DEVELOPMENT OF AN INDUSTRIAL WASTE INCINERATOR SYSTEM: PILOT TESTING THROUGH FULL-SCALE OPERATION

MIKE HILL
Shirco, Inc.
Dallas, Texas

FRANK RUTKEY
Schenectady Chemicals, Inc.
Rotterdam Junction, New York

ABSTRACT
Pilot testing, facility design, and full-scale operation of a co-disposal system are detailed in the following paper. The waste material consists of industrial sludge and solid wastes. The sludge, both from inventory and current production, contains phenolics. The feed mixing, transfer, and incineration equipment development are discussed, as well as system performance.

INTRODUCTION
In 1978, The Schenectady Chemicals, Inc. (SCI) phenolic resin plant in Rotterdam Junction, New York was faced with a multi-faceted waste disposal problem: an on-site inventory of sludge from the plant’s waste treatment facility had to be treated, sludge currently being produced was not acceptable for sanitary landfill, and containers, bags, etc. for raw chemicals were becoming expensive to dispose of separately. In addition, almost all these materials contained trace amounts of phenolics; as a result, their treatment and disposal as waste could well be governed by the then-pending Resource Conservation and Recovery Act (RCRA) hazardous waste management regulations proposed by the U.S. Environmental Protection Agency (EPA).

Shirco, Inc., a Dallas, Texas-based thermal process equipment manufacturer, was contracted to investigate on-site incineration of the wastes. Shirco personnel worked with SCI plant engineers to develop an efficient, cost-effective system using Shirco’s patented electric infrared incinerator.

A main reason for the selection of the electric furnace was its inherently low emissions. Because the incinerated material is not disturbed by tumbling or mass raking while passing through the furnace, particulate emissions are held to a minimum. In addition, emissions from combustion of fossil fuels are not present.

SYSTEM DEVELOPMENT
The first step in the development of the incineration system was to determine the compatibility of the wastes with Shirco’s moving-belt method of material transport within the incinerator. Candidate materials for thermal treatment included inventoried sludge alone, an inventoried/current sludge mixture, and a shredded container/current sludge mixture.

A program of concurrent incineration testing and material handling system design was undertaken, which lasted from late 1978 to mid-1979. During that time, pilot incineration testing of the waste streams was performed at Shirco’s Dallas, Texas pilot test facility, with SCI personnel on hand to observe not only the incinerator performance, but also any potential problems which occurred in material handling. Preventing such difficulties in the full-scale system would be the responsibility of SCI.

The most promising combination for thermal treatment was the mix of relatively dry inventoried sludge with the relatively wet sludge currently being produced. However this was at best an intermediate-term solution to the overall problem, since the inventoried sludge quantity was finite. Once this inventory was depleted, incineration of the wet sludge would be both difficult from a process standpoint, and expensive. A mix of wet sludge and shred-
sted containers was investigated to create a material which could be incinerated efficiently and inexpensively once the the inventoried sludge was depleted. Bench-scale tests in Shirco's laboratory indicated that all three of these wastes could be incinerated without major process changes.

In order to demonstrate compliance with the applicable New York state and pending EPA emissions regulations, pilot test results were required. In addition, the incinerator ash would be required to meet a State of New York limitation on leachable phenolics in order to be disposed of in a sanitary landfill.

To obtain the required data, two test sessions, a few months apart, were conducted in the Shirco pilot test facility in Dallas, Texas, on a variety of waste combinations involving the waste components in various proportions. The first of these sessions was concerned mostly with determining baseline process parameters (material residence time, layer thickness, temperature profile, etc.). Based on those tests, it was determined that both the inventoried sludge/current sludge and container waste/current sludge combinations were viable candidates for incineration.

During the tests, valuable insight into the overall disposal process was also gained. Material handling was a potential source of concern, due to the wide range of material consistencies expected. In reality, actual mixing of the components was not as difficult as had been expected. Methods of feeding the materials into the incinerator were also investigated, since the feed system selected for the full-scale system would be required to handle a variety of materials with little or no configuration change.

One problem was quickly found in this area: the inventoried sludge was found to contain foreign objects which, if not removed from the sludge, repeatedly jammed the incinerator feed airlock. While not a serious problem during testing, downtime for airlock maintenance, repair, and blockage clearance could be prohibitive in a full-scale unit. In addition, the mixing system required to prepare the materials for incineration would be subject to the same maintenance and operation problems.

When mixed with the shredded containers, the wet sludge tended to form a thick paste which would be difficult to convey and feed. This problem, unlike that of the foreign material in the inventoried sludge, could be resolved by use of a different airlock design. Potential problems in mixing and conveying the material, however, were noted by SCI.

