ABSTRACT

Heretofore disposal of sewage scum or skimmings from the settling tanks of waste water treatment plants has been by incineration in conjunction with other plant wastes. These skimmings are rich in hydrocarbons but high in moisture content, and with proper preparation and dewatering they become a source of energy for use as fuel in the generation of steam for process use and building heating.

In conjunction with the addition of tertiary treatment at the Southerly Wastewater Treatment Plant of the Cleveland Regional Sewer District, a steam generating unit fired with skimmings as the fuel source is used to provide the 425 psig (2.93E+06 Pa) saturated steam needed in the thermal conditioning process.

This paper presents the design parameters for this special steam generating unit and its air pollution control equipment.

INTRODUCTION

Many municipal and industrial waste treatment plants have faced difficult problems, such as how to dispose of skimmings, which are the light floatable substances removed from primary settling tanks, secondary settling tanks and gravity thickeners and which comprise grease, oils, soap, cork, wood, paper, vegetable and plant debris, etc.

Disposition of these wastes at many plants includes burial (landfill), pumping to anaerobic digesters, open pit burning, and dewatering with sewage sludge for incineration in multiple hearth furnace units or fluidized bed reactors. In each case the problems involved with disposal were worse than the original skimmings problem.

These skimmings are rich in hydrocarbons and high in moisture content. With proper preparation and dewatering they can become a source of energy for use as fuel for generation of steam.

The expansion of facilities at the Southerly Wastewater Treatment Plant of the Cleveland Regional Sewer District provided an opportunity to develop a steam generating unit fired with skimmings as the fuel source and thereby reduce the plant energy needs for fossil fuel in thermal conditioning. This process conditions sewage sludge by the application of heat and pressure to alter its physical characteristics and produce a relatively concentrated sludge with a high proportion of solids. Saturated steam at a suitable pressure is the source of the required heat and pressure. As proper plant operation is dependent upon the thermal conditioning system operation, a reliable source of steam is necessary.

OPERATION

The Southerly Plant is designed for treatment of an average flow of 200 mgd (8.76E+00 m³/s). At this flow, the skimmings collected and available as
fuel for steam generation is 2700 lb/hr (3.4E-01 kg/s) on a dry basis with a HHV of 16,000 Btu/lb (3.72E+07 J/kg).

With this skimmings quantity being fired at 50 percent moisture together with 25 percent of the total heat input as fuel oil (to support and maintain ignition at all times), the saturated steam capacity is 45,000 lb/hr (5.67E+00 kg/s) at 425 psig (2.93E+06 Pa). The system is capable of firing a peak capacity of 7500 lb/hr (9.45E+01 kg/s) of 50 percent moisture skimmings with 25 percent oil to generate a saturated steam flow of 61,600 lb/hr (7.76E+00 kg/s). The system is also capable of generating 100,000 lb/hr (1.26E+01 kg/s) with 100 percent oil firing.

FACILITY DESCRIPTION

The facility includes an outdoor skimmings decanting, mixing, storage area and electrical substation with a building housing the steam generating unit and its auxiliaries. (See Fig. 1)

The skimmings storage area comprises pumps, meters, and storage tanks for decanting the skimmings. In addition, No. 2 fuel oil storage and pumping facilities are provided for use as support fuel and as standby fuel.

The steam generating unit includes a skimmings burner, fuel oil burners, a fully water-cooled furnace arranged with hopper bottom for ash removal, a saturated steam boiler convection bank and a tubular airheater. The flue gases from the airheater enter a venturi scrubber and discharge through an induced draft fan and stack into the atmosphere. The system incorporates the latest available designs in combustion control and air pollution control. An oil fired package boiler is provided as standby for use during inspection and maintenance of the skimmings fired unit and for emergency operation (See Figs. 2 and 3).

Ash from the furnace and boiler collection hoppers will be discharged hydraulically to an ash disposal lagoon on the treatment plant site.

