**COMBUSTION TESTING AND HEAT RECOVERY STUDY
Frank E. Van Lare Wastewater Treatment Plant, Monroe County**

Final Report

Prepared for

**THE NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY**

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1704-ERER-MW-92

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NYSERDA
Report 95-5

January 1995

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First printing: January 1995

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ACKNOWLEDGMENTS

A special thanks to the Monroe County personnel, who provided information and assistance essential to the completion of this project. We would especially like to acknowledge the assistance of Mark K. Ballerstein, P.E., Associate Engineer with the Monroe County Department of Engineering. From the Monroe County Department of Pure Waters, we would like to thank John G. Kierecki, Solids Handling Supervisor, for his assistance during various plant inspections, during combustion/APC stack testing, and for providing operating information requested throughout the study period. Mr. Kierecki's assistance in installing a bypass stack within a short period of time is also acknowledged. Also from the Monroe County Department of Pure Waters, we acknowledge assistance from Roger Steiner, Plant Manager, Steven Schwartzmeir, Supervisor of Instrumentation, and Robert Hamilton, Senior Pollution Control Operator.

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EXECUTIVE SUMMARY

The objectives of the study were to record and analyze sludge management operations data and sludge incinerator combustion data; ascertain instrumentation and control needs; calculate heat balances for the incineration system; and determine the feasibility of different waste-heat recovery technologies for the Frank E. Van Lare (FEV) Wastewater Treatment Plant. As an integral part of this study, current and pending federal and state regulations were evaluated to establish their impact on furnace operation and subsequent heat recovery. Of significance is the effect of the recently promulgated federal 40 CFR Part 503 regulations on the FEV facility. Part 503 regulations were signed into law in November 1992, and, with some exceptions, affected facilities must be in compliance by February 19, 1994. Those facilities requiring modifications or upgrades to their incineration or air pollution control equipment to meet Part 503 regulations must be in compliance by February 19, 1995.

COMPLIANCE WITH PART 503 REGULATIONS

Total Hydrocarbons (THC)

A major concern of the Part 503 regulations is their limitation of incinerator THC emissions to 100 parts per million, dry volume (ppmdv) as propane, at 7 percent oxygen, based on a monthly average. Measurements performed during testing of one of the incinerators, Furnace No. 5, in May 1993 demonstrated that average THC levels exiting the exhaust stack during each two-day test were substantially less than 100 ppmv. The averages of measurements for the three conditions tested ranged from below 20 ppmv for the tests conducted with the exhaust temperature at 1,200°F and 1,300°F, to about 40 ppmv for the tests conducted with the exhaust temperature at 1,100°F.

Based on THC emissions measured, the multiple hearth furnaces (MHFs) and their respective internal afterburner systems do not need to be modified at this time. In fact, there is a substantial margin available in the event that future regulations further restrict THC concentrations.

Heavy Metals

The Part 503 regulations also address heavy metals emissions. Calculations were performed for the seven metals that are regulated under Part 503 (beryllium, mercury, lead, arsenic, cadmium, chromium, and nickel) to determine whether measured concentrations of metals in the processed sludge meet the Part 503 requirements. Results demonstrate that all metals are in compliance. Therefore, no apparent need exists to install alternative scrubber systems at this time. In fact, there is again a substantial margin available because the modeling was based on incinerating up to 155 dry tons per day (tpd) of sludge. All three MHFs would have to be operating simultaneously at their maximum capacity to achieve this rate.

Review of other relevant federal and state regulations resulted in the conclusion that emissions are in compliance with all current regulatory limits; however, further study of New York State Air Guide-1 is recommended.

New York State Air Guide-1 presents guidelines for making permitting decisions relating to air toxics for the New York State Department of Environmental Conservation (NYSDEC) Regional Air Pollution Control engineers and their staff.

Air Guide-1 has not been promulgated as a regulation; however, it has been required by NYSDEC in connection with permitting activities on several recent sludge-related projects. Any re-permitting at FEV may require demonstration of compliance with Air Guide-1. It is expected that further revisions will be incorporated before Air Guide-1 is promulgated as a regulation within the next several months.

When the final revision of Air Guide-1 is completed and becomes law, Monroe County should consider refining the modeling for emissions, since the final analysis may impact which alternative is selected for air pollution control equipment.

WASTE-HEAT RECOVERY ALTERNATIVES

Economic analyses were performed for several waste-heat recovery alternatives for the FEV Wastewater Treatment Plant. Investigation of the alternatives led to the following conclusions:

- A flue gas-to-air heat exchanger alternative shows a very favorable payback of approximately two to three years. There is a risk in selecting this alternative, however, since no known existing installations have applied this technique in their operations. The consequences for operational stability are not known. A decision on whether to pursue it's study should await the results of a similar project currently under construction.
- Steam generation with a turbine generator to supply power for use within the plant shows a payback of about seven to nine years based on the assumptions of capital cost. This is one of the few alternatives that shows a favorable payback. Optimization of the equipment and operating conditions used, such as size and selection of turbine generator set, the boiler system steam generating pressure, the selection of condenser back pressure, and consideration for rate schedule issues such as energy demand charges, could make this alternative even more favorable. A more detailed approach is strongly recommended for future study of this important alternative.
- The addition of a condensing heat exchanger to the turbine generator alternative described above does not appear to be justified. The incremental amount of additional energy recovered does not justify the additional cost and longer payback period for this system. In addition, there is a risk in selecting this alternative for use in

sewage sludge incineration applications since it has not previously been tried.

- Steam generation for space heating is not warranted as a stand-alone alternative; however, it may be incorporated into one of the other alternatives. If another alternative utilizing a steam boiler is selected, a potential secondary use for the steam might be for space heating. Further study would be justified once a decision was made to purchase a steam boiler.
- The relatively high capital cost for indirect sludge drying compared to the potential annual fuel savings makes this alternative economically unfavorable. This is a consequence of the limited amount of incineration fuel savings available. No further consideration of this system for FEV is recommended.
- Direct sludge drying results in increased costs for all operating conditions. The relatively high capital cost for this type of system cannot be recovered in terms of annual fuel savings. Further, the degree of risk with it's selection is great, since no known installations exist. No further consideration of this system for FEV is recommended at this time.

Section 1

INTRODUCTION

The Frank E. Van Lare (FEV) Wastewater Treatment Plant located in Rochester, New York, is one of three wastewater treatment facilities operated by the Monroe County Division of Pure Waters (Monroe County). This facility treats wastewater from both residential and industrial sources. Sewage sludge generated at this plant is incinerated in any of three multiple hearth furnaces (MHFs).

As an integral part of this study, current and pending federal and state regulations were evaluated to establish their impact on furnace operation and subsequent heat recovery. The effect of federal 40 CFR Part 503 regulations on the FEV facility was determined. Part 503 regulations were signed into law in November 1992; with some exceptions, affected facilities must be in compliance by February 19, 1994. Those facilities requiring modifications or upgrades to their incineration or air pollution control equipment to meet Part 503 regulations must be in compliance by February 19, 1995.

The regulations limit the concentrations of certain metals in sewage sludge by equating several interrelated factors, including: sludge throughput, emission rates, air pollution control efficiency, and ambient air quality. Total hydrocarbon emissions are also limited by Part 503. This study considered whether the new regulations will require modifications to the air pollution control equipment, and the impact this would have on the feasibility of additional heat recovery technologies.

In order to conduct a heat recovery evaluation that accurately reflects major operating variables this project:

- Inspected the FEV facilities to determine existing conditions, to record and analyze sludge management, incinerator operations and combustion data, and to evaluate instrumentation and control needs;
- Evaluated the impact of recent and pending air pollution control (APC) regulations on the existing facilities;
- Conducted full-scale combustion/APC stack testing using one of FEV's three MHFs;
- Prepared a comparative cost evaluation of several currently available heat recovery alternatives, including the impacts of sludge incineration regulations, the equipment required to achieve clean air goals, and the overall energy balance.

This report presents the following:

- A review of plant processes, including sludge handling and dewatering, furnace facilities, sludge generation trends, and observations made during a site audit.
- A summary of the inspection of existing facilities. The purpose of the inspection was to:
 - determine the current status of the MHF renovation work and condition of the APC equipment,
 - identify building and equipment clearances and constraints with respect to replacement or addition of equipment,
 - identify instrumentation currently in use, as well as the new equipment recently installed by Monroe County personnel,
 - collect and review historical treatment plant operating data, specifically those relating to sludge combustion, dewatering operations, and sludge production.
- The results of combustion/APC stack testing. Testing was performed to determine the effectiveness of the current system in meeting Part 503 regulations, and to obtain base cases for operating conditions to be used in mass and energy balances for combustion analysis. All relevant data are presented. The test data were used to assess the plant's compliance with applicable federal and state air pollution control regulations.
- A review of air quality modeling techniques used to assess compliance of the FEV plant with Part 503 regulations, and modeling results.
- A discussion of air pollution control alternatives available to meet current and pending regulations, and an economic analysis of each viable alternative.
- A review of waste heat recovery options available, potential energy uses, viable equipment arrangements, an economic analysis for each alternative equipment arrangement, and recommendations.

Section 2

EXISTING SLUDGE MANAGEMENT SYSTEMS

2.1 DESCRIPTION OF EXISTING SLUDGE MANAGEMENT SYSTEMS

At the Frank E. Van Lare Water Pollution Control Plant (FEV) primary and secondary sludge is thickened and dewatered, then incinerated in one of three multiple hearth furnaces (MHFs). Ash is stockpiled at the facility prior to disposal at a permitted sanitary landfill. Unit process information is summarized below.

Table 2-1	
FEV Unit Process Information	
Number of Thickeners	8
Number of Presses	10
Total Press Capacity (dry tons/day) ¹	180
Average Sludge Quantity (dry tons/day)	65
Number of Furnaces	3
Total Capacity (dry tons/day) ¹	135
Average Feed Rate (dry tons/day)	65
Ash Production (dry tons/day)	15 to 36
Ash Production (dry tons/year)	7,000
Ash Production As Stored (tons/year) ²	11,700

Footnotes:

1. Unit process capacities are based on original rated design capacity and all units in operation. Furnace capacity at FEV is limited by the capacity of a filter/scrubber water pump station (see text).
2. Ash production as stored is greater than actual ash production due to moisture gain in the slurry system and stockpile. Pile ash is typically 60 percent solids (40 percent moisture).

A detailed description of FEV's sludge management processes is presented in the following subsections.

2.2 FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT

The FEV plant generates approximately 65 dry tons/day of combined primary and secondary sewage sludge solids, which accounts for approximately 75 percent of the total sludge solids produced by the three county treatment plants. FEV processes sludge 24 hours per day, 7 days per week. Primary and secondary sludge is first fed to thickening tanks where gravity settling increases the solids concentration prior to subsequent processing. Thickened sludge is fed to day tanks, which hold sludge until dewatering. Scum collected from the primary clarifiers is fed to day tanks and is blended with thickened sludge prior to dewatering. Dewatering is accomplished using belt presses. Dewatered sludge is fed to one of three MHFs where it is incinerated. Ash from the MHFs is stored temporarily on site in a lagoon and in large storage piles. Ash from the piles is ultimately hauled to a local sanitary landfill.

2.2.1 Sludge Handling and Dewatering

Primary and secondary sludges undergo gravity setting in eight conventional gravity thickeners. Each thickener is 70 feet in diameter, has a side water depth of 10 feet, and has a total volume of 345,000 gallons. Each thickener is covered with a fiberglass dome to minimize the release of odors.

Thickened sludge is pumped from the thickeners to day tanks where it is held until dewatering. There are four 40,000-gallon, in-ground covered day tanks that feed the dewatering facilities. Normally two day tanks are used in series; the other two serve as backups. Scum from the primary clarifiers is pumped to the day tanks and blended with the thickened sludge prior to dewatering. Series operation of the day tanks helps to ensure proper blending of the scum and sludge.

A total of 12 piston pumps are used to feed the dewatering facility. Approximately 450,000 to 500,000 gal/day of thickened sludge with a solids content of 3.2 to 3.5 percent is fed to the filter presses. Liquid polymer is added directly to the sludge piping using four port injector rings and in-line mixers. Polymer conditions and improves the dewatering characteristics of the sludge. It is added at a rate of approximately 150 lbs/dry ton of sludge solids, which translates into an average feed rate of 1,150 gal/day. Due to the variable dewatering characteristics of the feed sludge, two polymer injection points are provided on each filter-press feed line. This option allows operators to fine-tune polymer addition in terms of the quality of the dewatered sludge.

The dewatering facilities include a total of ten belt filter presses. Eight 2-meter presses are available for feeding sludge cake to two of the three operational furnaces, Furnaces No. 4 and No. 5. Two 1.5-meter presses feed Furnace No. 3. Each press has the capacity to dewater 1,500 dry lbs/hour of sludge with an initial solids content of 3 percent.

The solids content of dewatered sludge cake typically ranges between 19 and 24 percent and averages approximately 22 percent. Sludge cake is fed to the furnaces via an inclined belt conveyor, which feeds a hollow-ribbon screw conveyor at the top of each furnace.

FEV also maintains two off-line sludge holding tanks that can be used for sludge storage in the event downstream sludge processing equipment needs to be taken off-line for repairs. The sludge holding tanks are not used unless operator scheduling, processing demands, equipment breakdown or some other factor requires that they be placed in service. The sludge holding tanks are converted floating cover digesters that have had their floating covers replaced with fixed fiberglass domes. Each holding tank has a capacity of 1.3 million gallons. The tanks are equipped with recirculation pumps, which are used to keep the sludge fully mixed while it awaits further processing. Under average sludge production conditions the holding tanks provide approximately 5½ days of off-line holding capacity.

2.2.2 Furnace Facilities

There are three active MHFs (Nos. 3, 4, and 5) at FEV; Furnaces No. 1 and 2 are inactive and have been dismantled. Furnaces No. 4 and 5 were installed in 1972, and both are 11-hearth, 22-foot-3-inch-diameter units with a nominal process rate of 55 dry tons of sludge per day, at 21 percent solids. Furnace No. 3 is a six-hearth, 22-foot-3-inch-diameter unit with a nominal process rate of 25 dry tons of sludge per day at the same solids concentration.

For each of Furnaces No. 4 and 5, two burners are mounted on the top hearth shell. These burners serve to elevate the temperature of the afterburner zone, as well as to minimize bypassing of unburned hydrocarbon gases from the furnace. The afterburners can operate on either natural gas or fuel oil.

Three dual-fuel burners exist in each of hearths No. 3, 5, 7 and 9. As with any MHF, these burners are used primarily for control of temperatures to promote the proper balance of drying, combustion, and ash cooling in the various furnace zones. All burners are fuel/air modulating: control is provided by programmable controllers taking their signals from temperature probes (thermocouples) located in each hearth of the furnace.

A large fraction of the combustion air is provided by recirculating air that has been used in cooling the center shaft and rabble arms back into the hearths. Of the 6,000 standard cubic feet per minute (scfm) that enters the center shaft and are heated to about 325°F, about 4,500 scfm are typically recirculated into any of hearths 7, 9, or 11. By recirculating this heated air, the use of auxiliary fuel in the combustion burners is minimized. A special feature of the FEV furnaces is their ability to provide additional air in the various hearths by means of nozzles located in the rabble arms. These nozzles provide additional air in the vicinity of the sludge bed as it burns on the hearths.

Additional features of Furnaces No. 4 and 5 are the controlled ambient air inlet ducts on hearth 11. These air inlets promote a more controlled influx of air into the furnaces to act as cooling and combustion air.

Furnace No. 3 is used as a back-up incinerator when either No. 4 or No. 5 is unavailable. Furnace No. 3 is a six-hearth design with an expanded top hearth, installed in 1972. Each hearth is 22-foot, 3-inch in diameter. Although Furnace No. 3 incorporates a top-hearth afterburner, it is of the older design, consisting of two self-contained afterburners in the vicinity of the furnace exit plane.

Above the afterburner section of each furnace, flue gases that have been elevated to temperatures of about 1,100°F to 1,350°F are drawn into a dedicated scrubber system, consisting of a water spray quench section and an impingement tray tower. These scrubber systems cool the flue gases and remove gaseous and particulate pollutants. The final temperature of the cooled flue gases is about 120°F. The water that is injected into the scrubber system, plus an additional small but measurable amount that is condensed out of the flue gas, is drained from the bottom of each scrubber.

Treated flue gases continue past the scrubber and enter the induced draft (I.D.) fan of each furnace. From the I.D. fan, flue gases are routed into a common breeching system, with final discharge to atmosphere through a common stack.

Scrubber water from the furnaces and filtrate from the filter press are routed to a floor sump and pump station, which is used to return wastewater to the head of the treatment plant. When more than two furnaces operate while all of the belt presses are operating, the combined filtrate and scrubber water volume exceeds the present capacity of the pump station. Therefore, the usual operating configuration is to have either Furnace No. 4 or No. 5 operating, with Furnace No. 3 as a backup. This limitation has not impeded operations, however, because the combined capacity of any two furnaces easily exceeds the rate at which sludge solids are produced.

2.2.3 Ash Handling

Ash drops from the bottom hearth of each incinerator into an ash/clinker grinder where the particle size is reduced to less than 1-inch. From the grinder, the ash drops into a mixing tank, where chlorinated treatment plant effluent is added to form a slurry.

Furnaces No. 4 and 5 share a common slurry mixing tank that can be partitioned to keep the ash from the two furnaces separate. The ash slurry from Furnaces No. 4 and 5 flows through a splitter box and is pumped through a force main to either of two dewatering lagoons. Ash from Furnace No. 3 is also mixed with chlorinated plant effluent in a slurry tank located beneath the furnace. The slurry from Furnace No. 3 flows by gravity through a 12-inch pipe to another ash-holding lagoon.

Water from the furnace flue gas scrubbers also may be diverted to the ash handling system, although this practice has been generally discontinued at the facility. Scrubber water is currently returned to the head of the treatment plant through the in-plant sewer system.

The ash dewatering lagoons are located at the northern end of the treatment plant site and are lined with impermeable soil. Overflow from the lagoons is directed to a pump station and is pumped to the head of the plant. The lagoons can be operated in series, parallel, or singly, depending upon the setting of a series of weirs and sluice gates. The lagoons have a sufficient capacity for up to three months of continuous use before dredging must be performed. Dredging with a clamshell bucket is performed an average of four times each year. The dredged ash is stockpiled on-site adjacent to the lagoons, allowing gravity to drain off additional water before the ash is hauled from the site.

Ash production at the FEV plant averages 7,000 dry tons/year. On-site storage capacity is available for up to five years' production. Ash is generally removed from the site and disposed of at a sanitary landfill in 5,000 ton-allotments.

Section 3

INSPECTION OF EXISTING FURNACE FACILITIES

An inspection of incineration equipment and systems at the Frank E. Van Lare (FEV) Wastewater Treatment Plant was conducted at the onset of the project, in July 1991. At that time Malcolm Pirnie inspected the furnaces and air pollution control equipment. Particular attention was given to building and equipment clearances and constraints for potential interferences with equipment modifications, or new equipment installations. Meetings were held with plant personnel to obtain and discuss historical plant operating records specifically relating to sludge production, dewatering operations, and sludge combustion processes.

The major components of all three furnaces at FEV have been completely rebuilt. Furnace No. 5 was undergoing a major rehabilitation during the July 1991 inspection. Since that time, Furnace No. 4 has undergone similar repair work. Furnace No. 3 was renovated several years earlier. The following subsections more fully describe their current conditions of the furnace facilities.

3.1 CURRENT CONDITIONS OF THE MULTIPLE HEARTH FURNACES AND AIR POLLUTION CONTROL EQUIPMENT

On an average annual basis, approximately 65 dry tons of sludge solids are combusted daily. Based upon records kept in 1990, daily sludge production at the facility during that year peaked at 105 dry tons/day. Records for 1991, 1992, and 1993 to date also show daily sludge production peaking at approximately 105 (± 5) dry tons/day. During normal operation, one of the 11-hearth units (Furnace No. 4 or No. 5) is run continuously as the "lead" furnace. Furnace No. 3 is operated on an as-needed basis as a function of sludge production.

3.1.1 Results of 1991 Visual Inspection

During inspection of the furnaces in July 1991, Furnace No. 4 was burning sludge solids, Furnace No. 3 was in stand-by mode firing only auxiliary fuel, and Furnace No. 5 was down for refurbishment.

3.1.1.1 Furnace No. 4 Based on a visual inspection of the outer shell, the furnace was found to be in relatively good condition for its age. One measure of determining the extent of any damage to the shell is the degree of deformation it has taken from its original true-to-round condition, as judged by the butt strap dimensions of the combustion zone hearths. The butt strap diameter in the evaporation and burning zones had increased by less than 1 inch, which is considered better than what is typical over the time period involved. In addition, doors and access ports were in reasonably good condition for their age. Since Furnace No. 4 was scheduled for major rehabilitation, many of the other observations made regarding the external features are no longer applicable.

Because the furnace was operational during the inspection, no assessment of the internal refractory or insulation conditions were made.

3.1.1.2 Furnace No. 5 Furnace No. 5 was in the process of being completely refurbished. Identical renovations were scheduled and performed for Furnace No. 4. The work involved complete rehabilitation of most of the major components.

Included in the work were: complete shell renovation and finishing, complete internal refractory and insulation removal and replacement, door and frame repairs, removal and replacement of certain castings (such as rabble arms, drive gears, and the center shaft), new center shaft hydraulic drive, new return air damper positioners, upper and lower center shaft bearing replacement, modifications of the center shaft cooling air recycle and exhaust system, and new dual-fuel burners.

In addition to the contracted work described below, plant instrumentation specialists installed a state-of-the art computer control system to replace the original analog-based relay system.

3.1.1.3 Exhaust System and Air Pollution Control Equipment The air pollution control equipment for control of metals and particulates, and flue gas exhaust systems, including breeching and dampers, appeared to require maintenance. All APC equipment appeared externally to be severely corroded. Patchwork fiberglass repairs were evident over extensive portions of the ducts and breeching. The scrubber tray towers were also repaired in places with fiberglass matting. Current efforts by the plant are underway to determine the status of internal components of the scrubber systems. Inspections of such items as trays, spray nozzles, mist eliminator equipment, and internal linings will offer additional information on the overall condition of the scrubbers.

3.1.2 Additional Instrumentation Recommendations

Certain additional instrumentation will be required for compliance with the Part 503 Regulations (discussed in Subsection 4.4.1). Other instrumentation is recommended for convenience of operation and process evaluation.

3.1.2.1 Regulatory Compliance Part 503 regulations impose monitoring requirements on the sewage sludge incineration facility at the FEV plant. The facility must have equipment in service to monitor the following:

- total hydrocarbon content of the exhaust stream, monitored continuously;
- oxygen content of the exhaust stream, monitored continuously;
- moisture content of the exhaust stream, monitored continuously;
- sludge feed rate;
- dry sludge and volatile solids content (samples of sludge being fed into the incinerator must be taken daily);
- pressure drop across the wet scrubber;
- temperature at each hearth: at a minimum, one thermocouple in the drying and cooling zone and two thermocouples in the combustion zone are required for measuring temperature.

The furnaces at the FEV facility already have installed and operating all of the equipment mentioned above, except instrumentation to continuously monitor total hydrocarbons, oxygen (dry basis), and moisture in the exhaust stream.

3.1.2.2 Operational Convenience Although the extensive plant upgrades have included numerous control features, the following instrumentation upgrades will improve evaluation of daily plant operation.

- continuously monitor and record auxiliary fuel consumption by both the afterburner and the furnace auxiliary fuel burners;
- install permanent airflow measurement instrumentation for the center shaft cooling air, burner combustion air, and afterburner combustion air.

3.2 REVIEW OF HISTORICAL OPERATING DATA

Plant records over recent years provide information on sludge generation trends, sludge solids content, and plant fuel use. This information is useful in projecting future sludge generation rates and in assessing auxiliary fuel use by the incinerators. Daily logs for the past three years were also consulted for information regarding daily peaks in sludge throughput.

3.2.1 Sludge Solids Generation

Sludge solids generation records for the period of January 1988 through September 1993 are summarized in Table 3-1. As shown, sludge production has been relatively consistent over the six years analyzed.

Table 3-1						
Sludge Solids Generation Data for the FEV Plant (January 1988 - September 1993)						
Sludge Generated (Dry Tons)						
	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>
January	2,009	2,309	1,942	1,787	1,934	1,936
February	1,887	1,689	1,592	1,676	1,593	1,486
March	1,943	2,117	1,613	1,993	2,088	1,950
April	2,218	1,629	2,043	2,352	1,933	1,686
May	2,106	2,082	1,875	1,987	2,110	1,997
June	2,361	2,262	2,188	2,152	1,764	2,297
July	1,958	2,042	2,461	1,957	2,065	1,975
August	2,049	1,903	2,026	1,926	2,310	1,951
September	1,813	1,932	1,937	1,760	1,972	1,956
October	1,791	1,814	2,048	1,989	1,789	N/A
November	1,738	1,672	1,378	1,925	1,980	N/A
December	<u>1,315</u>	<u>2,010</u>	<u>1,870</u>	<u>1,605</u>	<u>1,453</u>	<u>N/A</u>
Total	23,188	23,461	22,973	23,109	22,991	N/A
Monthly Average	1,932	1,955	1,914	1,926	1,916	1,915
Daily Average	63.4	64.3	62.9	63.3	62.8	63.1

Average sludge solids generation at FEV ranged from 1914 dry tons/month (62.9 dry tons/day) in 1990 to 1955 dry tons/month (64.3 dry tons/day) in 1989. The average sludge generation rate at FEV for the period of January 1988 through September 1993 was 1927 dry tons/month (63.3 dry tons/day). To date, the peak sludge production rate in 1993 has been approximately 105 dry tons/day. Peak rates observed for years 1988 through 1992 are comparable.

3.2.2 Sludge Solids Content

Sludge solids content is measured daily at the plant. From available plant data, percent sludge solids on a yearly average basis, along with minimum and maximum daily measurements for the period of January 1990 through September 1993, are listed in Table 3-2.

Table 3-2				
Sludge Solids Content (percent) at the FEV Plant				
	1990	1991	1992	1993
Average (yearly)	23.7	22.6	22.9	22.9
Minimum (daily)	19.5	19.0	18.5	17.9
Maximum (daily)	31.1	28.2	31.4	30.2

The average solids content in the sludge did not vary significantly over the four years studied. However, there is a notable difference between the minimum and maximum daily measurements and the yearly averages.

Measurements of percent solids content in the sludge were also made during combustion/APC stack testing (May 17-22, 1993). Over these six days, the average solids content was 19.4 percent, with a minimum of 17.1 percent and a maximum of 23.2 percent. The average solids content of the sludge measured by the plant for this same period of time was 21.5 percent. This variation in data is believed to be due to differences in measurement techniques. Sludge samples taken during combustion/APC stack testing were measured for solids content using ASTM method D 2216, while the plant uses measurements based on microwave heating and drying of the samples.

3.2.3 Plant Fuel Use

The incinerators at the FEV plant can use either No. 2 fuel oil or natural gas to supplement sludge for combustion. The north and south boilers also use fuel oil or natural gas to provide hot water for plant heating. For convenience, the plant has used natural gas exclusively since 1991.

The average equivalent amount of energy provided by auxiliary fuel (natural gas and fuel oil) during operation of the furnaces is shown in Table 3-3.

Table 3-3	
Average Equivalent Energy Used by Furnaces	
Year	Equivalent ¹ Btu/ton dry sludge incinerated
1990	9.6×10^6
1991	10.6×10^6
1992	11.0×10^6
1993	12.5×10^6

¹ Estimated higher heating value (HHV) of gas = 1000 Btu/ccf,
HHV of fuel oil = 142,000 Btu/gal.

The average equivalent amount of heat energy provided by auxiliary fuel to the furnaces has steadily increased over the past four years. Among factors that influence auxiliary fuel usage are operating temperatures in the furnace and afterburner, sludge characteristics including moisture and combustible content, furnace standby operation time, and operating practices such as opening of hearth doors and recycling of center shaft air.

Section 4

COMBUSTION/AIR POLLUTION CONTROL STACK TESTING RESULTS AND COMPLIANCE WITH AIR REGULATIONS

4.1 TESTING OBJECTIVES

The two primary objectives of combustion/air pollution control (APC) stack testing were:

- (1) To quantify emissions of the pollutants of concern, and to establish whether the furnaces complied with state and federal regulations
- (2) To determine current energy use and to collect data necessary to evaluate the feasibility of various heat/energy recovery options.

Combustion/APC stack testing consisted of three test conditions, each covering two continuous days (24 hours/day) of operation:

- (1) Full sludge throughput, afterburner temperature at approximately 1,100°F
- (2) Full sludge throughput, afterburner temperature at approximately 1,200°F
- (3) Full sludge throughput, afterburner temperature at approximately 1,300°F

Complete details of the testing requirements are specified in the test protocol, a copy of which is found in Appendix A.4. The appendices to this report may be obtained upon request.

4.2 SUMMARY OF COMBUSTION/AIR POLLUTION CONTROL STACK TESTING

Sludge sampling and simultaneous stack testing of Furnace No. 5 were conducted from May 17 through May 22, 1993. During testing, energy consumption data as well as emissions of certain heavy metals, hydrocarbons, particulate matter, sulfur dioxide, and other constituents specified in the test protocol were measured. Test results were included in a final report dated October 13, 1993, a copy of which is found in Appendix A.7. Test results in reduced form are presented on Tables A-1 through A-29 in Appendix A.1, and also included at the end of this Section.

4.3 TEST RESULTS

Appendix A.1 contains the Combustion/APC Stack testing results shown in tabular form. Figures in Appendix A.2 include all reduced data identified in the Data Evaluation and Analysis Plan, presented in Appendix A.6. Figures A-1 through A-14 of Appendix A.2 are also included at the end of this Section. Analyses of

the test data as described in the Data Evaluation and Analysis Plan were performed, and are summarized in the following subsections.

