ENERGY RECOVERY FROM A 100 TPD SOLID WASTE INCINERATOR

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ABSTRACT
A hot water generator system was installed to recover energy from a solid waste incinerator in an Arctic work camp. The heat recovery system was to provide heat for the incinerator, the domestic water and sewage treatment buildings, and other associated camp facilities. Excess heat was to be rejected to a cooling pond. A study was conducted to utilize excess heat for power generation using steam and Organic Rankine Cycles alternatives. Arctic conditions present special problems for design and construction. Some of the design considerations are described as well as experience during startup.

NOMENCLATURE
MBtu/hr = Millions of Btu/hr = 1.055 gJ/h
TPD = Tons Per Day = 907 kg per day
NFS = Non-Frost Susceptible

INTRODUCTION
A 100 TPD (90,700 kg/day) solid waste incinerator was installed at the central incinerator facility of Prudhoe Bay, Alaska in 1980 to replace two previously installed incinerators. The combustion gas to hot water heat exchangers on both of the older incinerators were leaking after 2½ years of operation and the duct work was badly corroded. Finned heat transfer surfaces were eroded. The incinerators suffered from continual overheating due to a buildup of solid calcium carbonate on the water side. These problems were causing excessively high operation and maintenance costs.

The new incinerator was installed with a gas to hot water heat exchanger system to match the previous incinerator heat recovery system. This paper describes the incinerator, the heat recovery system and the proposed system addition to the incinerator facility.

BACKGROUND
Prudhoe Bay is the northern terminus of the Alaska Crude Oil Pipeline and is the center of oil activity in northern Alaska. Oil production, exploration and support activities are carried out by short term imported crews. The population of approximately 3500 persons lives in a construction camp environment on one to three week rotations. Solid wastes are generated from the camps and related kitchens, drill rig sites and support shops in the area.

Prudhoe Bay is located in the North Slope Borough which governs all land north of the Brooks Range in Alaska. The seat of government is located in Barrow, Alaska. The Borough requires all solid waste generated in the Prudhoe Bay area to be processed at the Borough’s central incineration plant. Privately operated incinerators built prior to the enactment of the law are allowed to continue operation.

Prudhoe Bay is located just above 70°N latitude, in an area of continuous permafrost. The permafrost extends from the surface to depths as great as 2000 ft (610 m). There is an active surface layer on the permafrost which thaws and refreezes every year. The active layer extends to a depth of 4-6 ft (1.2-1.8 m) during the short summer from late June to early September. These conditions present special construction problems not found in more temperate climates.
FIG. 1 INCINERATOR W/HOT WATER HEAT RECOVERY FOR BLDG. HEAT

Temperatures experienced in the Prudhoe Bay area range from -55°F (-48°C) in the winter to +75°F (24°C) in the summer. There are approximately 20,000 heating degree days per year. Although it is located on the Beaufort Sea of the Arctic Ocean, the area is essentially an arctic desert receiving less than 6 in. of precipitation each year. The precipitation occurs as fine granular snow which in winter is driven by strong winds across the arctic plains, creating white-out conditions which impact daily operations.

The site imposes severe conditions on buildings and on solid waste facilities. Landfill operation is not feasible because the long periods of low temperatures prevents bacterial decomposition. The frozen condition of the earth makes it difficult to excavate and drainage of the contourless terrain is difficult. Only inert materials such as ash, glass and metals are permitted to be landfilled.

DESCRIPTION OF SITE CONDITIONS

In 1980 the Borough purchased a new 100 TPD (90, 700 kg/day) starved combustion, solid waste incinerator capable of 40 MBtu/hr (42 GJ/h) energy input. The incinerator design included a batch type, ram feeder and vibrating furnace floors. A gas to hot water heat exchange system capable of 30 MBtu/hr (32 GJ/h) absorption was selected to match the existing incinerator heat recovery system. (Fig. 1). Subsequently, a turnkey design/construct contract was let for the completion of all work, including the building, system installation and startup.