SKIMMINGS HANDLING

Raw sewage is composed of a variety of liquid and solid waste products. The components which float to the surface of settling tanks and thickeners
are separated by means of mechanical devices that skim the liquid surface, hence the term “skimmings”. Skimmings are basically spent grease from soap, detergents and service station discharges into the sewer system. Sand, rags and small twigs which pass through influent coarse screens at the head of a treatment plant are skimmed with the grease to form a fluid of inconsistent quality, texture and properties. On a moisture free basis, however, the skimmings have been found to have a substantial heating value, over 16,000 Btu/lb (3.72E+07 J/kg). The characteristics of skimmings and their value as fuel after preparation and dewatering are depicted in Table 1.

Skimmings are collected from a number of sources throughout the plant. They will be collected at greater than 95 percent water and then processed through a grinder, or macerater, located near the collection point. The wet, macerated skimmings will be pumped to any of three storage and settling tanks. Maceration will reduce solids to a maximum 1/16 in. (1.59E-03 m) dimension to allow ease of pumping. The pumps handling skimmings are positive displacement, progressing cavity type, and the piping is glass-lined cast iron, to decrease the possibility of grease accumulation on the pipe inner wall. The minimum piping is 4 in. (1.02E-01 m) nominal; smaller piping could result in plugging should no flow exist for a period

<table>
<thead>
<tr>
<th>% by</th>
<th>MOISTURE FREE BASIS</th>
<th>RAW BEFORE PROCESSING</th>
<th>AS FIRED AFTER PROCESSING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wgt.</td>
<td>Wgt.</td>
<td>Wgt.</td>
</tr>
<tr>
<td>Asm</td>
<td>4.93</td>
<td>0.2465</td>
<td>2.465</td>
</tr>
<tr>
<td>Carbon</td>
<td>68.20</td>
<td>3.410</td>
<td>34.10</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.03</td>
<td>0.0015</td>
<td>0.015</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>7.98</td>
<td>0.399</td>
<td>3.99</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>11.78</td>
<td>0.589</td>
<td>5.89</td>
</tr>
<tr>
<td>Oxygen</td>
<td>6.72</td>
<td>0.336</td>
<td>3.36</td>
</tr>
<tr>
<td>Sulphur</td>
<td>36</td>
<td>0.018</td>
<td>0.18</td>
</tr>
<tr>
<td>Water</td>
<td>-</td>
<td>95.000</td>
<td>50.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Heating Value

| Btu/lb (HHV) | 16,000 | 800 | 8,000 |
| J/kg (HHV)   | 3.72E+07 | 1.86E+06 | 1.86E+07 |
of days. A hot water wash is provided for flushing of the lines on a periodic and routine basis.

The tank farm will be equipped to receive other wastes by truck and pump them to one of the skimmings storage tanks. Prior to accepting wastes other than skimmings, a material analysis will be performed to determine if any components within the waste constitute a hazard to personnel or equipment and to ascertain its compatibility with the storage, transport or burning equipment.

Skimmings will be held in the storage and decant tanks for a minimum of 8 hr to allow full separation of floatables. The tank will be decanted manually by closing the drain valve upon visual identification of the grease components of the flow. The tank will be successively filled and decanted until the moisture content is determined to be approximately 75 percent and the tank is full. Sample connections will permit drawing off skimmings for laboratory or visual analysis of water content.

