drive. The furnace belt, which is also equipped with a variable speed drive, is woven of Nichrome-V wire, an 80 percent nickel - 20 percent chromium alloy.

The furnace is three meters long and is fabricated of Incalloy 800 (32 percent nickel, 20.5 percent chromium, and 46 percent iron alloy) and 321 stainless steel (a steel of 17 - 19 percent chromium and 8 - 11 percent nickel). The lower horizontal member is a semicylinder 20.3 centimeters in diameter, with a flat bottom which serves as a floor for the furnace belt. This is the primary combustion chamber. Above this, four flue risers connect with the upper (or secondary) 12.7 centimeter diameter combustion chamber. The furnace is shielded by 45 centimeters of firebrick insulation and the whole unit contained in a stainless steel gloved box.

The incinerator target temperature of 700 - 800° C is controlled primarily by the voltage applied to three 32 kw resistance heating elements. Feed rates and the incinerator belt speed also have an effect on temperature control. Residence time in the combustion chamber averages eight minutes. Air flow to the primary and secondary combustion chambers, indicated by rotameters, is approximately 0.2 cubic meter/minute.

The incinerator off-gas discharges through a combustible gas analyzer set to alarm at one percent combustibles in the off-gas. There has been no confirmed alarm from this analyzer. The gas then discharges through two cyclone separators in series. A small adjoining room houses the off-gas scrubber, which is 0.35 meter inside diameter by 2.7 meters high, set on a 0.75 meter diameter by 0.70 meter high pump tank. The scrubber contains a quench spray section, two impingement baffles, and a high velocity baffle plate stage. The original moisture de-entrainer (vane type) has been replaced with a tetrafluoroethylene mesh de-entrainer. Construction is 316 stainless steel throughout (10 - 14 percent nickel, 16 - 18 percent chromium, 1.75 - 2.5 percent molybdenum steel). Two heat exchangers cool the circulating sodium hydroxide solution. Rated efficiency of the scrubber system is greater than 90 percent for all particles larger than 0.3 micron in diameter.

Air flow to the scrubber includes both the incinerator off-gas and the leach hood exhaust. It is regulated for proper scrubbing action by a butterfly valve in the leach hood exhaust line. Rotameters indicate

the scrubber liquid flows to the top inlet, the plate spray, and the quench spray. Differential pressure gages on the scrubber are used to indicate plugging.

SAFETY CONSIDERATIONS

The many safety problems associated with a nuclear facility in which corrosive acids and high temperatures are involved required special attention in design. The prevention of criticality, fire, contamination spread, and personal injuries are among the more important.

Several techniques are used to provide for criticality prevention in the facility. The leach pots, conveyer, and incinerator are of limited geometry. The leach hood, chopper enclosure, and scrubber are equipped with neutron monitors and alarms. Administrative controls are also used successfully to prevent undetected accumulations of plutonium. These controls include maintenance of a running inventory, with clean-outs required at specified limits, frequent monitoring with portable gamma counters, and monthly inspection of pots and jackets.

Some question of the possibility of plutonium accumulating in the space between the incinerator and the surrounding firebrick has been raised by engineers since start-up. While accumulation of an amount sufficient to cause a nuclear incident is highly unlikely, during repairs to the incinerator proper, gamma and neutron surveys and inspection have been used to confirm this judgment. No accumulations of plutonium have been found in these areas.

The most difficult contamination control problem arises as a result of the frequent contact maintenance necessary on the off-gas system. This system, including the scrubber, is too large for containment in glove boxes. Physical entry into the contaminated room area is required, with attendant multiple layers of protective clothing and fresh-air masks. There are similar severe contamination control problems associated with repair of the incinerator proper. During these repair periods, temporary containment barriers of sheet plastic are constructed around the equipment being worked upon to control and limit the spread of contamination.

One of the most serious hazards in this facility is that of fire, and glove box fire protection equipment has been improved to a high degree of effectiveness. Despite all precautions, several brief localized glove box fires have occurred in the feed end of the

incinerator and the chopper effluent hopper. These fires were caused by flashback from the incinerator. A wire screen placed in the feed end of the incinerator has been very effective in preventing flashback. Also, nitrogen is added at the primary combustion chamber inlet to help prevent flame blow-back.

The chopper enclosure is protected with heat sensing elements which activate an alarm when heated to 88° C. At the same time, a limited (by criticality prevention considerations) supply of water is applied automatically in the enclosure through four spray nozzles. The system may also be operated manually. All glove boxes are fitted with attachments to allow introduction of carbon dioxide or dry chemical (sodium carbonate) from external portable extinguishers. Glove ports near the incinerator are protected with heat shields at all times it is in operation.

The entire building is provided with fire detectors which activate alarms in appropriate locations, including the area's central fire department. In addition, there is an automatic CO₂ extinguishment system of the total flooding type which protects the storage room housing boxes of scrap awaiting processing.

Protection for the operator's hands was provided by equipping the chopper with two "start" buttons widely spaced on the exterior of the glove box. These must be pressed simultaneously to start the chopper. Thus, the operator must remove both hands from the vicinity of the chopper before he can start it.

MAINTENANCE

The more serious maintenance problems have included furnace failures, inadequate temperature control, accumulation of solids in the off-gas system, and short furnace belt life. In 1963, the original combustion chamber failed and was replaced.