The first tests had confirmed that the Shirco infrared incinerator was capable of processing the candidate waste streams with a minimum of process and mechanical changes. Between this and the second test session conducted several months later, several items were discussed concerning both the second series of tests and the full-scale incinerator. Shirco laboratory personnel had determined the range of inventoried sludge/current sludge mixtures which the full-scale unit could process, using the laboratory's Thermogravimetric Analyzer (TGA) furnace. The TGA furnace is a bench-scale version of Shirco's infrared furnace which is used to incinerate 3.5 oz. (100 g) samples of a material while receiving real-time data on process temperature and combustion efficiency.

The material mixtures were finalized and a preliminary configuration developed for the feed system as a result of these tests. Shirco and SCI engineers also held discussions with the New York Department of Environmental Conservation (DEC) where emissions testing and permitting requirements were agreed upon. The goals of the second tests were, therefore, to determine the actual emissions of particulate and phenolics, determine whether or not an afterburner would be required, and verify the process parameters for incineration of the various waste streams.

During the second tests, accurate data on feed rate, scrubber water consumption, and exhaust gas flow rate were kept in addition to the process parameter data, since these quantities would determine not only the furnace size, but also the size and complexity of SCI's interface systems. To determine total phenol destruction efficiency, samples of feed material, ash, scrubber water, and furnace/afterburner/scrubber exhaust gas were taken at frequent intervals. The furnace was operated at steady-state conditions with and without the afterburner in operation, to determine the increase in combustion efficiency resulting from use of the afterburner.

TEST RESULTS

The tests verified the feasibility of feeding the final material mixes, and the process parameters defined earlier. Based on the afterburner on/off study and its effect on emissions, it was determined that both phenolic destruction and overall combustion efficiencies were sufficiently high in the furnace that an afterburner would not be required.

Emissions test results from this session are shown in Tables 1 and 2. The results show the uncontrolled particulate emissions to be 11.6 lb/dry ton of feed material (4.8 kg/tonne) for the sludge/sludge mixture, and 19.4 lb/ton (8.0 kg/tonne) for the shredded waste/sludge mixture. Both results were consistent with expected incinerator performance. Exhaust gas particulate loadings for the two wastes were 0.211 gr/dscf (0.482 g/Nm^3) and 0.366 gr/dscf (0.837 g/Nm^3), respectively. Tests for controlled particulate (stack) emissions were not conducted.

Calculation of phenolic destruction efficiency was based on phenolic content in the feed, ash, and furnace.
TABLE 1 PARTICULATE EMISSIONS TEST RESULTS (PILOT TEST)

<table>
<thead>
<tr>
<th>Feed Stream</th>
<th>No. of Tests</th>
<th>Particulate Loading gr/dscf</th>
<th>Particulate Loading g/Nm³</th>
<th>Particulate Loading lb/dry ton kg/dry tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge/Sludge</td>
<td>3</td>
<td>0.211</td>
<td>0.482</td>
<td>11.6</td>
</tr>
<tr>
<td>Waste/Sludge</td>
<td>3</td>
<td>0.366</td>
<td>0.837</td>
<td>19.4</td>
</tr>
</tbody>
</table>

*Weight of particulate emitted per dry ton (tonne) of material fed

TABLE 2 PHENOLIC DESTRUCTION TEST RESULTS (PILOT TEST)

<table>
<thead>
<tr>
<th>Feed Stream</th>
<th>No. of Tests</th>
<th>Phenolic Content in Sludge (%)</th>
<th>Phenolic Destruction Efficiency (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge/Sludge</td>
<td>6</td>
<td>27.4</td>
<td>99.999</td>
</tr>
<tr>
<td>Waste/Sludge</td>
<td>6</td>
<td>30.8</td>
<td>99.73</td>
</tr>
</tbody>
</table>

* Based on total phenolic in filter catch, ash residue, scrubber water exhaust gases. The total destruction efficiency for the sludge/sludge mixture was found to be 99.999 percent, with five of the six samples indicating an efficiency slightly greater than that figure. For the shredded waste/sludge mix, the destruction efficiency was slightly lower at 99.73 percent. The lower efficiency for this material was partly due to inconsistent mixing which would be eliminated in the full-scale system.

FULL-SCALE INSTALLATION (MATERIAL HANDLING)

The material handling system for the incinerator was developed by SCI personnel headed by Mr. Frank Rutkey, Project Engineer. The system would be required to remove foreign objects from the inventoried material, properly mix the various waste components, and assure even feeding to the incinerator. A process diagram of the material handling system appears in Fig. 1.