4.3.1 Mass and Energy Balance/Combustion Analyses

Mass and energy balances of the system at each of the three test conditions were performed. Figures 4-1, 4-2, and 4-3 present the mass and energy balance information based on mean values of all measured parameters for the three test conditions, respectively. Results of computer-generated mass and energy balance analyses representing each of the three test conditions are presented in Appendix C.1. The mass and energy balances were based on average measurements of the following parameters during each test condition:

- sludge feed rate,
- sludge solids concentration,
- sludge ultimate analysis (C, H, O, N, S, Cl, moisture, ash),
- gross calorific value of sludge,
- top hearth and afterburner temperatures,
- center shaft return air temperature,
- ash discharge temperature,
- center shaft cooling airflow rate,
- center shaft return airflow rate,
- burner and afterburner combustion airflow rate,
- auxiliary fuel flow rate,
- flue gas composition (percent O₂) at stack,
- flue gas flow rate at the stack, and
- ambient air temperature (cooling air inlet temperature).

The values of auxiliary fuel (natural gas) usage estimated by Environment/One, the testing firm, appeared inexplicably high (See tables in Appendix A.8 for details). The testing firm had assumed prorated estimates (as a simplified assumption) for the subject furnace, based on records of total plant auxiliary fuel consumption in 24-hour increments. Computer-generated estimates of natural gas use by Furnace No. 5, based upon operating parameters measured during testing, were 10 to 40 percent lower than the prorated estimates of natural gas use determined by the testing firm. The plant's daily fuel use log includes natural gas use by all sludge incinerators, as well as other heating systems which the testing firm's estimate neglects to consider. In addition, while Furnace No. 5 was being tested under optimum operating conditions, Furnace No. 3 was most likely operating less efficiently, at less than optimum conditions. Thus, an accurate estimate of fuel use by each of the two furnaces cannot be prorated from the daily fuel consumption records, based solely on sludge feed rates. For the purpose of this presentation, and for use in the subsequent waste heat recovery economic analyses, natural gas consumption was calculated using the computer-based mass and energy analyses.

Also, flue gas flow rates measured at the stack were consistently higher than values calculated by the mass and energy balances. The measured values were believed to be influenced by possible infiltration of ambient air into the breeching system by the I.D. fan, leaking dampers, and leaking ducts. The

FIGURE 4-1
COMBUSTION TESTING AND MONITORING
MEAN OF MEASURED PARAMETERS – VAN LARE INCINERATOR #5
TEST CONDITION NO. 1

FIGURE 4-2
COMBUSTION TESTING AND MONITORING
MEAN OF MEASURED PARAMETERS - VAN LARE INCINERATOR #5
TEST CONDITION NO. 2

FIGURE 4-3
COMBUSTION TESTING AND MONITORING
MEAN OF MEASURED PARAMETERS - VAN LARE INCINERATOR #5
TEST CONDITION NO. 3

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quantity was estimated to be 2,000 to 2,500 scfm. The estimate of air infiltration in the mass and energy balance calculations was selected by trial and error calculations to arrive at the same oxygen concentration in the stack that was reported. Thus, the calculations for all three conditions approximate the actual measured results.

The mass and energy balances were used as a base case to evaluate the heat recovery options. Summary results (not the complete calculation) of the base case calculations are presented in Appendix C.2. Projected flue gas conditions were used to estimate heat recovery potential for the alternatives. Mass and energy balances utilizing waste heat recovery alternatives were performed to forecast fuel savings. The summary results for these alternatives are presented in Appendix C.3.

4.3.2 THC Emissions versus Afterburner Temperature

Total hydrocarbon (THC) measurements were taken at both the furnace exit duct and the stack during May 1993 testing. Hourly THC measurements are shown in Tables A-20 through A-22, while Table A-29 shows a summary of THC data for each test condition. The tables are included at the end of this section. The range of hourly average THC emissions measured during each test condition is summarized in Table 4-1.

Table 4-1	
THC Emissions vs. Afterburner Temperature	
Approximate Afterburner Temperature (°F)	Average Hourly THC Emissions @ Stack (ppmdv as propane, at 7% O ₂)
1,100	11 - 122
1,200	15 - 30
1,300	6 - 29

Hourly THC emissions at the furnace exit duct (afterburner exit) and at the stack versus afterburner temperature are shown graphically in Figures A-1 and A-2, respectively. The figures indicate that there is a relationship between THC emissions and temperature, with THC concentrations at both the furnace exit and the stack dropping off rapidly when the afterburner temperature exceeds about 1,120°F. At temperatures at or below about 1,120°F, THC emissions at the stack exceeded 100 ppmdv (as propane at 7 percent oxygen) during two 4-hour periods of data collection. With the afterburner temperature at or above 1,200°F, there was little variation in THC emissions, with measurements typically below about 20 ppmdv (as propane at 7 percent oxygen). As the afterburner temperature is increased above about 1,200°F, a few THC emissions readings showed a slight increase, which is normally unexpected. It may be a result of measurement error, a result of the afterburners operating at a point on their turndown range where

emissions control is not optimized, or the result of some other unknown phenomenon.

4.3.3 CO Emissions versus THC Emissions

Figures A-3 and A-4 show the relationship between CO and THC measured at the furnace exit duct and the stack, respectively. At both locations, little or no correlation between THC emissions and CO emissions is evident.

4.3.4 Metals Content in Sludge versus Metals Content in Flue Gas

Metals content in the sludge and in the flue gas were measured during each run of the May 1993 Test program (three runs for each of the three conditions). Test results are included in Tables A-7 through A-18.

Emission rates of beryllium, chromium, copper, nickel, lead, and zinc were reduced by over 90 percent from the rate of metal feed in the sludge. Emission rates of arsenic and cadmium were reduced from feed rates by more than 80 percent. Based on results of the three test runs, the emission rate of selenium was reduced by an average ranging from 39 to 52 percent, as compared to the rate of feed to the incinerator.

Mercury emissions readings were widely variable. Test data included mercury emission rates both above and below corresponding readings of mercury feed rates, indicating an obvious error in measurement. From our experience, mercury control efficiencies are typically extremely low (less than ten percent). Therefore, we have assumed a zero percent mercury control efficiency to be conservative. Even with no removal, mercury emissions at the FEV plant are well within regulation standards.

4.3.5 Energy Usage

Auxiliary fuel used by the furnace and afterburner was calculated using the computer-generated mass and energy balances. Results of these calculations based on mean values of the operating parameters appear in Appendix C.1 (Appendices to this report are available upon request). Estimated fuel usage for the three test conditions is summarized in Table 4-2 below. Also presented are normalized fuel usages, based on natural gas used per pound of dry sludge incinerated, as well as per pound of wet sludge incinerated.

Table 4-2			
Auxiliary Fuel (Natural Gas) Usage During Testing			
	Condition 1	Condition 2	Condition 3
Furnace (Mcf/day)	0.259	0.290	0.263
Afterburner (Mcf/day)	0.142	0.275	0.423
Total (Mcf/day)	0.401	0.565	0.686
<u>Furnace</u>			
scf/dry lb sludge	2.7	3.0	2.6
scf/wet lb sludge	0.52	0.56	0.51
<u>Afterburner</u>			
scf/dry lb sludge	1.5	2.8	4.1
scf/wet lb sludge	0.29	0.53	0.82
<u>Total</u>			
scf/dry lb sludge	4.2	5.8	6.7
scf/wet lb sludge	0.81	1.09	1.33

Electric energy consumed by major motors associated with Furnace No. 5 was measured during testing. The results of these measurements are presented in Tables A-27 and A-28.

Primary electric energy users in the sludge incineration system include the induced draft (I.D.) fan, the center shaft drive motor, the burner and afterburner combustion air blowers, and the center shaft cooling fan. The induced draft fan motor had the highest rate of energy use, ranging from 43 to 53 hp (32 to 40 kW) during the three test conditions. Actual energy use by the I.D. fan increased by several horsepower with higher afterburner temperatures, as compared to the 1,100°F test condition. The increased power draw was no doubt a result of higher stack flow rates accompanying the higher temperature conditions. Rates of average energy usage during all three test conditions are presented in Table 4-3.

Table 4-3	
Average of Electrical Energy Usage Measured for Major Motors During All Three Test Conditions	
Induced Draft Fan	43 to 53 hp*
Center Shaft Drive Motor	8 hp
Burner Combustion Air Blower	20 to 21 hp
Afterburner Combustion Air Blower	14 to 19 hp
Center Shaft Cooling Air Fan	24 hp
TOTAL	109 to 125 hp (80 to 93 kW)

* Average energy use increases with higher afterburner temperatures

4.3.6 Sulfur Dioxide Content of the Flue Gas

Sulfur dioxide (SO_2) emission rates during stack testing ranged from 0.11 lb/hr to 3.84 lb/hr. Both extremes were recorded during test condition 1. Tables A-23 and A-24 (Appendix A.1) show measured emissions values during testing. These emission rates are well below the maximum allowable emission rate of 103 lb/hr imposed by New York State 6 NYCRR, Part 212. Compared to the average sulfur content in the sludge during test condition 2, uncontrolled SO_2 emissions are projected at approximately 63 lb/hr, indicating that the air pollution control equipment is removing over 95 percent of the SO_2 from the incinerator exhaust stream.

4.3.7 Hexavalent Chromium and Total Chromium Content

Hexavalent chromium (Cr^{+6}) is of interest in characterizing chromium emissions because of its potential health impact. Both Cr^{+6} and total chromium emissions were measured at the exit stack during three runs at each of the three test conditions. Table A-11 shows measured values of Cr^{+6} emissions, while Table A-18 compares Cr^{+6} emissions with total Cr emissions. Although the results do not indicate conclusively a trend of increasing total chromium emissions with increasing afterburner temperature, the percentage of chromium in the hexavalent form does appear to increase as the afterburner temperature increases.

4.3.8 Combustion Efficiency

The combustion efficiency is based on the conversion of the carbon in the sludge solids to carbon dioxide (CO_2), as compared to an intermediary compound, carbon monoxide (CO). The combustion efficiency was determined using the mean data for the three test conditions. The combustion efficiency calculated did not include losses due to unburned carbon in the ash residue. The equation below was used to determine this efficiency:

$$n = \frac{(\text{HHV}_s)(M_s) + (\text{HHV}_f)(M_f) - \frac{10,143(C)(\text{CO})}{\text{CO}_2 + \text{CO}}}{(\text{HHV}_s)(M_s) + (\text{HHV}_f)(M_f)}$$

where:

n = carbon conversion efficiency

C = lb of carbon per hour introduced into furnace (in sludge and aux. fuel)

CO = percent of CO in flue gas

CO_2 = percent of CO_2 in flue gas

HHV_s = higher heating value of sludge

M_s = mass flow rate of sludge into furnace

HHV_f = higher heating value of auxiliary fuel

M_f = mass flow rate of aux. fuel into furnace and afterburner

Mean data measurements during each test condition were used in the above equation. Data used and results are summarized in Table 4-4.

Table 4-4			
Carbon Combustion Efficiency Data			
	Condition 1	Condition 2	Condition 3
Carbon Comb. Efficiency (percent)	99.42	99.51	99.46
HHV _s (Btu/lb)	1,465	1,424	1,552
M _s (wet lb/hr)	20,625	21,483	21,433
HHV _f (Btu/scf)	1,000	1,000	1,000
M _f (scfh)	16,700	23,542	28,583
C (lb/hr)	1,543	1,566	1,683
CO @ Furn. Exit (%Vol)	0.20	0.19	0.19
CO ₂ @ Furn. Exit (%Vol)	11.37	11.09	9.52

The calculated carbon combustion efficiency for the three conditions, representing furnace operation at three different afterburner temperatures, does not vary significantly. The results indicate no relationship between furnace exit temperature and carbon combustion efficiency.

4.3.9 CO and CO₂ Content of the Furnace Exhaust Gas

Measurements of CO and CO₂ concentrations in the flue gas were compared with various furnace operating conditions. These comparisons are discussed below.

4.3.9.1 CO and CO₂ Concentrations in the Furnace Exhaust Gas versus Excess Air

A reduction in CO emissions with increased excess air would indicate an increase in the carbon conversion efficiency with increased excess air, thus implying an increase in the furnace combustion efficiency. Measured CO concentration in the furnace exhaust is plotted against measured excess air (combined excess air for the furnace and the afterburner) in Figure A-5 of Appendix A.2. The graph does not show a relationship between CO concentration in the furnace exit and excess air. Figure A-5 (Appendix A.2) shows that the CO concentration in the furnace exhaust gas remains fairly constant with changes in excess air. Figure 4-6 shows that the concentration of CO₂ in the exhaust gas is reduced as excess air increases.

Figure A-6 of Appendix A.2 shows the concentration of CO₂ measured in the furnace exit, plotted against measured excess air. As would be expected, the CO₂ concentration is reduced as the excess increases and causes dilution of the products of combustion in exhaust gas.

Of interest is whether an increase in excess air will improve the carbon conversion efficiency (discussed in Section 4.3.8). Referring to the equation for carbon conversion efficiency, a net reduction in CO concentration in the flue gas is an indication of an increase in carbon conversion efficiency. Conversely, a net reduction in CO₂ concentration in the flue gas indicates a decrease in carbon conversion efficiency. Thus, the data shown in Figures A-5 and A-6 indicates that increased excess air will not improve carbon conversion efficiency.

4.3.9.2 CO and CO₂ Concentrations versus Moisture Content in the Furnace Exhaust Gas Figure A-7 is a plot of CO emissions against moisture content in the furnace exhaust gas. The plot shows no relationship between the two variables. The concentration of CO₂ in the exhaust gas is plotted against the moisture content in Figure A-8. The plot shows that the CO₂ concentration increased as the moisture content increased. As was shown previously, the concentration of CO₂ in the exhaust gas decreases with increased excess air. Since water vapor is also a product of combustion, its concentration would also be expected to track the CO₂ concentration, decreasing with increased excess air.

4.3.9.3 CO and CO₂ Concentrations versus Combustion Hearth Temperature Figures A-9 and A-10 show plots of CO and CO₂, respectively, against the measured temperature in Hearth 5 during combustion testing. During all three test conditions, the combustion hearth temperature remained between approximately 1,400°F and 1,500°F, with a standard deviation during each condition of less than 10 percent of the mean. (See Table A-4 of Appendix A.1.)

A significant increase in combustion hearth temperature would be expected to result in an increase in combustion efficiency, thus lowering concentrations of CO in the exhaust gas. Figure A-9 does not indicate this relationship. An increase in combustion temperature is expected to result in a slight increase in CO₂ concentrations, as the carbon conversion efficiency increases. A relationship between CO₂ concentration and combustion hearth temperature is not evident from Figure A-10. Increased combustion hearth temperature appears to have little effect on CO and CO₂ concentrations within the range of combustion hearth temperatures achieved during testing. A possible explanation for the lack of correlation is the postulate that the duration of temperature swings within the combustion hearth was not sufficient to result in variations in combustion efficiency.

4.3.9.4 CO and CO₂ Concentrations in the Furnace Exhaust Gas versus Top Hearth Temperature Measurements of CO and CO₂ concentrations in the furnace exhaust were plotted against the temperature in the top hearth (Hearth 2), prior to the internal afterburner. Results are shown in Figures A-11 and A-12 of Appendix A.2. As with the combustion hearth temperature, the top hearth temperature did not vary significantly during each condition, nor between conditions (see Table A-4 of Appendix A.1). A relationship between CO and CO₂ emissions and top hearth temperature was not evident within the temperature range achieved during testing.

4.3.9.5 CO and CO₂ Concentrations in the Furnace Exhaust Gas versus Furnace Exit Temperature The furnace exit temperature was varied during the three test conditions by control of the internal afterburner. Because testing was done at three different furnace exit temperatures, with each condition being maintained

for an extended period of time (approximately two days), the data should give a good indication of whether or not relationships between CO and CO₂ concentrations in the exhaust gas and furnace exit temperatures exist. The CO concentration in the exhaust gas is plotted against the furnace exit temperature in Figure A-13. The concentration of CO in the exhaust gas was not reduced with increased exit temperature, indicating that, within the range of temperatures tested, the internal afterburner does not affect the efficiency of carbon combustion. An increase in CO₂ concentration with increased temperature would indicate increased carbon conversion efficiency at higher afterburner temperatures. The data in Figure A-14 does not support this relationship.

The autoignition temperature of CO (the lowest temperature at which inflammation occurs) is relatively high, generally 1,200°F to 1,300°F, depending on excess air and gas pressure. The test results indicate that the internal afterburner temperature, in combination with the gas retention time at that temperature, was not sufficient to achieve complete oxidation of CO.

If, at some point in the future, CO were to become a regulated emission, the plant may need to implement system modifications beyond the internal afterburner. No future limits on CO emissions have been established, and an estimate of potential operating parameters to substantially reduce CO emissions is beyond the scope of this study.

4.4 COMPLIANCE WITH REGULATIONS

4.4.1 Federal 40 CFR Part 503 and NESHAP

4.4.1.1 Metals Calculations were made for the seven metals that are regulated by Federal 40 CFR Part 503 (beryllium, mercury, lead, arsenic, cadmium, chromium, and nickel) to determine whether recorded concentrations of metals in the sludge going to the incinerator met the Part 503 requirements. (The calculations are included in Appendix B.2, which is available upon request.)

The total incineration capacity of 155 dry tons of sludge per day was used in the calculations to establish allowable Part 503 concentrations for the metals. The metal control efficiencies determined during May 1993 stack testing on Furnace No. 5 and a dispersion factor determined by site-specific modeling were used to compute the maximum concentrations allowed by Part 503 regulations. The calculated maximum allowable concentrations were compared to the maximum metal concentrations measured in the incineration feed sludge in recent years. Metal concentrations in the sludge were measured during stack testing performed in May 1993; they were measured monthly by the Monroe County Department of Engineering during 1992. As shown in Table 4-5 below, the maximum measured metal concentrations in the sludge are well below Part 503 maximum allowable concentrations.

Table 4-5				
Part 503 Allowable Concentrations of Metals in Sludge at FEV				
	Maximum Allowable Concentration (mg/dry kg sludge)	Highest Measured Concentration During 1992 (mg/dry kg sludge)	Highest Measured Concentration, 5/93 Stack Testing	Maximum Measured Concentration in Recent Years (mg/dry kg sludge)
Arsenic	110	7.6	3.91	9.0
Cadmium	212	26.0	10.44	38.0
Chromium	18,534	165.8	77.60	386.3
Lead	2,789	245.4	159	265.7
Nickel	322,327	132.4	48.4	132.4

Part 503 requires that facilities ensure that beryllium and mercury fall below the National Emissions Standards for Hazardous Air Pollutants (NESHAP) limits of 10 g/day and 3,200 g/day respectively. Measurements of beryllium during 1992 were below the detection limit of 10 mg/dry kg sludge. The highest beryllium concentration measured in recent years was 1.65 mg/dry kg sludge, and the lowest control efficiency during May 1993 Stack Testing was 95.8 percent. The highest concentration of mercury measured during recent years was 3.7 mg/dry kg sludge. During May 1993 stack testing, the control efficiency for mercury was found to be around zero percent. Taking the highest measured concentrations of each metal, and the total incineration capacity of 155 dry tons per day, the maximum daily emissions of these metals are estimated as follows:

Beryllium:

$$1.65 \frac{\text{mg}}{\text{dry kg}} \times 141,000 \frac{\text{dry kg}}{\text{day}} \times 0.001 \frac{\text{g}}{\text{mg}} \times (1 - 0.958) = 9.7 \frac{\text{g}}{\text{day}}$$

Mercury:

$$3.7 \frac{\text{mg}}{\text{dry kg}} \times 141,000 \frac{\text{dry kg}}{\text{day}} \times 0.001 \frac{\text{g}}{\text{mg}} \times (1 - 0.0) = 522 \frac{\text{g}}{\text{day}}$$

At maximum measured concentration levels, both beryllium and mercury emissions are calculated to remain below the NESHAP limits. With the control efficiencies measured during May 1993 stack testing, the maximum allowable concentration of mercury when operating at capacity is 227.0 mg/dry kg, significantly higher than maximum measured concentration of 3.7 mg/dry kg.

The maximum measured concentration of beryllium in recent years is 1.65 mg/dry kg; this value is within 3 percent of the Part 503 limit of 1.69 mg/dry kg.

4.4.1.2 Total Hydrocarbons Part 503 limits total hydrocarbon (THC) emissions to 100 ppm_{dv} as propane, at 7 percent oxygen, based on a monthly average. Measurements of total hydrocarbons, O₂, and moisture at the stack were conducted during testing of Furnace No. 5 in May 1993 for each of three afterburner temperatures; 1100°F, 1200°F, and 1300°F (± about 50°F). Average THC measurements during each condition are shown in Table A-19. One-hour averages of the THC measurements are included in Tables A-20 through A-22. At all three conditions, the average THC measurement over two days was less than 100 ppm_{dv} as propane at 7 percent oxygen. At an afterburner temperature of about 1100°F, however, the average hourly THC measurement exceeded 100 ppm_{dv} as propane at 7 percent oxygen on several occasions. With the afterburner at 1,200°F and above, no average hourly THC measurements exceeded 100 ppm_{dv} as propane at 7 percent oxygen.

4.4.2 New Source Performance Standards for Sewage Sludge Treatment Plants (NSPS), 40 CFR, Part 60.150

NSPS applies to sewage sludge incinerators on which construction or modification began after June 11, 1973. An incinerator modification affects NSPS compliance if it causes air emissions to increase. Construction of the MHFs operating at the FEV facility began in 1972. The installation of thermal afterburners in 1980 is not considered a modification because it resulted in a decrease in air emissions. Similarly, if the wet scrubber were to be replaced, it would not be considered a modification. Therefore, NSPS does not currently apply to these units.

4.4.3 Guideline for the Control of Toxic Ambient Air Contaminants, New York State Proposed Air Guide-1

New York State Air Guide-1 presents the Division of Air Resources' basic programmatic guidelines for making air toxics-related permitting decisions for the New York State Department of Environmental Conservation (NYSDEC) Regional Air Pollution Control engineers and their staff. Calculations were performed to determine if metals concentrations in the stack gas meet the new proposed New York State Air Guide-1 criteria (Appendix B.3). No attempt was made to determine applicability to individual organic species because of the difficulty in quantifying specific organic species emitted through the stack.

The minimum control efficiencies measured during May 1993 stack testing were used to determine concentration limits. Short-term emission rates in lb/hr were calculated using the highest concentrations observed during 1992 and a maximum sludge throughput of 155 tons per day. (Note that since the "maximum measured concentrations in recent years" used in the Part 503 permit application, were not typical of FEV sludge, these values were not used for determination of compliance with Air Guide-1.) Long-term emission rates in lb/year were calculated using average concentrations observed over a one-year period (1992) and an annual average sludge throughput of 65 dry tons per year.

The Air Guide-1 calculations show that seven of the nine metals passed the Air Guide-1 initial screening procedure for short-term exposure (cadmium and hexavalent chromium failed), and six of the nine passed the Air Guide-1 initial screening procedure for long-term exposure (arsenic, cadmium, and hexavalent chromium failed). The Air Guide-1 analysis was then performed using the screening results from the air modeling done for the Part 503 permit application. These calculations showed emissions of all nine metals pass short-term exposure limits, but the calculated annual impacts of arsenic, cadmium, and hexavalent chromium still exceeded the long term exposure limits.

Performance of more refined air modeling may demonstrate compliance with Air Guide-1. However, since the initial screening estimated ambient concentrations one and two orders of magnitude higher than Air Guide-1 guidelines, some actions may be required to achieve compliance. Reduction of metal concentrations in sludge and/or improvement of air pollution control equipment may be necessary.

Air Guide-1 has not been promulgated as a regulation. However, it has been required by NYSDEC in connection with permitting activities on several recent sludge-related projects. Any re-permitting activities at FEV may require demonstration of compliance with Air Guide-1. It is expected that further revisions will be incorporated before Air Guide-1. It is expected that further revisions will be incorporated before Air Guide-1 is promulgated as a regulation within the next several months.

When the final revision of Air Guide-1 is completed, Monroe County should perform more refined modeling, since the final analysis may impact the recommended alternative for air pollution control equipment.

4.4.4 Prevention of Significant Deterioration (PSD), 40 CFR, Part 52.21

The federal PSD program is only applicable to major sources, based upon the annual emissions of regulated pollutants. The FEV facility would be considered a major source only if it had the potential to emit more than 250 tons per year of a regulated pollutant, taking into consideration air pollution control equipment and enforceable restrictions of operations. Incinerators are normally the largest source of emissions in a wastewater treatment plant. According to the EPA compilation of emission factors, AP-42 (October, 1986 Supplement), Table 2.5.1 lists NO_x as having the highest emission factor at 5 lb/dry ton. Given a facility-wide annual average sludge throughput of 65 dry tons per day, the NO_x annual emission rate would be 59 tons per year far less than the triggering threshold of 250 tons per year. Therefore, the FEV facility would not be considered a major source and PSD would not apply.

4.4.5 Non-attainment New Source Review (NSR), New York State 6 NYCRR, Part 231

Non-attainment NSR is not applicable to this facility because the region surrounding the facility is currently in attainment with all of the State and National Ambient Air Quality Standards.

4.4.6 Air Permits

The FEV furnaces are operating with a valid NYSDEC Certificate to Operate, which is due for renewal in October of 1994. The Certificate to Operate limits emissions of SO₂, particulates, and non-specific odors from the three MHFs as shown in Table 4-6.

Table 4-6		
Limits of Emissions in Certificate to Operate		
	Limits, Furnace No. 3 (lb/hr)	Limits, Furnaces No. 4, No. 5 (lb/hr)
SO ₂	23	40
Particulates	2.5	5
Non-specific Odors	0.555	1.11

Measured particulate emissions from Furnace No. 5 peaked at 1.4 lb/hr during May 1993 stack testing (Table A-25), and SO₂ emissions during this period peaked at 3.8 lb/hr (Table A-24). Measured emissions were well below the Certificate to Operate limits.

4.4.7 Incineration Processes, New York State 6 NYCRR, Part 212

Part 212 air pollution regulations were applied by the NYSDEC in the most recent Certificate to Operate issued for the furnaces. NYSDEC assigned a maximum particulate matter concentration of 0.050 grains per dry standard cubic foot (gr/dscf) and a maximum SO₂ emission rate of 103 lb/hr.

4.4.8 Sulfur Content of Fuel, New York State 6 NYCRR, Part 225-1

Part 225-1 limits the sulfur content of the liquid fuels used by the furnaces. While the sulfur content of the fuel oil, when indeed burned, is not known, it is believed to be less than the limit of 1.5 percent by weight.