The starved combustion achieves low particulate emissions by substoichiometrically burning the solid waste in a chamber to drive off the volatile components of the fuel. Combustion of resulting smoke and vapors is completed in a second chamber at a controlled temperature to insure complete oxidization. Ideally the process would result in complete burning of the fixed carbon in the first chamber, leaving only ash at the end of the vibratory grates.

The heat of incineration is recovered by a radiation furnace section and a convection section downstream of the secondary combustion zone. The radiation section is a water wall chamber surrounding the substoichiometric combustion process designed to absorb 10 MBtu/hr (11 GJ/h). The convection section consists of approximately 15 rows of bare and 7 rows of finned tubes. This section was designed to absorb 18 MBtu/hr (19 GJ/h) at a gas inlet temperature of 1400°F (760°C) which is controlled by recirculating the exhaust gas. The hot gas recirculation is used to lower ash temperature below the softening point to prevent buildup in the convection tubes. Gas recirculation accomplishes this goal without loss of efficiency or increase in exist gas mass flow that would occur if cold air is used for cooling. The outlet gas temperature was held to 400°F (204°C) to minimize condensation of corrosion products at the cold end of the heat exchanger.

The building that encloses the incinerator covers 16,600 ft² (1680 m²) and has a 48 ft (14.6 m) eave height. The
building is constructed adjacent to the previously existing 16,000 square foot (1720 m²) incinerator building and shares a common wall. The existing unloading and shredding facility was retained and a fuel conveyor from the shredder to the new incinerator was installed. The building and incinerator were constructed on a refrigerated slab on grade. The only penetration below grade is by the ash scoop hopper.

Incinerator combustion air is delivered to the building through an air handling unit which preheats the arctic air to acceptable room temperature. The waste heat is recovered in a high pressure hot water heating system which is used to heat glycol for building heating. Excess heat is rejected to a pond located approximately 1000 ft (328 m) from the facility. The heat exchange to the glycol loop was designed for 12 MBtu/hr (12 gJ/h) to heat existing facilities, the new incinerator building and future expansion of the North Slope Borough facility. All heat for the incinerator building and the adjacent camp is provided by the glycol heating system. The glycol heating system is shown in Fig. 2.

During the course of the construction it was determined that the amount of energy actually required for building heating was only 25 percent to 30 percent of heat available from the incinerator. A study was performed to evaluate alternatives for generating electric power using the excess energy. Later sections describe the existing hot water heat system and the alternatives studied for production of power from the existing facility and from a second 100 TPD (90,700 kg/day) incinerator planned to meet the projected solid waste loads.

**CONSTRUCTION OF FACILITY**

The primary guideline for facility design in permafrost regions is to prevent thawing of the ground below the normal active layer by eliminating heat flow into the earth. Most structures are built on piling about 4-6 ft (1.2-1.8 m) above the ground. This allows air to circulate under the building to assure refreezing of the ground during winter and removal of heat absorbed during the summer.

Where it is necessary to construct a slab on grade the design must prevent flow of heat into the ground on a continuous basis. The design used at this facility was a refrigerated slab as shown in Fig. 3. This design consists of providing a non-frost susceptible (NFS) gravel base over the tundra which is then covered with sand to a depth of 6 in. (15.2 cm). Refrigeration coils are embedded in the sand which is covered with rigid urethane foam insulation, a layer of gravel and a reinforced concrete floor. For additional safety, the major load points are supported on wood piles. The piles are placed in holes drilled in the ground and back filled with a dirt slurry. The slurry freezes back against the pile to provide the necessary load carrying capability.