The first step in the system involves removing any foreign objects from the inventoried sludge by screening. The screened material is then transported in carts to the material handling building, which also houses the incinerator.

At this point in the system, the inventoried material is mixed with freshly produced sludge from the facility's centrifuge. This material, which is thirteen percent solid, is not cost-effective to incinerate alone. The inventoried material is mixed with it to produce a material approximately fifty percent solid having fifty percent combustible content on a dry weight basis.

The freshly produced sludge is transported to the material handling building in self-dumping carts from the adjacent centrifuge building and dumped into a two cubic yard (1.53 m³) mixing hopper. The hopper contains two rotating spiral blades. Sorted material is brought by cart from the sorting area (during moderate weather) or front loader (from the indoor stockpile in winter) to the mixer room, where it is dumped through a chute into the mixture. The nominal mixing cycle lasts 10 min.

The composition (dry solid content) of the mixed material is verified by a slump cone test. While the nominal material is equal parts sludge and inventoried material by weight, it is at times biased in favor of a drier material

473
USED CONTAINERS

INVENTORIED SLUDGE

SHREDDER

COARSE DEBRIS

SORTING (NORMAL ROUTE)

(ALTANTIVE ROUTE)

MIXER

STORAGE

CENTRIFUGE

SLUDGE

FIG. 1 PROCESS FLOW SCHEMATIC

OFFGAS SYSTEM

ASH

DAY TANK

FINE SORTING

DEBRIS

DEBRIS
(more inventoried material in the mix) if the currently produced sludge has an unusually low solids content.

After mixing, the material batch is automatically dumped to a hopper and lifted vertically by a hoist to either a screening tank or, if fine screening is not required, to the sludge day tank for subsequent feeding to the incinerator.

The screening unit is a vibrating type fed by a metering tank. Material discharges from the screen into a day tank. Debris is rinsed prior to discharge to a hopper.

The day tank holds enough material for approximately one hundred hours (100 hr) of incinerator operation. Feed to the incinerator is through a horizontal screw conveyor and knife gate, and an inclined belt conveyor. An operator has "line-of-sight" contact with the incinerator feed hopper and can start or stop the conveyor as needed. As a precaution, the feed hopper is fitted with a high level alarm system.

**FULL-SCALE INSTALLATION (INCINERATOR)**

The infrared incineration system consists of a continuous conveyor belt furnace with associated material feed and discharge systems, process control and instrumentation equipment, combustion air preheater, and emission control equipment. The furnace has nominal dimensions of 5 ft 6 in. (1.7 m) width, 31 ft 0 in. (9.5 m) length, and 8 ft 6 in. (2.6 m) height. When processing the mixed centrifuge/inventoried sludge, the unit has a capacity of 530 lb/hr (240 kg/h), for a belt loading of 6.8 lb/hr/ft² (33.1 kg/h/m²).

The material is fed by the inclined belt conveyor into a feed hopper with a metering conveyor built into the bottom, located at the feed end of the furnace. The metering belt is synchronized with the furnace conveyor to control the material feed rate. This metering system includes a wiper blade to distribute the material across the width of the metering belt. Material drops off the metering belt and enters the furnace through a rotary airlock. The airlock is a "clothes wringer" type consisting of two counter-rotating cylinders which maintain an air seal on the furnace. The airlock has a gap between the cylinders while passing small debris objects.

The material moves through the furnace on a high-temperature metal belt and is exposed to heat from infrared heating elements arranged in two zones. Zone temperatures are controlled by varying the input power to maintain a set-point temperature. In order to maximize process rates the material layer is stirred at several points in the furnace by means of rotating transverse shafts equipped with alloy "fingers" which slowly break up the material layer to expose all portions of the layer to the furnace environment. Upon completion of the incineration process the material is discharged through the furnace bottom into a hopper.

The overall flow of the furnace gases (air and combusted products) is countercurrent to the material flow. This process feature allows for supplemental heating of the combustion air as it passes over the burned out portions of the material layer and more rapid heating/drying of incoming material; hence, a more energy-efficient process is achieved.

Combustion air flow rate is maintained by an oxygen analyzer in the furnace exhaust, a panel-mounted closed loop controller, and a mechanical/electrical actuator and damper system on the outlet of the combustion air blower. The oxygen controller can be set to maintain a specific oxygen or excess air content in the exhaust. Typical values of excess air are in the 50-100 percent range.