APPENDIX A: Combustion/APC Stack Testing

A.1 Tables A-1 through A-29

Table A-1: Mean Values of Sludge Cake Analyses
 Samples Taken During Combustion and Stack Testing, May 17, 1993 – May 22, 1993
 FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

PROXIMATE ANALYSIS (Percent by Weight)

<i>Test Condition:</i>	<u>1</u>	<u>2</u>	<u>3</u>
Ash	6.32	6.23	6.34
Volatile	12.40	12.08	12.90
Fixed C	0.59	0.66	0.75
Moisture	<u>80.70</u>	<u>81.02</u>	<u>80.00</u>
<i>TOTAL:</i>	100.01	99.99	99.99

ULTIMATE ANALYSIS (Percent by Weight)

<i>Test Condition:</i>	<u>1</u>	<u>2</u>	<u>3</u>
Total Sulfur	0.15	0.15	0.15
Carbon	7.48	7.29	7.85
Hydrogen	1.06	1.12	1.19
Nitrogen	0.72	0.68	0.74
Oxygen	3.55	3.52	3.70
Chlorine	0.02	0.02	0.02
Ash	6.32	6.23	6.34
Moisture	<u>80.70</u>	<u>81.02</u>	<u>80.00</u>
<i>TOTAL:</i>	100.00	100.03	99.99
Gross Calorific Value (Btu/lb)	1465	1424	1552

Table A-2: Sludge Cake Analyses of Samples Taken During Combustion and Stack Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		PROXIMATE ANALYSIS					ULTIMATE ANALYSIS						
		Ash % by Wgt	Volatile % by Wgt	Fixed C % by Wgt	Dry Solids % by Wgt	Moisture % by Wgt	Tot. Sulfur % by Wgt	Carbon % by Wgt	Hydrogen % by Wgt	Nitrogen % by Wgt	Oxygen % by Wgt	Chlorine % by Wgt	BTU /lb
TEST COND. #1													
5/17/93	0000-0400 hrs	7.22	13.3	0.81	21.3	78.7	0.16	7.92	0.86	0.8	4.31	0.04	1540
	0400-0800 hrs	5.86	11.2	0.49	17.5	82.5	0.13	6.56	0.99	0.67	3.27	0.02	1270
	0800-1200 hrs	6.34	11.9	0.70	18.9	81.1	0.14	7.16	0.97	0.75	3.52	0.02	1370
	1200-1600 hrs	6.04	12.4	0.60	19.1	80.9	0.15	7.70	1.18	0.7	3.29	0.02	1500
	1600-2000 hrs	6.94	15.5	0.43	22.8	77.2	0.19	9.60	1.48	0.79	3.79	0.03	1880
	2000-2400 hrs	6.49	13.8	0.41	20.7	79.3	0.17	8.38	1.29	0.72	3.62	0.03	1630
5/18/93	0000-0400 hrs	5.96	11.5	0.45	18	82	0.14	6.95	1.04	0.66	3.22	0.02	1330
	0400-0800 hrs	5.59	11.1	0.66	17.3	82.7	0.13	6.64	0.96	0.66	3.30	0.01	1310
	0800-1200 hrs	6.66	13.6	0.65	20.9	79.1	0.16	7.98	0.97	0.84	4.26	0.02	1540
	1200-1600 hrs	6.10	11.3	0.45	17.9	82.1	0.16	6.71	1.02	0.68	3.20	0.02	1490
	1600-2000 hrs	6.43	11.5	0.72	18.6	81.4	0.17	7.14	1.09	0.63	3.13	0.02	1360
	2000-2400 hrs	6.17	11.7	0.71	18.6	81.4	0.15	7.03	0.86	0.71	3.67	0.02	1360
MEAN		6.32	12.4	0.59	19.3	80.7	0.15	7.48	1.06	0.72	3.55	0.02	1465
MINIMUM		5.59	11.1	0.41	17.3	77.2	0.13	6.56	0.86	0.63	3.13	0.01	1270
MAXIMUM		7.22	15.5	0.81	22.8	82.7	0.19	9.60	1.48	0.84	4.31	0.04	1880
STD DEV (% OF MEAN)		7%	11%	22%	9%	2%	11%	11%	16%	9%	11%	32%	11%
VARIANCE		0.20	1.7	0.02	2.7	2.7	0.00	0.72	0.03	0.00	0.15	0.00	26992
TEST COND. #2													
5/19/93	0000-0400 hrs	5.79	10.9	0.47	17.2	82.8	0.14	6.42	0.92	0.65	3.28	0.02	1240
	0400-0800 hrs	6.05	11.6	0.73	18.4	81.6	0.14	6.97	0.96	0.71	3.53	0.02	1320
	0800-1200 hrs	5.93	11.9	0.66	18.5	81.5	0.14	7.16	1.08	0.67	3.49	0.02	1420
	1200-1600 hrs	5.70	10.8	0.67	17.1	82.9	0.13	6.52	0.99	0.63	3.13	0.02	1250
	1600-2000 hrs	6.21	11.6	0.57	18.4	81.6	0.15	6.92	1.07	0.65	3.37	0.02	1290
	2000-2400 hrs	6.85	13.1	0.62	20.6	79.4	0.16	7.85	1.18	0.73	3.79	0.03	1580
5/20/93	0000-0400 hrs	6.39	12.4	0.80	19.6	80.4	0.15	7.53	1.13	0.69	3.69	0.02	1490
	0400-0800 hrs	6.36	12.3	0.63	19.3	80.7	0.15	7.31	1.1	0.7	3.65	0.02	1410
	0800-1200 hrs	6.58	12.7	0.86	20.2	79.8	0.16	7.66	1.44	0.74	3.90	0.03	1480
	1200-1600 hrs	6.39	11.9	0.74	19	81	0.17	7.26	1.11	0.64	3.42	0.02	1430
	1600-2000 hrs	6.51	13.5	0.52	20.5	79.5	0.17	8.41	1.29	0.65	3.46	0.03	1690
	2000-2400 hrs	6.03	12.3	0.64	19	81	0.15	7.47	1.11	0.68	3.55	0.02	1490
MEAN		6.23	12.1	0.66	19.0	81.0	0.15	7.29	1.12	0.68	3.52	0.02	1424
MINIMUM		5.70	10.8	0.47	17.1	79.4	0.13	6.42	0.92	0.63	3.13	0.02	1240
MAXIMUM		6.85	13.5	0.86	20.6	82.9	0.17	8.41	1.44	0.74	3.90	0.03	1690
STD DEV (% OF MEAN)		5%	6%	16%	6%	1%	8%	7%	12%	5%	6%	19%	9%
VARIANCE		0.11	0.6	0.01	1.2	1.2	0.00	0.28	0.02	0.00	0.04	0.00	16674
TEST COND. #3													
5/21/93	0000-0400 hrs	5.73	11.9	0.87	18.5	81.5	0.13	7.29	1.04	0.72	3.55	0.02	1400
	0400-0800 hrs	6.33	13.5	0.74	20.5	79.5	0.15	8.18	1.23	0.79	3.81	0.02	1600
	0800-1200 hrs	5.70	11.5	0.74	18	82	0.13	7.02	1.09	0.65	3.38	0.03	1410
	1200-1600 hrs	7.50	15.1	0.56	23.2	76.8	0.18	9.16	1.41	0.81	4.13	0.02	1800
	1600-2000 hrs	7.07	13.6	0.81	21.5	78.5	0.17	8.6	1.31	0.82	3.51	0.02	1940
	2000-2400 hrs	7.37	13.9	0.62	21.9	78.1	0.17	8.32	1.32	0.77	3.92	0.02	1640
5/22/93	0000-0400 hrs	6.81	13.5	0.88	21.2	78.8	0.17	8.31	1.25	0.78	3.84	0.02	1630
	0400-0800 hrs	6.73	13.3	0.67	20.7	79.3	0.16	8.05	1.19	0.8	3.73	0.02	1570
	0800-1200 hrs	5.59	11.7	0.80	18.1	81.9	0.13	7.11	1.07	0.68	3.49	0.02	1330
	1200-1600 hrs	6.22	13.5	0.94	20.7	79.3	0.14	8.24	1.26	0.74	4.06	0.02	1600
	1600-2000 hrs	5.81	11.8	0.70	18.3	81.7	0.14	7.06	1.08	0.62	3.57	0.03	1370
	2000-2400 hrs	5.22	11.5	0.66	17.4	82.6	0.14	6.89	1.05	0.67	3.41	0.02	1330
MEAN		6.34	12.9	0.75	20.0	80.0	0.15	7.85	1.19	0.74	3.70	0.02	1552
MINIMUM		5.22	11.5	0.56	17.4	76.8	0.13	6.89	1.04	0.62	3.38	0.02	1330
MAXIMUM		7.50	15.1	0.94	23.2	82.6	0.18	9.16	1.41	0.82	4.13	0.03	1940
STD DEV (% OF MEAN)		11%	9%	15%	9%	2%	12%	9%	10%	9%	7%	17%	12%
VARIANCE		0.52	1.3	0.01	3.2	3.2	0.00	0.51	0.01	0.00	0.06	0.00	33814

Table A-3: Mean Temperature Values (Deg. F) During Combustion and Stack Testing, May 17 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

Test Condition	Furnace Exit AB	Hearth 1		Hearth 2 2E	Hearth 3 3E	Hearth 4		Hearth 5		Hearth 6		Hearth 7		Hearth 8 8E	Hearth 9 9E	Hearth 10 10E	Hearth 11 11E	Post- Quench
		1E	1W			4E	4W	5E	5W	6E	6W	7E	7W					
1	1,121	1,232	1,146	1,006	1,171	1,242	1,233	1,498	1,475	1,472	1,484	1,262	1,139	1,065	343	187	109	171
2	1,215	1,271	1,227	970	1,130	1,178	1,219	1,481	1,463	1,464	1,519	1,259	1,129	1,119	375	179	106	172
3	1,302	1,317	1,275	957	1,116	1,183	1,198	1,525	1,412	1,488	1,476	1,371	1,223	1,276	452	204	117	172

NOTE:

"E" denotes thermocouple on east end of furnace.

"W" denotes thermocouple on west end of furnace.

Table A-4: Incinerator Temperatures During Combustion and Stack Testing, May 17 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Furnace Exit AB	Hearth 1 1E 1W		Hearth 2 2E	Hearth 3 3E	Hearth 4 4E 4W		Hearth 5 5E 5W		Hearth 6 6E 6W		Hearth 7 7E 7W		Hearth 8 8E	Hearth 9 9E	Hearth 10 10E	Hearth 11 11E	Post - Quench
TEST COND. #1																			
5/17/93	0000-0400 hrs	1123	1175	1117	971	1128	1179	1169	1422	1485	1577	1500	1433	1357	1241	472	225	137	173
	0400-0800 hrs	1120	1188	1120	961	1114	1137	1212	1409	1560	1422	1275	1293	1358	1114	428	218	120	171
	0800-1200 hrs	1121	1222	1139	1023	1204	1239	1316	1477	1704	1455	1752	1342	1329	959	378	236	102	174
	1200-1600 hrs	1121	1286	1191	1102	1350	1415	1466	1708	1722	1576	1688	1075	937	831	253	166	100	173
	1600-2000 hrs	1119	1245	1147	1004	1197	1245	1148	1582	1462	1583	1449	1333	1081	1225	340	178	110	174
	2000-2400 hrs	1120	1226	1143	1161	1218	1594	1181	1594	1422	1610	1433	1341	1201	1212	385	191	112	173
5/18/93	0000-0400 hrs	1121	1246	1147	979	1183	1242	1150	1528	1304	1433	1321	1205	1025	1101	332	177	104	168
	0400-0800 hrs	1111	1261	1113	1014	1242	1283	1205	1486	1358	1317	1444	1072	981	1012	299	168	100	166
	0800-1200 hrs	1121	1247	1173	988	1139	1183	1315	1549	1443	1532	1530	1227	1064	966	252	158	97	170
	1200-1600 hrs	1120	1227	1155	957	1077	1109	1239	1379	1402	1363	1466	1189	1104	972	292	154	101	170
	1600-2000 hrs	1119	1241	1154	980	1137	1172	1251	1376	1542	1355	1587	1254	1141	1063	351	197	110	171
	2000-2400 hrs	1141	1223	1152	927	1061	1101	1140	1462	1290	1440	1359	1374	1087	1089	339	176	109	169
MEAN		1,121	1,232	1,146	1,006	1,171	1,242	1,233	1,498	1,475	1,472	1,484	1,262	1,139	1,065	343	187	109	171
MINIMUM		1,111	1,175	1,113	927	1,061	1,101	1,140	1,376	1,290	1,317	1,275	1,072	937	831	252	154	97	166
MAXIMUM		1,141	1,286	1,191	1,161	1,350	1,594	1,466	1,708	1,722	1,610	1,752	1,433	1,358	1,241	472	236	137	174
STD DEV (% OF MEAN)		1%	2%	2%	6%	6%	11%	7%	6%	9%	7%	9%	9%	12%	11%	18%	14%	10%	1%
VARIANCE		43	821	467	3935	5784	18040	8254	9041	17646	9311	18170	11780	18926	14143	3998	663	113	6

NOTE:

"E" denotes thermocouple on east end of furnace.

"W" denotes thermocouple on west end of furnace.

Table A-4: Incinerator Temperatures During Combustion and Stack Testing, May 17 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Furnace Exit AB	Hearth 1		Hearth 2	Hearth 3	Hearth 4		Hearth 5		Hearth 6		Hearth 7		Hearth 8	Hearth 9	Hearth 10	Hearth 11	Post - Quench
			1E	1W	2E	3E	4E	4W	5E	5W	6E	6W	7E	7W	8E	9E	10E	11E	
TEST COND. #2																			
5/19/93	0000-0400 hrs	1203	1240	1210	955	1098	1158	1283	1318	1538	1280	1555	1233	948	1000	373	153	100	170
	0400-0800 hrs	1203	1251	1224	978	1132	1163	1255	1522	1383	1493	1438	1124	991	937	259	145	102	171
	0800-1200 hrs	1189	1274	1211	964	1103	1136	1215	1397	1489	1357	1554	1253	1144	1109	368	169	107	172
	1200-1600 hrs	1212	1281	1212	964	1109	1136	1235	1371	1522	1322	1586	1207	1140	1006	324	168	103	172
	1600-2000 hrs	1212	1264	1206	955	1082	1117	1214	1268	1536	1242	1556	1191	1150	1002	339	176	111	173
	2000-2400 hrs	1190	1282	1218	964	1110	1171	1222	1569	1409	1522	1515	1272	1098	1122	319	161	107	172
5/20/93	0000-0400 hrs	1208	1287	1225	998	1161	1222	1292	1609	1542	1604	1633	1324	1243	1183	489	201	111	173
	0400-0800 hrs	1213	1297	1228	1001	1178	1240	1279	1644	1486	1623	1586	1226	1126	1082	435	179	105	172
	0800-1200 hrs	1214	1267	1206	952	1117	1160	1182	1467	1427	1456	1504	1279	1211	1194	521	225	108	172
	1200-1600 hrs	1212	1288	1215	992	1182	1239	1107	1609	1321	1603	1331	1373	1167	1302	309	195	105	171
	1600-2000 hrs	1211	1297	1221	981	1196	1243	1185	1519	1497	1598	1492	1311	1121	1256	353	180	101	171
	2000-2400 hrs	1310	1228	1348	938	1093	1145	1153	1483	1405	1472	1475	1318	1213	1238	415	193	113	173
MEAN		1,215	1,271	1,227	970	1,130	1,178	1,219	1,481	1,463	1,464	1,519	1,259	1,129	1,119	375	179	106	172
MINIMUM		1,189	1,228	1,206	938	1,082	1,117	1,107	1,268	1,321	1,242	1,331	1,124	948	937	259	145	100	170
MAXIMUM		1,310	1,297	1,348	1,001	1,196	1,243	1,292	1,644	1,542	1,623	1,633	1,373	1,243	1,302	521	225	113	173
STD DEV (%OF MEAN)		2%	2%	3%	2%	3%	4%	4%	8%	5%	9%	5%	5%	7%	10%	20%	12%	4%	1%
VARIANCE		893	450	1381	358	1397	1922	2837	13458	4765	16770	5890	4277	6820	12613	5408	453	16	1

NOTE:

"E" denotes thermocouple on east end of furnace.

"W" denotes thermocouple on west end of furnace.

Table A-4: Incinerator Temperatures During Combustion and Stack Testing, May 17 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Furnace Exit AB	Hearth 1		Hearth 2	Hearth 3	Hearth 4		Hearth 5		Hearth 6		Hearth 7		Hearth 8	Hearth 9	Hearth 10	Hearth 11	Post- Quench
			1E	1W	2E	3E	4E	4W	5E	5W	6E	6W	7E	7W	8E	9E	10E	11E	
TEST COND. #3																			
5/21/93	0000-0400 hrs	1308	1318	1243	968	1133	1183	1270	1480	1405	1515	1473	1328	1228	1313	428	200	113	170
	0400-0800 hrs	1303	1340	1265	1018	1190	1264	1229	1610	1352	1225	1428	1295	1099	1123	334	175	105	171
	0800-1200 hrs	1312	1292	1258	933	1076	1225	1230	1506	1349	1474	1415	1400	1182	1343	323	194	113	160
	1200-1600 hrs	1307	1301	1251	946	1148	1293	1171	1581	1489	1578	1504	1358	1452	1287	549	214	116	172
	1600-2000 hrs	1300	1271	1248	915	1069	1104	1105	1427	1345	1442	1409	1412	1238	1355	513	248	133	172
	2000-2400 hrs	1301	1324	1427	966	1128	1181	1248	1576	1493	1554	1542	1314	1205	1153	432	206	123	173
5/22/93	0000-0400 hrs	1310	1338	1260	965	1125	1158	1180	1493	1421	1433	1483	1279	1188	1135	424	190	123	177
	0400-0800 hrs	1245	1332	1258	955	1086	1138	1185	1522	1453	1511	1527	1425	1282	1340	582	210	118	176
	0800-1200 hrs	1309	1341	1273	984	1162	1233	1187	1655	1453	1688	1513	1463	1247	1361	517	203	122	175
	1200-1600 hrs	1302	1301	1267	943	1095	1138	1152	1465	1397	1451	1452	1397	1214	1330	438	199	110	172
	1600-2000 hrs	1311	1318	1274	934	1068	1115	1198	1467	1445	1443	1514	1369	1186	1249	437	204	113	172
	2000-2400 hrs	1311	1324	1275	956	1112	1165	1218	1522	1337	1539	1456	1409	1151	1318	446	205	116	171
MEAN		1302	1317	1275	957	1116	1183	1198	1525	1412	1488	1476	1371	1223	1276	452	204	117	172
MINIMUM		1245	1271	1243	915	1068	1104	1106	1427	1337	1225	1409	1279	1099	1123	323	175	105	160
MAXIMUM		1312	1341	1427	1018	1190	1293	1270	1655	1493	1688	1542	1463	1452	1361	582	248	133	177
STD DEV (% OF MEAN)		1%	2%	4%	3%	3%	5%	4%	4%	4%	7%	3%	4%	7%	7%	17%	8%	6%	2%
VARIANCE		307	427	2200	699	1383	3233	1833	4155	2915	11185	1842	2961	6832	7281	5586	271	50	16

NOTE:

"E" denotes thermocouple on east end of furnace.

"W" denotes thermocouple on west end of furnace.

Table A-5: Mean Temperature Values and Flow Rates During Combustion Testing, May 17 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

Test Condition	Cooling Air Inlet		Center Shaft Discharge		Ctr Shf Return Temp Deg.F	Sludge Feed			Combustion Air Flow		Total Plant N.G. Use		Ash		Slack	
	Temp Deg. F	Flow Rate scfm	Temp Deg. F	Flow Rate scfm		Dry Solids % by Wgt.	Wet lb/hr	Dry lb/hr	Burner scfm	Afterburner scfm	Daily KCF	Avg. Hourly CFH	Temp Deg.C	Temp Deg.F	Temp Deg. F	Flow Rate dscfm
1	46	6,827	313	2,044	311	19.3	20,625	3,990	1,909	1,715	936	39,000	23	73	115	13,395
2	53	6,116	326	1,784	325	19.0	21,483	4,075	2,063	2,308	1033	43,042	25	77	121	14,329
3	50	6,356	328	1,822	327	20.0	21,433	4,285	1,998	2,755	1055	43,938	24	75	114	16,084

Table A-6: Temperature Values and Flow Rates During Combustion Testing, May 17, 1995 - May 22, 1995
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

Cooling Air Inlet		Center Shaft Discharge		Cr. Shf Return		Sludge Feed		Combustion Air Flow		Total Natural Gas Use		Ash		Stack	
Temp Deg. F	Flow Rate acfm	Temp Deg. F	Flow Rate acfm	Temp Deg. F	% by Wgt.	Dry Solids Wt lb/hr	Dry lb/hr	Burner acfm	Afterburner acfm	Daily KCF	Avg. Hourly CFH	Temp Deg. C	Temp Deg. F	Temp Deg. F	Flow Rate ddctm
43	6835	300	2204	231	21.3	18,200	3877	1980	1700	927	38,625	25	77	120	13,556
48	6996	310	2191	307	17.5	21,600	3780	2060	1700			24	75	118	8,367
0800-1200 hrs	6496	290	2601	329	18.9	21,900	4139	2140	1700			22	72		
1200-1600 hrs	6518	325	2203	346	19.1	22,400	4278	1400	1490			20	68		
1600-2000 hrs	7327	324	1920	325	22.8	22,400	5107	1800	1790			23	73		
2000-2400 hrs	6443			316	20.7	22,900	4740	1810	1760			24	75		
0000-0400 hrs	6835	315	2258	308	18.0	21,300	3834	1830	1640	945	39,375	23	73	110	14,053
0400-0800 hrs	6795	310	1972	308	17.3	15,100	2612	2060	1850			23	73	118	15,381
0800-1200 hrs	7058	314	1526	315	20.9	20,200	4222	2220	1840			22	72		
1200-1600 hrs	7127	319	1996	315	17.9	20,700	3705	2050	1630			22	72		
1600-2000 hrs	6468	315	1726	317	18.6	21,200	3943	1980	1680			23	73		
2000-2400 hrs	6443	322	1887	316	18.6	19,600	3546	1980	1760			24	75	115	13,618
MEAN	6827	313	2044	311	18.3	20,625	3990	1909	1715			23	73	116	13,395
MINIMUM	6468	290	1526	231	17.3	15,100	2612	1400	1490			20	68	110	8,367
MAXIMUM	7327	325	2601	346	22.8	22,900	5107	2220	1850			25	77	120	16,053
STD DEV (% OF MEAN)	71999	346	1496	896	946	4373542	345952	63741	9508	81	140625	546	346	12	7273119
VARIANCE	51	325	2601	346	22.8	22,900	5107	2220	1850	196	39,375	25	77	120	2096

Table A-6: Temperature Values and Flow Rates During Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

	Cooling Air Inlet		Center Shaft Discharge		Gr Shf Return	Sludge Feed			Combustion Air Flow		Total Natural Gas Use		Ash		Stack		
	Temp Deg F	Flow Rate scfm	Temp Deg F	Flow Rate scfm	Temp Deg F	Dry Solids % by Wgt.	Wet lb/hr	Dry lb/hr	Burner scfm	Afterburner scfm	Daily KCF	Avg. Hourly CFH	Temp Deg C	Temp Deg F	Temp Deg F	Flow Rate dscfm	
TEST COND. #2																	
5/19/93	0000-0400 hrs	49	5437	316	2104	315	17.2	20,400	3509	2220	2180	1105	46,042	25	77	128	17,566
	0400-0800 hrs	55	6213	330	1848	338	18.4	22,500	4140	2070	2270			24	75	124	14,090
	0800-1200 hrs	52	5817	324	1487	322	18.5	21,700	4015	2060	2300			25	77		
	1200-1600 hrs	66	6143	321	1637	322	17.1	22,200	3796	2140	2290			26	79		
	1600-2000 hrs	63	6517	320	1625	317	18.4	21,800	4011	2140	2370			25	77		
2000-2400 hrs	48	6220	325	1536	321	20.6	19,800	4079	2140	2370			25	77	111	14,043	
5/20/93	0000-0400 hrs	46	6624	334	2251	321	19.6	21,700	4253	2220	2260	961	40,042	25	77	120	14,752
	0400-0800 hrs	49	6235	334	2189	332	19.3	21,900	4227	2140	2250			25	77	116	11,196
	0800-1200 hrs	49	6174	327	1548	327	20.2	20,300	4101	2140	2280			25	77		
	1200-1600 hrs	49	5781	325	1619	327	19.0	22,600	4294	1890	2360			26	79		
	1600-2000 hrs					337	20.5	21,400	4387	1720	2420			26	79		
2000-2400 hrs					323	19.0	21,500	4085	1880	2350			26	79			
MEAN		53	6116	326	1784	325	19.0	21,483	4075	2053	2308	1033	43,042	25	77	121	14,329
MINIMUM		46	5437	316	1487	315	17.1	19,800	3509	1720	2180	961	40,042	24	75	116	11,196
MAXIMUM		66	6624	334	2251	338	20.6	22,600	4387	2220	2420	1105	46,042	26	79	128	17,566
STD DEV (% OF MEAN)		12%	5%	2%	16%	2%	6%	4%	6%	7%	3%	7%	7%	2%	1%	3%	14%
VARIANCE		41	111938	31	76864	49	1	714722	50926	21672	4114	5184	9000000	0	1	17	4122341

Table A-6: Temperature Values and Flow Rates During Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

	Cooling Air Inlet		Center Shaft Discharge		Gr Shf Return	Sludge Feed			Combustion Air Flow		Total Natural Gas Use		Ash		Stack	
	Temp Deg F	Flow Rate scfm	Temp Deg F	Flow Rate scfm	Temp Deg F	Dry Solids % by Wgt.	Wet lb/hr	Dry lb/hr	Burner scfm	Afterburner scfm	Daily KCF	Avg. Hourly CFH	Temp Deg C	Temp Deg F	Temp Deg F	Flow Rate dscfm
TEST COND. #3																
5/21/93 0000-0400hrs	46	6827	334	2376	320	18.5	22,200	4107	2050	2630	1022	42,583	24	75	127	18,917
0400-0800hrs	48	6380	333	1966	326	20.5	21,700	4449	2050	2630			24	75		
0800-1200hrs	50	6224	317	1441	330	18.0	21,000	3780	1960	2594			23	73		
1200-1600hrs	49	6301	325	1443	325	23.2	21,600	5011	1640	2790			23	73		
1600-2000hrs	53	6142			323	21.5	21,700	4666	1960	2870			24	75		
2000-2400hrs					329	21.9	21,300	4665	2040	3050			24	75		
5/22/93 0000-0400hrs	49	6839	331	2138	328	21.2	20,800	4410	2050	2580	1088	45,333	24	75	117	15,778
0400-0800hrs	50	6627	325	2023	322	20.7	20,000	4140	2130	2680			23	73	123	11,361
0800-1200hrs	50	5784	334	1563	333	18.1	21,100	3819	1960	2670			23	73		
1200-1600hrs	52	6016	326	1628	329	20.7	22,000	4554	1960	2690			24	75		
1600-2000hrs	52	6426			333	18.3	22,000	4026	2050	2910			24	75		
2000-2400hrs					330	17.4	21,800	3793	2130	2960			25	77	129	18,281
MEAN	50	6356	328	1822	327	20.0	21,433	4285	1928	2755	1055	43,958	24	75	124	16,084
MINIMUM	46	5784	317	1441	320	17.4	20,000	3780	1640	2580	1022	42,583	23	73	117	11,361
MAXIMUM	53	6839	334	2376	333	23.2	22,200	5011	2130	3050	1088	45,333	25	77	129	18,917
STD DEV (%OF MEAN)	4%	5%	2%	18%	1%	9%	3%	9%	6%	5%	3%	3%	3%	1%	4%	18%
VARIANCE	4	104268	31	107686	16	3	358889	147057	15114	22699	1089	1890625	0	1	21	8813266

Table A-7: Arsenic Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			Control Efficiency (CE)
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg-sludge	lb/dry ton-sludge	
TEST COND. #1	Run 1	2.64	1.23E-02	1.97E-03	0.42	8.42E-04	84.05%
	Run 2	2.97	1.37E-02	9.62E-04	0.21	4.16E-04	93.00%
	Run 3	3.64	1.42E-02	1.16E-03	0.30	5.94E-04	91.84%
	MEAN	3.08	1.34E-02	1.36E-03	0.31	6.17E-04	89.63%
	MINIMUM	2.64	1.23E-02	9.62E-04	0.21	4.16E-04	84.05%
	MAXIMUM	3.64	1.42E-02	1.97E-03	0.42	8.42E-04	93.00%
	STD DEV (%OF MEAN)	13%	6%	32%	28%	28%	4%
	VARIANCE	0.17	6.09E-07	1.90E-07	0.01	3.05E-08	0.16%
TEST COND. #2	Run 1	3.78	1.48E-02	1.15E-03	0.29	5.88E-04	92.22%
	Run 2	3.91	1.50E-02	1.05E-03	0.27	5.48E-04	92.99%
	Run 3	3.06	1.34E-02	1.14E-03	0.26	5.21E-04	91.49%
	MEAN	3.58	1.44E-02	1.11E-03	0.28	5.52E-04	92.24%
	MINIMUM	3.06	1.34E-02	1.05E-03	0.26	5.21E-04	91.49%
	MAXIMUM	3.91	1.50E-02	1.15E-03	0.29	5.88E-04	92.99%
	STD DEV (%OF MEAN)	10%	5%	4%	5%	5%	1%
	VARIANCE	0.14	4.96E-07	1.94E-09	0.00	7.66E-10	0.00%
TEST COND. #3	Run 1	3.50	1.44E-02	8.83E-04	0.22	4.30E-04	93.85%
	Run 2	3.53	1.45E-02	9.28E-04	0.23	4.52E-04	93.59%
	Run 3	3.05	1.13E-02	9.96E-04	0.27	5.31E-04	91.21%
	MEAN	3.36	1.34E-02	9.36E-04	0.24	4.71E-04	92.88%
	MINIMUM	3.05	1.13E-02	8.83E-04	0.22	4.30E-04	91.21%
	MAXIMUM	3.53	1.45E-02	9.96E-04	0.27	5.31E-04	93.85%
	STD DEV (%OF MEAN)	7%	11%	5%	9%	9%	1%
	VARIANCE	0.05	2.14E-06	2.17E-09	0.00	1.87E-09	0.01%

Table A-8: Beryllium Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK R. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			Control Efficiency (CE)
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg- sludge	lb/dry ton- sludge	
TEST COND. #1	Run 1	0.16	7.25E-04	< 2.32E-05	0.005	< 9.91E-06	> 96.80%
	Run 2	0.19	8.97E-04	< 3.19E-05	0.007	< 1.38E-05	> 96.44%
	Run 3	0.22	8.45E-04	< 3.19E-05	0.008	< 1.64E-05	> 96.23%
	MEAN	0.19	8.22E-04	2.90E-05	0.01	1.34E-05	96.49%
	MINIMUM	0.16	7.25E-04	2.32E-05	0.00	9.91E-06	96.23%
	MAXIMUM	0.22	8.97E-04	3.19E-05	0.01	1.64E-05	96.80%
	STD DEV (% OF MEAN)	14%	9%	14%	20%	20%	0%
	VARIANCE	0.00	5.19E-09	1.69E-11	0.00	7.04E-12	0.00%
TEST COND. #2	Run 1	0.21	8.08E-04	< 3.22E-05	0.008	< 1.65E-05	> 96.02%
	Run 2	0.20	7.52E-04	< 3.21E-05	0.008	< 1.67E-05	> 95.74%
	Run 3	0.19	8.45E-04	< 3.20E-05	0.007	< 1.46E-05	> 96.21%
	MEAN	0.20	8.02E-04	3.21E-05	0.01	1.59E-05	95.99%
	MINIMUM	0.19	7.52E-04	3.20E-05	0.01	1.46E-05	95.74%
	MAXIMUM	0.21	8.45E-04	3.22E-05	0.01	1.67E-05	96.21%
	STD DEV (% OF MEAN)	3%	5%	0%	6%	6%	0%
	VARIANCE	0.00	1.47E-09	3.60E-15	0.00	8.62E-13	0.00%
TEST COND. #3	Run 1	0.21	8.41E-04	< 3.14E-05	0.008	< 1.53E-05	> 96.27%
	Run 2	0.19	7.92E-04	< 3.25E-05	0.008	< 1.58E-05	> 95.91%
	Run 3	0.17	6.46E-04	< 3.20E-05	0.009	< 1.72E-05	> 95.05%
	MEAN	0.19	7.60E-04	3.19E-05	0.01	1.61E-05	95.74%
	MINIMUM	0.17	6.46E-04	3.14E-05	0.01	1.53E-05	95.05%
	MAXIMUM	0.21	8.41E-04	3.25E-05	0.01	1.72E-05	96.27%
	STD DEV (% OF MEAN)	7%	11%	1%	5%	5%	1%
	VARIANCE	0.00	6.86E-09	1.99E-13	0.00	6.65E-13	0.00%