Prior to pumping the skimmings from the storage tank, the agitator will be energized to fully mix the skimmings into a reasonably uniform mass of liquid. Immediately after mixing, the skimmings flow through a suction heat exchanger, another macerater and will be pumped by a positive displacement pump to one of the two skimmings feed tanks. The suction heater is designed to bring the temperature of the skimmings to 120 F (322 K) and the feed tanks are provided with external heat exchanger surfaces to keep the skimmings in storage at that temperature. The skimmings grease fraction becomes more fluid and less miscible with an increase in temperature. After a period of 4 to 6 hr at 120 F (322 K), further settlement will occur with further decanting to approximately 50 percent moisture. Any further decanting would result in a sharp increase in skimmings viscosity and make it very difficult to pump. Mixing equipment is also provided in the feed tanks and the skimmings are mixed, macerated and pumped to the skimmings holding tank within the Steam Generating Building. The holding tank has less than 2 hr storage and is equipped with external heating coils and a mixer. It will heat the skimmings to 180 F (355 K) at which temperature any grease fraction not yet liquid will melt and the viscosity will be at a minimum value. The skimmings are fully prepared for burning and from this tank, at 180 F (355 K), will be mixed, macerated again, and pumped to the burner.

SKIMMINGS BURNING AND STEAM GENERATION

Investigation of a steam generating and burning system sized for the design and peak conditions detailed in the operating section of this paper was based on achieving continuous and reliable operation with full utilization of the energy available in the skimmings. As this application constitutes the initial facility using skimmings as fuel and no previous data as to the corrosive, erosive or fouling factors from its combustion could be ascertained, it was established that the design parameters considered necessary for waste fired steam generation would be followed at both the design and peak operating conditions, namely:

1. The processed skimmings are accumulated for firing at a constant rate through a steam atomizing burner with a 1/2 in. (1.27E-02 m) minimum orifice for passage to avoid skimmings pluggage. Should the supply of skimmings decrease below the firing rate, the atomizer would be taken out of service until sufficient supply accumulated to resume its use.

2. Fuel oil of No. 2 grade is fired with adjacent conventional steam atomizing oil burners at a minimum of 25 percent of the heat input to the unit at all times. This avoids a possible flame interruption from a surge of water entering with the skimmings.

3. Monitor the burning conditions with flame safeguard system in full compliance with Industrial Risk Insurers (IRI), formerly Factory Insurance Association (FIA).

4. The combustion chamber or furnace is a fully water cooled enclosure employing membrane construction and incorporating a hopper bottom with 50 deg. sloping sides of similar construction for ash removal. Other than the furnace wall area immediately adjacent to the burners, which is studded and coated with plastic chrome ore to a thickness of 5/8 in. (1.59E-02 m) to promote and maintain combustion temperatures, the furnace and hopper walls are bare metal, water cooled surface that resists ash attachment.

5. The combustion chamber or furnace is sized for a heat release of 16,000 Btu/ft³ (5.96E+08 J/m³) when firing skimmings with 25 percent oil at 61,600 lb/hr (7.76E+00 kg/s). This provides more than 5 sec retention time for complete combustion and destruction of odors.

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6. The water-cooled combustion chamber is also sized for 50,000 Btu/ft² (5.68E+08 J/m²) of flat projected water cooled area when firing skimmings with 25 percent oil at 61,600 lb/hr (7.76E+00 kg/s) steaming rate to reduce the gas temperature to 1600°F (1144 K) at the furnace outlet measured on a high velocity thermocouple basis.

7. The convection tube section comprises vertical tubes so any ash accumulation may be removed with retractable soot blowers and collected in the hopper beneath which is designed with a 55 deg. minimum valley slope and equipped with a rotary discharge valve to avoid pluggage.

8. The convection bank of only bare tubes arranged in-line is also arranged to avoid erosion and fouling from ash as follows:
   (a) A single horizontal passage of combustion gas over the tubes without any diversion or deflection baffles.
   (b) With gas temperature above 1000°F (811 K) maintain 2 1/2 in. (6.35E-02 m) clear space between the bare tubes and a maximum gas velocity of 25 ft/sec (7.62E+00 m/s).
   (c) With gas temperature below 1000°F (811 K) maintain a 2 in. (5.08E-02 m) clear space between the bare tubes and a maximum gas velocity of 30 ft/sec (9.14E+00 m/s).