**ANALYSIS OF WASTE MATERIAL**

A study was performed to determine the fuel characteristics of the waste and project the future solid waste volume that could be expected based on the growing oil development activity at Prudhoe. The author served as the process design consultant to evaluate methods for power
### TABLE 1 ANALYSIS OF WASTE SAMPLES

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Moisture %</th>
<th>Ash %</th>
<th>HHV BTU/lb</th>
<th>SO₂ %</th>
<th>C %</th>
<th>H₂ %</th>
<th>O₂ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.6</td>
<td>21.9</td>
<td>6,540</td>
<td>0.3</td>
<td>36.2</td>
<td>5.8</td>
<td>36.1</td>
</tr>
<tr>
<td>2</td>
<td>32.2</td>
<td>21.3</td>
<td>7,300</td>
<td>0.6</td>
<td>46.2</td>
<td>7.4</td>
<td>33.8</td>
</tr>
<tr>
<td>3</td>
<td>51.8</td>
<td>14.9</td>
<td>9,210</td>
<td>0.5</td>
<td>50.7</td>
<td>7.3</td>
<td>29.2</td>
</tr>
<tr>
<td>4</td>
<td>47.5</td>
<td>12.0</td>
<td>8,810</td>
<td>0.1</td>
<td>48.5</td>
<td>7.5</td>
<td>33.7</td>
</tr>
<tr>
<td>5</td>
<td>47.0</td>
<td>12.3</td>
<td>9,990</td>
<td>0.1</td>
<td>47.3</td>
<td>6.3</td>
<td>35.5</td>
</tr>
<tr>
<td>6</td>
<td>51.6</td>
<td>10.2</td>
<td>9,160</td>
<td>0.2</td>
<td>47.3</td>
<td>6.3</td>
<td>35.5</td>
</tr>
<tr>
<td>7</td>
<td>31.5</td>
<td>10.7</td>
<td>8,140</td>
<td>0.2</td>
<td>47.3</td>
<td>6.3</td>
<td>35.5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>41.0</strong></td>
<td><strong>14.6</strong></td>
<td><strong>8,450</strong></td>
<td><strong>0.3</strong></td>
<td><strong>45.2</strong></td>
<td><strong>6.8</strong></td>
<td><strong>33.1</strong></td>
</tr>
</tbody>
</table>

generation. The study was further motivated by high electrical costs of 20 to 25¢ per kW·h and the high electrical energy demands of the plant to operate the shredders, the incinerator and auxiliary equipment.

The solid waste comes from three sources; drill rigs, shops and camp waste. Representative samples were taken from each of the sites. The samples were analyzed for moisture content, ash and heat value. A ultimate analysis of selected samples was made to determine the carbon, hydrogen, and oxygen contents for combustion analysis. A summary of the results of these analyses is shown in Table 1. The ash content of the waste is lower than typical municipal solid wastes which generally produce between 25 percent to 30 percent residual ash. A major constituent of the waste from the drill rigs was solid wood; however, drilling mud and gypsum wallboard were observed in the mix.

Moisture content varied considerably within the sample. Samples were taken in January, a period when winds deposit snow in the bins holding the solid waste. It is expected that the moisture would actually be lower in the summer or when there is little or no wind.

The existing plant design required shredded solid waste that was injected into the incinerator through a ram feed or stuffer tube. The solid waste from the camps is shredded to 0.5 to 2 in. (1.3 to 5.1 cm) size in a Heil shredder. Loads from the rigs or shops which contain large pieces are first reduced in a Saturn low speed shredder and then further reduced in the Heil shredder. The fuel is then conveyed to a compactor. Two compactors are required for each incinerator. The one compactor is filled while the other is used to feed incinerator. All the shredded fuel is compacted and then conveyed to the incinerator. This process ultimately caused serious combustion problems in the new incinerator.

The fuel delivery system for the new incinerator was configured to use the shredded fuel. A feed system conveyed the shredded fuel to two compactors. Fuel is fed out of one compactor to the incinerator fuel hopper where it is pushed into the combustion chamber on a timed cycle. The shredded, compacted fuel would burn on the top surface, but the heat and air required to initiate combustion could not reach the interior of the pile. As a result combustion was inconsistent, heat release fluctuated violently and much of the material reached the end of the vibrating grates largely unburned.

The water walls surrounding the combustion chamber also adversely affected combustion and volatilization of the fuel by reducing temperatures in the chamber, further complicating the incinerator operation. The incinerator did not pass the Alaska Department of Environmental Conservation standards' major modifications to the fuel system, which are now being installed along with other modifications to meet compliance with the emission standard.

