TWO CHEMICAL INCINERATOR PLANTS
WITH BY-PRODUCT RECOVERY

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ABSTRACT

Two special-purpose incinerator plants are described. One is designed to handle sodium-bearing hydrocarbon residues. It recovers the ash from the incineration process as sodium carbonate, or soda ash—a marketable by-product. The other plant handles a broad spectrum of wastes including many which contain silicon compounds. The fume silica produced from burning such wastes is collected in a wet electrostatic scrubber which represents relatively new technology. Precious metal catalysts are recovered from the solid wastes. In both cases, the recovery of by-products is incidental to the primary objective of the plants, but the recovery is economic.

INTRODUCTION

Chemical plants utilize many types of incinerators to destroy waste residues by thermal oxidation. This paper will discuss two special-purpose incinerator plants of differing design. Both of these plants provide for the recovery of valuable by-products from the thermal oxidation of chemical residues, and one recovers some heat as well. The main function of each of these plants is to destroy the residues in an environmentally acceptable manner. The recovery of by-products is incidental to this main function; however, such recovery does partially offset the cost of operating the incinerator plants.

For each of the incinerator plants, the waste residue streams will be characterized, the design basis will be outlined, and the equipment configuration will be described.

This paper is intended for presentation at the Seventh National Waste Processing Conference and Exhibit on May 23-26, 1976. Actual operating experience on at least one of the plants will have accumulated by that date and may be reported then as part of the part of the presentation.

AN INCINERATOR PLANT FOR
SODIUM BEARING RESIDUES

BASIS FOR DESIGN

Many petrochemical manufacturing processes use caustic soda either as a raw material or as a chemical additive at some point in the process. The waste residues from such processes consist primarily of hydrocarbon liquids which have a substantial heating value and would otherwise make a satisfactory fuel for boilers or process heaters. However, the sodium content, although small, often makes these residues unfit for combustion in conventional fireboxes. Sodium concentrations as low as 0.1 percent cause deterioration of most refractories including those of premium grade. High concentrations of sodium can cause extensive slagging and bridging on the fireside of the heat transfer surfaces.

The author's company has initiated a project to provide an incinerator plant to handle several...
waste hydrocarbon streams contaminated with sodium. The sodium concentrations range up to 9 percent by weight. The hydrocarbons have varying physical properties, some resembling No. 2 fuel oil and others being viscous liquids at ambient temperatures.

The design feed rate is 17,600 lb/hr (7980 kg/hr) of residue, and the design maximum heat release rate is 91 M* Btu/hr (27 MJ/s) including input from the residue, pilot fuel, and supplementary fuel.

DESCRIPTION OF FACILITIES

A scale model of the plant is shown in Figure 1. It consists of a vertical, cylindrical thermal oxidizer fired with four horizontal burners arranged 90 degrees apart at its base. The thermal oxidizer is 12 ft. (3.7 m) in diameter and approximately 30 ft (9.1m) high. Each burner is 53 in (1.3 m) in diameter and approximately 7.5 ft (2.3 m) deep.

The liquid residues are fired in each of the four burners simultaneously. Each burner has two guns, each capable of burning 5 gpm (0.3 1/s) of residue.

Each burner also has a supplementary fuel gas ring rated at 10 M Btu/hr (3 MJ/s).

The products of combustion converge in the base of the thermal oxidizer, turn from a horizontal path to a vertical path, and travel up and out the thermal oxidizer where they pass into a conditioning tower mounted on top of the oxidizer. The conditioning tower is approximately 10 ft (3.0 m) in diameter and 40 ft (12.2 m) high. Water is injected into the conditioning tower to cool the combustion gases and lower the resistivity of the particulate matter before introduction into a conventional electrostatic precipitator.

The electrostatic precipitator is 99.85 percent efficient. The design ash collection rate is 1500 lb/hr (680 kg/hr). After the gases leave the precipitator, they flow into a heat exchanger where low-level heat is recovered in circulating water. The gases then flow into a stack.

The figure does not show all the supporting systems in the plant. One system of tanks and pumps stores the sodium-bearing residues and feeds them to the burners. Another system processes the ash collected in the electrostatic precipitator.

A few other minor points may be of interest on this incinerator design. The four burners at the base of the thermal oxidizer are equipped to

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*In this paper, the abbreviation "M" denotes million and "k" denotes thousand.

FIG. 1
use either steam or air atomization. Test work with various residues indicated that some burn better with air atomization, but steam is more economical. Field tests will be conducted to confirm the optimum atomization medium for each residue.

The conditioning tower has sixteen spray nozzles to control gas temperature. To give good turn-down capability, various clusters of nozzles are put in service as needed by an automatic programmer operating from a temperature controller. Clean steam condensate is used for the spray water.