Table A-9: Cadmium Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			Control Efficiency (CE)
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg-sludge	lb/dry ton-sludge	
TEST COND. #1	Run 1	7.43	3.48E-02	7.24E-03	1.55	3.10E-03	79.15%
	Run 2	7.20	3.33E-02	2.50E-03	0.54	1.08E-03	92.50%
	Run 3	8.91	3.47E-02	3.71E-03	0.95	1.90E-03	89.31%
	MEAN	7.85	3.42E-02	4.48E-03	1.01	2.03E-03	86.99%
	MINIMUM	7.20	3.33E-02	2.50E-03	0.54	1.08E-03	79.15%
	MAXIMUM	8.91	3.48E-02	7.24E-03	1.55	3.10E-03	92.50%
	STD DEV (% OF MEAN)	10%	2%	45%	41%	41%	7%
	VARIANCE	0.57	4.65E-07	4.06E-06	0.17	6.86E-07	0.32%
TEST COND. #2	Run 1	9.44	3.69E-02	3.73E-03	0.96	1.91E-03	89.87%
	Run 2	10.20	3.91E-02	3.54E-03	0.92	1.84E-03	90.96%
	Run 3	8.90	3.90E-02	3.72E-03	0.85	1.70E-03	90.44%
	MEAN	9.51	3.83E-02	3.66E-03	0.91	1.82E-03	90.42%
	MINIMUM	8.90	3.69E-02	3.54E-03	0.85	1.70E-03	89.87%
	MAXIMUM	10.20	3.91E-02	3.73E-03	0.96	1.91E-03	90.96%
	STD DEV (% OF MEAN)	6%	3%	2%	5%	5%	0%
	VARIANCE	0.28	1.07E-06	8.39E-09	0.00	7.76E-09	0.00%
TEST COND. #3	Run 1	9.66	3.96E-02	3.27E-03	0.80	1.60E-03	91.74%
	Run 2	10.44	4.29E-02	3.41E-03	0.83	1.66E-03	92.05%
	Run 3	8.28	3.07E-02	3.46E-03	0.92	1.84E-03	88.76%
	MEAN	9.46	3.77E-02	3.38E-03	0.85	1.70E-03	90.85%
	MINIMUM	8.28	3.07E-02	3.27E-03	0.80	1.60E-03	88.76%
	MAXIMUM	10.44	4.29E-02	3.46E-03	0.92	1.84E-03	92.05%
	STD DEV (% OF MEAN)	9%	14%	2%	6%	6%	2%
	VARIANCE	0.80	2.63E-05	5.88E-09	0.00	1.09E-08	0.02%

Table A-10: Chromium Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			Control Efficiency (CE)
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg- sludge	lb/dry ton- sludge	
TEST COND. #1	Run 1	65.40	3.06E-01	1.02E-03	0.22	4.34E-04	99.67%
	Run 2	65.60	3.03E-01	1.33E-03	0.29	5.74E-04	99.56%
	Run 3	75.70	2.95E-01	7.98E-04	0.20	4.10E-04	99.73%
	MEAN	68.90	3.01E-01	1.05E-03	0.24	4.73E-04	99.65%
	MINIMUM	65.40	2.95E-01	7.98E-04	0.20	4.10E-04	99.56%
	MAXIMUM	75.70	3.06E-01	1.33E-03	0.29	5.74E-04	99.73%
	STD DEV (% OF MEAN)	7%	2%	21%	15%	15%	0%
	VARIANCE	23.13	2.18E-05	4.72E-08	0.00	5.25E-09	0.00%
TEST COND. #2	Run 1	77.20	3.01E-01	8.06E-04	0.21	4.13E-04	99.73%
	Run 2	77.60	2.98E-01	9.72E-04	0.25	5.07E-04	99.67%
	Run 3	71.40	3.13E-01	8.04E-04	0.26	5.11E-04	99.74%
	MEAN	75.40	3.04E-01	8.60E-04	0.24	4.77E-04	99.72%
	MINIMUM	71.40	2.98E-01	8.04E-04	0.21	4.13E-04	99.67%
	MAXIMUM	77.60	3.13E-01	9.72E-04	0.26	5.11E-04	99.74%
	STD DEV (% OF MEAN)	4%	2%	9%	10%	10%	0%
	VARIANCE	8.03	4.05E-05	6.20E-09	0.00	2.05E-09	0.00%
TEST COND. #3	Run 1	74.80	3.07E-01	8.11E-04	0.20	3.95E-04	99.74%
	Run 2	76.90	3.16E-01	9.38E-04	0.23	4.57E-04	99.70%
	Run 3	66.30	2.46E-01	7.14E-04	0.19	3.81E-04	99.71%
	MEAN	72.67	2.90E-01	8.21E-04	0.21	4.11E-04	99.72%
	MINIMUM	66.30	2.46E-01	7.14E-04	0.19	3.81E-04	99.70%
	MAXIMUM	76.90	3.16E-01	9.38E-04	0.23	4.57E-04	99.74%
	STD DEV (% OF MEAN)	6%	11%	11%	8%	8%	0%
	VARIANCE	21.00	9.56E-04	8.45E-09	0.00	1.10E-09	0.00%

Table A-11: Hexavalent Chromium feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK H. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS		
		Total Cr Content mg/kg dry	Total Cr Feed Rate lb/hr	lb/hr	mg/dry kg- sludge	lb/dry ton- sludge
TEST COND. #1	Run 1	65.40	3.06E-01	1.82E-05	0.004	7.77E-06
	Run 2	65.60	3.03E-01	4.96E-05	0.011	2.14E-05
	Run 3	75.70	2.95E-01	5.44E-05	0.014	2.79E-05
	MEAN	68.90	3.01E-01	4.07E-05	0.01	1.91E-05
	MINIMUM	65.40	2.95E-01	1.82E-05	0.00	7.77E-06
	MAXIMUM	75.70	3.06E-01	5.44E-05	0.01	2.79E-05
	STD DEV (% OF MEAN)	7%	2%	39%	44%	44%
	VARIANCE	23.13	2.18E-05	2.58E-10	0.00	7.06E-11
TEST COND. #2	Run 1	77.20	3.01E-01	4.46E-05	0.011	2.29E-05
	Run 2	77.60	2.98E-01	4.71E-05	0.012	2.46E-05
	Run 3	71.40	3.13E-01	5.28E-05	0.012	2.41E-05
	MEAN	75.40	3.04E-01	4.82E-05	0.01	2.38E-05
	MINIMUM	71.40	2.98E-01	4.46E-05	0.01	2.29E-05
	MAXIMUM	77.60	3.13E-01	5.28E-05	0.01	2.46E-05
	STD DEV (% OF MEAN)	4%	2%	7%	3%	3%
	VARIANCE	8.03	4.05E-05	1.16E-11	0.00	5.13E-13
TEST COND. #3	Run 1	74.80	3.07E-01	4.69E-05	0.011	2.28E-05
	Run 2	76.90	3.16E-01	7.56E-05	0.018	3.68E-05
	Run 3	66.30	2.46E-01	5.97E-05	0.016	3.22E-05
	MEAN	72.67	2.90E-01	6.07E-05	0.02	3.06E-05
	MINIMUM	66.30	2.46E-01	4.69E-05	0.01	2.28E-05
	MAXIMUM	76.90	3.16E-01	7.56E-05	0.02	3.68E-05
	STD DEV (% OF MEAN)	6%	11%	19%	19%	19%
	VARIANCE	21.00	9.56E-04	1.38E-10	0.00	3.37E-11

Table A-12: Copper Feed and Emission Rates during Combustion Testing, May 17, 1993 – May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			Control Efficiency (CE)
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg-sludge	lb/dry ton-sludge	
TEST COND. #1	Run 1	668	3.12E+00	1.56E-02	3.33	6.65E-03	99.50%
	Run 2	679	3.14E+00	1.08E-02	2.33	4.65E-03	99.66%
	Run 3	785	3.06E+00	1.16E-02	2.97	5.95E-03	99.62%
	MEAN	711	3.11E+00	1.26E-02	2.88	5.75E-03	99.59%
	MINIMUM	668	3.06E+00	1.08E-02	2.33	4.65E-03	99.50%
	MAXIMUM	785	3.14E+00	1.56E-02	3.33	6.65E-03	99.66%
	STD DEV (% OF MEAN)	7%	1%	17%	14%	14%	0%
	VARIANCE	2783	1.23E-03	4.38E-06	0.17	6.85E-07	0.00%
TEST COND. #2	Run 1	818	3.19E+00	1.19E-02	3.06	6.12E-03	99.63%
	Run 2	793	3.04E+00	1.24E-02	3.22	6.44E-03	99.59%
	Run 3	701	3.07E+00	1.12E-02	2.55	5.11E-03	99.64%
	MEAN	771	3.10E+00	1.18E-02	2.94	5.89E-03	99.62%
	MINIMUM	701	3.04E+00	1.12E-02	2.55	5.11E-03	99.59%
	MAXIMUM	818	3.19E+00	1.24E-02	3.22	6.44E-03	99.64%
	STD DEV (% OF MEAN)	7%	2%	4%	10%	10%	0%
	VARIANCE	2531	4.39E-03	2.36E-07	0.08	3.24E-07	0.00%
TEST COND. #3	Run 1	736	3.02E+00	1.21E-02	2.96	5.91E-03	99.60%
	Run 2	769	3.16E+00	1.25E-02	3.04	6.07E-03	99.61%
	Run 3	649	2.41E+00	1.10E-02	2.95	5.89E-03	99.54%
	MEAN	718	2.86E+00	1.19E-02	2.98	5.96E-03	99.58%
	MINIMUM	649	2.41E+00	1.10E-02	2.95	5.89E-03	99.54%
	MAXIMUM	769	3.16E+00	1.25E-02	3.04	6.07E-03	99.61%
	STD DEV (% OF MEAN)	7%	11%	5%	1%	1%	0%
	VARIANCE	2562	1.06E-01	3.66E-07	0.00	6.59E-09	0.00%

Table A-13: Lead Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			Control Efficiency (CE)
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg- sludge	lb/dry ton- sludge	
TEST COND. #1	Run 1	123	5.75E-01	2.63E-02	5.63	1.13E-02	95.43%
	Run 2	119	5.50E-01	7.66E-03	1.66	3.32E-03	98.61%
	Run 3	147	5.73E-01	1.12E-02	2.87	5.74E-03	98.05%
	MEAN	130	5.66E-01	1.51E-02	3.38	6.77E-03	97.36%
	MINIMUM	119	5.50E-01	7.66E-03	1.66	3.32E-03	95.43%
	MAXIMUM	147	5.75E-01	2.63E-02	5.63	1.13E-02	98.61%
	STD DEV (% OF MEAN)	10%	2%	54%	49%	49%	1%
	VARIANCE	153	1.28E-04	6.54E-05	2.76	1.10E-05	0.02%
TEST COND. #2	Run 1	159	6.21E-01	8.99E-03	2.30	4.61E-03	98.55%
	Run 2	157	6.02E-01	9.48E-03	2.47	4.94E-03	98.43%
	Run 3	125	5.47E-01	7.76E-03	1.77	3.54E-03	98.58%
	MEAN	147	5.90E-01	8.74E-03	2.18	4.36E-03	98.52%
	MINIMUM	125	5.47E-01	7.76E-03	1.77	3.54E-03	98.43%
	MAXIMUM	159	6.21E-01	9.48E-03	2.47	4.94E-03	98.58%
	STD DEV (% OF MEAN)	11%	5%	8%	14%	14%	0%
	VARIANCE	243	9.73E-04	5.22E-07	0.09	3.55E-07	0.00%
TEST COND. #3	Run 1	133	5.46E-01	7.77E-03	1.89	3.79E-03	98.58%
	Run 2	142	5.83E-01	8.20E-03	2.00	3.99E-03	98.59%
	Run 3	112	4.16E-01	7.68E-03	2.05	4.10E-03	98.15%
	MEAN	129	5.15E-01	7.88E-03	1.98	3.96E-03	98.44%
	MINIMUM	112	4.16E-01	7.68E-03	1.89	3.79E-03	98.15%
	MAXIMUM	142	5.83E-01	8.20E-03	2.05	4.10E-03	98.59%
	STD DEV (% OF MEAN)	10%	14%	3%	3%	3%	0%
	VARIANCE	158	5.13E-03	5.20E-08	0.00	1.66E-08	0.00%

Table A-14: Mercury Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			Control Efficiency (CE)
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg-sludge	lb/dry ton-sludge	
TEST COND. #1	Run 1	1.16	5.43E-03	3.78E-03	0.81	1.61E-03	30.42%
	Run 2	1.10	5.09E-03	8.27E-03	1.79	3.58E-03	-62.60%
	Run 3	1.22	4.75E-03	7.38E-03	1.89	3.79E-03	-55.29%
	MEAN	1.16	5.09E-03	6.47E-03	1.50	2.99E-03	-29.16%
	MINIMUM	1.10	4.75E-03	3.78E-03	0.81	1.61E-03	-62.60%
	MAXIMUM	1.22	5.43E-03	8.27E-03	1.89	3.79E-03	30.42%
	STD DEV (% OF MEAN)	4%	5%	30%	33%	33%	145%
	VARIANCE	0.00	7.53E-08	3.78E-06	0.24	9.59E-07	17.83%
TEST COND. #2	Run 1	1.29	5.04E-03	6.70E-03	1.72	3.43E-03	-32.97%
	Run 2	1.99	7.63E-03	6.30E-03	1.64	3.29E-03	17.44%
	Run 3	1.41	6.17E-03	8.09E-03	1.85	3.69E-03	-30.98%
	MEAN	1.56	6.28E-03	7.03E-03	1.74	3.47E-03	-15.50%
	MINIMUM	1.29	5.04E-03	6.30E-03	1.64	3.29E-03	-32.97%
	MAXIMUM	1.99	7.63E-03	8.09E-03	1.85	3.69E-03	17.44%
	STD DEV (% OF MEAN)	20%	17%	11%	5%	5%	150%
	VARIANCE	0.09	1.13E-06	5.85E-07	0.01	2.85E-08	5.43%
TEST COND. #3	Run 1	1.60	6.56E-03	5.17E-03	1.26	2.52E-03	21.20%
	Run 2	1.93	7.92E-03	8.55E-03	2.08	4.16E-03	-7.86%
	Run 3	1.42	5.27E-03	5.92E-03	1.59	3.19E-03	-12.22%
	MEAN	1.65	6.59E-03	6.55E-03	1.65	3.29E-03	0.37%
	MINIMUM	1.42	5.27E-03	5.17E-03	1.26	2.52E-03	-12.22%
	MAXIMUM	1.93	7.92E-03	8.55E-03	2.08	4.16E-03	21.20%
	STD DEV (% OF MEAN)	13%	16%	22%	20%	20%	3997%
	VARIANCE	0.04	1.17E-06	2.10E-06	0.11	4.55E-07	2.20%

Table A-15: Nickel Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg- sludge	lb/dry ton- sludge	Control Efficiency (CE)
TEST COND. #1	Run 1	38.9	1.82E-01	4.83E-04	0.103	2.06E-04	99.73%
	Run 2	37.7	1.74E-01	1.10E-03	0.237	4.74E-04	99.37%
	Run 3	44.2	1.72E-01	1.84E-04	0.047	9.47E-05	99.89%
	MEAN	40.3	1.76E-01	5.88E-04	0.13	2.58E-04	99.67%
	MINIMUM	37.7	1.72E-01	1.84E-04	0.05	9.47E-05	99.37%
	MAXIMUM	44.2	1.82E-01	1.10E-03	0.24	4.74E-04	99.89%
	STD DEV (% OF MEAN)	7%	2%	65%	62%	62%	0%
	VARIANCE	8.0	1.75E-05	1.44E-07	0.01	2.54E-08	0.00%
TEST COND. #2	Run 1	47.6	1.86E-01	2.80E-04	0.072	1.43E-04	99.85%
	Run 2	48.4	1.86E-01	3.67E-04	0.096	1.92E-04	99.80%
	Run 3	44.2	1.94E-01	3.74E-04	0.085	1.71E-04	99.81%
	MEAN	46.7	1.88E-01	3.41E-04	0.08	1.69E-04	99.82%
	MINIMUM	44.2	1.86E-01	2.80E-04	0.07	1.43E-04	99.80%
	MAXIMUM	48.4	1.94E-01	3.74E-04	0.10	1.92E-04	99.85%
	STD DEV (% OF MEAN)	4%	2%	13%	12%	12%	0%
	VARIANCE	3.3	1.35E-05	1.84E-09	0.00	3.89E-10	0.00%
TEST COND. #3	Run 1	45.3	1.86E-01	3.35E-04	0.082	1.63E-04	99.82%
	Run 2	47.5	1.95E-01	3.05E-04	0.074	1.49E-04	99.84%
	Run 3	38.8	1.44E-01	3.77E-04	0.101	2.01E-04	99.74%
	MEAN	43.9	1.75E-01	3.39E-04	0.09	1.71E-04	99.80%
	MINIMUM	38.8	1.44E-01	3.05E-04	0.07	1.49E-04	99.74%
	MAXIMUM	47.5	1.95E-01	3.77E-04	0.10	2.01E-04	99.84%
	STD DEV (% OF MEAN)	8%	13%	9%	13%	13%	0%
	VARIANCE	13.6	4.92E-04	8.76E-10	0.00	4.89E-10	0.00%

Table A-16: Selenium Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK R. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg- sludge	lb/dry ton- sludge	Control Efficiency (CE)
TEST COND. #1	Run 1	< 0.316	< 1.48E-03	1.05E-03	0.225	4.50E-04	28.79%
	Run 2	< 0.313	< 1.45E-03	7.92E-04	0.171	3.43E-04	45.24%
	Run 3	< 0.350	< 1.36E-03	7.72E-04	0.198	3.96E-04	43.37%
	MEAN	0.326	1.43E-03	8.72E-04	0.198	3.96E-04	39.13%
	MINIMUM	0.313	1.36E-03	7.72E-04	0.171	3.43E-04	28.79%
	MAXIMUM	0.350	1.48E-03	1.05E-03	0.225	4.50E-04	45.24%
	STD DEV (% OF MEAN)	5%	3%	15%	0.110	11%	19%
	VARIANCE	0.000	2.33E-09	1.63E-08	0.000	1.92E-09	0.54%
TEST COND. #2	Run 1	< 0.356	< 1.39E-03	6.40E-04	0.164	3.28E-04	53.98%
	Run 2	< 0.345	< 1.32E-03	6.76E-04	0.176	3.53E-04	48.87%
	Run 3	< 0.324	< 1.42E-03	6.89E-04	0.157	3.15E-04	51.40%
	MEAN	0.342	1.38E-03	6.68E-04	0.166	3.32E-04	51.42%
	MINIMUM	0.324	1.32E-03	6.40E-04	0.157	3.15E-04	48.87%
	MAXIMUM	0.356	1.42E-03	6.89E-04	0.176	3.53E-04	53.98%
	STD DEV (% OF MEAN)	4%	3%	3%	0.047	5%	4%
	VARIANCE	0.000	1.60E-09	4.44E-10	0.000	2.47E-10	0.04%
TEST COND. #3	Run 1	< 0.333	< 1.37E-03	5.82E-04	0.142	2.84E-04	57.43%
	Run 2	< 0.316	< 1.30E-03	6.53E-04	0.159	3.18E-04	49.68%
	Run 3	< 0.345	< 1.28E-03	6.59E-04	0.176	3.52E-04	48.52%
	MEAN	0.331	1.31E-03	6.31E-04	0.159	3.18E-04	51.88%
	MINIMUM	0.316	1.28E-03	5.82E-04	0.142	2.84E-04	48.52%
	MAXIMUM	0.345	1.37E-03	6.59E-04	0.176	3.52E-04	57.43%
	STD DEV (% OF MEAN)	4%	3%	6%	0.087	9%	8%
	VARIANCE	0.000	1.35E-09	1.24E-09	0.000	7.71E-10	0.16%

Table A-17: Zinc Feed and Emission Rates during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		SLUDGE FEED		EMISSIONS			
		Metal Content mg/kg dry	Metal Feed Rate lb/hr	lb/hr	mg/dry kg- sludge	lb/dry ton- sludge	Control Efficiency (CE)
TEST COND. #1	Run 1	763	3.57	5.03E-02	10.76	2.15E-02	98.59%
	Run 2	756	3.49	2.10E-02	4.53	9.07E-03	99.40%
	Run 3	864	3.37	2.25E-02	5.78	1.16E-02	99.33%
	MEAN	794	3.48	3.13E-02	7.03	1.41E-02	99.11%
	MINIMUM	756	3.37	2.10E-02	4.53	9.07E-03	98.59%
	MAXIMUM	864	3.57	5.03E-02	10.76	2.15E-02	99.40%
	STD DEV (% OF MEAN)	6%	2%	43%	38%	38%	0%
	VARIANCE	2435	0.01	1.82E-04	7.23	2.89E-05	0.00%
TEST COND. #2	Run 1	836	3.26	2.51E-02	6.43	1.29E-02	99.23%
	Run 2	876	3.36	2.85E-02	7.43	1.49E-02	99.15%
	Run 3	801	3.51	2.17E-02	4.97	9.93E-03	99.38%
	MEAN	838	3.38	2.51E-02	6.28	1.26E-02	99.25%
	MINIMUM	801	3.26	2.17E-02	4.97	9.93E-03	99.15%
	MAXIMUM	876	3.51	2.85E-02	7.43	1.49E-02	99.38%
	STD DEV (% OF MEAN)	4%	3%	11%	16%	16%	0%
	VARIANCE	939	0.01	7.62E-06	1.03	4.10E-06	0.00%
TEST COND. #3	Run 1	848	3.48	2.10E-02	5.12	1.02E-02	99.40%
	Run 2	881	3.62	2.37E-02	5.78	1.16E-02	99.34%
	Run 3	763	2.83	2.29E-02	6.11	1.22E-02	99.19%
	MEAN	831	3.31	2.25E-02	5.67	1.13E-02	99.31%
	MINIMUM	763	2.83	2.10E-02	5.12	1.02E-02	99.19%
	MAXIMUM	881	3.62	2.37E-02	6.11	1.22E-02	99.40%
	STD DEV (% OF MEAN)	6%	10%	5%	7%	7%	0%
	VARIANCE	2471	0.12	1.32E-06	0.17	6.78E-07	0.00%

Table A-18: Hexavalent Chromium vs. Total Chromium Emissions
FRANKE. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

<u>Condition</u>	<u>Run</u>	<u>Emission Rates (lb/hr)</u>		<u>% Chromium as Hex. Chromium</u>
		<u>Chromium</u>	<u>Hex. Chromium</u>	
1	1	1.02E-03	1.82E-05	1.8%
	2	1.33E-03	4.96E-05	3.7%
	3	7.98E-04	5.44E-05	6.8%
	avg.	1.05E-03	4.07E-05	3.9%
2	1	8.06E-04	4.46E-05	5.5%
	2	9.72E-04	4.71E-05	4.8%
	3	1.12E-03	5.28E-05	4.7%
	avg.	9.66E-04	4.82E-05	5.0%
3	1	8.11E-04	4.69E-05	5.8%
	2	9.38E-04	7.56E-05	8.1%
	3	7.06E-04	5.97E-05	8.5%
	avg.	8.18E-04	6.07E-05	7.4%

Table A-19: Mean Values of CBM Data during Combustion and Stack Testing, May 17, 1993 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

Test Condition	FURNACE EXIT						STACK				
	Hydrocarbons PPM-wet	Hydrocarbons PPMDV @ 7% O ₂	CO ₂ % dry	CO PPMDV	CO PPMDV @ 7% O ₂	O ₂ % dry	Hydrocarbons PPM-wet	Hydrocarbons PPMDV @ 7% O ₂	CO PPMDV	CO PPMDV @ 7% O ₂	O ₂ % dry *
1	94.4	156.2	11.37	2003	1821	5.39	31.3	40.6			8.05
2	5.3	8.1	11.09	1933	1795	5.39	13.6	17.6	1649	1649	8.70
3	17.2	22.6	9.52	1887	1931	6.79	10.8	14.1	1181	1542	8.68

* Percent oxygen in stack based on daily average.

Table A-20: CEM Data: One-Hour Averages for Condition 1: May 17, 1993 - May 18, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

FURNACE EXIT		STACK	
CO	CO ₂	CO	CO ₂
PPMDV	%	PPMDV	%
dy	@ 7% O ₂	dy	@ 7% O ₂
14.01	13.05	15.11	2.72
1981	13.05	1515	2.72
2047	13.05	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
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1981	13.05	1515	2.72
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2047	13.24	1551	2.55
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2047	13.03	1601	3.12
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2047	13.24	1557	2.63
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1892	11.60	1750	5.87
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2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
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2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
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2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
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1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05	1515	2.72
2047	14.01	1511	2.72
1874	11.64	1714	5.70
1892	11.60	1750	5.87
2047	13.14	1642	3.60
2047	12.65	1661	3.77
2047	13.03	1601	3.12
2047	13.24	1551	2.55
2047	13.24	1557	2.63
1981	13.05		

* Percent oxygen in stack based on daily averages.

FURNACE EXIT									
Hydrocarbons	Hydrocarbons	CO	CO	CO	CO	CO	CO	CO	CO
PPM-wet	PPM-wet	%	PPMDV	%	PPMDV	%	PPMDV	%	PPMDV
@ 7% O ₂	@ 7% O ₂	dy	@ 7% O ₂	dy	@ 7% O ₂	dy	@ 7% O ₂	dy	@ 7% O ₂
4.0	6.6	5.20	8.01	16.82	5.06	11.7	17.45	4.60	3.22
5.2	6.9	12.35	20.45	16.08	5.06	11.7	17.45	4.60	3.22
4.5	6.7	11.09	18.85	16.54	5.06	11.8	17.7	4.61	3.24
5.1	8.5	9.59	17.34	17.23	6.91	13.4	17.7	4.61	3.24
7.2	11.4	10.10	20.47	19.28	6.14	13.9	17.7	4.61	3.24
8.3	11.39	20.35	20.47	19.28	6.14	13.9	17.7	4.61	3.24
8.9	10.23	20.12	16.77	15.00	5.36	14.0	17.7	4.61	3.24
12.1	8.88	16.77	16.77	15.00	5.36	14.0	17.7	4.61	3.24
12.1	8.88	16.77	16.77	15.00	5.36	14.0	17.7	4.61	3.24
10.16	7.9	10.16	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.16	7.9	10.16	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.03	11.03	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.03	11.03	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.21	11.21	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.21	11.21	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.52	11.52	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.52	11.52	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.31	10.31	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.31	10.31	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.10	11.10	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.10	11.10	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.99	10.99	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.99	10.99	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.23	11.23	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.23	11.23	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.50	11.50	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.50	11.50	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.12	11.12	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.12	11.12	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.38	11.38	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.38	11.38	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
12.10	12.10	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
12.10	12.10	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.46	11.46	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.46	11.46	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.91	10.91	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.91	10.91	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.22	10.22	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
10.22	10.22	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
13.11	13.11	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
13.11	13.11	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.80	11.80	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.80	11.80	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
12.15	12.15	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
12.15	12.15	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.87	11.87	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
11.87	11.87	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
12.78	12.78	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
12.78	12.78	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
13.53	13.53	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
13.53	13.53	10.97	20.47	19.28	6.14	13.9	17.7	4.61	3.24
8.7	8.7	11.0	10.97	19.28	6.14	13.9	17.7	4.61	3.24
8.7	8.7	11.0	10.97	19.28	6.14	13.9	17.7	4.61	3.24
15.4	15.4	12.78	20.47	19.28	6.14	13.9	17.7	4.61	3.24
15.4	15.4	12.78	20.47	19.28	6.14	13.9	17.7	4.61	3.24
5.3	5.3	9.59	20.47	19.28	6.14	13.9	17.7	4.61	3.24
5.3	5.3	9.59	20.47	19.28	6.14	13.9	17.7	4.61	3.24
8.7	8.7	10.50	20.40	20.09	6.79	15.0	17.7	4.61	3.24
8.7	8.7	10.50	20.40	20.09	6.79	15.0	17.7	4.61	3.24
4.7	4.7	11.48	20.10	18.94	6.15	15.0	17.7	4.61	3.24
4.7	4.7	11.48	20.10	18.94	6.15	15.0	17.7	4.61	3.24
4.0	4.0	11.87	18.77	17.20	5.73	15.0	17.7	4.61	3.24
4.0	4.0	11.87	18.77	17.20	5.73	15.0	17.7	4.61	3.24
3.9	3.9	12.15	16.71	15.05	5.47	15.0	17.7	4.61	3.24
3.9	3.9	12.15	16.71	15.05	5.47	15.0	17.7	4.61	3.24
7.4	7.4	13.17	20.47	16.98	4.14	15.0	17.7	4.61	3.24
7.4	7.4	13.17	20.47	16.98	4.14	15.0	17.7	4.61	3.24
8.0	8.0	11.83	18.67	16.98	5.65	15.0	17.7	4.61	3.24
8.0	8.0	11.83	18.67	16.98	5.65	15.0	17.7	4.61	3.24
7.5	7.5	12.20	20.46	18.20	5.28	15.0	17.7	4.61	3.24
7.5	7.5	12.20	20.46	18.20	5.28	15.0	17.7	4.61	3.24
8.6	8.6	12.15	20.47	18.07	5.16	15.0	17.7	4.61	3.24
8.6	8.6	12.15	20.47	18.07	5.16	15.0	17.7	4.61	3.24
9.8	9.8	11.80	20.47	18.00	5.60	15.0	17.7	4.61	3.24
9.8	9.8	11.80	20.47	18.00	5.60	15.0	17.7	4.61	3.24
6.1	6.1	13.11	20.30	16.23	3.52	15.0	17.7	4.61	3.24
6.1	6.1	13.11	20.30	16.23	3.52	15.0	17.7	4.61	3.24
9.3	9.3	10.22	20.46	20.61	7.11	15.0	17.7	4.61	3.24
9.3	9.3	10.22	20.46	20.61	7.11	15.0	17.7	4.61	3.24
6.1	6.1	10.91	17.71	17.12	6.52	15.0	17.7	4.61	3.24
6.1	6.1	10.91	17.71	17.12	6.52	15.0	17.7	4.61	3.24
7.6	7.6	11.46	18.60	17.31	5.96	15.0	17.7	4.61	3.24
7.6	7.6	11.46	18.60	17.31	5.96	15.0	17.7	4.61	3.24
7.1	7.1	12.10	20.31	17.65	4.91	15.0	17.7	4.61	3.24
7.1	7.1	12.10	20.31	17.65	4.91	15.0	17.7	4.61	3.24
7.7	7.7	11.83	20.47	18.34	5.38	15.0	17.7	4.61	3.24
7.7	7.7	11.83	20.47	18.34	5.38	15.0	17.7	4.61	3.24
8.3	8.3	11.57	20.46	18.87	5.82	15.0	17.7	4.61	3.24
8.3	8.3	11.57	20.46	18.87	5.82	15.0	17.7	4.61	3.24
7.2	7.2	13.40	20.47	16.48	3.63	15.0	17.7	4.61	3.24
7.2	7.2	13.40	20.47	16.48	3.63	15.0	17.7	4.61	3.24
11.2	11.2	11.02	18.76	18.19	6.57	15.0	17.7	4.61	3.24
11.2	11.2	11.02	18.76	18.19	6.57	15.0	17.7	4.61	3.24
4.0	4.0	5.11	8.42	15.25	6.81	15.0	17.7	4.61	3.24
4.0	4.0	5.11	8.42	15.25	6.81	15.0	17.7	4.61	3.24
4.1	4.1	11.19	20.47	19.02	5.94	15.0	17.7	4.61	3.24
4.1	4.1	11.19	20.47	19.02	5.94	15.0	17.7	4.61	3.24
2.3	2.3	3.5	20.47	18.54	5.56	15.0	17.7	4.61	3.24
2.3	2.3	3.5	20.47	18.54	5.56	15.0	17.7	4.61	3.24
2.9	2.9	10.86	20.46	19.22	6.11	15.0	17.7	4.61	3.24
2.9	2.9	10.86	20.46	19.22	6.11	15.0	17.7	4.61	3.24
4.1	4.1	11.38	20.47	18.40	5.44	15.0	17.7	4.61	3.24
4.1	4.1	11.38	20.47	18.40	5.44	15.0	17.7	4.61	3.24
3.2	3.2	5.0	20.06	18.56	5.88	15.0	17.7	4.61	3.24
3.2	3.2	5.0	20.06	18.56	5.88	15.0	17.7	4.61	3.24
6.7	6.7	11.50	20.47	18.00	5.10	15.0	17.7	4.61	3.24
6.7	6.7	11.50	20.47	18.00	5.10	15.0	17.7	4.61	3.24
4.6	4.6	7.0	20.47	18.05	5.64	15.0	17.7	4.61	3.24
4.6	4.6	7.0	20.47	18.05	5.64	15.0	17.7	4.61	3.24
4.7	4.7	10.99	20.47	18.86	5.81	15.0	17.7	4.61	3.24
4.7	4.7	10.99	20.47	18.86	5.81	15.0	17.7	4.61	3.24
7.2	7.2	11.10	20.47	18.76	5.73	15.0	17.7	4.61	3.24
7.2	7.2	11.10	20.47	18.76	5.73	15.0	17.7	4.61	3.24
4.6	4.6	10.31	19.03	17.51	5.79	15.0	17.7	4.61	3.24
4.6	4.6	10.31	19.03	17.51	5.79	15.0	17.7	4.61	3.24
11.5	11.5	11.52	20.47	17.18	4.34	15.0	17.7	4.61	3.24
11.5	11.5	11.52	20.47	17.18	4.34	15.0	17.7	4.61	3.24
4.7	4.7	11.21	20.47	17.53	4.67	15.0	17.7	4.61	3.24
4.7	4.7	11.21	20.47	17.53	4.67	15.0	17.7	4.61	3.24
5.7	5.7	8.4	20.47	18.01	5.10	15.0	17.7	4.61	3.24
5.7	5.7	8.4	20.47	18.01	5.10	15.0	17.7	4.61	3.24
12.2	12.2	11.03	20.47	17.08	4.81				