### DESCRIPTION OF THE HEAT RECOVERY SYSTEM

The primary purpose of the incinerator is to process solid waste as it is received and secondarily to provide heat to the building facility through a high temperature hot water system as shown in Fig. 3. The incinerator is the only device supplying heat, although backup auxiliary oil fired glycol heaters are installed (Fig. 4). The main design
problem was control of the hot water temperature, as the
combustion rate changed due to the change in fuel feed
rate or fuel heat value.

The incinerator output capacity of 30 MBtu/hr (32
gJ/h) was much higher than the potential heat demand of
8-10 MBtu/hr (8.4 - 10.5 gJ/h), requiring a portion of the
heat to be rejected to a cooling pond. Water is circulated
through the convection and radiation section at a constant
rate with the exit temperature controlled to 350°F
(177°C) while the inlet temperature varies from 210°F
(99°C) and up depending on heat absorption. The hot
water flows either to the glycol heat exchanger or the heat
rejection heat exchanger. There is a controlled bypass
loop which is used to maintain constant flow through heat
transfer surfaces exposed to high temperatures gases to
prevent steam formation.

Glycol in the system is circulated through the glycol
heat exchange at a constant flow. Its temperature is con­trolled to 200°F (93°C) by modulating the hot water flow
so that the glycol has first call on any heat produced in
the incinerator. The demand on the glycol heater could
vary from 0 to 12 MBtu/hr (13 gJ/h). The remaining hot
water flows either through the heat rejection heat ex­changer or the bypass line controlled by the boiler water
exist temperature controller. Valves TCV2 and TCV2A
receive the same signal from the boiler TIC but act oppo­site to each other. As the hot water temperature rises the
heat rejection valve opens to provide more cooling while
the bypass valve closes. As the hot water temperature
drops the reverse occurs. This control is particularly critical
because the heat flux within the incinerator could change
at a rapid rate, causing temperature changes as high as
200°F (93°C) per hour. This condition occurs during
startup when the auxiliary oil boiler in the incinerator is
turned on and off, adding or removing up to 14 MBtu/hr
(15 gJ/h) instantaneous heat change. A low cost digital 3
mode controller with an automatic/manual position with
bumpless shift between positions was installed. This con­troller could maintain the outlet temperature ot within
several degrees of the setpoint temperature.

The cooling water for heat rejection came from a pond
adjacent to the plant. The pond was filled by the Sagan­vanuktok River and was deep enough to sustain a 6 ft
(2.0 m) insulating cover of ice without freezing solid. This
source of water provided all cooling, process and drinking
water for the NSB facility. The cooling water was pumped
to the building through a 10 in. (254 mm) supply and 8 in.
(203 mm) return line. The cooling water flow was con­trolled by the outlet temperature of the cooling water.
This arrangement was selected to insure that cooling water
would continuously flow through the heat exchanger and
not be heated above its boiling point.

Operational control of the incinerator and all asso­ciated equipment, including the fuel conveyors, ash
removal and heat recovery, system was performed by a
programmable logic controller (PLC). This unit main­tained control of the fuel feed rate, the operation of
auxiliary burners, the ash handling, all alarms and safety
trips. The PLC was provided by the incinerator manufac­
turer who worked closely with the mechanical and elec­
trical engineers and contractors to integrate all the neces­
sary control logic normally provided by relay devices.

POTENTIAL HEAT RECOVERY FOR
POWER GENERATION

During the design/installation of the incinerator, a
study was performed to project future solid waste deliveries
and to evaluate methods for further recovering energy to generate electrical power. This study, based on analysis of current deliveries and historical data, and interviews of the oil field operators (Sohio and Arco) and service contractors suggested that growth of camp and drilling activities would continue for the next several years. Deliveries were projected to reach 90,700 kg/day) by the end of the year* when the incinerator would have been in operation for only one year. During the time more than 65 percent of the heat produced would be rejected to the cooling pond while the Borough would consume close to $1 million a year in electrical power for operation of the incinerator and the camp.

Potential power generation methods from the new incinerator were evaluated to maximize energy recovery with a system that was simple to operate and maintain and would have a minimum operational risk in an arctic environment.