**OPERATING CONDITIONS**

At the conditions controlled in the thermal oxidizer, the sodium present in the hydrocarbon wastes is converted to sodium carbonate. The temperature is controlled at 1800°F (982°C). At this temperature, the attack on the refractory is minimized, although not entirely eliminated. Fuel gas is introduced in each of the four burners. The temperature is controlled by increasing fuel gas flow to increase temperature, and by injecting water into the thermal oxidizer immediately above the burners to decrease the temperature.

The gas temperature leaving the conditioning tower is controlled at 650°F (343°C) by additional water injection. After further cooling in the heat exchanger located downstream of the precipitator, the flue gas enters the stack at 400°F (204°C).

The entire unit is instrumented for automatic operation, although there will be an operator present. It will trip all fuel if the gas temperature exceeds 2200°F (1204°C) at the thermal oxidizer outlet, or 750°F (399°C) at the conditioning tower outlet. Each burner has a full time flame scanner which trips only the respective burner upon loss of flame. An oxygen and combustible analyzer is installed in the breeching at the precipitator outlet. This analyzer is not in control of the fuel gas flow but it does alarm and shut down the unit in the event high combustibles are detected. The stack is fitted with an opacity meter which also alarms and shuts down the unit in the event that the emission exceeds 10 percent opacity.

**BY-PRODUCT RECOVERY**

As mentioned before, the ash collected in the precipitator is essentially all sodium carbonate. Sodium is the only inorganic element present to any appreciable extent in the waste residues. The remainder consists of organic compounds which completely burn in the thermal oxidizer. The sodium carbonate (soda ash) produced in the thermal oxidizer and collected in the precipitator may contain trace amounts of metals or other inorganic materials, but its chemical properties are suitable for many processes that utilize commercial-grade soda ash.

The ash may be marketed for a variety of end uses. It can be further processed, if necessary, to make its physical properties similar to commercial grade soda ash. This may require agglomeration of the particles to form a larger particle size. Test work has indicated that the particle size expected in the electrostatic precipitator hopper will be in the range of 0.1 to 6 microns (μm). Commercial glass grade soda ash has a size range of 150 to 600 microns (μm).

**A VERSATILE MULTIPURPOSE INCINERATOR FOR SOLIDS AND LIQUIDS**

**BASIS FOR DESIGN**

In another chemical plant, a broad variety of residues are generated ranging from solids through semisolids and gels to liquids. Some of these residues are relatively clean solvents and can be used as reliable supplemental fuel. Others have widely fluctuating compositions. The solids generally consist of filter cake saturated with hydrocarbons and the usual mixture of general plant trash. The incinerator plant is extremely versatile and can handle all these wastes in various combinations.

The wastes are delivered to the incinerator plant in metal drums, fiber drums, paper boxes, dumpster boxes, dump trucks, and by pipeline. The pumpable liquids are stored in storage tanks. Five different storage tanks ranging from 4,000 gal (15 m³) to 10,000 gal (38 m³) in capacity are provided for pumpable liquids and emulsions. Non-pumpable semisolids and gels, and some special solids, are stored in their collection containers — drums or boxes. Bulk solids are stored in large below-grade concrete hoppers: one for filter cake and one for general plant trash.

The overall design rating of the plant is 72,000 lb/day (33,100 kg/day) of waste materials and 42 M Btu/hr (12 MJ/s) heat release rate. At full rating, it will operate 24 hr/day, 8000 hr/yr.
DESCRIPTION OF FACILITIES

The basic incinerator plant is schematically shown in Figure II. The primary combustion chamber is a rotary kiln. The kiln is 10 ft (3 m) in diameter inside the refractory and 27 ft (8.2 m) in length. Solids, semisolids, and liquid residues are fired in the kiln. The feed end of the kiln is fitted with a hydraulic ram feeder for bulk and containerized solids, and with atomizing guns to fire pumpable liquids. Viscous liquids and lighter liquids are fired in separate burners. Either air or steam atomization is used, depending on the characteristics of the residue. Supplemental fuel gas or clean liquid solvent is also fired in the feed end of the kiln for temperature control.

A clam shell bucket on an overhead trolley hoist is used to transfer solid material to the ram feeder from the below-grade storage hoppers. The clam shell can pick up general plant trash from one hopper or filter cake from the other hopper. The feeder mechanism is isolated from the rotary kiln by a guillotine-type door with automatic sequencing controls and interlocks.

An unusual feature of this incinerator plant is its ability to burn containerized waste residues. Many of the materials collected at various places in the plant are transported to the incinerator plant in fiber drums or paper boxes. The kiln feeder has the ability to handle these materials by feeding them to the kiln in their containers without additional handling. Fiber drums are consumed in the kiln and the metal rims and closures are rejected in the ash hopper at the end of the kiln. This feature is extremely useful in the plant because some of the material tends to solidify after being put into the containers, making it difficult to remove. It also reduces the labor required to handle small items such as laboratory sample bottles.

The gases from the rotary kiln pass into the secondary combustion chamber, commonly referred to as the afterburner. The afterburner normally utilizes clean waste solvents as supplementary fuel. When such solvents are not available in sufficient quantities, fuel gas is used as the backup fuel. When they are in excess, part of them can be burned in the kiln.