Table A-22: CEM Data: Gas-Phase Averages for Condition 2: May 21, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

	Time	FURNACE EXIT						STACK					
		Hydrocarbons PPM-wet	Hydrocarbons PPMDV @ 7% O ₂	CO ₂ % dry	CO PPMDV	CO PPMDV @ 7% O ₂	O ₂ % dry	Hydrocarbons PPM-wet	Hydrocarbons PPMDV @ 7% O ₂	CO PPMDV	CO PPMDV @ 7% O ₂	O ₂ % dry *	
5/21/93	00:00	10.5		8.65	1460					569	752	8.85	
	01:00	6.7	8.9	11.53	1833	1745	6.30			868	1146	8.85	
	02:00	2.2	2.5	13.35	2047	1688	4.04			1338	1768	8.85	
	03:00	5.5	6.4	13.17	2039	1702	4.25			1082	1429	8.85	
	04:00	10.5	12.7	12.67	2006	1738	4.86			886	1171	8.85	
	05:00	10.2	12.6	12.49	1984	1746	5.10	5.0	6.6	805	1144	8.85	
	06:00	9.7	12.2	12.15	1980	1779	5.43	4.5	5.9	874	1154	8.85	
	07:00	9.7	12.9	11.51	2010	1899	6.19	4.5	5.9	886	1171	8.85	
	08:00	7.0	9.1	11.84	2046	1909	6.00	5.0	6.6	845	1116	8.85	
	09:00	8.2	14.1	8.88	1646	2021	9.58	5.5	7.3	908	1199	8.85	
	10:00	6.2	10.5	7.73	1498	1810	9.40	5.5	7.3	1018	1346	8.85	
	11:00	6.5	9.4	10.44	1949	2035	7.58	8.5	11.2	1033	1365	8.85	
	12:00	8.6	11.7	11.14	2040	1989	6.65	8.0	10.6	866	1145	8.85	
	13:00	18.3	27.9	7.64	1917	2097	8.20	34.2	45.2	1113	1471	8.85	
	14:00	36.3	52.2	5.81	2024	2088	7.42	12.0	15.9	1602	2116	8.85	
	15:00	24.8	38.9	5.25	1556	1751	8.55	8.5	11.2	1157	1528	8.85	
	16:00	21.4	39.1	6.03	1714	2247	10.30	23.6	31.2	1477	1952	8.85	
	17:00	43.0	62.3	7.04	2029	2107	7.52	7.0	9.2	2032	2685	8.85	
	18:00	22.6	45.0	4.78	1584	2266	11.18	45.6	60.3	1932	2553	8.85	
	19:00	44.0	59.5	7.86	2047	1982	6.55	11.1	14.7	1494	1974	8.85	
	20:00	23.9	35.4	7.16	1976	2093	7.78	12.4	16.4	1167	1542	8.85	
	21:00	32.8	47.9	6.14	2001	2094	7.62	11.8	15.5	1513	2000	8.85	
	22:00	23.8	37.4	6.49	1837	2069	8.56	8.0	10.6	1312	1734	8.85	
	23:00	17.2	30.3	6.80	1916	2424	9.91	8.0	10.6	941	1244	8.85	
5/21/93	00:00	11.4		4.44	834			6.1	7.9	908	1171	8.50	
	01:00	6.9		5.45	686			7.6	9.9	1375	1773	8.50	
	02:00	8.1		8.88	1762			7.3	9.4	1421	1833	8.50	
	03:00	26.7		12.38	1916			10.0	12.9	1345	1736	8.50	
	04:00	29.9		12.79	2047			12.0	15.5	1332	1718	8.50	
	05:00	32.5		13.50	1938			10.0	12.9	1308	1688	8.50	
	06:00	28.6		11.13	2047			12.3	15.8	1032	1332	8.50	
	07:00	42.4		11.55	2047			12.0	15.5	1412	1822	8.50	
	08:00	18.9		10.96	2047			23.0	29.7	1059	1367	8.50	
	09:00	18.6		10.40	2047			9.5	12.2	749	966	8.50	
	10:00	17.1		9.14	2047			9.0	11.6	292	377	8.50	
	11:00	27.4		8.14	1862			8.0	10.3	1308	1687	8.50	
	12:00	23.7		10.56	1839			9.3	12.0	1279	1650	8.50	
	13:00	21.3		10.62	2039			9.0	11.6	1327	1712	8.50	
	14:00	22.3	34.7	8.74	2047	1924	6.11	7.5	9.7	1496	1930	8.50	
	15:00	9.9	13.8	10.32	2047	1726	4.42	7.5	9.7	787	1015	8.50	
	16:00	7.3	10.9	9.97	2047	1854	5.55	9.0	11.6	1372	1770	8.50	
	17:00	7.0	10.5	9.84	2017	1826	5.55	8.8	11.4	1275	1644	8.50	
	18:00	7.4	10.8	10.27	2047	1795	5.05	9.5	12.3	1227	1583	8.50	
	19:00	7.5	10.6	10.78	2047	1754	4.68	8.0	10.3	1324	1708	8.50	
	20:00	7.5	11.2	10.56	2047	1851	5.53	10.8	14.0	1463	1887	8.50	
	21:00	7.6	10.8	10.94	2047	1760	4.74	11.4	14.7	1322	1706	8.50	
	22:00	7.6	12.3	9.52	2047	2013	6.76	8.5	11.0	1325	1709	8.50	
MEAN		17.2	22.6	9.52	1887	1931	6.79	10.8	14.1	1181	1542	9	
MINIMUM		2.2	2.5	4.44	686	1688	4.04	4.5	5.9	292	377	9	
MAXIMUM		44.0	62.3	13.50	2047	2424	11.18	45.6	60.3	2032	2685	9	
STD DEV (% OF MEAN)		65%	74%	26%	15%	9%	28%	70%	71%	27%	27%	2%	
VARIANCE		123	284	6	81608	33584	4	58	102	103035	175935	0	

* Percent oxygen in stack based on daily average.

Table A-23: Mean Values of Emission Rates and Concentrations for SO₂
Samples Taken During Combustion and Stack Testing, May 17, 1993 – May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

Test Condition	Sludge Feed lb/hr (dry)	% Oxygen dry	mg SO ₂	Vol. STP	Flow Rate dscfm	Flow Rate dscmh	lbs/hr	lb/ton – sludge	mg/dscm	ppmdv	ppmdv (7% O ₂)
1	4399	8.7	0.869	22.57	14,930	25,367	2.14	0.99	38.63	14.61	18.13
2	4039	8.8	0.385	24.47	14,730	25,026	0.87	0.43	16.07	6.08	6.91
3	3974	8.7	0.356	21.68	15,355	26,089	0.93	0.47	16.15	6.11	6.97

Table A-24: Emission Rates and Concentrations of SO₂
Samples Taken During Combustion and Stack Testing, May 17, 1993 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

	Run	Sludge Feed lb/hr (dry)	% Oxygen dry	mg SO ₂	Vol. STP	Flow Rate dscfm	Flow Rate dscmh	lbs/hr	lb/ton - sludge	mg/dscm	ppmdv	ppmdv (7% O ₂)
TEST COND. #1	1a	4677	11.6	0.967	22.03	13,789	23,428	2.27	0.97	43.89	16.60	24.81
	1b	4677	11.6	1.274	21.72	13,789	23,428	3.03	1.29	58.66	22.18	33.15
	1c	4677	11.6	1.621	21.81	13,789	23,428	3.84	1.64	74.32	28.10	42.00
	2a	4623	8.6	0.045	22.18	14,952	25,403	0.11	0.05	2.03	0.77	0.87
	2b	4623	8.6	0.728	21.25	14,952	25,403	1.92	0.83	34.26	12.95	14.64
	2c	4623	8.6	0.087	23.29	14,952	25,403	0.21	0.09	3.72	1.41	1.59
	3a	3896	6	0.846	22.91	16,050	27,270	2.22	1.14	36.93	13.96	13.03
	3b	3896	6	1.050	22.67	16,050	27,270	2.78	1.43	46.32	17.51	16.34
	3c	3896	6	1.201	25.25	16,050	27,270	2.86	1.47	47.56	17.99	16.78
	MEAN	4399	8.7	0.869	22.57	14,930	25,367	2.14	0.99	38.63	14.61	18.13
	MINIMUM	3896	6.0	0.045	21.25	13,789	23,428	0.11	0.05	2.03	0.77	0.87
	MAXIMUM	4677	11.6	1.621	25.25	16,050	27,270	3.84	1.64	74.32	28.10	42.00
	STD DEV (% OF MEAN)	8%	26%	57%	5%	6%	55%	55%	55%	57%	70%	70%
	VARIANCE	126823	5.2	0.244	1.26	852,159	2,459,843	1.39	0.30	491.35	70.25	161.67
TEST COND. #2	1a	3904	9	0.094	22.49	15,888	26,993	0.25	0.13	4.18	1.58	1.85
	1b	3904	9	0.417	32.66	15,888	26,993	0.76	0.39	12.77	4.83	5.64
	1c	3904	9	0.123	27.63	15,888	26,993	0.26	0.14	4.45	1.68	1.97
	2a	3835	8.8	0.182	22.31	13,207	22,439	0.40	0.21	8.16	3.08	3.54
	2b	3835	8.8	0.581	23.62	13,207	22,439	1.22	0.63	24.60	9.30	10.68
	2c	3835	8.8	0.418	22.43	13,207	22,439	0.92	0.48	18.64	7.05	8.09
	3a	4378	8.5	0.47	23.17	15,094	25,645	1.15	0.52	20.28	7.67	8.60
	3b	4378	8.5	0.286	23.15	15,094	25,645	0.70	0.32	12.35	4.67	5.24
	3c	4378	8.5	0.893	22.77	15,094	25,645	2.22	1.01	39.22	14.83	16.62
	MEAN	4039	8.8	0.385	24.47	14,730	25,026	0.87	0.43	16.07	6.08	6.91
	MINIMUM	3835	8.5	0.094	22.31	13,207	22,439	0.25	0.13	4.18	1.58	1.85
	MAXIMUM	4378	9.0	0.893	32.66	15,888	26,993	2.22	1.01	39.22	14.83	16.62
	STD DEV (% OF MEAN)	6%	2%	62%	13%	8%	8%	66%	62%	65%	65%	64%
	VARIANCE	58254	0.0	0.057	10.76	1,264,076	3,648,882	0.34	0.07	110.73	15.83	19.85
TEST COND. #3	1a	4102	9	0.793	22.07	14,317	24,324	1.93	0.94	35.93	13.59	15.87
	1b	4102	9	0.0852	12.95	14,317	24,324	0.35	0.17	6.58	2.49	2.91
	1c	4102	9	0.047	22.37	14,317	24,324	0.11	0.05	2.10	0.79	0.93
	2a	4106	8.7	0.0969	21.58	16,042	27,256	0.27	0.13	4.49	1.70	1.93
	2b	4106	8.7	0.418	20.38	16,042	27,256	1.23	0.60	20.51	7.76	8.84
	2c	4106	8.7	0.502	21.38	16,042	27,256	1.41	0.69	23.48	8.88	10.12
	3a	3713	8.5	0.239	28.14	15,707	26,686	0.50	0.27	8.49	3.21	3.60
	3b	3713	8.5	0.658	24.05	15,707	26,686	1.61	0.87	27.36	10.35	11.60
	3c	3713	8.5	0.364	22.17	15,707	26,686	0.97	0.52	16.42	6.21	6.96
	MEAN	3974	8.7	0.356	21.68	15,355	26,089	0.93	0.47	16.15	6.11	6.97
	MINIMUM	3713	8.5	0.047	12.95	14,317	24,324	0.11	0.05	2.10	0.79	0.93
	MAXIMUM	4106	9.0	0.793	28.14	16,042	27,256	1.93	0.94	35.93	13.59	15.87
	STD DEV (% OF MEAN)	5%	2%	70%	17%	5%	5%	66%	66%	68%	68%	68%
	VARIANCE	33976	0.0	0.062	14.02	557,980	1,610,665	0.38	0.10	119.26	17.05	22.64

**Table A-25: Particulate Emission Rates during Combustion Testing, May 17, 1993 – May 22, 1993
FRANKE. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK**

		SLUDGE FEED RATE	EMISSIONS		
		Dry lb/hr	lb/hr	lb/dry ton – sludge	gr/dscf @ 7% O ₂
TEST COND. #1	Run 1	4677	1.400	0.599	0.0177
	Run 2	4623	1.157	0.500	0.0102
	Run 3	3896	1.003	0.515	0.0078
	MEAN	4399	1.187	0.538	0.0119
	MINIMUM	3896	1.003	0.500	0.0078
	MAXIMUM	4677	1.400	0.599	0.0177
	Std Dev (%of Mean)	8%	14%	8%	35%
	VARIANCE	126823	0.027	0.002	0.0000
TEST COND. #2	Run 1	3904	0.892	0.457	0.0077
	Run 2	3835	1.143	0.596	0.0094
	Run 3	4378	0.967	0.442	0.0084
	MEAN	4039	1.001	0.498	0.0085
	MINIMUM	3835	0.892	0.442	0.0077
	MAXIMUM	4378	1.143	0.596	0.0094
	Std Dev (%of Mean)	6%	11%	14%	8%
	VARIANCE	58254	0.011	0.005	0.0000
TEST COND. #3	Run 1	4102	0.773	0.377	0.0074
	Run 2	4106	0.695	0.339	0.0058
	Run 3	3713	0.811	0.437	0.0068
	MEAN	3974	0.760	0.384	0.0066
	MINIMUM	3713	0.695	0.339	0.0058
	MAXIMUM	4106	0.811	0.437	0.0074
	Std Dev (%of Mean)	5%	6%	10%	10%
	VARIANCE	33976	0.002	0.002	0.0000

**Table A-26: Summary of Moisture Content Determination at Incinerator Outlet
Samples Taken during Combustion and Stack Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK**

	Date	Time	Duration (min.)	% H ₂ O	Daily Avg.
TEST COND. #1	05/17/93	0107-0129	22	48.61	46.77
	05/17/93	0426-0446	20	50.26	
	05/17/93	0743-0803	20	48.14	
	05/17/93	1200-1215	15	41.79	
	05/17/93	1600-1623	23	38.60	
	05/17/93	2100-2125	25	53.24	
	05/18/93	0012-0032	20	42.54	
	05/18/93	0402-0422	20	32.38	
	05/18/93	0804-0822	18	33.40	
	05/18/93	1215-1235	20	41.46	
	05/18/93	1650-1712	22	43.28	38.50
	05/18/93	2006-2026	20	37.96	
MEAN				42.64	
MINIMUM				32.38	
MAXIMUM				53.24	
STD DEV (%OF MEAN)				15%	
VARIANCE				38.96	
TEST COND. #2	05/19/93	0116-0136	20	42.99	40.41
	05/19/93	0515-0536	21	39.41	
	05/19/93	0915-0952	37	38.34	
	05/19/93	1400-1423	23	41.97	
	05/19/93	1800-1829	29	40.91	
	05/19/93	2203-2223	20	38.83	
	05/20/93	0200-0220	20	41.22	
	05/20/93	0558-0619	21	40.12	
	05/20/93	1000-1024	24	43.61	
	05/20/93	1450-1516	26	46.85	41.56
	05/20/93	1925-1943	18	36.01	
MEAN				40.93	
MINIMUM				36.01	
MAXIMUM				46.85	
STD DEV (%OF MEAN)				7%	
VARIANCE				7.81	
TEST COND. #3	05/21/93	0150-0210	20	37.25	28.34
	05/21/93	0558-0619	21	34.09	
	05/21/93	1020-1043	22.5	26.83	
	05/21/93	1430-1456	26	24.79	
	05/21/93	1607-1631	24	25.05	
	05/21/93	2202-2225	23	22.06	
	05/22/93	0208-0228	20	33.11	
	05/22/93	0611-0631	20	43.21	
	05/22/93	1115-1143	28.25	43.26	
	05/22/93	1415-1440	25	35.41	39.56
	05/22/93	1815-1833	18	44.03	
	05/22/93	2157-2217	20	38.31	
MEAN				33.95	
MINIMUM				22.06	
MAXIMUM				44.03	
STD DEV (%OF MEAN)				22%	
VARIANCE				55.18	

Table A-27: Electric Energy Consumption by Auxiliaries (kWh) - During Combustion Testing, May 17, 1993 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Induced Draft Fan		Center Shaft Drive Motor		Burner Combustion Air Blower		Afterburner Burner Air Fans		Center Shaft Cooling Air Fan	
		Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)
TEST COND. #1											
5/17/93	0000-0400 hrs	89.61	89.61	23.42	23.42	63.29	63.29			72.14	72.14
	0400-0800 hrs	91.91	181.52	23.71	47.13	64.08	127.37			72.43	144.57
	0800-1200 hrs	120.09	301.61	23.48	70.61	66.31	193.68			70.26	214.83
	1200-1600 hrs	155.13	456.74	24.97	95.58	50.85	244.53			72.44	287.27
	1600-2000 hrs			27.98	123.57	53.93	298.46	39.54	39.54	72.66	359.93
	2000-2400 hrs			26.70	150.27	59.94	358.40	41.12	80.66	74.17	434.10
5/18/93	0000-0400 hrs			22.45	172.72	59.41	417.81	41.46	122.12	73.86	507.96
	0400-0800 hrs			22.88	195.60	65.40	483.21	40.38	162.51	73.12	581.08
	0800-1200 hrs	151.13	607.87	22.21	217.81	65.70	548.91	40.90	203.41	72.86	653.94
	1200-1600 hrs	143.03	750.90	23.02	240.83	65.92	614.83	40.81	244.22	73.08	727.02
	1600-2000 hrs	141.09	891.99	23.10	263.93	64.48	679.31	40.84	285.06	72.27	799.29
	2000-2400 hrs	133.80	1025.79	23.15	287.07	61.22	740.53	41.16	326.22	71.64	870.93
MEAN		128		24		62		41		73	
MINIMUM		90		22		51		40		70	
MAXIMUM		155		28		66		41		74	
STD DEV (%OF MEAN)		19%		7%		8%		1%		1%	
VARIANCE		568		3		23		0		1	

Table A-27: Electric Energy Consumption by Auxiliaries (kWh) - During Combustion Testing, May 17, 1993 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Induced Draft Fan		Center Shaft Drive Motor		Bumer Combustion Air Blower		Afterburner Bumer Air Fans		Center Shaft Cooling Air Fan	
		Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)
5/19/93	TEST COND. #2										
	0000-0400 hrs	160.34	1186.13	23.45	310.52	65.56	806.09	47.83	374.05	71.75	942.68
	0400-0800 hrs	171.13	1357.26	23.84	334.36	65.31	871.40	48.30	422.36	71.10	1013.78
	0800-1200 hrs	152.16	1509.42	23.19	357.56	65.54	936.94	48.66	471.01	71.41	1085.19
	1200-1600 hrs	151.61	1661.03	23.58	381.13	65.90	1002.84	48.44	519.45	71.06	1156.25
	1600-2000 hrs	149.08	1810.11	23.42	404.55	65.31	1068.15	48.81	568.26	71.64	1227.89
5/20/93	2000-2400 hrs	145.38	1955.49	23.08	427.63	63.71	1131.86	47.32	615.58	71.79	1299.68
	0000-0400 hrs	139.52	2095.01	23.30	450.92	65.91	1197.77	46.81	662.38	71.65	1371.33
	0400-0800 hrs	143.86	2238.87	23.13	474.05	65.75	1263.52	46.21	708.59	71.89	1443.22
	0800-1200 hrs	151.76	2390.63	23.93	497.97	64.74	1328.26	48.97	757.56	70.77	1513.99
	1200-1600 hrs	148.49	2539.12	23.26	521.23	56.90	1385.16	47.37	804.93	71.63	1585.62
	1600-2000 hrs	148.69	2687.81	23.38	544.61	55.85	1441.01	45.56	850.49	69.51	1655.13
	2000-2400 hrs	134.00	2821.81	23.77	568.38	59.25	1500.26	47.09	897.58	71.10	1726.23
	MEAN	150		23		63		48		71	
	MINIMUM	134		23		56		46		70	
	MAXIMUM	171		24		66		49		72	
	STD DEV (% OF MEAN)	6%		1%		6%		2%		1%	
	VARIANCE	83		0		13		1		0	

Table A-27: Electric Energy Consumption by Auxiliaries (kWh) - During Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Induced Draft Fan		Center Shaft Drive Motor		Burner Combustion Air Blower		Afterburner Burner Air Fans		Center Shaft Cooling Air Fan	
		Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)	Interval (kWh)	Cumulative (kWh)
5/21/93	TEST COND. #3										
	0000-0400 hrs	137.74	2959.55	23.39	591.76	61.59	1561.85	54.88	952.46	71.82	1798.05
	0400-0800 hrs	138.79	3098.34	22.71	614.47	57.75	1619.60	53.22	1005.68	72.67	1870.72
	0800-1200 hrs	141.12	3239.46	23.80	638.27	59.73	1679.33	53.77	1059.45	71.60	1942.32
	1200-1600 hrs	157.90	3397.36	25.56	663.83	51.75	1731.08	57.92	1117.37	71.29	2013.61
	1600-2000 hrs	170.07	3567.43	26.25	690.09	57.50	1788.58	59.76	1177.13	71.43	2085.04
5/22/93	2000-2400 hrs	172.59	3740.02	25.27	7153.5	62.08	1850.66	59.25	1236.38	71.66	2156.70
	0000-0400 hrs	145.25	3885.27	25.03	740.39	61.59	1912.25	54.21	1290.59	71.75	2228.45
	0400-0800 hrs	150.71	4035.98	26.06	766.44	63.93	1976.18	56.82	1347.41	72.96	2301.41
	0800-1200 hrs	159.82	4195.80	25.93	792.37	59.97	2036.15	56.11	1403.52	70.74	2372.15
	1200-1600 hrs	174.80	4370.60	26.62	818.99	59.04	2095.19	58.32	1461.84	71.88	2444.03
	1600-2000 hrs	173.93	4544.53	26.39	845.37	62.34	2157.53	59.24	1521.07	71.18	2515.21
	2000-2400 hrs	176.08	4720.61	26.32	871.70	62.42	2219.95	59.15	1580.22	73.05	2588.26
	MEAN	158		25		60		57		72	
	MINIMUM	138		23		52		53		71	
	MAXIMUM	176		27		64		60		73	
	STD DEV (% OF MEAN)	9%		5%		5%		4%		1%	
	VARIANCE	209		2		10		5		0	

Table A-28: Electric Energy Consumption by Auxiliaries (HP) - During Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Induced Draft Fan		Center Shaft Drive Motor		Burner Combustion Air Blower		Afterburner Burner Air Fans		Center Shaft Cooling Air Fan	
		Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)
TEST COND. #1											
5/17/93	0000-0400 hrs	30	120	.8	31	21	85			24	97
	0400-0800 hrs	31	243	8	63	21	171			24	194
	0800-1200 hrs	40	404	8	95	22	260			24	288
	1200-1600 hrs	52	612	8	128	17	328			24	385
	1600-2000 hrs			9	166	18	400	13	53	24	483
	2000-2400 hrs			9	202	20	481	14	108	25	582
5/18/93	0000-0400 hrs			8	232	20	560	14	164	25	681
	0400-0800 hrs			8	262	22	648	14	218	25	779
	0800-1200 hrs	51	815	7	292	22	736	14	273	24	877
	1200-1600 hrs	48	1007	8	323	22	824	14	328	25	975
	1600-2000 hrs	47	1196	8	354	22	911	14	382	24	1072
	2000-2400 hrs	45	1376	8	385	21	993	14	437	24	1168
MEAN		43		8		21		14		24	
MINIMUM		30		7		17		13		24	
MAXIMUM		52		9		22		14		25	
STD DEV (% OF MEAN)		19%		7%		8%		1%		1%	
VARIANCE		64		0		3		0		0	

Table A-28: Electric Energy Consumption by Auxiliaries (HP) - During Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Induced Draft Fan		Center Shaft Drive Motor		Burner Combustion Air Blower		Afterburner Burner Air Fans		Center Shaft Cooling Air Fan	
		Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)
TEST COND. #2											
5/19/93	0000-0400 hrs	54	1591	8	416	22	1081	16	502	24	1264
	0400-0800 hrs	57	1820	8	448	22	1169	16	566	24	1359
	0800-1200 hrs	51	2024	8	479	22	1256	16	632	24	1455
	1200-1600 hrs	51	2227	8	511	22	1345	16	697	24	1551
	1600-2000 hrs	50	2427	8	542	22	1432	16	762	24	1647
	2000-2400 hrs	49	2622	8	573	21	1518	16	825	24	1743
5/20/93	0000-0400 hrs	47	2809	8	605	22	1606	16	888	24	1839
	0400-0800 hrs	48	3002	8	636	22	1694	15	950	24	1935
	0800-1200 hrs	51	3206	8	668	22	1781	16	1016	24	2030
	1200-1600 hrs	50	3405	8	699	19	1857	16	1079	24	2126
	1600-2000 hrs	50	3604	8	730	19	1932	15	1141	23	2220
	2000-2400 hrs	45	3784	8	762	20	2012	16	1204	24	2315
MEAN		50		8		21		16		24	
MINIMUM		45		8		19		15		23	
MAXIMUM		57		8		22		16		24	
STD DEV (% OF MEAN)		6%		1%		6%		2%		1%	
VARIANCE		9		0		1		0		0	

Table A-28: Electric Energy Consumption by Auxiliaries (HP) - During Combustion Testing, May 17, 1993 - May 22, 1993
FRANK B. VAN LARE WATER POLLUTION CONTROL PLANT, MONROE COUNTY, NEW YORK

		Induced Draft Fan		Center Shaft Drive Motor		Burner Combustion Air Blower		Afterburner Burner Air Fans		Center Shaft Cooling Air Fan	
		Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)	Interval (HP)	Cumulative (HP-hour)
5/21/93	TEST COND. #3										
	0000-0400 hrs	46	3969	8	794	21	2094	18	1277	24	2411
	0400-0800 hrs	47	4155	8	824	19	2172	18	1349	24	2509
	0800-1200 hrs	47	4344	8	856	20	2252	18	1421	24	2605
	1200-1600 hrs	53	4556	9	890	17	2321	19	1498	24	2700
	1600-2000 hrs	57	4784	9	925	19	2398	20	1579	24	2796
	2000-2400 hrs	58	5015	8	959	21	2482	20	1658	24	2892
5/22/93	0000-0400 hrs	49	5210	8	993	21	2564	18	1731	24	2988
	0400-0800 hrs	51	5412	9	1028	21	2650	19	1807	24	3086
	0800-1200 hrs	54	5627	9	1063	20	2730	19	1882	24	3181
	1200-1600 hrs	59	5861	9	1098	20	2810	20	1960	24	3277
	1600-2000 hrs	58	6094	9	1134	21	2893	20	2040	24	3373
	2000-2400 hrs	59	6330	9	1169	21	2977	20	2119	24	3471
		53		8		20		19		24	
MEAN		46		8		17		18		24	
MINIMUM		59		9		21		20		24	
MAXIMUM		9%		5%		5%		4%		1%	
STD DEV (% OF MEAN)		23		0		1		1		0	
VARIANCE											

Table A-29: THC Emissions vs. Afterburner Temperature during Combustion Testing, May 17, 1993 - May 22, 1993
FRANK E. VAN LARE WATER POLLUTION CONTROL PLANT, MONPOE COUNTY, NEW YORK

		Afterburner Temperature (Deg. F)	Hydrocarbons in Duct PPMDV @ 7% O ₂	Hydrocarbons in Stack PPMDV @ 7% O ₂
TEST COND. #1				
5/17/93	0000-0400 hrs	1123	56.2	21.4
	0400-0800 hrs	1120	32.9	19.9
	0800-1200 hrs	1121	149.5	50.3
	1200-1600 hrs	1121	129.5	10.6
	1600-2000 hrs	1119	272.0	113.3
	2000-2400 hrs	1120	316.7	122.5
5/18/93	0000-0400 hrs	1121	193.5	34.5
	0400-0800 hrs	1111	96.0	30.3
	0800-1200 hrs	1121	233.3	17.4
	1200-1600 hrs	1120	183.6	42.3
	1600-2000 hrs	1119	96.3	11.2
	2000-2400 hrs	1141	19.6	13.8
MEAN		1,121	150	41
MINIMUM		1,111	20	11
MAXIMUM		1,141	317	122
STD DEV (% OF MEAN)		1%	59%	90%
VARIANCE		46	6598.6	1372.3
TEST COND. #2				
5/19/93	0000-0400 hrs	1203	7.3	16.2
	0400-0800 hrs	1203	9.3	16.7
	0800-1200 hrs	1189	11.5	17.0
	1200-1600 hrs	1212	9.3	16.8
	1600-2000 hrs	1212	7.3	16.0
	2000-2400 hrs	1190	5.1	16.7
5/20/93	0000-0400 hrs	1208	10.1	29.7
	0400-0800 hrs	1213	7.7	14.9
	0800-1200 hrs	1214	7.8	16.0
	1200-1600 hrs	1212	7.9	15.9
	1600-2000 hrs	1211	5.3	
	2000-2400 hrs	1310	10.1	
MEAN		1,215	8	18
MINIMUM		1,189	5	15
MAXIMUM		1,310	12	30
STD DEV (% OF MEAN)		2%	22%	23%
VARIANCE		944	3.5	18.0
TEST COND. #3				
5/21/93	0000-0400 hrs	1308	5.9	
	0400-0800 hrs	1303	12.6	6.2
	0800-1200 hrs	1312	10.8	8.1
	1200-1600 hrs	1307	32.7	20.7
	1600-2000 hrs	1300	51.5	28.9
	2000-2400 hrs	1301	37.8	13.3
5/22/93	0000-0400 hrs	1310		10.0
	0400-0800 hrs	1245		14.9
	0800-1200 hrs	1309		16.0
	1200-1600 hrs	1302	24.2	10.8
	1600-2000 hrs	1311	10.7	11.4
	2000-2400 hrs	1311	11.4	13.2
MEAN		1,302	22	14
MINIMUM		1,245	6	6
MAXIMUM		1,312	51	29
STD DEV (% OF MEAN)		1%	67%	43%
VARIANCE		331	190.4	30.5

APPENDIX A: Combustion/APC Stack Testing

A.2 Figures A-1 through A-14

Fig. A-1: FEV Combustion/APC Stack Test

THC @ Furn. Exit vs. Temp. @ Furn. Exit

Fig. A-2: FEV Combustion/APC Stack Test

THC @ Stack vs. Temp. @ Furnace Exit

Fig. A-3: Combustion/APC Stack Test

CO @ Furn. Exit vs. THC @ Furn. Exit

Fig. A-4: Combustion/APC Stack Test

CO @ Stack vs. THC @ Stack

CO (ppmdv @ 7% O₂)
(Thousands)
4-59

Fig. A-5: FEV Combustion/APC Stack Test

CO vs. % Excess Air @ Furnace Exit

Fig. A-6: FEV Combustion/APC Stack Test

CO₂ vs. % Excess Air @ Furnace Exit

Fig. A-7: FEV Combustion/APC Stack Test

CO vs. % Moisture @ Furnace Exit

Fig. A-8: FEV Combustion/APC Stack Test

% CO₂ vs. % Moisture @ Furnace Exit

Fig. A-9: FEV Combustion/APC Stack Test

CO @ Furn. Exit vs. Comb. Hearth Temp.