Three methods of power production were evaluated:

(a) steam;
(b) high temperature organic rankine cycle; and
(c) low temperature organic rankine cycle.

Three methods were considered for producing steam within the existing incinerator;

*(a) replace the hot water convection section with a steam boiler section and modify the existing radiation section to be compatible with steam production;
(b) provide a high volume, hot water circulation system with an external steam separator to operate within the pressure and temperature limits of the existing hot water equipment; and
(c) duct hot incinerator gases to an external steam generator.

The first approach was rejected because of the high cost to replace the convection section and the extensive delays and loss of operation of the incinerator during the construction.

In the second approach, shown in Fig. 5, water is circulated through the boiler at a pressure of 350 psig (2410 kPa) and heated to 415°F (213°C), approximately 15°F (8°C) below the saturation temperature. Water is expanded from the hot water generator into a steam separator maintained at 150 psig (1030 kPa). A portion of the water flashes to steam while the remainder is recirculated to the hot water generator. Saturated steam is delivered to a condensing turbine capable of producing a maximum of 1500 kW under summer conditions when heat demand for the buildings is at a minimum. Average power generation is estimated at 1000 kW. Glycol heating would be achieved by taking water off the steam drum to the glycol heater and returning it to the deaerator. The major disadvantages of this design is the difficulty in controlling pressures, temperatures and levels throughout the

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**FIG. 5 RETROFIT STEAM/POWER GENERATION**

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**FIG. 6 LOW-TEMP ORGANIC RANKINE CYCLE ADDITION TO EXISTING INCINERATOR**
loop and the high parasitic horsepower required by the recirculating pump.

At the time of the study the Organic Rankine Cycle (ORC) was an emerging technology that appeared to offer some advantages over the steam cycle for low to medium temperature waste heat. High and low temperature ORC designs were evaluated. The low temperature organic rankine cycle (LT-ORC) is shown in Fig. 6. Several manufacturers offer designs using refrigerants as the working fluid for low temperature waste hot streams 200-350°F (93-177°C). The design is suitable for geothermal heat or recovery of low temperature steam for process plants. The system analyzed is designed by Mechanical Technology Inc. of Latham, New York. The advantage of the low temperature system is that hot water, already available, from the incinerator could be used as the heat source for the freon and required minimal piping changes to the incinerator’s hot water system.

Hot water is circulated to the evaporator and then to the preheater (economizer) and back to the hot water generator. The refrigerant is circulated from the condenser by a condensate pump to the vaporizer feed pump then to the preheater and evaporator. The evaporator pressure is set at approximately 75 psig (kPa) for R114 and the saturation temperature set at approximately 240°F (116°C). The vapor passes to a turbine which drives both the generator and the feed pump. The turbine, generator and feed pump is enclosed in a hermetic housing and is capable of producing approximately 900 kW. The refrigerant exhaust from the turbine is condensed at 75°F (24°C) by pond cooling water.

The high temperature organic rankine cycle (HT-ORC) shown in Fig. 7, uses combustion gases from the incinerator as a source of heat. The HT-ORC designed by Sundstrand Corp utilizes toluene as a drive medium. The hot gases are taken off the incinerator prior to the convection section at a blended temperature of 1100°F (593°C) and brought to the vaporizer. The vaporizer consists of the boiler and economizer sections. The toluene is evaporated at a temperature of 550°F (288°C) and at a pressure of approximately 300 psig (2070 kPa). Careful control of the hot gases and the toluene temperature is required to prevent degradation of the toluene above 550°F (288°C). The vaporized toluene powers the turbine which drives a generator and a feed pump similar to the freon system except the generators are air cooled and hot hermetically enclosed. After passing through the turbine, the toluene is a superheated vapor at a temperature of 379°F (193°C). A regenerative heat exchanger reduces the exhaust temperature by preheating the feed liquid. An air cooled condenser is used to prevent toluene contamination of the water supply and is effective because of the high condensing temperature of the toluene. The toluene condensate is then pumped through the feed pump to the regenerator section and the vaporizer.