The combustion air is pre-heated by passing the air through a shell-and-tube heat exchanger which utilizes the hot exhaust gases from the furnace as the heating source. The preheater is designed to provide air to the incinerator in the 500-800°F (260-425°C) range. To prevent overtemperature conditions in the incinerator, the preheater uses a bypass loop and control system. A thermocouple mounted in the exhaust duct sends a signal to a control panel-mounted controller. If the incinerator exhaust temperature exceeds a preset value, the controller opens a damper which bypasses the preheater on the exhaust gas side, reducing the amount of heat transferred to the combustion air and lowering the temperature of the air entering the furnace.

Once the exhaust gas leaves the air preheater, it passes through a venturi scrubber which cools and cleans the gas stream to acceptable levels. This system consists of a venturi section in the exhaust duct containing water sprays which inject a fine water mist into the exhaust gas. The water droplets are sized to "capture" particulate grains by having the grains impact the droplets as they pass through the sprays. The water-covered particulate grains are then removed from the air stream in the separator tower. The scrubber also cools the gases from 800-1200°F (425-650°C) to 120°F (49°C).

In order to keep the furnace from pressurizing, an induced draft fan is used. The fan maintains a sufficient draft on the furnace, assuring flow out of the furnace while preventing excess, unmetered air leakage. The furnace draft is adjusted by use of an actuator/damper/controller system on the induced draft fan outlet. The method of control is similar to that used for combustion air.

**OPERATIONAL HISTORY**

As installation of all equipment approached completion, SCI personnel determined that the current sludge/
TABLE 3 EMISSIONS TEST RESULTS (FULL-SCALE INSTALLATION)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>No. of Tests</th>
<th>Gas Loading</th>
<th>Emission Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>gr/dscf</td>
<td>g/Nm³</td>
</tr>
<tr>
<td>Particulate</td>
<td>3</td>
<td>0.0047</td>
<td>0.011</td>
</tr>
<tr>
<td>Beryllium</td>
<td>3</td>
<td>-----</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td>Cadmium</td>
<td>3</td>
<td>-----</td>
<td>0.012</td>
</tr>
<tr>
<td>Chromium</td>
<td>3</td>
<td>-----</td>
<td>0.071</td>
</tr>
<tr>
<td>Phenolic</td>
<td>3</td>
<td>0.008</td>
<td>-----</td>
</tr>
</tbody>
</table>

* Emission rate X 10⁵

TABLE 4 ASH LEACHATE TEST RESULTS (FULL-SCALE INSTALLATION)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>No. of Tests</th>
<th>Content in Ash Leachate (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenolic</td>
<td>2</td>
<td>0.007*</td>
</tr>
<tr>
<td>Cadmium</td>
<td>2</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Chromium</td>
<td>2</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Lead</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>Mercury</td>
<td>2</td>
<td>&lt;0.0004</td>
</tr>
</tbody>
</table>

* Test results were 0.004 and 0.010 mg/l for individual samples

waste paper mixture would not be processed at that time. The main priority for the plant was to thermally treat the inventoried sludge. Therefore, treatment of the sludge/paper material would not be undertaken until the inventoried sludge was substantially depleted.

By early May 1981, the system was processing material at design capacity, and the ash quality was marginally higher than the State of New York phenolic allowable for sanitary landfill. Testing continued into early June, with furnace belt tracking being the only significant area of attention.

Operation of the system continued through the end of 1981, while adjustments and modifications to several of the component systems were made to accommodate changing material feed properties. The fine-weave belt originally installed in the furnace was replaced by one having a heavier weave, which improved belt tracking. The "cakebreaker" assemblies in the furnace were modified to add fingers more suited to the furnace atmosphere.

Operational data showed that the highly volatile sludge was producing temperatures of 1800°F (985°C) in the incinerator, well above the 1600°F (870°C) setpoint tem-
perature in the hottest furnace zone. Operation under this condition allowed the unit to be run continuously with essentially no electric power being applied to the infrared heating elements. The only energy consumed by the incinerator under this condition was approximately 15 kW for system motors. However, the combustion air preheater and offgas handling system could potentially be damaged by this mode of operation, so the incinerator feed rate was reduced while combustion air flow was maintained, to the point at which the heating elements were not required, but the incineration temperature was reduced to the 1600°F (870°C) level. This feed rate, under normal conditions, was 350 lb/hr (158 kg/h).

In June of 1982, emissions testing was performed on the incinerator. The test results, shown in Table 3, indicated compliance with DEC requirements for particulate and heavy metals. Ash leachate test results, shown in Table 4, showed phenolic content in the ash leachate to be above the State of New York allowable limit for sanitary landfill. The ash is currently being stored.

Since the completion of testing, the entire system has been in essentially continuous operation. The only major modifications made during that period have been the replacement of the incinerator exhaust system with internally insulated ducting and addition of an exhaust gas cooling system to allow operation at the high exhaust temperature condition noted earlier.