9. Assist combustion with combustion air heated to a minimum of 550°F (561 K) while reducing the stack gas temperature to 350°F (450 K) using a tubular air heater arranged vertically with the flue gas flowing downward through the tubes to facilitate cleaning with straightline soot blowers located above and below the tubes to avoid pluggage.

POLLUTION CONTROL SYSTEM

An advanced air pollution control system has been incorporated into the design of this facility. It was deemed necessary to optimize the air pollution control system to the utmost of available technology because the noxious gases and particulates from the combustion of the wastes are expected to vary continuously.

Flue gases at approximately 350°F (450 K) from the air heater of the skimmings burning steam generator enter the high energy venturi where most of the particulate matter will be removed in passing the throat zone in which a 30 in. H₂O (7.47E+03 Pa) pressure drop is created. The venturi throat area can be varied, activated by the differential pressure signal measured across the venturi to achieve the optimum efficiency for particulate removal with varying gas flows.

The gases from the venturi will pass upward through a two-stage tower for subcooling and demisting. The tower is designed so its recirculation system can introduce chemical injection for pH control if operation indicates it is desirable to remove sulfur dioxide and hydrochloric acid from the gas by absorption to form sodium sulfite or sulfate and sodium chloride.

The scrubbed flue gases will continue to flow upward to a dewatering tower (demister) for removal of water droplets. The demister is provided with a wash system which may be used periodically for washing salts from the elements.

The gases will be drawn from the demister by an induced draft fan and discharged to the atmosphere through a free standing, 91 ft (2.77E+01 m) high self supported stack at a discharge velocity of 60 ft/sec (1.83E+01 m/s).

As a means to minimize corrosion in the pollution control system, the following features are provided:
   1. Venturi scrubber and tower construction will be 3/16 in. (4.76E-03 m) thick, Inconel 625 alloy.
   2. Induced draft fan housing construction will be 3/8 in. (9.53E-03 m) thick, Inconel 625 alloy.
   3. Induced draft fan wheel construction will be of Inconel 625 alloy.
   4. Stack construction will be single wall Corten steel with 1 in. (2.54E-02 m) thick refractory lining applied over wire mesh reinforcing firmly fastened to the stack with studs.

TESTING

The testing of the skimmings fired steam generating unit will encompass determination of:
   1. Thermal performance compliance with guarantees.
   2. Environmental compliance with federal, state and local regulations for emissions.

The testing will include the following laboratory determinations from representative samples of skimmings, fuel oil, bottom ash from the furnace hopper, fly ash from the scrubber discharge, and venturi-scrubber supply and discharge water.
   1. Proximate analysis of skimmings and fuel oil for content of moisture, combustible, ash,
higher heating value, specific gravity, and viscosity.

2. Ultimate analysis of skimmings and fuel oil for content of carbon, hydrogen, oxygen, nitrogen, sulfur and chlorine.

3. Analysis of venturi-scrubber supply and discharge water for content of total solids, fixed solids, sulfur, chlorine, asbestos, pH, BOD and COD.

4. Quantitative analysis of skimmings and fuel oil for content of total solids and fixed solids.

5. Semiquantitative emissions spectrographic analysis of skimmings and fuel oil fixed solids for content of sulfur, chlorine and asbestos.

6. Atomic absorption spectrophotometry determination of content of cadmium, zinc, lead, copper, chromium, beryllium, barium, nickel, selenium and mercury in skimmings, fuel oil, and venturi-scrubber supply and discharge water.

7. Calorimetric analysis of skimmings, fuel oil, venturi-scrubber supply and discharge water for content of arsenic.

8. Spectrographic mineral analysis of bottom ash, fly ash, and solids from scrubber discharge, venturi-scrubber supply and discharge water to establish the content of oxides of aluminum, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury and molybdenum.

The skimmings fired steam generating unit will be tested using ASME procedures of PTC 4.1 firing fuel oil at a steaming capacity of 100,000 lb/hr (1.26E+01 kg/s) to establish its compliance with guarantees for the overall thermal efficiency and energy use for operation.