A comparison of the advantages and disadvantages of the three systems evaluated is presented in Table 2. The primary advantages of the ORC in the arctic environment is its relative simplicity, and lack of freezeup potential. The high temperature system provides efficiencies close to that of steam but with the risk of using toluene, a flammable, toxic medium.

**INCIsoft OPERATOR - STATUS OF POWER GENERATOR MODIFICATIONS**

The incinerator was initially fired in August 1981 utilizing the shredded solid waste. Difficulties with the conveyor system prevented consistent operation of the incinerator. The compactor discharge system prevented the uniform release of fuel and required extensive modifications. During that time it was determined that the vibrating floors would not move the shredded waste through the furnace at a proper rate. Modifications to the system required increased air compressor capacity to significantly increase the vibration frequency.

Problems were experienced in maintaining constant boiler water temperature because of rapid changes in heat flux during combustion experienced during the startup process. The original 3 mode analog controller was subsequently replaced with a 3 mode digital controller with an automatic/manual position. The automatic/manual position allowed setting the controller more quickly and also provided the operator with greater flexibility in reducing the potential for overheating of the hot water.

After modification of the fuel feed system the incinerator could not sustain a consistent burning rate because the shredded fuel compacted on the grates and prevented
### TABLE 2
North Slope Borough Incinerator
CHARACTERISTICS OF VARIOUS POWER GENERATION METHODS

<table>
<thead>
<tr>
<th>System Features</th>
<th>High Pressure Steam</th>
<th>High Temperature Organic Rankine Cycle</th>
<th>Low Temperature Organic Rankine Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Manufacturers</td>
<td>Many component manufacturers, no system manufacturer or assembler.</td>
<td>Sundstrand</td>
<td>*MTI, Ormat, Eco1aire</td>
</tr>
<tr>
<td>2. Working Fluid</td>
<td>Water</td>
<td>Toluene</td>
<td>Freon R113 or R114</td>
</tr>
<tr>
<td>Freezing Point</td>
<td>32°F</td>
<td>-139°F</td>
<td>-137°F</td>
</tr>
<tr>
<td>3. Operating Experience</td>
<td>Many waste heat steam system installed but few with power generation. None currently operating with municipal waste as fuel.</td>
<td>Approximately 6 systems operating in utility and industrial sites.</td>
<td>U.S. systems have no units installed in field. Developmental experience only. Ormat has one or more installed at industrial sites.</td>
</tr>
<tr>
<td>4. Heat Transfer Path</td>
<td>Direct steam production by hot combustion gases.</td>
<td>Direct vapor production by hot combustion gases.</td>
<td>Hot gases heat water, oil, or generate steam, which then vaporizes organic fluid. This additional intermediate heat transfer loop required to prevent localized decomposition of organic fluid.</td>
</tr>
<tr>
<td>5. Complexity</td>
<td>Much system support equipment, such as water treatment system, boiler blowdown system, etc. Such systems are high maintenance and operator intensive.</td>
<td>No system support equipment required, other than fire protection system and alarm systems. These are low maintenance and require no operator attendance.</td>
<td>Intermediate heat transfer loop required, not necessary on steam or High Temperature ORC system. Maintenance and operator requirements expected higher than High Temperature ORC, lower then steam system.</td>
</tr>
<tr>
<td>6. Operating Personnel Requirements</td>
<td>Estimated 1-1/2 additional operator positions required to maintain and operate steam power system.</td>
<td>Expect no additional operator positions required to maintain and operate ORC power system.</td>
<td>Expect no addition operator positions required to maintain and operate ORC power system.</td>
</tr>
<tr>
<td>7. Expected Maintenance Requirements</td>
<td>Anticipate high maintenance typical of a steam system. Will include boiler maintenance, water treatment maintenance, turbine maintenance, pump maintenance, steam line maintenance, condensor maintenance, etc.</td>
<td>Anticipate low maintenance of power module. Some gas side maintenance of fluid vaporizer expected.</td>
<td>Anticipate low maintenance.</td>
</tr>
<tr>
<td>8. Cycle Efficiency</td>
<td>22%</td>
<td>21%</td>
<td>15%</td>
</tr>
</tbody>
</table>

*Ormat has at present one standard size, 300 KW system. Three complete systems, including generators are required to use all heat in the hot water system.