Fig.A-10: FEV Combustion/APC Stack Test

% CO₂ @ Furn Exit vs. Comb Hearth Temp

CO @ Furn. Exit vs. Furnace Temp

Fig.A-12: FEV Combustion/APC Stack Test

CO₂ @ Furn. Exit vs. Furnace Temp

Fig.A-13: FEV Combustion/APC Stack Test

CO vs. Temp. @ Furnace Exit

Fig.A-14: FEV Combustion/APC Stack Test

% CO₂ vs. Temp. @ Furnace Exit

Section 5

AIR QUALITY MODELING

A dispersion factor (DF) is required by Part 503 for calculating allowable levels of arsenic, cadmium, chromium, nickel, and lead. The DF is a unitized annual average air concentration in terms of $\mu\text{g}/\text{m}^3$ per g/s, and is determined by atmospheric dispersion modeling.

5.1 MODELING TECHNIQUES

The modeling analysis was conducted with the SCREEN model (USEPA, 1988), which has been approved for use in Part 503 analyses (USEPA, 1993a,b). The hourly impacts predicted by this model were converted into annual impacts with the use of a 0.08 conversion factor (USEPA, 1993b).

Dispersion models, such as SCREEN, require four different types of input: source data, meteorological data, receptor locations, and model control options. The selection of these inputs is discussed below.

5.1.1 Source Data

Four operating scenarios were studied:

- I. Current operations at the plant with a sludge feed rate of 65 dry tons per day.
- II. All three furnaces (No. 3, 4, 5) operating at maximum continuous throughput, with an overall sludge feed rate of 155 dry tons per day.
- III. Two furnaces (No. 4 and No. 5) operating at maximum continuous throughput, with an overall sludge feed rate of 122 dry tons per day.
- IV. Either Furnace No. 4 or No. 5, and Furnace No. 3 operating at maximum continuous throughput, with an overall sludge feed rate of 94 dry tons per day.

The flue gas was modeled at 110°F (317°K), which is approximately 10°F (6°K) lower than actually measured during combustion/APC stack testing (May 1993). This conservative stack temperature represents a safety margin to accommodate an anticipated future condition when wet electrostatic precipitators (WESPs) are installed (potentially lowering the stack gas temperature to 110°F), as well as other contingencies.

The analyses considered contaminants in gaseous or fine (<20 m) particulate form. In order to determine DF, the stack was modeled with a unitized emission rate of 1 g/s. The model output then appears in units of g/m^3 per g/s.

When the wind blows around a building, it generates a region of low pressure and high turbulence in the lee of the building. This region is known as the building wake. If there is a stack or other emission source nearby, there is a potential for the emissions from that source to become trapped in the wake (down wash), reducing the height of the plume of emissions and causing high concentrations of emissions near the source. If the height of the stack is sufficient, however, there will be little or no effect of the wake on the stack plume. This stack height is known as GEP, or "good engineering practice" stack height. EPA modeling guidance (USEPA, 1986) states that the use of a stack height credit in excess of the GEP height is prohibited in the development of emissions limitations. The GEP stack height is defined in 40 CFR 51.1 (ii) as the greater of:

1. 65 meters measured from the ground elevation at the base of the stack;
2. (a) for stacks in existence on January 12, 1979, and for which the owner or operator had obtained all applicable permits or approvals required under 40 CFR Parts 51 and 52,

$$H_g = 2.5 H$$

provided the owner or operator produces evidence that this equation was actually relied upon in designing the stack or establishing an emission limitation to ensure protection against downwash;

- (b) for all other stacks,

$$H_g = H + 1.5 L$$

where: H_g = good engineering practice stack height, measured from the ground-level elevation at the base of the stack,

H = height of nearby structure(s), measured from the ground level elevation at the base of the stack,

L = lesser dimension, height or projected width, of nearby structures,

provided that the EPA, State, or local control agency may require the use of a field study or fluid model to verify GEP stack height for the source;

3. The height demonstrated by a fluid model or a field study approved by the EPA, State, or local control agency, which ensures that the emissions from the stack do not result in excessive concentrations of any air pollutant as a result of atmospheric downwash, wakes, or eddy effects created by the source itself, nearby structures, or nearby terrain features.

The FEV stack has an elevation of 202.08 feet at the top, with a grade elevation of 40 feet. The actual stack height is 162.08 feet, or 49.4 meters. However,

the controlling building has a height of 53 feet (i.e., 93 feet at the top, with a 40-foot base grade). In this case, the height is the lesser dimension, L. Therefore, the GEP stack height is 132.5 feet or 40.4 meters. Since this is below the maximum allowable GEP height of 65 meters, the stack was modeled at the actual stack height of 162.08 feet, or 49.4 meters.

5.1.2 Receptor Data

The SCREEN model was run with the automated receptor array from 0 to 5000 meters. The SCREEN model then interpolates to find the location of the maximum downwind impact. Since the terrain in the vicinity of the site is relatively flat, the terrain elevation was set to zero, simulating flat terrain.

5.1.3 Meteorological Data

The SCREEN model includes an array of 33 combinations of wind speed and stability included as a "full meteorology" option. These conditions represent the set of worst-case meteorological conditions likely to occur. This option was used in this analysis.

5.1.4 Model Control Options

The determination of the appropriate dispersion coefficients for the modeling analysis, i.e., rural or urban coefficients, was made after a review of USGS topographical maps of the area around the facility. The maps indicate that the area is clearly rural in character; therefore, the rural coefficients were selected for the analysis.

USEPA has recommended certain selections when the model is to be used for regulatory purposes (USEPA, 1986). These "regulatory default" selections, namely, the use of final plume rise, buoyancy-induced dispersion, and stack-tip downwash are used in the SCREEN model when point sources, such as the FEV stack, are modeled.

5.2 MODELING RESULTS

Using an emission rate of 1 g/s leads to a SCREEN model output in units of $\mu\text{g}/\text{m}^3$ per g/s. The SCREEN impacts represent maximum hourly impacts at each receptor distance. In order to determine DF, the overall maximum SCREEN hourly impact was multiplied by 0.08 to estimate the maximum annual average impact. This factor has recently been approved by USEPA (USEPA, 1993b) for the conversion of hourly to annual averages for point sources. The values of DF predicted for each operating scenario are presented in Table 5-1 below.

Table 5-1	
Predicted Values of DF for SCREEN Model	
Case	DF (g/m ³ per g/s)
I - current operations	1.26
II - furnaces 3,4,5 at maximum	1.46
III - furnaces 4 and 5 at maximum	1.72
IV - furnace 4 or 5 and 3 at maximum	2.11

The analysis indicates that Case IV results in the highest value of DF. The reason for this is the low exhaust velocity, which minimizes momentum flux, thereby lowering the height of the emissions plume and inhibiting dispersion.

The four values of DF were used in a further analysis to determine which operating scenario would lead to the lowest sludge concentration (C). Results of this analysis were discussed in Section 4.4.1.

Section 6

AIR POLLUTION CONTROL EQUIPMENT ALTERNATIVES

Air pollution control equipment at the Frank E. Van Lare Plant must reliably reduce emissions of pollutants to within regulated limits. Of greatest concern are hydrocarbon emissions and heavy metals. The following section describes a number of alternatives available to achieve specific reductions in these pollutant emissions.

6.1 TOTAL HYDROCARBON (THC) CONTROL

Because many hydrocarbon species are insoluble in water, only marginal control of THC emissions (less than 50 percent removal) can be achieved in a conventional wet scrubber. A more effective means to reduce THC emissions involves raising the temperature of the exhaust gas above the autoignition temperature of most hydrocarbon compounds, and maintaining a minimum temperature above which reaction equilibrium coefficients favor completion of combustion to inert products (carbon dioxide and water vapor). Possible alternatives for THC control are discussed below.

6.1.1 External Afterburner

An external afterburner is a separate combustion chamber through which the exhaust gas passes after exiting the furnace. The temperature of the incoming flue gas is typically raised to between 1,200°F and 1,800°F, (or even higher depending on the application), by auxiliary fuel burner(s) firing natural gas, fuel oil, or propane. The size of the chamber determines the gas retention time, which is traditionally in the range of 0.5 to 2 seconds. Figure 6-1 presents a schematic of a typical external afterburner.

In the case of FEV, the location of such a device would be following the furnace exit section. In this way, the auxiliary fuel needed to increase the temperature of the flue gases would be that amount required to raise the temperature from about 950°F to the range identified above. This rate of energy addition is significantly lower than that required if the afterburner were located in the post-scrubber position.

An advantage of the external afterburner is the high efficiency of THC destruction that can be achieved by the combination of elevated temperature, good mixing of reactants, and increased retention time. This performance can be achieved independently of the process, in this case, the furnace operation. The system can be forgiving in many instances, such as when a furnace suffers a temporary upset in feed rate or temperature. The afterburner system has the means to compensate for these upsets, in part by virtue of its high thermal inertia, and in part by its ability to increase or decrease burner heat release

FIGURE 6-1
EXTERNAL AFTERBURNER

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rate to maintain set temperatures. The degree of compensation is governed by the sizing of the chamber, the response time, and the capability of the burner(s).

Disadvantages of an external afterburner include the relatively high capital cost compared to other possible alternatives and the relatively high operating costs for auxiliary fuel. In certain cases, partial heat recuperation in the form of preheated combustion air is practiced to defray fuel costs, however, these require additional capital costs for heat exchanger equipment.

A separate, but related, disadvantage is the relatively large space required for a typical installation. As a general rule, based on past experiences with external afterburners on multiple hearth furnaces (MHFs), the chamber is about three-quarters the size of the furnace itself. For this reason, and to minimize the routing of high-temperature furnace gases, sufficient space must be available to accommodate these within very close proximity to the furnaces.

Space appears to exist under the furnace exit breeching from each of Furnaces No. 4 and 5 for such a unit. Installation here would require that the existing scrubber systems be relocated, probably to lower floor elevations. The resulting space would accommodate reasonably sized afterburners, about 20 feet in height. A separate combustion air supply system for the afterburners can probably be located at the site of the existing blowers. Because of anticipated increased pressure losses, replacement of the respective I.D. fans will probably be required. Furnace No. 3 would be similarly retrofitted; however, location of new equipment must be verified.

The estimated capital cost for installation of individual external afterburners for the three FEV MHFs is about \$2,330,000. The economic aspects of this alternative are presented in Section 8. (Specific equipment cost estimates showing the major contributions to the total cost, with assumptions and references identified, are available separately under Item I-A in Appendix D.1.)

6.1.2 Internal Afterburner

Each of the furnaces at the FEV plant has been retrofitted with an internal afterburner zone. A description of the physical arrangement, which is typical of such installations, is provided in Section 2.2.2.

The May 1993 test results indicate that use of the existing internal afterburner system is sufficient to maintain THC emissions within Part 503-regulated limits. Referring to Section 4.3.2, an afterburner temperature of 1,100°F appears to be sufficient to maintain a monthly average THC emission rate below 100 ppm_{dv} (as propane at 7 percent oxygen). Test results at 1,100°F did show, however, that THC emissions at the stack exceeded 100 ppm_{dv} (as propane at 7 percent oxygen) during one test run, and during six one-hour periods.

Testing with an afterburner exit temperature at or above 1,200°F resulted in average THC emissions below 100 ppm_{dv} during all runs and all one-hour periods.

One of the objectives of this study was to determine whether compliance with federal Part 503 THC limits was achievable using the existing equipment. The

results of air emissions testing have demonstrated compliance at all test conditions.

6.1.3 Regenerative Thermal-Oxidizer/Afterburner

The "RHOX" process is a proprietary arrangement which integrates air pollution control (APC) equipment with an MHF and afterburner system. A generic example of a regenerative heat exchanger/afterburner, or regenerative thermal oxidizer - type afterburner was considered. A schematic of a regenerative thermal oxidizer is shown in Figure 6-2.

Most vendors propose the regenerative thermal oxidizer be located after the existing APC equipment. The gas must be relatively clean prior to the regenerative thermal oxidizer, since the thermal storage system consists of porous alumino-silicate medium heat exchanger, which is prone to plugging by particulate matter entrained in the flue gas.

The principle components of the regenerative heat exchanger/afterburner process are a set of direct heat-exchange medium containing porous medium. These vessels transfer heat from outgoing high-temperature flue gases to the porous medium and then to incoming relatively cool fuel gases. Control of gas direction is achieved by way of a breeching system. Since the basic operation of a heat exchange vessel is not steady state, several vessels (three to five) are typically furnished.

After leaving the scrubber system, the relatively cool (80°F to 120°F) flue gases enter the regenerative heat exchanger. In the heat exchanger, the exhaust gases are heated to within 100°F to 250°F of the afterburner exhaust temperature by passing through the previously heated medium. Auxiliary fuel (estimated to be 8 to 12 gallons of fuel oil per ton of dry solids) is used to make up the energy deficit, while a certain amount of combustion air may be added to promote combustion of the hydrocarbons. Once the flue gases have achieved the target temperature, they are passed back through the next heat exchanger vessel, where their heat energy is transferred into the medium, and subsequently to the incoming cooler scrubber gases in the next cycle. The cooled, treated flue gases exit the heat exchanger at 200°F to 350°F. They are subsequently routed to a stack, which in the case of FEV would be the existing main stack.

This regenerative thermal oxidizer is a relatively new technology, and only one installation is known to exist in a sewage sludge incineration system. This new system is being installed in Hatfield, Pennsylvania, as part of a new MHF facility. The plant is expected to start operation by the end of 1993.

In addition to achieving control of THC emissions, the regenerative thermal oxidizer process is promoted as a means of improving fuel efficiency by separating the combustion process into two stages. In the first stage (combustion within the MHF), moderate combustion temperature and low excess air (50 to 75 percent) combine to limit fuel use, limit NO_x production, and retain a majority of the heavy metals in the ash.

FIGURE 6--2
REGENERATIVE THERMAL OXIDIZER

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Most of the heat energy of the exiting gases is transferred back to the incoming gases in the heat exchanger. Only a fractional amount of auxiliary fuel, as compared to the case of an afterburner with no heat exchanger, is used to raise the temperature of the reheated exhaust gases to the target temperature.

The regenerative thermal oxidizer may offer an advantage over a conventional external afterburner in a situation where the exhaust gas requires a high temperature and retention time to reduce THC, or where afterburning at a high temperature is required by a state or local authority.

For FEV, such a system would have to be installed outside the building, either along the west wall or north wall of the Solids Handling Building. A single unit should be capable of treating flue gas over a range of flows, from Furnace No. 3 operating alone to both Furnaces No. 4 and 5 operating together. Dimensions for such a single unit are quite large, with the footprint being a minimum of 40 feet by 16 feet, and a height of about 20 feet. To allow adequate clearances, an area of at least 60 feet by 24 feet is needed. To route the existing flue gases to the regenerative thermal oxidizer, a connection from the existing common breeching system to the unit would be required, with a return duct to the existing stack. As an alternative, three independent ducts from the discharges of the three I.D. fans could be routed to and combined at the unit.

Because the regenerative thermal oxidizer would include its own I.D. fan system, existing fans are not necessarily affected by this alternative. The unit's I.D. fan would be sized at about 250 hp.

In the case of the FEV plant, where THC emissions have been documented to be well under current Part 503 limitations, the process could not be justified simply for THC destruction. The selection of this alternative depends on whether the capital, operating, and maintenance costs compare favorably to the potential savings in auxiliary fuel use of the internal afterburners.

The estimated capital cost for installing a single regenerative thermal oxidizer for the three FEV MHFs is about \$1,790,000. Equipment cost estimates are available separately as Item I-B of Appendix D.1. More detailed discussions of economics are provided in Section 8.

6.2 METALS AND PARTICULATE CONTROL

Most heavy metals contained in sewage sludge are vaporized at the high temperatures within the incinerator; they are emitted either in the volatile state or, if condensation has occurred, attached to particulate matter. The remainder of the metals are contained in the incinerator ash. Because heavy metals tend to condense onto fine particulates, control of fine particulates is imperative for the reduction of heavy metals from the exit gas stream.

Section 4.4.1.1 describes how all sludge metal concentrations at FEV fall within the limits of Part 503 regulations. Of the seven regulated metals, measured sludge concentrations of six were well below the limit. The concentration of beryllium, however, was at one point measured to be very close to the concentration limit. Three of nine metals (arsenic, cadmium, and chromium)

exceeded the proposed Air Guide-1 initial screening procedure. It is important to note that Air Guide-1 has not been promulgated, and, according to a NYSDEC Region 8 representative, demonstration of compliance is not required for permit (Certificate to Operate) renewal.

Though the existing scrubbers meet all current regulatory requirements, their physical condition may warrant their eventual replacement. Descriptions of some of the alternatives investigated may be relevant for future reference because equipment upgrades to meet the potential future regulations may be justified at the time of replacement. Alternative APC equipment to be considered for controlling emissions of metals are presented below.

6.2.1 High-Energy Venturi Scrubber/Impingement Tray Tower

High-energy venturi scrubbing, in conjunction with multiple-tray impingement cooling towers, has been used almost exclusively in the past decade for sludge furnace APC systems. Wet scrubbers are well suited to wastewater treatment plants, since the plant effluent can be used as the scrubbing liquid and returned to the head of the plant after use. A rendering of a high-energy venturi scrubber with an impingement tray tower is shown in Figure 6-3.

Venturi scrubbers operate by passing the gas stream through a narrow throat, increasing its velocity and causing the atomization of the counterflowing scrubbing liquid. The large surface area provided by the liquid droplets and the high kinetic energy associated with the high velocity combine to create an ideal condition for absorption of the particulate matter. As the pressure drop across the venturi increases, kinetic energy increases, thus increasing the device's particulate collection efficiency. The exhaust gas then flows through an impingement tray tower for further cooling of gases and reduction of particulates. The gas flows upward through openings in perforated trays with impingers above these openings. The countercurrent and atomization of liquid cause intimate contact of gas and liquid, resulting in absorption of gases, odors, vapors, and particles.

A significant amount of emissions data exists for high energy venturi/impingement tray tower scrubbers. For most metals, control efficiencies of greater than 90 percent are possible. Based on historical data, removal efficiency of cadmium may be slightly lower.

If high-energy venturi scrubbers were added at FEV, they would be installed in the approximate locations of the existing quench sections. Based on a preliminary equipment arrangement, a new venturi scrubber and impingement tray system capable of handling design flow conditions and required collection efficiency would fit in the existing scrubber space.

Because of the high pressure drop across a venturi scrubber, the existing I.D. fans as well as their drives would need to be replaced with units having much higher powered motors. The high energy venturi scrubber system is estimated to require an I.D. fan with a motor size of up to 250 hp. In addition to the fan and motor upgrade requirements, electrical control and distribution systems must be upgraded.

FIGURE 6-3
HIGH ENERGY VENTURI SCRUBBER/IMPINGEMENT TRAY TOWER

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Since the wet scrubbers are located in the Solids Handling Building, installation of new scrubbers of the size anticipated may require demolition and subsequent replacement of major roof sections, or of major sections of side walls.

The estimated capital cost for installing three venturi scrubbers and tray towers for the three FEV MHFs is \$1,660,000. Details on equipment cost estimates are presented under Item II-A of Appendix D.2 (available upon request). A more detailed presentation of economics is provided in Section 8.

6.2.2 Dry Scrubber/Baghouse Combination

Dry scrubbers, consisting of alkali treatment such as a spray dryer absorber or lime injection followed by a baghouse, historically have not been used in sewage sludge incineration applications. A possible schematic of this system is shown in Figure 6-4.

The moist nature of the exhaust gas from a sludge incinerator tends to cause problems in dry scrubbers, such as formation of muddy "cake" on the bags. Another disadvantage of this system is its relatively large size. Because these systems operate at a much higher temperature than a "wet" system, condensation and removal of volatile metals are not expected to be as effective as in a wet scrubber system. For these reasons, in addition to a lack of a proven record, the dry scrubber system will not be considered further.

6.2.3 Dry Scrubber/Dry Electrostatic Precipitator

As with the dry scrubber/baghouse, the dry scrubber/dry electrostatic precipitator (ESP) arrangement shown in Figure 6-5 has never been used in sewage sludge incinerator applications. Dry ESPs are cleaned by a hammer mechanism, which periodically raps the collection plates. This rapping dislodges the layer of particulates that has built up on the plates and collects particulates in a fly-ash hopper. When a dry ESP is used with a sewage sludge incinerator, the particulate matter may have a tendency to cake on the plates.

One sewage sludge incineration system, located in Longuill, Quebec, uses a dry ESP. The system consists of two fluid-bed incinerators followed by two waste-heat boilers. The exhaust gas enters the ESP at a temperature of 400°F to 550°F and a moisture content of up to 35 percent. Since the unit is located in Canada, different regulations apply. Apparently, no limits on metal emissions are imposed. Particulate emissions are limited to 0.073 gr/dscf at 50 percent excess air.

As with the dry scrubber/baghouse system, the dry scrubber/dry ESP system is not recommended for this application and will not be considered further.

6.2.4 Venturi Scrubber/Wet Electrostatic Precipitator Combination

As described in Section 6.2.1, venturi scrubbers with impingement tray towers have been the prevalent form of APC equipment installed on sludge incinerators

FIGURE 6-4
DRY SCRUBBER/BAGHOUSE

FIGURE 6-5
DRY SCRUBBER/DRY ELECTROSTATIC PRECIPITATOR

6-11

in recent times. Wet electrostatic precipitators (WESPs) are now becoming prevalent as a means for controlling particulate and metal emissions from both existing and new sewage sludge incinerators. WESPs are typically installed after the impingement tray tower. WESPs lend themselves well to retrofits, in situations where a wet scrubber alone cannot meet regulations. WESPs can also be installed downstream of new wet scrubbers to boost control efficiencies. They are relatively compact in size. A depiction of one manufacturer's equipment is shown in Figure 6-6.

WESPs operate by imparting an electrostatic charge on the suspended particle through intense electric fields caused by high voltage discharge electrodes. In addition to particulates, gas molecules such as volatile metals that can be ionized may be captured. A constant flow of water over the collection tubes washes down captured material.

Because metal and particulate emissions limits can be achieved using the existing quench and impingement tray arrangement, a high-pressure venturi scrubber/tray tower with WESP combination is not considered necessary at FEV.

If future regulations mandate further reductions of metal or particulate emissions, it may be desirable to install a WESP to augment the performance of the existing scrubber system. Such an installation would be outside the building, with one WESP dedicated to each MHF system. Ducts carrying the discharge from the scrubbers would be routed to each respective WESP, with return ductwork sent back inside the building to the I.D. fan inlet. The WESPs would be located along the west and north walls of the Solids Handling Building. Although pressure losses through the WESP amount to only 1 inch w.c., or so, I.D. fan upgrades (or an additional fan on each WESP) may be needed to help overcome system losses imposed by the lengthy interconnecting ducts.

The estimated capital cost for installing three individual WESPs for the three at MHFs at FEV is about \$1,770,000. A discussion of economic aspects of this alternative is presented in Section 8. (Specific equipment cost estimates showing the basis of the equipment costs and major contributions, with assumptions and references identified, are presented under Item II-B, in Appendix D.2.)

6.2.5 Quencher Scrubber

The existing APC system on each of the MHFs at FEV consist of a pre-quench section followed by a two-tray impingement tower. Total pressure loss across the system is approximately 5 inches w.c. Based on combustion/APC stack testing conducted in May 1993, this system is in compliance with all current air emissions regulations.

The replacement cost for a similar quench scrubber system for each of the furnaces at FEV is estimated to be approximately \$700,000. (This estimate is detailed under Item II-C of Appendix D.2.)

FIGURE 6-6
WET ELECTROSTATIC
PRECIPITATOR

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Source: Sonic Corporation

Section 7

WASTE -HEAT RECOVERY AND UTILIZATION FEASIBILITY

7.1 EXISTING PLANT ENERGY UTILIZATION

7.1.1 Fuel Usage

The majority of fuel consumed at the Frank E. Van Lare Plant is for the sludge incineration process. Sludge solids generated and incinerated average about 65 dry tons/day, as reported in Section 3.2.1. Based on recent energy requirements for each dry ton of sludge solids (Table 3-3), the fuel used for incineration is presented in Table 7-1.

Table 7-1	
Fuel Usage for Sludge Solids Incineration at FEV	
Year	Equivalent ⁽¹⁾ Btu/hr fuel usage for incineration
1990	25.2×10^6
1991	28.0×10^6
1992	28.8×10^6
1993	32.9×10^6

¹-Estimated higher heating value (HHV) of gas = 1000 Btu/scf, HHV of fuel oil = 142,000 Btu/gal.

Additional fuel is used for space heating. A hot-water system provides heating for the buildings at the FEV facility. The heating system consists of two Cleaver Brooks hot-water generators (north and south "boilers"), each capable of firing either No. 2 fuel oil or natural gas. Records of plant fuel use for heating purposes were available for the 1990-91 heating season. The records indicate that only one hot-water generator is operated at a time. From these records, the monthly average plant heating loads in Btu/hour were calculated, and are shown graphically in Figure 7-1. Plant records indicate that the plant is heated from September through June. During the 1990-91 season, the heat load peaked in January, at approximately 7.4 million Btu/hr. The plant records for heat load are consistent with the boiler ratings, each of which has a rated output of 300 hp (approximately 10 million Btu/hr).

From comparison of the above, the energy used for heating during the most demanding heating periods of the year is about 30 percent of the amount used for the incineration process on an average hourly basis (7.4 million Btu/hr versus about 28 million Btu/hr).