The environmental determinations will establish the emissions for particulate in the stack discharge and the discharge of heavy metals and hazardous materials in the gaseous atmospheric discharge, the bottom ash, and the venturi-scrubber discharge of solids and liquids. The air emission testing will develop the following:

1. Complete orsat analysis \( (O_2, CO, CO_2, N_2) \) at airheater outlet and upstream of any quenching.

2. Complete orsat analysis \( (O_2, CO, CO_2, N_2) \) at stack outlet.

3. Gas analysis at airheater gas outlet upstream of any quenching and also at stack outlet for quantity determination of \( SO_2, SO_3, HI, \) and oxides of Nitrogen present at each location.

4. A determination of carbon content in representative samples of bottom ash.

5. BAHCO particle size determination of particles in gas stream as well as the bottom ash.

**OPERATING REQUIREMENTS AND SAVINGS**

The plant steam requirements are listed in Table 2.

### TABLE 2 STEAM REQUIREMENTS OF PLANT

<table>
<thead>
<tr>
<th>Steam Use</th>
<th>% Use</th>
<th>( 10^4 ) lb/hr</th>
<th>( 10^4 ) lb/yr</th>
<th>SI Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge Thermal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditioning</td>
<td>100</td>
<td>45.6</td>
<td>399.5</td>
<td>5.75E+00</td>
</tr>
<tr>
<td>Building Heating</td>
<td>58</td>
<td>11.4</td>
<td>58.0</td>
<td>8.43E-01</td>
</tr>
<tr>
<td>Nonpotable Water Heating</td>
<td>80</td>
<td>5.0</td>
<td>35.0</td>
<td>5.03E-01</td>
</tr>
<tr>
<td>Skimmings Tank Farm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating</td>
<td>80</td>
<td>1.0</td>
<td>7.0</td>
<td>1.01E-01</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>499.5</td>
<td>7.20E+00</td>
<td></td>
</tr>
</tbody>
</table>
With 100 percent oil firing, an oil quantity of 34.3 x 10^6 lb/yr (4.93E-01 kg/s) is needed to provide the plant steam requirements. This is equivalent to 14.6 lb steam generated per pound of fuel oil (14.6 kg/kg).

Utilization of the skimmings fired boiler at a steaming capacity of 45,000 lb/hr (5.67E+00 kg/s) and an availability of 95 percent (two week annual outage) results in steam production and fuel oil requirements as shown in Table 3.

<table>
<thead>
<tr>
<th>TABLE 3 STEAM PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Oil</td>
</tr>
<tr>
<td>lb/yr</td>
</tr>
<tr>
<td>Skimmings Alone</td>
</tr>
<tr>
<td>Supplemental Fuel</td>
</tr>
<tr>
<td>Steam from Other Oil</td>
</tr>
<tr>
<td>Total Plant Usage</td>
</tr>
</tbody>
</table>

Operation of the skimmings fired boiler at 95 percent availability and an average steaming capacity of 45,000 lb/hr (5.67E+00 kg/s) which is 73 percent of peak capacity achieves the following:

1. skimmings fired boiler provides 290.0 x 10^6 lb/yr (4.17E+00 kg/s) steam production or 58 percent of the plant requirements from skimmings alone.

2. The annual fuel oil required for the plant is reduced from 34.3 x 10^6 lb/yr (4.93E-01 kg/s) to 14.3 x 10^6 lb/yr (2.06E-01 kg/s), which is a saving of 20.0 x 10^6 lb/yr (2.88E-01 kg/s). With a density of 7.2 lb/gal (8.63E+02 kg/m^3), the annual saving in fuel oil totals 2,800,000 gallons (1.06E+04 m^3).