The temperature at the outlet of the afterburner is controlled by either increasing the supplementary fuel to increase temperature or increasing the secondary (quench) air to decrease temperature.

The combustion gases pass from the afterburner into a quencher where water sprays reduce the temperature to about 175°F (79°C). The cool gases then pass to the packed tower scrubber. These gases often contain acid vapors. The packed tower scrubs these vapors from the flue gases and further reduces their temperature to about 100°F (38°C).

From the packed tower scrubber, the flue gas passes to a two-stage wet electrostatic scrubber. Each of the stages is identical and they are arranged in series. Many of the waste residues fed to the incinerator plant contain silicon compounds. When these compounds burn, they produce silicon dioxide, or silica. The flue gas produced from this combustion processes may contain fume silica with a particle size of 50 percent less than 1/2 micron (um). This very fine particle size requires special equipment for its removal. The two-stage wet electrostatic scrubber was selected for this purpose.

From the second stage of the wet electrostatic scrubber, the gas flows through an induced draft fan and on to the stack.

The packed tower scrubber and the wet electrostatic scrubbers, together with their interconnecting ductwork, are made entirely of fiberglass reinforced plastic. Water for the quencher, the packed tower scrubber, and the wet electrostatic precipitators is supplied from various wastewater streams collected within the plant. This wastewater is largely surface drainage, spent cooling water, and process water that has been neutralized and settled. The water in the wet electrostatic scrubbers is recirculated internally. The blowdown from the scrubbers is ultimately treated in a UNOX wastewater treatment plant on the site. The blowdown from the packed tower scrubber containing the acid is neutralized before it passes to the wastewater treatment plant.

The system has a number of safety features. There are multiple burners both in the feed end of the kiln and in the afterburner. Each burner is equipped with a full time flame scanner, which will shut down the burner in the event of loss of flame. In addition, the entire unit will be shut down if high temperatures are detected in the rotary kiln outlet, in the afterburner outlet, in the quencher outlet, or in the induced draft fan suction. If the water supply to the quencher or scrubber is interrupted, the unit will be shut down.

Loss of combustion air from the combustion air fan will shut the unit down, as will the loss of the induced draft fan. Because of the extensive use of FRP equipment, loss of quencher water is of paramount concern. A backup source of water...
from the plant firewater system is provided. The shutdown system also opens a damper on the top of the afterburner, venting the hot gases to the atmosphere, and closes a damper between the quencher and the packed tower scrubber.

OPERATING CONDITIONS

The facility is designed to handle up to 4000 lb/hr (1814 kg/hr) of solids and semisolids at the feed end of the rotary kiln. These materials range between 5 and 8 k Btu/lb (12 and 19 J/g). The burning rates cannot be at maximum for all materials at the same time without exceeding the heat release capability of the equipment, but the mix of materials and burning rates can be varied over a broad range.

The temperature of the flue gases leaving the kiln and entering the afterburner varies over a wide range, but normally is controlled in the range of about 1600 to 1800°F (871 to 982°C). The flue gas leaving the afterburner is controlled at about 2000°F (1094°C). The scrubber water circulated through the packed tower scrubber amounts to about 1421 gpm (90 l/s), and that circulated through the electrostatic scrubber is about 225 gpm (14 l/s).

BY-PRODUCT RECOVERY

Some of the solid material fed to the kiln is filter cake containing precious metal catalysts. The kiln is a particularly effective device for burning the hydrocarbons out of the filter cake because it provides vigorous agitation with hot gas flow through the agitated material. The filter cake ash is discharged out the end of the kiln into the afterburner which has a hopper bottom. It is collected in a small steel box fitted with a gas-tight filling nozzle. The box rests on a carriage that runs on rails so it can be easily moved and accurately positioned under the hopper. Because the precious metal is quite heavy and has a large particle size, very little is lost through entrainment in the combustion gases. The precious metal then is recovered as a dry inert solid. Filter cake can be burned in batches so that the precious metal is not diluted with inert materials of lesser value other than the diatomaceous earth filter media.

CONCLUSION

Because incinerator plants are nonproductive facilities, in the sense that they do not produce a product for sale, they often reflect minimum-investment designs. Both of the incinerator plants described above are designed to destroy waste residues generated by chemical plants that operate at high load factors on a continuous basis. These plants operate in compliance with strict environmental regulations; therefore, it is imperative that the incinerator plants have on-stream times comparable to the manufacturing processes they support. Although both incinerator plants are equipped with a certain amount of storage to allow for flexibility in their burning schedules, they do not have excess capacities that would permit long periods of downtime. Standards of quality in these incinerator plants for equipment, control systems, piping, electrical supply, etc., are comparable to the standards for the process units they serve. These standards determine the safety, operability, and maintainability of the incinerator plant and must be consistent with the production facilities at the same plant site.

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