Eco1aire is developing standard sizes @ 500 & 1000 KW. They have heat transfer design and manufacturing capability but no turbine or system packaging and control experience.

MTI offers only an induction generator design which is not suitable for stand alone operation or in a small power generation system.
<table>
<thead>
<tr>
<th>System Features</th>
<th>High Pressure Steam</th>
<th>High Temperature Organic Rankine Cycle</th>
<th>Low Temperature Organic Rankine Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Working Fluid</td>
<td>Not toxic</td>
<td>Moderately toxic, above 200 ppm in air</td>
<td>R113 Moderately toxic</td>
</tr>
<tr>
<td>Toxicity</td>
<td>Non-flammable</td>
<td>NFPA Class 3 Flammability Rating</td>
<td>R114 Not toxic</td>
</tr>
<tr>
<td>10. Water Treatment</td>
<td>None required.</td>
<td>None required. Fluid system sealed.</td>
<td>None required. Fluid system sealed.</td>
</tr>
<tr>
<td>13. Package System</td>
<td>Individual components from various manufacturers, assembled to complete installation. System design by architect/engineer required.</td>
<td>Complete, pre-packaged vaporizer and power module from one manufacturer.</td>
<td>Complete, pre-packaged system from one manufacturer.</td>
</tr>
<tr>
<td>or Component System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Vapor Detector</td>
<td>None required.</td>
<td>Alarm and shutdown provided at 75% of lower explosive limit. Personnel alarm system is also recommended.</td>
<td>Personnel alarm system is recommended.</td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Fire Suppression</td>
<td>None required.</td>
<td>Required on all toluene equipment. Manufacturer recommends a CO₂ system. Halon will be considered as possible alternative.</td>
<td>None required.</td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. High Temperature</td>
<td>Required. Approximately 100', constructed of high alloy steel or refractory lined carbon steel.</td>
<td>Required. Approximately 100', constructed of high alloy steel or refractory lined carbon steel.</td>
<td>None required. Require hot water, hot oil or steam intermediate heat transfer loop to protect the freon.</td>
</tr>
<tr>
<td>Gas Ductwork</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
rapid combustion from occurring. The vibratory grates were unable to tumble the fuel and expose the unburned material to the combustion process. The welded water wall radiation chambers surrounding the furnace floors also prevented sufficient heat retention in the combustion chamber to assure completion of the combustion process within the confines of the furnace section. Modification is presently underway to eliminate the high speed shredder and bypass the compactors for normal feed directly to the ram feed hopper. This modification will eliminate compacting of the fuel and allow hot gases to reach the material so combustion can proceed more rapidly.

CONCLUSION

The major influence of arctic conditions on the incinerator installation was the need to elevate the incinerator above the building slab to minimize below-grade pits in the refrigerated slab. The only part of the system below the slab was the ash hopper pit. Normally the top of the ram feeder would have been at slab level to allow solid waste dumped on the floor to be pushed into the feeder by a bobcat loader. This type of furnace floor does not require processing or shredding of the fuel prior to input into the incinerator. Eliminating the processing will reduce the bulk density of the fuel significantly and improve the combustion properties of the fuel.

Another cause of combustion problems was the welded water wall radiation section, the shredded, compacted fuel and the low temperature of the combustion air. The water walls and cold combustion air keep furnace temperatures low while the shredded fuel increases the time required for combustion.

Power generation is a feasible alternative for a solid waste incinerator in an arctic region because of the high cost of electrical power in the region. ORC offers advantages over conventional steam power generation because of its simplicity, and its freedom from freezeup. The technology is not widespread as yet and remains to be proven in a variety of applications such as recovery from diesel engine exhaust and jacket water heat, geothermal source and industrial waste heat streams.

Once the combustion problems are resolved, it is expected that power generation will be incorporated to reduce the high electrical cost at the incinerator facility.

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