SUMMARY AND CONCLUSIONS

It is feasible to design for recovery of the energy in skimmings because such design will reduce the usage of fuel oil and operating costs. The savings realized by recovering energy by using skimmings as fuel is the generation of steam which is utilized at the Southerly Plant in Cleveland as follows:

1. Provide steam at the required temperature and pressure for operation of the thermal conditioning process.
2. Provide the heating requirements for the nonpotable water system.
3. Provide the heating requirements for the skimmings and waste tank farm system.
4. Provide the heating requirements for heating of the following facility structures:
   (a) Thermal conditioning building
   (b) Incinerator building
   (c) Incinerator auxiliary building
   (d) Vacuum filter building
   (e) Excess activated sludge thickening building
   (f) Waste liquor handling building
   (g) Steam generator building
5. The skimmings steam generating unit will provide 58 percent of the steam capacity used in the plant. The yearly savings in fuel oil by generating steam using skimmings as fuel is 2,800,000 gallons (1.06E+04 m^3).

The expected advantages derived from the conversion of skimmings to a useful fuel provide the following conclusions:

1. The disposal of skimmings and similar liquid wastes is no longer necessary.
2. Utilization of skimmings as fuel is accomplished without environmental problems and within the Federal, State and municipal emission requirements.
3. Elimination of the conventional oil fired steam generators and the conventional skimmings disposal equipment or facility permits the capital cost saving from these omissions to be credited to reduce the capital cost of the skimmings burning steam generating facility.

Key Words

Boiler
Disposal
Energy
Incineration
Refuse Derived Fuel
Scrubber
Sewage
Discussion by

Richard B. Engdahl
Battelle Memorial Institute
Columbus, Ohio

This paper proposed in excellent technical detail a very advanced energy recovery system using conventional waste burning components. However, it cannot be evaluated realistically without having cost estimates. The implication in the conclusions is that the heat value of dewatered skimmings is so high that the cost of its recovery doesn’t matter. Thus the statement is made: "It is feasible to design for recovery of the energy in skimmings because such a design will reduce usage of fuel oil and operating costs." But the proposed system will add to the plant operating costs. In fact, in many other waste-to-energy systems it costs as much or more to finance and pay interest on the plant than it does to operate them. Granted, we must seek more and more ways to replace fuel oil. But each new way we consider must face up realistically to its cost. I hope that a cost evaluation on this proposed plant is favorable and that the authors will then have an opportunity to demonstrate its technical and economic feasibility.

Discussion by

Joseph W. Ruzika
Nichols Engineering and Research Corp.
Belle Mead, New Jersey

The paper was very well written and was indeed complete. I would question, however, if the authors considered the following items:

1. Corrosion of the boiler tubes, as the skimmings being incinerated can contain many elements that corrode tubes very rapidly if boiler outlet temperatures are too low.
2. Use of less expensive equipment such as the watergate incinerator. The use of this type of equipment could eliminate a great deal of the preparation equipment. It is true that no watergate incineration systems have been built which incorporate waste heat recovery equipment, but there is no reason why it could not be incorporated.

Discussion by

John J. Baffa
John J. Baffa Consulting Engineers
Fort Lee, New Jersey

Skimmings disposal has been a problem at municipal wastewater treatment plants in years past. Difficulties have been encountered due to heterogeneity of the material, difficulty of dewatering, putrescibility, clogging of pumps and piping and caking on heating surfaces. Former attempts at beneficiation have included use for soap manufacture and burning with sludge. The method described in the paper is innovative. It is the first design, in this writer’s experience, in which the material was burned alone to produce a substantial proportion (60 percent) of the wastewater treatment plant steam capacity requirements. The heat balance calculations indicate feasibility.

The amount of skimmings shown by the authors to be available is several times that available at most treatment works. Thus, the quantity per million gallons of flow should not be considered as being universally true. The production of skimmings will vary with locale. Communities wherein a market exists for restaurant grease, for fats from rendering plants and for spent oils, will tend to have less skimmings at the treatment works. Screenings arrangements will also affect skimmings.