The original incinerator was a one-piece unit welded from sections of cast high temperature, high nickel alloy steel. This incinerator was removed when massive fractures of the chamber occurred after one year of operation due to the effects of thermal expansion and contraction. After 22 more months, failure occurred a second time, prompting complete redesign of the combustion chamber to eliminate differential thermal expansion stresses between its various members. This is shown in the next slide. The redesign eliminated the all-welded construction, and in its place, ball and socket and slip joints

were installed at the top and bottom of each of the flue tube risers. This unit performed for only nine months when stress corrosion cracking occurred. The furnace was constructed of Incalloy 800, both wrought and cast.

Investigation revealed that the cause of failure was high temperature and temperature cycling outside the 700 - 800° C range as a result of excessive feed rates. Further, in a portion of the combustion chambers, a rotationally cast Incalloy 800 material was used which had extremely large grain structure. These sections were replaced with wrought 321 stainless steel. In addition, temperature sensors were moved from the exterior wall of the incinerator and placed directly in the off-gas. This provided improved control because of its faster response. This incinerator has been running for two years without failure, with down time necessitated only by problems with the off-gas treatment equipment.

Stretching of the wire mesh furnace belt is a recurring problem, but has been reduced by selection of improved alloys. Addition of a positive belt drive was also helpful, and this was achieved by adding spots of weld metal on the drive drum. More careful attention during sorting, to keep tramp metal out of the choppers and belts, has been helpful. Belts currently in use cost about \$500 and are giving up to six months of service before replacement is necessary. Changing of the incinerator belts is accomplished by spot welding a new belt to the old belt and pulling the new belt into position as the old belt is removed.

A continuing problem has been the lack of good air flow control through the incinerator. There is no direct control here, since total air input varies as the leach hood exhaust is varied, and this greatly affects the collection efficiency of the cyclones.

De-entrainer pads were added to the scrubber to reduce liquid entrainment to the filters. With a constant sodium hydroxide spray, these must be replaced every three to four weeks. Plugging occurs in two weeks if the spray is not applied continuously.

Cleaning the flue risers in the incinerator without dismantling the whole system was accomplished with ingenuity. A spade-shaped piece of carbon steel, known as a "knocker head" in the boiler industry, was threaded on a short flexible shaft. Entering from the end of the top combustion chamber, a curved piece of pipe around the shaft guided the spade into the vertical flues. Sections of rod are added to the

shaft to extend the spade to the furthest flues. Rotation of the spade is provided with a variable speed reversible motor and the flue is effectively freed of soot.

PERFORMANCE

Accurate assessment of the plutonium input is difficult because of the heterogeneous nature of the scrap. It is estimated that about 98 percent of the plutonium entering the facility is recovered in the ash and leach solutions. Unrecoverable plutonium is routed to underground storage. Only trace plutonium is found on the filters downstream of the scrubber through which air is exhausted to the stack. For the material actually incinerated, there is a volume reduction of 98 percent.

Leaching of the incinerator ash product in a mixture of boiling 9 - 10 molar nitric acid and 0.5 - 0.7 molar hydrofluoric acid has proved to be a fairly effective means of plutonium recovery. The filterability of the leached ash presents operating problems, as the residues are fine and have a pronounced tendency to blind filters. Filterability has not been consistently improved by use of various types of deflocculating agents or filter precoats. Recent experimental work indicates that poor filtration of ash leach solutions is caused in major part by incomplete combustion. When reburned for an additional 20 minutes, the ash loses about 25 - 30 percent of its weight. The ash from this re-ignition leaches more completely and is much more easily filtered.

Performance of the cyclone separators is variable and strongly dependent upon off-gas flow rates. Normally, it has been estimated that they remove about 98 percent of the solids in the off-gas. Occasionally their efficiency is almost negligible. Particle size data on these solids are not available.

Throughput rates are quite dependent on manpower availability because of the many hand operations in sorting, leaching, and belt-feeding. Full capacity operation requires a crew of four to five men per eight-hour shift. In this time, three 0.13 cubic meter boxes can be sorted and processed. Presently, the incineration and leaching of scrap is current with generation rates and excess capacity exists. It was estimated that economic payout of the facility was achieved during its first year of operation.

On the basis of experience to date, there are two recommendations to be made in the design of a new facility. First, there should be improved access to the system for clean-out of the flues and combustion chambers. Second, more positive controls on air input to the incinerator are required to provide better control of off-gas handling and to provide uniformly high cyclone efficiency. Better air controls, coupled with increased residence time in the incinerator, would provide more complete combustion and, in turn, would enhance subsequent dissolution of the ash.

Taking into account the rugged nature of the process and the equipment requirements, it has been concluded that the large-scale incinerator and leaching facility described has contributed materially to the recovery of plutonium-bearing scrap in the Atlantic Richfield Hanford Company at Richland, Washington.

ILLUSTRATIONS ATTACHED

FIGURE 1: CONTAMINATED WASTE RECOVERY FACILITY
(Process Flow Diagram)

FIGURE 2: CONTAMINATED WASTE RECOVERY FACILITY
(Cutaway)

FIGURE 3: INCINERATOR FOR PLUTONIUM RECOVERY

CONTAMINATED WASTE RECOVERY FACILITY

FIGURE 1

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FIGURE 1

CONTAMINATED WASTE RECOVERY FACILITY

(Flowsheet)

FIGURE 2

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FIGURE 2

CONTAMINATED WASTE RECOVERY FACILITY

(Cutaway)

INCINERATOR FOR PLUTONIUM RECOVERY

FIGURE 3

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FIGURE 3

INCINERATOR FOR PLUTONIUM RECOVERY