Fig. 7-1: Monroe County, N.Y. FEV Plant
Average Plant Heat Load: 1990/91 Season

7.1.2 Electrical Energy Usage

Electrical energy is used at the FEV plant to power various wastewater processing equipment, to provide lighting, and to support the various sludge incineration activities. Electrically powered equipment at FEV includes numerous pumps, aeration blowers, thickeners, clarifiers, belt filter presses, clarifier drives and actuators. Based on discussions with plant personnel, about 31 million kWh of electrical energy are consumed annually. This is equivalent to an average power requirement of 3,500 kW. Base load power is conservatively estimated to be at least half of this value.

The electrical energy used by the Furnace No. 5 system was measured during the combustion/APC stack testing (May 1993). Primary electric energy users in the sludge incineration system include the induced draft fan, the center shaft drive motor, the burner and afterburner combustion air blowers, and the center shaft cooling air fan. Measured energy use by this equipment during May 1993 testing is presented in Table 4-3.

The measured average electrical energy use ranged from 109 to 125 hp (81 to 93 kW) for Furnace No. 5. When Furnaces No. 4 and 5 operate simultaneously, about 250 hp (187 kW) is required for the incineration process. A somewhat lower power draw is required when Furnace No. 3 operates along with either No. 4 or No. 5; this amount is estimated at about 200 hp (150 kW).

7.2 REVIEW OF INDIVIDUAL TECHNOLOGIES

The following waste heat recovery alternatives have been reviewed for possible implementation. In each case, a discussion of potential physical locations for the proposed equipment is presented. The underlying premise for all alternatives considered favorable, or necessary, is to minimize disturbance of existing equipment, to the greatest extent possible. In most cases, certain breaching, existing APC equipment, steel work, and/or other structural features would have to be relocated, or modified.

Capital cost estimates are provided for each alternative. Details of these estimates are available separately as Appendix D.1.

7.2.1 Flue Gas-to-Air Heat Exchanger

A flue gas-to-air heat exchanger can be used to extract heat from the flue gas and transfer it to the combustion air, thus reducing auxiliary fuel requirements in the furnace. As applied to multiple hearth furnaces (MHFs), preheated air could be used in several alternative air streams. Ambient air could be preheated for use in either the MHF burners, the afterburners, or for use as sludge combustion air through direct injection into the furnace zones.

Of the options for preheated air use, the only alternative that is known to have been applied in practice is preheating the burner air for the afterburner. This has been limited to external afterburners that operate in a relatively close control range. The difficulty in applying this alternative to an internal

afterburner stems from the added complexity of temperature-compensated air/fuel control, and the higher grade of materials required for elevated temperature.

There are no known installations of MHFs using preheated combustion air for individual hearth burners. Because the hearth burners closely resemble the internal afterburners on the FEV furnaces, the same problems as discussed above would be expected from preheating combustion air to the hearth burners. Without operating experience to cite, this alternative cannot be recommended.

For the purpose of this report, consideration was given to preheating combustion air for the hearths. A schematic of this alternative is presented in Figure 7-2. This concept is an extension of one already practiced, the use of recycled air from the center shaft cooling air as combustion air. As described in Section 2.2.2, center shaft air at 325°F is returned to the combustion hearths, thus reducing auxiliary fuel consumption.

If the air to the hearths were to be further heated prior to its introduction, yet additional fuel savings would result. Based on a project that is currently under construction at the Northeast Ohio Regional Sewer District's Westerly Plant (Cleveland, Ohio), a final preheat air temperature of 1,000°F was selected for consideration. This project involves two MHFs, each of which is being retrofitted with a flue gas-to-air heat exchanger in which where ambient air will be heated to 1,000°F prior to introduction into the furnace.

Two types of heat exchangers could be considered. The first is a tubular-type heat exchanger, in which the combustion air flows through vertically oriented tubes and incinerator flue gas flows over the tubes. Most hot-windbox fluid-bed sewage sludge incinerators use this type of heat exchanger. A plate heat exchanger could also be considered. However, no installations of this type on a sewage sludge incinerator are known to exist, and reliability issues are therefore not well defined.

Consequences of introducing such high temperature combustion air are not currently known. As was mentioned in Metcalf and Eddy's preliminary design report of October 24, 1988, "Incinerator Modifications for the Frank E. Van Lare Water Pollution Control Plant," preheating the sludge combustion air may have some serious limitations. Limited experience in preheating sludge combustion air for multiple-hearth incinerators exists. As the report states, preheating must be carefully controlled to keep hearth temperatures below about 1,900°F, at which point slagging and clinker formation occurs. In addition, other aspects involving operational instability may come into play.

If installation of a flue gas-to-air heat exchanger were considered, then some existing equipment must be upgraded. Because of the additional pressure losses of about 8 inches w.c. estimated on the air side of the exchanger, the center shaft cooling air fan and drive must be replaced with more powerful units. Also, the existing recycle-air ducts, dampers, and control system would have to be upgraded to meet the special requirements of high-temperature operation. For the purpose of this study, it was assumed that sufficient margin exists in the I.D. fan to account for additional flue-gas-side pressure losses. Although the flue-gas-side pressure losses would increase because of the newly added system

FIGURE 7-2
FLOW SCHEMATIC
FLUE GAS TO AIR
HEAT EXCHANGER

TYPICAL OF UNIT NOS. 4 AND 5
(SIMILAR FOR UNIT NO. 3)

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resistance of about 2 inches w.c., the total quantity of flue gas would decrease as a result of decreasing the auxiliary fuel combustion products.

With the lower flue gas flow rate resulting from installing a flue gas-to-air heat exchanger, the existing I.D. fans' performance may be sufficient. For example, based on the mass and energy balance calculations performed for a 1300°F afterburner case, and assuming sludge solids at 20 percent, the flue gas volume flow rate is expected to decrease from a value of 15,500 acfm to 13,000 acfm with air preheat, based on 120°F I.D. fan inlet temperature. These calculated values assume that air infiltration into the I.D. fan will be eliminated by appropriate measures. This aspect would require further study before implementation.

Based on the mass and energy balance calculations performed for a 1,300°F afterburner, and assuming sludge solids of 20 percent, the flue gas flow rate is expected to decrease from a volume of 15,500 actual cubic feet per minute (acfm) to 13,000 acfm with additional air preheat, based on a 120°F I.D. fan inlet temperature. These calculated values assume that air infiltration into the I.D. fan will be eliminated. (This concept would require further study before implementation).

If this alternative is implemented, provisions should be made to allow modulation of the final preheat temperature, to control hearth temperatures. For example, modulation may be necessary if a preheat temperature of 1,000°F results in hearth temperatures exceeding 1,900°F. A bypass damper system could be provided to allow for only a portion of the center shaft air to be sent to the preheater. As an alternative, or even in addition, a portion of the 1,000°F preheated air could be sent to a discharge point in the main stack, to provide a location to discharge the hot air as well as to help reduce the visible moisture plume that typically forms at the stack discharge.

The flue gas-to-air heat exchanger would be located just below the opening in the exit breeching from the furnaces. In the case of Furnaces No. 4 and No. 5, there is sufficient space for an appropriately sized unit to be installed, provided that the existing quench section and tray tower are relocated to the area two floors below.

When installed, such a system would require maintenance to assure continued operation. The plant's own instrumentation and electrical staff are believed to be capable of maintaining the control aspects of this installation.

Discussions were held with several heat exchanger manufacturers to select the appropriate equipment for the FEV application. Using the cost information supplied, with additional estimates for auxiliary equipment, system upgrades, and installation, the capital cost for this alternative is estimated to be approximately \$1,030,000 for all three furnaces.

7.2.2 Waste-Heat Boiler

Waste heat can be recovered in the form of steam generated in a boiler located at the furnace exit. Potential uses of the steam are space conditioning, steam for shaft power to operate either rotating equipment or other plant equipment,

or steam for use in sludge dryers. These alternative steam uses are discussed in greater detail in subsequent sections, while this subsection describes the means to generate the steam to supply these alternatives.

A water-tube boiler, vertically oriented and with bare tubes, is recommended for this application. The waste gas from MHFs has a relatively high ash content that would likely build up on finned boiler tubes. Water-tube boilers generate steam within the tubes by passing hot gases over the tube banks. Water-tube boilers have been used in applications involving ash-laden flue gases such as hospital, municipal solid waste, and sewage sludge incineration. In these applications, the area through which the gas passes is maximized to prevent ash clogging. Dry ash falls off the vertical tubes by force of gravity into ash hoppers or, into the quench section of the scrubber system. Ash accumulation on tube surfaces can be dislodged by soot blowers.

At rated capacity, a waste heat boiler sized to utilize the 1,300°F flue gases from Furnace No. 4 or No. 5 would produce approximately 16,500 lb/hr of 250 psig saturated steam. Two such furnaces operating together could generate up to 33,000 lb/hr of steam. Based on scaling criteria for a waste-heat boiler for Furnace No. 3, and assuming sufficient space and clearance exist to install one (not confirmed), operation of either Furnace No. 4 or No. 5, in combination with Furnace No. 3 would result in about 25,000 lb/hr of steam generation.

As with the flue gas-to-air heat exchanger, boilers for Furnaces No. 4 and 5 can be located just below the opening in the exit breeching from the furnaces. There is sufficient space for an appropriately sized unit to be installed, provided that the existing APC quench section and tray tower are relocated to the area two floors below.

Also required would be a "bypass" condenser system to allow the boilers to continue to generate steam when no steam demand exists. In the case of a turbine generator set, the condenser would operate as part of the closed-loop system to recover steam from the exhaust of the turbine. This steam would be condensed and returned to the deaerator tank for use as boiler feed water. The cooling water for the condenser could be taken from the FEV plant effluent flow (87,000 gpm). By withdrawing about 6,000 gpm (determined to be sufficient for the turbine) and allowing for a temperature elevation of about 10°F (say from 70 to 80°F), before returning the flow to the outfall, overall plant effluent temperature would increase only a fraction of a degree fahrenheit.

The use of a so-called by-pass, or dump condenser for periods when no steam is needed precludes the need for large flue-gas bypass breeching and dampers around each waste-heat boiler. The condenser would be located in the general vicinity of the boiler-water treatment, storage, and supply equipment, on the floor area previously occupied by Furnaces No. 1 and 2.

Because of the presence of the high-pressure boilers and new process equipment, specialized operator training would be required. In addition, it may be necessary to obtain Stationary Engineer Licenses for the operations staff.

Based on information supplied by several boiler manufacturers, cost estimates were prepared for the installation of three boilers sharing common auxiliary

systems including such items as feed water treatment, storage, and delivery, and condenser equipment. The capital cost for this alternative is approximately \$2,090,000 for all three furnaces.

7.2.3 Turbine Power

The steam generated in the waste-heat boiler system described in Section 7.2.2 could be used to generate shaft power. The principal alternative considered was a steam-turbine generator set to generate electricity for in-plant use. A schematic of a waste-heat boiler with a turbine generator is presented in Figure 7-3. Steam could also be used in individual turbine drives to supply power for existing plant fans and pumps.

Based on the assumption that 25,000 lb/hr of 250 psig steam is available from two operating incinerators (and their waste-heat boilers), about 1,500 kW of electrical power could be generated. If Furnaces No. 4 and 5 are in operation, the resulting 33,000 lb/hr steam could result in over 2,000 kW generated.

In the case of a turbine generator, the type of equipment typically used for the quantity and pressure range of steam anticipated would be mounted on a pre-packaged skid. Other miscellaneous skid-mounted equipment such as lubrication oil coolers and pumps, speed governors, a local control panel, shaft vibration monitoring equipment, and piping and equipment features such as steam jet ejectors (to provide condenser vacuum) would typically be incorporated into a compact design. These could be located on separate skids, but would be designed to mate with the main skid.

For this alternative, a condensing turbine was selected because this type of turbine is designed to maximize energy extraction from the steam. Despite this goal of design, there is typically a great amount of energy still contained in the exhausted steam (usually about three to five times the amount converted to useful work).

In Section 7.2.2, the proposal to use about 6,000 gpm of plant effluent water as circulating water for the condenser was discussed. Based on plant records, this water is available at all times and never exceeds about 80°F, making it ideal for the intended use.

Of separate interest is the differential in the height of the plant's discharge point relative to the effluent channel: the plant effluent, at a nominal rate of 87,000 gpm, drops a distance of 20 feet to the effluent channel. About 180 kW of electrical power could be generated in an axial-flow hydraulic turbine, based on an overall system efficiency of 75 percent.

The output of the electric generator may be connected in parallel with the electric utility company's service line to the main plant distribution system, or, alternatively to dedicated branch feeders at the plant where appropriate. The use of an induction generator may simplify electrical equipment needed for interfacing with the local electric utility. The electricity is assumed to be generated at 4160v, with switch gear located on site.

FIGURE 7-3
FLOW SCHEMATIC
WASTE HEAT BOILER
WITH TURBINE-GENERATOR

TYPICAL OF UNIT NOS. 4 AND 5
(SIMILAR FOR UNIT NO. 3)

Based on the dimensions of a 2000-kW turbine generator set, the skid is expected to measure about 10 feet wide by 25 feet long. The condenser would be located alongside the turbine, and would occupy an area about 6 feet wide by 26 feet long. As with the boiler auxiliary equipment, this equipment can be located in the Solids Building, in the area formally occupied by Furnaces No. 1 and 2.

Based on estimates from several manufacturers, the capital cost for a 2,000-kW turbine generator set and auxiliaries is about \$1,500,000. The prerequisite for this alternative is the waste-heat boiler system described in Section 7.2.2, resulting in a total capital cost of about \$3,590,000.

A second alternative is to use steam generated in the waste-heat boiler system in individual turbine drives to supply power for existing rotating equipment, such as I.D. fans and ash pumps. Because of the relative remote locations of such equipment throughout the building and beyond, turbine drives would probably require separate condensing systems, as well as extensive valves, pipes, and controls. In addition, each unit would still have to be coupled to an electric drive to operate when no steam exists (such as during incinerator start-up). Multiple changes to many relatively low-powered devices (10 to 250 hp) is less favorable than the single turbine alternative.

For these apparent reasons, the second alternative was not considered further.

7.2.4 Condensing Heat Exchanger

By using corrosion-resistant materials for construction, a condensing heat exchanger (also referred to as a condensing economizer) can extract waste heat from the exhaust gas at temperatures below the acid dew point. Both sensible heat and latent heat in the furnace exhaust gas can be recovered in a condensing heat exchanger. The exhaust gas temperature will drop in proportion to the amount of sensible heat extracted. Latent heat recovery will occur when the water vapor present in the flue gas condenses.

Many condensing heat exchangers have been installed in industrial plants either at the boiler exhaust, or following a conventional economizer, where the flue gas has been partially cooled. Even with boilers using low-sulfur fuel oil or natural gas, corrosive chlorides and acids will result from combustion, and the surfaces of the condensing heat exchanger must be protected. Typically, the non-corroding materials used in condensing heat exchangers are good for temperatures up to 400°F to 500°F. Waste heat energy from the condensing heat exchanger is typically used to heat water to 180°F for makeup boilers, plant heating, or process use, or to preheat combustion air. Plants utilizing fuel oil or natural gas typically operate condensing heat exchangers with exit gas temperatures of approximately 110°F, and sometimes as low as 90°F.

While no known installations of condensing heat exchangers on sewage sludge incinerators exist, they have been installed on medical and municipal solid waste incinerator systems. On these units, the exit temperature of the exhaust gas is usually maintained at temperatures above 180°F, so they cannot be considered "true" condensing heat exchangers. One manufacturer (Cannon Technology) has tried numerous construction materials, including graphite, Teflon, glass,

borosilicate, and stainless steels, and found that all will corrode when exposed to acid gas. In general, for any type of waste incineration, manufacturers are hesitant to design systems for temperatures below the dew point, because of the unknown corrosives in the exhaust gas. Another potential drawback of installing a condensing heat exchanger after a sludge incinerator is the relatively high particulate content of the exhaust gas. The particulate matter can combine with the condensate to form a muddy cake, which can coat the heat exchanger tubes, inhibiting heat transfer and gas flow. In addition, if a Teflon coating is used, the abrasive particulates in the flue gas may degrade it.

In 1989, Monroe County and Condensing Heat Exchanger Corporation of Warnerville, New York investigated installation of a condensing heat exchanger following one of the MHFs at the FEV plant. The design called for a bypass to divert flue gas to a quench section, where the temperature was to be reduced to 470°F prior to entering the condensing heat exchanger. The gases were to be cooled to approximately 270°F in the condensing heat exchanger, where water would be heated to 180° to provide building heat. All exposed surfaces of the heat exchanger, including tubes, tube sheets, and side sheets, were to be Teflon-coated. Although the system was projected to save money in fuel costs, the two parties eventually decided that a heat recovery option extracting energy at low temperatures should not be pursued before energy recovery of the high-temperature gas at the furnace exit was ruled out. At higher temperatures, a higher grade of energy can be recovered more efficiently, and, since the corrosive condensates will not exist at high temperatures, less expensive materials can be used.

An example of a possible equipment arrangement incorporating a condensing heat exchanger is presented in Figure 7-4. Because of limited allowable inlet temperatures, the condensing heat exchanger is shown following a waste-heat boiler. A subsequent spray water quench is also shown to lower flue-gas temperatures to allowable levels so as not to damage the materials of construction.

7.2.5 Sludge Dryer

Waste heat recovered from the furnace exhaust gas can be used to dry the sludge, thus increasing its heating value and reducing the need for auxiliary fuel. A schematic of a possible arrangement using a direct-heat sludge dryer is presented in Figure 7-5.

Autogenous operation (operation during which the combustion process is sustained without the use of auxiliary fuel) can be achieved by drying the sludge to a solids concentration exceeding approximately 29 percent solids by weight. (The combustion analysis for this case is available separately in Appendix C.3.) Even during autogenous operation, a marginal amount of fuel will be required to control the combustion process and maintain the burning zones.

At a solids concentration of 29 percent, the rated capacity of each furnace will increase to approximately 75 dry tons per day (tpd). The average sludge production rate of 65 dry tpd could easily be handled by one unit (Furnace No. 4 or No. 5). Solids throughput at higher solids concentrations will be limited by the maximum allowable heat release rate within the furnace. The benefits of

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FIGURE 7-5
FLOW SCHEMATIC
DIRECT SLUDGE DRYER

TYPICAL OF UNIT NOS. 4 AND 5

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sludge drying will not increase proportionally beyond a solids concentration of about 29 percent. Since incineration is already autogenous at 29 percent solids, additional drying will not result in significant fuel savings. A slight decrease in exhaust gas flow will occur: as the solids concentration increases from 30 percent to 70 percent, the exhaust gas flow rate decreases by approximately 20 percent.

Either a rotary unit or a paddle-type unit could be used to dry FEV sludge. A rotary unit consists of a cylindrical vessel in which heat is applied to the sludge as it is continuously rotated, exposing damp material and maximizing heat transfer. Either direct or indirect heat can be used to dry the sludge in a rotary unit. At lower solids concentrations, sewage sludge tends to turn into a sticky, tarlike substance within the rotary dryer. To avoid dealing with this hard-to-handle phase, most rotary dryers are designed to "back-blend" the dried sludge. A portion of the sludge leaving the dryer at 5 to 10 percent moisture is mixed with the wet sludge to obtain a consistency that can be fed to the dryer. This process is illustrated in Figure 7-6. Paddle-type units are dryers with mechanical agitators that allow processing of a wider range of materials. Paddle-type dryers typically require indirect heat transfer. Since the characteristics of different sludges can vary greatly, many sludge dryer manufacturers utilize pilot-scale units to test the sludge prior to selecting an appropriate method.

Both direct and indirect heat dryers require off-gas treatment to remove moisture, volatile organic compounds (VOC) and other malodorous compounds evaporated from the sludge. The off-gas from the dryer could be treated in a venturi or barometric condenser to remove moisture, then rerouted to the MHF afterburner to destroy volatiles.

The direct and indirect heat methods of sludge drying are described in detail below.

7.2.5.1 Direct-Heat Dryer In a direct-heat dryer, the sludge is brought into direct contact with currents of heated air or gas that pass through the interior of the cylinder. A typical system is shown schematically in Figure 7-5. The hot gases could be recirculated gases from the incinerator, exhaust gases from a separate furnace (natural gas, propane, fuel oil, etc.), or heated air from a flue gas-to-air heat exchanger. The wet sludge and the hot gases can be introduced into the dryer at the same end (co-current), or opposite ends (countercurrent). Co-current operation is typically used for partially drying materials with a high moisture content, such as the sludge at Monroe County's FEV plant, while countercurrent operation is used in applications where a relatively low-moisture product is desired.

Manufacturers of direct-heat sludge dryers have supplied cost estimates for a system sized to dry 65 dry tons per day of sewage sludge from 80 percent moisture to 70 percent moisture. The dryer would utilize the hot flue gases leaving the operating furnace(s) at a temperature of at least 1,200°F. One furnace incinerating 65 dry tons per day of sludge with a 30 percent solids content (70 percent moisture), at a flue gas exhaust temperature of 1200°F, could easily supply the heat necessary to dry the sludge from 80 percent moisture to 70 percent moisture.

FIGURE 7-6
SLUDGE DRYER WITH
BACK BLENDING

NOTE:

FLOW RATES BASED ON
65 DTPD AT 20% SOLIDS
(27,000 LB/HR TOTAL SLUDGE)
THERMALLY DRIED TO 29% SOLIDS

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The total capital cost for a direct-heat dryer for FEV, including auxiliary equipment and installation, is estimated at \$4,160,000. (Details of the estimate are available in Appendix D.3.)

7.2.5.2 Indirect-Heat Dryer An indirect dryer utilizes steam, water, heat-transfer oil, brine, or other medium to transfer heat to a cylindrical vessel containing the sludge. The heat radiated from the surrounding atmosphere or heated cylinder is the primary means by which moisture is evaporated from the sludge. One advantage of the indirect-heat dryer is the smaller volume of off-gas, which would require a smaller and less expensive off-gas treatment system.

At the FEV plant, either steam from a waste-heat boiler or hot oil from a flue gas-to-oil heat exchanger would be used as the heat-transfer medium. If a higher temperature heat-transfer medium was desired, due to the properties of the material being dried, hot oil would have an advantage over steam. Hot oil can be heated to 600°F, while the steam is limited to a pressure of 300 psig (about 400°F saturated). Since manufacturers have indicated that the higher temperature heat-transfer medium would not have an advantage over steam in drying municipal sludge, a steam-dried system was investigated. Figure 7-7 is a schematic of such a system.

One waste-heat boiler utilizing the 1,200° flue gas from the incineration of 65 dry tons per day of sludge at 30 percent solids (70 percent moisture) would only produce enough steam to dry the sludge to approximately 27 percent solids (73 percent moisture). Therefore, use of an indirect-heat sludge dryer would not eliminate the need for auxiliary fuel to sustain combustion in the MHF.

The cost for indirect sludge drying using steam for heating is estimated to be \$5,550,000. This estimate includes the cost for installation of the waste heat boiler system described in Subsection 7.2.2. (A detailed cost estimate is available separately in Appendix D.1, Item III-B.)

7.2.6 Regenerative Thermal Oxidizer/Afterburner

The regenerative thermal oxidizer is promoted as a fuel-efficient means of controlling THC emissions. The RHOX process is a proprietary arrangement involving integration of APC equipment with an MHF and scrubber system; it is described in detail in Subsection 6.1.3 and illustrated in Figure 6-2.

In the regenerative thermal oxidizer, the incoming cooled flue gases are heated using energy from the exiting gases along with a small amount of auxiliary fuel. The RHOX thermal oxidizer/afterburner requires less auxiliary fuel than a conventional internal or external afterburner.

The capital cost for one regenerative thermal oxidizer system, sized to accept the exhaust streams from all three MHFs at FEV, is approximately \$1,786,000. Details of the cost estimate are available separately in Appendix D.1, Item I-B.

FIGURE 7-7
FLOW SCHEMATIC
WASTE HEAT BOILER
WITH INDIRECT SLUDGE DRYER

TYPICAL OF UNIT NOS. 4 AND 5
(SIMILAR FOR UNIT NO.3)

7.3 REVIEW OF POTENTIAL ENERGY USES

7.3.1 Space Conditioning

Occupied spaces in the FEV plant are heated by a forced hot water system, with hot water supplied by two dual-fueled (No. 2 fuel oil and natural gas) boilers. Either a waste-heat boiler or a condensing heat exchanger could be used to supply a portion of the heat required by the existing hot water system.

The waste-heat boiler would be designed to produce saturated steam at a minimum pressure of 150 psig. Hot water for heating the facility would be generated in a steam-to-hot water shell- and tube-heat exchanger. Approximately 8,500 lb/hr of 150 psig steam is required. By operating one MHF at an average throughput of 52 dry tons of sludge per day with an afterburner exhaust temperature of 1,200°F, a waste-heat boiler could be sized to produce approximately 13,000 lb/hr of steam at 150 psig.

A condensing heat exchanger would need to follow a waste-heat boiler, or other means of reducing the temperature of the incineration flue gas to less than 500°F. The flue gas would enter the condensing heat exchanger at 470°F and exit at approximately 270°F. Latent and sensible heat from the flue gas would be transferred to hot water for the plant heating system. With one MHF operating at an average throughput of 52 dry tons per day, approximately 5.25 million Btu/hour could be recovered by a condensing heat exchanger. While not sufficient to meet the full design heating load of the plant, the recovered heat would greatly reduce the auxiliary fuel usage.

7.3.2 Preheating Combustion Air

The hot exhaust gases leaving the MHF can be used to preheat a portion of the combustion air in a flue gas-to-air heat exchanger. The heat exchanger could heat recirculated center shaft cooling air to a temperature of 1,000°F, assuming the furnace exit temperature is maintained above about 1,200°F.

By heating the center shaft cooling air that is recirculated into the combustion zone hearths to a higher temperature than is currently practiced, additional auxiliary fuel savings can be realized. However, whether the sludge incineration process can accommodate the extremely high temperature air while maintaining desired parameters such as emissions limits and throughput capacity is not known.

In such a case, a certain degree of experimentation may be needed to optimize the operation. A flue-gas bypass arrangement is recommended for this purpose, so that the air temperature could be adjusted, as needed. Alternatively, the heated air could be routed to the main stack or breeching for use in visible plume suppression.

7.3.3 Electric Energy Generation

Steam generated in a waste-heat boiler system can be used to operate a turbine generator set for in-plant production of electricity. Based on the estimated

amount of energy available in the flue gases, between 25,000 lb/hr and 33,000 lb/hr of steam at 250 psig (saturated) can be made available for a major portion of the year. These steam rates are based on a range of possibilities: either Furnace No. 4 or No. 5 operating simultaneously with Furnace No. 3, or both Furnaces No. 4 and 5 operating. At a minimum, about 16,500 lb/hr can be generated if either Furnace No. 4 or No. 5 is operating. Operation of any furnace in a standby mode will allow for additional steam, since flue gas at elevated temperature is still generated, though at reduced flow rates.

This steam generation rate represents about 1,500 kW to 2,000 kW in electrical generating capacity under normal circumstances, using a condensing turbine and electrical generator. At a minimum, about 1,000 kW can be generated when only one of the 11 hearth furnaces operating.

This electrical power could offset an equal amount purchased from the local utility company, Rochester Gas and Electric Company (RG&E). FEV's average instantaneous power demand based on annual energy totals is about 3,500 kW. Without a specific plant energy use profile, it is believed that at least half of this energy can be considered as base load, if not even more. Therefore, it is assumed that all electrical energy generated by a condensing turbine/generator can be used by the FEV plant.

In this particular example, there is no incentive to engage in a buy-back arrangement (the payment by the utility company to the generator, in this case FEV) with the utility company. The most recent RG&E Service Classification Rate Schedule shows that buy-back rates are consistently lower than energy service charges for the same periods of time. For example, based on the rate schedule effective August 28, 1993, the buy-back rate per kilowatt hour for subtransmission energy is \$0.07033/kWh during peak summer hours, whereas the service cost is \$0.11162/kWh for the same period. The same trend holds for off-peak and shoulder-peak periods, and peak periods throughout the year as well. Thus, FEV would benefit more by utilizing the generated electrical energy within the plant and reducing service charges.

If FEV could generate more electrical energy than it uses, then buy-back agreements with RG&E might make economic sense. Since this is not a foreseeable case for the FEV plant (based on current sludge incineration practices), it is more advantageous to reduce purchased energy and thus reduce energy costs, rather than to sell energy back to the utility company.

7.3.4 Steam Supply for Local Electric Utility

As a related alternative to providing steam to an on-site turbine generator set, the possibility of providing the steam to RG&E for their use was investigated. In relation to typical electric utility company needs, the relatively low steam generation quantities possible from the FEV incinerators, and the low pressures at which steam can be practically generated, led to the expectation that this alternative was not feasible.

Many factors determine the suitability of steam for purposes such as electrical energy generation or district heating. Among these are the steam quantities and

pressures available, distances to potential users, and the users' abilities to accept these in their existing equipment.

Following discussions with RG&E representatives, it was confirmed that none of the above requirements could be satisfied in the case of FEV.

7.3.5 Sludge Drying

As explained in Subsection 7.2.5, sludge could be dried prior to combustion in either a direct-heat dryer utilizing the hot incinerator exhaust gas, or in an indirect-heat dry utilizing steam produced by a waste-heat boiler.

In a direct-heat dryer, approximately 13 million Btu/hr would be required to dry the sludge from 80 percent moisture to 70 percent moisture. Relying on the exhaust of one incinerator combusting 65 dry tons per day of sludge at 30 percent solids, approximately 61,000 lb/hr of flue gas at 1,200°F would be available. Through cooling to 300°F, the flue gas could provide up to about 16 million Btu/hr in a direct dryer.

An indirect dryer would require roughly 16,000 lb/hr of 150 psig steam to dry 65 dry tons per day of sludge to 70 percent moisture. The energy in the flue gas from incinerating 65 dry tpd of sludge at 70 percent moisture would only provide about 13,000 lb/hr of 150 psig steam. Supplemental fuel would be required to boost the capacity of the boiler to produce the required steam load.