Bacterial action relationships are not mentioned in the paper. The holding times described for collection storage tanks and heated feed tanks are such that digestion will start particularly with the stimulation provided by temperature rise. There could thus be some escape of volatile materials. The volatile contents will vary with local conditions. Normal expectancy is 60 to 80 percent volatiles in the raw material. The reduction of as-fired heating values by a few percent should be anticipated. The commencement of digestion will be in the acid stage with production of volatile acids. The synthesis of bacterial jellies will tend to interfere with free flow of the material. Products of combustion will tend to cake on heated surfaces. The provisions, by the designers for maceration, glass lined piping and progressive cavity type pumps are all in the right direction. The space provided between boiler tubes will also facilitate cleaning thereof.

The authors are urged to publish operating data at the earliest opportunity. The system described represents an important contribution to
energy conservation at municipal wastewater treatment plants.

Discussion by

Robert S. Rochford
Babcock & Wilcox Company
North Canton, Ohio

The authors have described a pioneer system for disposing of an annoying waste in an ecologically acceptable manner. The fuel oil savings are very impressive and it appears the design parameters specified for the system are conservative and should result in a plant capable of very satisfactory operation.

One figure in the text that might bear checking is the matter of furnace retention time at the 61,600 lb/hr steam flow condition. The authors claim the skimmings boiler furnace will have a retention time of 5 sec at this rating, which appears unusually long. By the writer's calculations, if one employed an average furnace temperature and a furnace volume measured from the center line of the lowest burner to the furnace outlet, the retention time at this steam flow would be about 3.2 sec. This time with the furnace temperatures involved should still be very adequate to complete the combustion and destroy any odors present.

AUTHORS REPLY

To Richard B. Engdahl

Mr. Engdahl comments on a very practical aspect - cost effectiveness.

The paper as presented was purposefully devoted to the technical aspects for reducing the usage of fuel oil through the use of skimmings as fuel. Accordingly, the cost data was omitted because to present it would have confused the technical features.

A separate paper devoted to the cost effective aspects is worthy of preparation. In the authors' opinion such should be postponed until actual operation of the plant takes place.

Currently, it is sufficient to state that analysis of the project was made using EPA guidelines. This established that the capital cost of the skimmings fired steam generating facility is cost effective. The project has EPA approval and funding to the same extent as the remainder of the Cleveland Regional Sewer District Southerly Plant.

To Joseph W. Ruzika

In consideration of the skimmings fired steam generating unit, consideration was given to the following areas.

1. Corrosion of boiler tubes. The boiler operates at 425 psig and all the pressure parts (drums, headers, tubes, etc.) are at the saturated steam temperature – namely 454 F. This temperature is above the dew point of the elements present in the skimmings to combine with moisture to produce an acid and corrode the metal parts.

The airheater was designed to minimize potential corrosion with:

- Steam coil airheater located at the inlet so as to raise the entering air temperature and maintain the temperature of the airheater tubes well above the dew point at which corrosion starts.
- The initial several rows of airheater tubes are wide-spaced, which reduces the rate of heat transfer in these tubes and allows the tube metal temperature to be above the dew point at which corrosion starts.

2. Mr. Ruzika actually answered his own inquiry as to whether consideration was given to the use of steam generating equipment with considerably less total capital cost such as the watergrate incinerator. The plant is dependent upon a reliable source of steam to operate the thermal conditioning system and untried equipment or systems were not considered.

While the actual use of skimmings as fuel is new, the steam generating unit comprises conventional waste burning and steam generating components which have provided reliable service for similar applications in the past. The unit is capable of generating the needed steam with fuel oil alone as well as with skimmings and supplementary fuel oil. As no watergrate incineration system has been built which incorporates steam generating capability, considerable design and pilot plant work is needed to establish an application. Even with a design, actual operation is essential to establish reliability. The timing of this project did not provide for the preparation of a design and establishment of its reliability.

Editors Note: The discussions of Mr. Baffa and Mr. Rochford were not submitted to the authors because of a filing error.