Section 8

SUMMARY AND RECOMMENDATIONS

8.1 AIR POLLUTION CONTROL EQUIPMENT

8.1.1 Total Hydrocarbons (THC) Control

A major concern of the federal Part 503 regulations is its limitation of incinerator THC emissions to 100 ppm_{dv} as propane, at 7 percent oxygen, based on a monthly average. Measurements performed during testing of Furnace No. 5 in May 1993 demonstrated that average THC exiting the stack over each two day test condition was substantially less than 100 ppm_{dv}, as propane at 7 percent oxygen. The average measured THC concentration (corrected) over a two- day period (based on one-minute averages) was about 40 ppm_{dv} at the 1,100°F afterburner condition. At both the 1,200°F and 1,300°F conditions, the two-day averages of THC concentration were below 20 ppm_{dv}.

Based on these results, no apparent need exists to alter the multiple hearth furnaces or their respective internal afterburner systems to address THC emissions at this time. In fact, there is a substantial margin available in the event some further limitation in THC concentration is imposed by future regulations.

As a part of the study, economic evaluations were performed for two other THC control alternatives described in Section 6, the external afterburner and regenerative thermal oxidizer (RHOX) systems. Capital costs were based on information supplied by major vendors. Operation and maintenance costs were based on a varying percentage of the capital cost, as a function of the complexity of the system.

As shown on Table 8-1, the capital cost for three external afterburner systems for three MHFs is \$2,330,000. The annualized cost of this amount is \$203,000 based on 20-year financing, and 6 percent interest. With provisions for additional annual operating and maintenance costs (above current levels) and net differential energy costs, the estimated additional annual cost for this alternative ranges from \$231,000 to \$338,000 above the current operation, representing the range of afterburner temperatures from 1,100°F to 1,300°F. This alternative has no advantage over current operations.

Table 8-2 presents an economic analysis for the regenerative thermal oxidizer system. The capital cost for a single system to treat the flue gas from the three MHFs is estimated to be \$1,790,000. The annualized cost of capital is \$156,000 based on a 20-year term, and 6 percent interest. Annual operating and maintenance costs (compared to current levels) and net differences in energy costs result in the estimated annual savings ranging from \$16,000 to \$518,000, when compared to the current operation, at the three afterburner operating temperatures. Based on these savings and the simple payback estimates shown, the regenerative thermal oxidizer system warrants future consideration.

Table 8--1
Economic Evaluation
External Afterburner

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A. CAPITAL COSTS				
1. Three External Afterburner Systems		\$2,330,000	\$2,330,000	\$2,330,000
TOTAL CAPITAL OUTLAY		\$2,330,000	\$2,330,000	\$2,330,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$203,000	\$203,000	\$203,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT				
1. Operating and Maintenance Labor (Assume 1/2% of capital cost)		\$11,700	\$11,700	\$11,700
2. Repairs and Maintenance (Assume 1% of capital cost)		\$23,300	\$23,300	\$23,300
3. Electrical Power for Afterburner Fan		\$6,000	\$11,000	\$17,000
4. Natural Gas		\$330,000	\$600,000	\$920,000
TOTAL OPERATION AND MAINTENANCE COSTS		\$371,000	\$646,000	\$972,000
TOTAL ANNUAL COST		\$574,000	\$849,000	\$1,175,000
C. ANNUAL SAVINGS IN ENERGY COSTS				
1. Natural Gas		\$337,000	\$530,000	\$829,000
2. Electricity (Existing AB combustion air fans)		\$5,700	\$6,700	\$7,900
TOTAL SAVINGS IN ENERGY COSTS		\$343,000	\$537,000	\$837,000
NET ANNUAL SAVINGS		(\$231,000)	(\$312,000)	(\$338,000)
NET SAVINGS PER TON OF DRY SLUDGE		(\$9.95)	(\$13.45)	(\$14.57)
SIMPLE PAYBACK PERIOD - YEARS		NA	NA	NA

NOTES

1. Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
2. Average sludge incineration rate of 65 dry tons per day assumed.
3. Sludge incinerators assumed to operate 357 days per year.
4. Average cost for natural gas assumed to be \$0.45/CCF.
5. Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
6. Assume 100% equipment availability.
7. Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
8. Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
9. Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

Table 8-2
Economic Evaluation
Regenerative Thermal Oxidation System

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A. CAPITAL COSTS				
1. One Regenerative Thermal Oxidation System		\$1,790,000	\$1,790,000	\$1,790,000
TOTAL CAPITAL OUTLAY		\$1,790,000	\$1,790,000	\$1,790,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$156,000	\$156,000	\$156,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT				
1. Operating and Maintenance Labor (Assume 1/2% of capital cost)		\$9,000	\$9,000	\$9,000
2. Repairs and Maintenance (Assume 1% of capital cost)		\$17,900	\$17,900	\$17,900
3. Electrical Power for RTO Fan		\$78,000	\$78,000	\$78,000
4. Natural Gas		\$70,000	\$70,000	\$70,000
TOTAL OPERATION AND MAINTENANCE COSTS		\$175,000	\$175,000	\$175,000
TOTAL ANNUAL COST		\$331,000	\$331,000	\$331,000
C. ANNUAL SAVINGS IN ENERGY COSTS				
1. Natural Gas		\$337,000	\$530,000	\$829,000
2. Electricity (Existing I.D. fans and afterburner combustion air fans)		\$9,500	\$12,500	\$20,000
TOTAL SAVINGS IN ENERGY COSTS		\$347,000	\$543,000	\$849,000
NET ANNUAL SAVINGS		\$16,000	\$212,000	\$518,000
NET SAVINGS PER TON OF DRY SLUDGE		\$0.69	\$9.14	\$22.32
SIMPLE PAYBACK PERIOD - YEARS		10.4	4.9	2.7

NOTES

1. Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
2. Average sludge incineration rate of 65 dry tons per day assumed.
3. Sludge incinerators assumed to operate 357 days per year.
4. Average cost for natural gas assumed to be \$0.45/CCF.
5. Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
6. Assume 100% equipment availability.
7. Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
8. Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
9. Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

8.1.2 Metals and Particulates Control

Calculations were performed for the seven metals that are regulated by Part 503 (beryllium, mercury, lead, arsenic, cadmium, chromium, and nickel) to determine whether recorded concentrations of these metals in the sludge met the requirements. All metal concentrations were found to be within Part 503 requirements. There is again, a substantial margin available in that the modeling was performed based on incinerating up to 155 dry tpd of sludge. All three MHFs would have to be operating simultaneously at their maximum capacity to achieve this rate. Therefore, no apparent need exists to install alternative scrubber systems to address Part 503 metals control at this time.

Regarding calculations to check compliance with New York State Air Guide-1, these showed that emissions of all nine pass short-term exposure limits, but the calculated annual impacts of arsenic, cadmium, and hexavalent chromium exceeded the long-term exposure limits.

Performance of more refined air modeling may demonstrate compliance with Air Guide-1. However, if unsuccessful, reduction of metal concentrations in sludge and/or improvement of air pollution control equipment would be necessary.

Because of uncertain ramifications of the proposed Air Guide-1 regulations, and the questionable physical condition of the existing scrubbers, some of the alternatives investigated may be relevant in the future.

As shown on Table 8-3, the capital cost for three high-energy venturi scrubbers for three MHFs is \$1,660,000. The annualized cost of this amount is \$145,000 based on a 20-year term, and 6 percent interest. With provisions for additional annual operating and maintenance costs (above current levels), and net differential energy costs, the estimated additional annual cost for this alternative ranges from \$284,000 to \$306,000 compared to current operation, representing the range of afterburner temperatures from 1,100°F to 1,300°F.

As an alternative to installing a high-energy venturi scrubber, the current quencher scrubber could be replaced. However, vendors may be reluctant to guarantee the collection efficiencies required to achieve compliance with Part 503 regulations. The excellent performance of the scrubber system demonstrated during the May 1993 stack testing is not typical of similar scrubber systems. Further, it is not certain that results will be duplicated if a replacement were installed. Therefore, there is a degree of risk with replacing the current scrubber with a similar quencher scrubber.

As shown on Table 8-4, the capital cost for replacement with three similar quench and impingement tray scrubbers is estimated to be \$700,000. The annualized cost of this amount is \$61,000 based on a 20-year term, and 6 percent interest. With provisions for additional annual operating and maintenance costs (above current levels), and net differential energy costs, the estimated additional annual cost for this alternative ranges from \$120,000 to \$132,000 more than current operation, over the range of afterburner temperatures from 1,100°F to 1,300°F.

Another alternative is the addition of a wet electrostatic precipitator (WESP). Costs for this alternative are analyzed in Table 8-5. The capital cost for three

Table 8-3
Economic Evaluation
High Energy Venturi Scrubber

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A. CAPITAL COSTS				
1. Three High Energy Venturi Scrubber Systems	\$1,660,000	\$1,660,000	\$1,660,000	\$1,660,000
TOTAL CAPITAL OUTLAY		\$1,660,000	\$1,660,000	\$1,660,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$145,000	\$145,000	\$145,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT				
1. Operating and Maintenance Labor (Assume 1/2% of capital cost)	\$8,300	\$8,300	\$8,300	\$8,300
2. Repairs and Maintenance (Assume 1/2% of capital cost)	\$8,300	\$8,300	\$8,300	\$8,300
3. Electricity				
a. I.D. fan power	\$84,000	\$87,000	\$95,000	\$95,000
b. scrubber water pumping	\$38,000	\$45,000	\$49,000	\$49,000
TOTAL OPERATION AND MAINTENANCE COSTS		\$139,000	\$149,000	\$161,000
TOTAL ANNUAL COST		\$284,000	\$294,000	\$306,000
NET COST PER TON OF DRY SLUDGE		\$12.24	\$12.67	\$13.19

NOTES

1. Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
2. Average sludge incineration rate of 65 dry tons per day assumed.
3. Sludge incinerators assumed to operate 357 days per year.
4. Average cost for natural gas assumed to be \$0.45/CCF.
5. Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
6. Assume 100% equipment availability.
7. Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
8. Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
9. Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

Table 8-4
Economic Evaluation
Quencher Scrubber

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A. CAPITAL COSTS				
1. Three Quencher Scrubber Systems		\$700,000	\$700,000	\$700,000
TOTAL CAPITAL OUTLAY		\$700,000	\$700,000	\$700,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$61,000	\$61,000	\$61,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT				
1. Operating and Maintenance Labor (Assume 1/2% of capital cost)		\$3,500	\$3,500	\$3,500
2. Repairs and Maintenance (Assume 1/2% of capital cost)		\$3,500	\$3,500	\$3,500
3. Electricity				
a. I.D. fan power		\$13,500	\$14,000	\$15,400
b. scrubber water pumping		\$38,000	\$45,000	\$49,000
TOTAL OPERATION AND MAINTENANCE COSTS		\$59,000	\$66,000	\$71,000
TOTAL ANNUAL COST		\$120,000	\$127,000	\$132,000
NET COST PER TON OF DRY SLUDGE		\$5.17	\$5.47	\$5.69

NOTES

1. Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
2. Average sludge incineration rate of 65 dry tons per day assumed.
3. Sludge incinerators assumed to operate 357 days per year.
4. Average cost for natural gas assumed to be \$0.45/CCF.
5. Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
6. Assume 100% equipment availability.
7. Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
8. Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
9. Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

Table 8-5
Economic Evaluation
Wet Electrostatic Precipitator (WESP)

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A.	<u>CAPITAL COSTS</u>			
1.	Three WESP Systems	\$1,770,000	\$1,770,000	\$1,770,000
TOTAL CAPITAL OUTLAY		\$1,770,000	\$1,770,000	\$1,770,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$154,000	\$154,000	\$154,000
B.	<u>OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT</u>			
1.	Operating and Maintenance Labor (Assume 1/4% of capital cost)	\$4,400	\$4,400	\$4,400
2.	Repairs and Maintenance (Assume 1/2% of capital cost)	\$8,900	\$8,900	\$8,900
3.	Electricity			
a.	fogging water pumping	\$1,500	\$1,500	\$1,500
b.	purge air blower	\$4,600	\$4,600	\$4,600
c.	transformer/rectifier	\$12,500	\$12,500	\$12,500
d.	additional I.D. fan power	\$5,400	\$5,600	\$6,100
TOTAL OPERATION AND MAINTENANCE COSTS		\$37,000	\$38,000	\$38,000
TOTAL ANNUAL COST		\$191,000	\$192,000	\$192,000
NET COST PER TON OF DRY SLUDGE		\$8.23	\$8.27	\$8.27

NOTES

1. Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
2. Average sludge incineration rate of 65 dry tons per day assumed.
3. Sludge incinerators assumed to operate 357 days per year.
4. Average cost for natural gas assumed to be \$0.45/CCF.
5. Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
6. Assume 100% equipment availability.
7. Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
8. Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
9. Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

WESPs is estimated at \$1,770,000. The annualized capital cost is estimated to be \$154,000 based on a 20-year term, and 6 percent interest. The estimated additional operating and maintenance costs are more than \$190,000 for all afterburner temperature operating conditions. In the event that future particulate or metals emissions limits are more stringent, it may be possible to install a WESP system to complement the existing scrubber system. If future regulations mandate further reductions in emissions of particulates or metals, this alternative should be considered for implementation.

8.2 WASTE-HEAT RECOVERY ALTERNATIVES

Economic analyses were performed for each of the waste-heat recovery alternatives described in Section 7. The individual analyses are presented in Tables 8-6 through 8-11.

8.2.1 Flue Gas-to-Air Heat Exchanger

The flue gas-to-air heat exchanger analysis in Table 8-6 shows that this alternative has a very favorable payback, with resulting net annual savings of from \$238,000 to \$399,000 (depending on the afterburner temperature), for an initial capital investment of \$1,030,000. There is a risk in selecting this alternative, however, since no known existing sludge incinerators have installed this equipment, and consequences on operational stability are not currently known. Following the start-up of the Northeast Ohio Regional Sewer District's project referenced in Section 7.2.1, more information will be available about this alternative. A decision on whether to further pursue it should wait until the new project has been operating long enough to demonstrate its effectiveness.

8.2.2 Steam Generation for Turbine/Generator Set

The alternative of steam generation with a turbine generator to supply power for use within the plant shows a payback of about seven to nine years, with a capital cost of \$3,590,000 (Table 8-7). This is one of the few proven waste heat recovery alternatives that shows a favorable payback. Since very conservative assumptions were incorporated into most of the economic analyses, it is possible that a closer analysis could yield more favorable results.

While investigating this alternative, it was discovered that a substantial amount of potential energy exists in the effluent wastewater discharged to the effluent channel. It is estimated that a difference in height between the plant's discharge point and the effluent channel of about 20 feet exists. With a nominal flow of 125 million gallons per day (87,000 gpm) and a 15-foot effective head, about 180 kW of electrical power could be generated in an axial-flow hydraulic turbine, based on an overall system efficiency of 75 percent.

Further detailed review to determine the economics of installing a hydraulic turbine to extract energy from the plant effluent flow is recommended.

Table 8-6
Economic Evaluation
Flue Gas-to-Air Heat Exchanger

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A. CAPITAL COSTS				
1. Three Flue Gas-to-Air Heat Exchanger Systems		\$1,030,000	\$1,030,000	\$1,030,000
TOTAL CAPITAL OUTLAY		\$1,030,000	\$1,030,000	\$1,030,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$90,000	\$90,000	\$90,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT				
1. Operating and Maintenance Labor (Assume 1% of capital cost)		\$10,300	\$10,300	\$10,300
2. Repairs and Maintenance (Assume 1% of capital cost)		\$10,300	\$10,300	\$10,300
3. Electricity for additional fan power		\$900	\$150	\$0
TOTAL OPERATION AND MAINTENANCE COSTS		\$22,000	\$21,000	\$21,000
TOTAL ANNUAL COST		\$112,000	\$111,000	\$111,000
C. ANNUAL SAVINGS IN ENERGY COSTS				
1. Natural Gas		\$350,000	\$480,000	\$510,000
2. Electricity		\$0	\$0	\$200
TOTAL SAVINGS IN ENERGY COSTS		\$350,000	\$480,000	\$510,000
NET ANNUAL SAVINGS		\$238,000	\$369,000	\$399,000
NET SAVINGS PER TON OF DRY SLUDGE		\$10.26	\$15.90	\$17.19
SIMPLE PAYBACK PERIOD - YEARS		3.1	2.2	2.1

NOTES

1. Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
2. Average sludge incineration rate of 65 dry tons per day assumed.
3. Sludge incinerators assumed to operate 357 days per year.
4. Average cost for natural gas assumed to be \$0.45/CCF.
5. Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
6. Assume 100% equipment availability.
7. Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
8. Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
9. Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

Table 8-7
Economic Evaluation
Steam Generation to Power Turbine/Generator Set

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A. CAPITAL COSTS				
1. Three Waste Heat Boilers		\$2,090,000	\$2,090,000	\$2,090,000
2. Turbine Generator Set		\$1,500,000	\$1,500,000	\$1,500,000
TOTAL CAPITAL OUTLAY		\$3,590,000	\$3,590,000	\$3,590,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$313,000	\$313,000	\$313,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT				
1. Operating Labor		\$45,000	\$45,000	\$45,000
(Assume operator required 1/2 time, 3 shifts/day, \$15,000/shift/yr.)				
2. Maintenance Labor		\$15,000	\$15,000	\$15,000
(Assume maint. required 1/2 time, 1 shift/day, \$15,000/shift/yr.)				
3. Repairs and Maintenance		\$71,800	\$71,800	\$71,800
(Assume 2% of capital cost)				
4. Electricity				
a. additional I.D. fan power		\$3,200	\$3,500	\$4,200
b. feedwater, circulating water and condensate return pumps		\$35,600	\$35,600	\$35,600
TOTAL OPERATION AND MAINTENANCE COSTS		\$171,000	\$171,000	\$172,000
TOTAL ANNUAL COST		\$484,000	\$484,000	\$485,000
C. ANNUAL SAVINGS IN ENERGY COSTS				
1. Natural Gas		\$0	\$0	\$0
2. Electricity		\$448,900	\$568,600	\$687,400
TOTAL SAVINGS IN ENERGY COSTS		\$449,000	\$569,000	\$687,000
NET ANNUAL SAVINGS		(\$35,000)	\$86,000	\$202,000
NET SAVINGS PER TON OF DRY SLUDGE		(\$1.51)	\$3.66	\$8.71
SIMPLE PAYBACK PERIOD - YEARS		NA	9.0	7.0

NOTES

- Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
- Average sludge incineration rate of 65 dry tons per day assumed.
- Sludge incinerators assumed to operate 357 days per year.
- Average cost for natural gas assumed to be \$0.45/CCF.
- Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
- Assume 95% equipment availability.
- Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
- Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
- Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

8.2.3 Steam Generation for Turbine/Generator Set with Condensing Heat Exchanger

The addition of the condensing heat exchanger to the turbine generator set alternative described above does not appear to be justified, based on the economic analysis in Table 8-8. The incremental amount of additional energy recovered does not justify the additional cost and longer payback for this system. In addition, there is a risk in selection of this technology since it has not previously been tried in sewage sludge incineration applications.

8.2.4 Steam Generation for Space Heating

As shown in Table 8-9, the use of a waste-heat recovery steam boiler system is not economically feasible for space heating. The nature of such pressure-vessel technology is that capital costs generally are high, even after attempts are made to match generation with demand.

Based on past experiences with small water-tube boilers, it has been found that only minor reductions in costs result from selecting smaller boilers. For example, the annual cost for a water tube boiler of similar design (three-pass), but with only one-ninth the surface area is about \$100,000, versus the type proposed which is about \$200,000. Even if the capital cost for the waste-heat boiler system were halved to about \$1,000,000, the annual savings would still be negative. There simply is not enough space heating demand at FEV to offset and justify such large capital expenses.

No further consideration of steam generation for space heating is warranted as a stand-alone alternative; however, it may be incorporated into one of the other alternatives. Further study could parallel the implementation of other alternatives.

8.2.5 Steam Generation for Sludge Drying

As Table 8-10 shows, the relatively high capital cost for indirect sludge drying compared to the potential annual fuel savings is economically unfavorable for any afterburner operating condition. This is a consequence of the limited amount of incinerator fuel savings available. No further consideration of this system for FEV is recommended.

8.2.6 Direct Sludge Drying

Direct sludge drying results in increased costs for all afterburner operating conditions. Table 8-11 presents the economic analysis. The relatively high capital cost for this type of system cannot be recovered in terms of annual fuel savings. Further, the degree of risk with its selection is great, since no known installations exist. No further consideration of this system for FEV is recommended.

Table 8-8
Economic Evaluation
Steam Generation to Power T/G Set, with Condensing Heat Exchanger

	FURNACE EXIT TEMPERATURE (DEG. F)		
	1,100	1,200	1,300
A. CAPITAL COSTS			
1. Three Waste Heat Boilers	\$2,090,000	\$2,090,000	\$2,090,000
2. Turbine Generator Set	\$1,500,000	\$1,500,000	\$1,500,000
3. Condensing Heat Exchanger	\$1,500,000	\$1,500,000	\$1,500,000
TOTAL CAPITAL OUTLAY	\$5,090,000	\$5,090,000	\$5,090,000
ANNUALIZED TOTAL CAPITAL OUTLAY	\$444,000	\$444,000	\$444,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT			
1. Operating Labor (Assume operator required 1/2 time, 3 shifts/day, \$15,000/shift/yr.)	\$45,000	\$45,000	\$45,000
2. Maintenance Labor (Assume maint. required 1/2 time, 1 shift/day, \$15,000/shift/yr.)	\$15,000	\$15,000	\$15,000
3. Repairs and Maintenance (Assume 2% of capital cost)	\$101,800	\$101,800	\$101,800
4. Electricity			
a. additional I.D. fan power	\$9,700	\$10,500	\$12,600
b. feedwater, circulating water and condensate return pumps	\$35,600	\$35,600	\$35,600
d. hot water circulating pump	\$3,900	\$3,900	\$3,900
TOTAL OPERATION AND MAINTENANCE COSTS	\$211,000	\$212,000	\$214,000
TOTAL ANNUAL COST	\$655,000	\$656,000	\$658,000
C. ANNUAL SAVINGS IN ENERGY COSTS			
1. Natural Gas	\$103,300	\$103,300	\$103,300
2. Electricity	\$448,900	\$568,600	\$729,600
TOTAL SAVINGS IN ENERGY COSTS	\$552,000	\$672,000	\$633,000
NET ANNUAL SAVINGS	(\$103,000)	\$16,000	\$175,000
NET SAVINGS PER TON OF DRY SLUDGE	(\$4.44)	\$0.69	\$7.54
SIMPLE PAYBACK PERIOD - YEARS	NA	11.1	8.2

NOTES

1. Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
2. Average sludge incineration rate of 65 dry tons per day assumed.
3. Sludge incinerators assumed to operate 357 days per year.
4. Average cost for natural gas assumed to be \$0.45/CCF.
5. Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
6. Assume 95% equipment availability.
7. Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
8. Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
9. Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

Table 8-9
Economic Evaluation
Steam Generation for Space Conditioning

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A. CAPITAL COSTS				
1. Three Waste Heat Boilers		\$2,090,000	\$2,090,000	\$2,090,000
2. Circulating Hot Water System		\$110,000	\$110,000	\$110,000
TOTAL CAPITAL OUTLAY		\$2,200,000	\$2,200,000	\$2,200,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$192,000	\$192,000	\$192,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT				
1. Operating Labor		\$30,000	\$30,000	\$30,000
(Assume operator required 1/3 time, 3 shifts/day, \$10,000/shift/yr.)				
2. Maintenance Labor		\$15,000	\$15,000	\$15,000
(Assume maint. required 1/2 shift/day, \$15,000/shift/yr.)				
3. Repairs and Maintenance		\$44,000	\$44,000	\$44,000
(Assume 2% of capital cost)				
4. Electricity				
a. circulating hot water pump		\$6,900	\$6,900	\$6,900
b. additional I.D. fan power		\$3,200	\$3,500	\$4,200
c. feedwater, circulating water and condensate return pumps		\$35,600	\$35,600	\$35,600
TOTAL OPERATION AND MAINTENANCE COSTS		\$135,000	\$135,000	\$136,000
TOTAL ANNUAL COST		\$327,000	\$327,000	\$328,000
C. ANNUAL SAVINGS IN ENERGY COSTS				
1. Natural Gas		\$128,000	\$128,000	\$128,000
2. Electricity		\$0	\$0	\$0
TOTAL SAVINGS IN ENERGY COSTS		\$128,000	\$128,000	\$128,000
NET ANNUAL SAVINGS		(\$199,000)	(\$199,000)	(\$200,000)
NET SAVINGS PER TON OF DRY SLUDGE		(\$8.58)	(\$8.58)	(\$8.62)
SIMPLE PAYBACK PERIOD - YEARS		NA	NA	NA

NOTES

1. Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
2. Average sludge incineration rate of 65 dry tons per day assumed.
3. Sludge incinerators assumed to operate 357 days per year.
4. Average cost for natural gas assumed to be \$0.45/CCF.
5. Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
6. Assume 95% equipment availability.
7. Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
8. Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
9. Cost/savings components are displayed rounded to nearest \$100.
Subtotals and totals are displayed rounded to nearest \$1,000.

Table 8-10
Economic Evaluation
Steam Generation for Indirect Sludge Drying

	FURNACE EXIT TEMPERATURE (DEG. F)		
	1,100	1,200	1,300
A. CAPITAL COSTS			
1. Three Waste Heat Boilers	\$2,090,000	\$2,090,000	\$2,090,000
2. Indirect Sludge Dryer	\$3,460,000	\$3,460,000	\$3,460,000
TOTAL CAPITAL OUTLAY	\$5,550,000	\$5,550,000	\$5,550,000
ANNUALIZED TOTAL CAPITAL OUTLAY	\$484,000	\$484,000	\$484,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT			
1. Operating Labor (Assume operator required 1/2 time, 3 shifts/day, \$15,000/shift/yr.)	\$45,000	\$45,000	\$45,000
2. Maintenance Labor (Assume maint. required 1/2 time, 1 shift/day, \$15,000/shift/yr.)	\$15,000	\$15,000	\$15,000
3. Repairs and Maintenance (Assume 2% of capital cost)	\$111,000	\$111,000	\$111,000
4. Electricity			
a. additional I.D. fan power	\$3,200	\$3,500	\$4,200
b. feedwater and condensate return pumps, etc.	\$31,900	\$31,900	\$31,900
c. sludge dryer	\$70,700	\$70,700	\$70,700
d. sludge conveying	\$3,500	\$3,500	\$3,500
TOTAL OPERATION AND MAINTENANCE COSTS	\$280,000	\$281,000	\$281,000
TOTAL ANNUAL COST	\$764,000	\$765,000	\$765,000
C. ANNUAL SAVINGS IN ENERGY COSTS			
1. Natural Gas	\$465,400	\$592,900	\$801,100
2. Electricity	\$0	\$0	\$0
TOTAL SAVINGS IN ENERGY COSTS	\$465,000	\$593,000	\$801,000
NET ANNUAL SAVINGS	(\$299,000)	(\$172,000)	\$36,000
NET SAVINGS PER TON OF DRY SLUDGE	(\$12.89)	(\$7.41)	\$1.55
SIMPLE PAYBACK PERIOD - YEARS	NA	NA	10.7

NOTES

- Capital recovery factor = 0.0872 (6% interest rate over 20 year period).
- Average sludge incineration rate of 65 dry tons per day assumed.
- Sludge incinerators assumed to operate 357 days per year.
- Average cost for natural gas assumed to be \$0.45/CCF.
- Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
- Assume 85% equipment availability.
- Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
- Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
- Cost/savings components are displayed rounded to nearest \$100. Subtotals and totals are displayed rounded to nearest \$1,000.

Table 8-11
Economic Evaluation
Direct Sludge Dryer

		FURNACE EXIT TEMPERATURE (DEG. F)		
		1,100	1,200	1,300
A. CAPITAL COSTS				
1. Direct Sludge Dryer		\$4,160,000	\$4,160,000	\$4,160,000
TOTAL CAPITAL OUTLAY		\$4,160,000	\$4,160,000	\$4,160,000
ANNUALIZED TOTAL CAPITAL OUTLAY		\$363,000	\$363,000	\$363,000
B. OPERATION AND MAINTENANCE COSTS FOR NEW EQUIPMENT				
1. Operating Labor (Assume operator required 1/2 time, 3 shifts/day, \$15,000/shift/yr.)		\$45,000	\$45,000	\$45,000
2. Maintenance Labor (Assume maint. required 1 shift/day, \$30,000/shift/yr.)		\$30,000	\$30,000	\$30,000
3. Repairs and Maintenance (Assume 2% of capital cost)		\$83,200	\$83,200	\$83,200
4. Electricity				
a. additional I.D. fan power		\$6,500	\$7,000	\$8,000
b. sludge dryer system		\$26,600	\$26,600	\$26,600
c. sludge conveying		\$3,500	\$3,500	\$3,500
d. exhaust gas recirculation fan		\$7,500	\$7,500	\$7,500
5. Natural Gas to Reheat Exhaust Gas		\$405,900	\$450,500	\$495,100
TOTAL OPERATION AND MAINTENANCE COSTS		\$608,000	\$653,000	\$699,000
TOTAL ANNUAL COST		\$971,000	\$1,016,000	\$1,062,000
C. ANNUAL SAVINGS IN ENERGY COSTS				
1. Natural Gas		\$607,800	\$756,500	\$806,400
2. Electricity		\$0	\$0	\$0
TOTAL SAVINGS IN ENERGY COSTS		\$608,000	\$757,000	\$806,000
NET ANNUAL SAVINGS		(\$363,000)	(\$259,000)	(\$256,000)
NET SAVINGS PER TON OF DRY SLUDGE		(\$15.64)	(\$11.16)	(\$11.03)
SIMPLE PAYBACK PERIOD - YEARS		NA	NA	NA

NOTES

- Capital recovery factor = 0.0672 (6% interest rate over 20 year period).
- Average sludge incineration rate of 65 dry tons per day assumed.
- Sludge incinerators assumed to operate 357 days per year.
- Average cost for natural gas assumed to be \$0.45/CCF.
- Average cost for electricity assumed to be \$0.065/kWh, with the average annual equivalent of 1.5 incinerators operating.
- Assume 85% equipment availability.
- Equipment sizes based on capacity for 1,300 deg. F furnace exit temperature.
- Annual Savings in Energy Costs calculated as difference between current operational costs and operational costs for system under evaluation.
- Cost/savings components are displayed rounded to nearest \$100. Subtotals and totals are displayed rounded to nearest \$1,000.