NYSERDA -- 96-2

TESTING FLUIDIZED BED INCINERATORS FOR ENERGY-EFFICIENT OPERATION

SOUTHTOWNS SEWAGE TREATMENT AGENCY

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

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Final Report

Prepared for

THE NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

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ABSTRACT

Two methods for improving the energy efficiency of fluidized bed sludge incinerators were evaluated. The first method used paper pulp and polymer as conditioning agents for municipal sludge instead of lime and ferric chloride. Automatic control of the incinerator was the second method evaluated for energy savings.

To evaluate the use of paper pulp and polymer as conditioning agents, varying quantities of paper pulp were added to the liquid sludge to determine the optimal sludge-to-paper pulp ratio. The effect of the paper pulp and polymer-conditioned sludge on plant operations also was evaluated. When compared to sludge conditioned with lime and ferric chloride, the paper pulp and polymer-conditioned sludge had similar cake release and feed characteristics, higher BTU values for the dry sludge solids, required less auxiliary fuel for incineration, and generated less ash for disposal. The paper pulp and polymer did not have any appreciable negative effects on the operation of the wastewater treatment plant. It was estimated that processing and incinerating the sludge conditioned with paper pulp and polymer resulted in a cost savings of up to $91.73 per dry ton of activated sludge solids.

To evaluate the effect of automatic control, all the incinerator operating parameters including air flow rates, fuel oil feed rates, and sludge feed rates, were automatically monitored and controlled to minimize auxiliary fuel oil use and to keep the incinerator running at optimal conditions. Although effective, the estimated cost savings for automatic control of the incinerator were small.

Keywords:

fluidized bed incinerators
municipal sludge incineration
paper pulp and polymer conditioned sludge
lime and ferric chloride conditioned sludge
automatic incinerator control
waste heat recovery

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This report is dedicated to the memory of Mr. Samuel Oliver, of Automatic Firing, Inc., who passed away during the course of this demonstration project. Mr. Oliver's knowledge and expertise were invaluable to the conception and early progress of this project.

We also wish to acknowledge the contributions of the following people who were instrumental and greatly appreciated in the completion of this project:

NYSERDA; Lawrence J. Pakenas, P.E.; Erie County DEP: Gerald L. Devlin, P.E., Peter Ruffino; Southtowns Sewage Treatment Plant: Glenn Absolom, Mark Fitzgerald, Don Dole, all Plant Operating Staff and Personnel; URS Consultants, Inc., Robert Hoffman, Ralph Gall, Donald McCall, James Lanzo, P.E.; Automatic Firing, Inc.: Jim Pellegrino, Frank Silvernail; IEA, Inc.; and E3 - Killam, Inc.

This project could not have been completed without the patience and persistence of all people involved, sometimes under very trying circumstances

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SUMMARY

A project to improve the energy efficiency of fluidized bed sludge incinerators was demonstrated at the Erie County Southtowns Sewage Treatment Plant in Hamburg, New York.

Plant personnel believed that the cost of sludge incineration could be reduced significantly by using automatic incinerator control, waste heat recovery, and alternative auxiliary fuels, and increasing dewatering efficiency.

The demonstration project, performed on a single fluidized bed incinerator process train at the plant, had three objectives. The primary objective was to determine the effect on sludge incineration using paper pulp and polymer, instead of lime and ferric chloride, as sludge conditioners. It was believed that using paper pulp as an auxiliary fuel and polymer in place of the inert conditioning chemicals would decrease the amount of fuel oil required to sustain combustion. The optimal ratio of paper pulp and polymer to sludge also was determined. The second objective was to compare operating the incineration system in automatic control to operating it in manual control. The third objective was to calculate heat balances for the incineration system and determine the feasibility of waste heat recovery and use.

PAPER PULP AND POLYMER ADDITION

The amount of paper pulp added to the liquid sludge varied from 0% to 20% of the sludge on a dry weight basis. A total of six paper pulp ratios were tested and evaluated. Of the paper pulp ratios tested, adding 5% by weight of sludge was determined to be the optimal ratio from both an economic and an operational standpoint. Pulp addition at 20% by weight was unacceptable. Based on bench scale trials by plant personnel and URS, the polymer dosage rate was held at 12 lbs per dry ton of sludge throughout the project. Paper pulp was added to the sludge in the existing sludge conditioning tank. Polymer was added after the filter press feed pumps and before the filter press.

The effect of the paper pulp and polymer on the conditioned sludge and the various aspects of the incineration process were determined in these areas:

- Sludge Dewaterability;

- Sludge Cake Release and Feed Characteristics;
- Sludge BTU Value;
- Auxiliary Fuel Consumption;
- Air Pollution Control;
- Ash Quality/Quantity; and
- Overall Incinerator Combustion Quality and Efficiency.

Sludge Dewaterability

Ferric chloride and lime will generally produce a dewatered sludge cake with higher solids than sludge conditioned solely with polymer. Adding paper pulp to the liquid sludge did not improve the dewatering capabilities of the polymer. The average total solids of the dewatered sludge conditioned with lime and ferric chloride was 26%. The dewatered sludge conditioned with paper pulp and polymer was consistently less than 25% solids. It is assumed that the lack of improvement in dewaterability is due to the tendency of pulp to bind water. It is difficult to separate the pulp from the water using a conventional filter press.

Sludge Cake Release and Feed Characteristics

The dewatering-press release and incinerator-feed characteristics of sludge conditioned with paper pulp and polymer was comparable to sludge conditioned with lime and ferric chloride. However, the sludge conditioned with only polymer was sticky and unacceptable.

An advantage of conditioning liquid sludge with paper pulp and polymer is that sludge throughput for the complete sludge management system could be increased approximately 25% (based on 5% paper pulp addition) compared to the sludge conditioned with lime and ferric chloride. Much of the increase in throughput is due to significantly smaller amounts of conditioning agents being added to the sludge, and a reduction in the amount of time required to complete a filter press cycle.

Sludge BTU Value

The BTU value of dry conditioned sludge solids increased significantly using paper pulp and polymer as conditioning agents. Lime and ferric chloride add significant solids to the sludge and have essentially no heat content. In contrast, the heat content of the dry pulp solids is very close to the heat content of the dry sludge solids. The calculated heat content of the wet sludge conditioned with polymer and 5% by weight of paper pulp was 28% higher than the calculated heat content of the wet sludge conditioned with lime and ferric chloride. The benefit of adding paper pulp above 10% by weight of sludge appeared to be minimal.

Auxiliary Fuel Consumption

Because the BTU value of the conditioned sludge increased using paper pulp and polymer, the amount of auxiliary fuel oil to incinerate the sludge decreased significantly. The conditioned sludge mix containing 5% pulp showed a 54% decrease in fuel oil use when the incinerator was under manual control, and a 70% decrease when the incinerator was under automatic control. To be conservative (due to the short-term duration of the test) it was assumed that the fuel oil savings would be approximately 30% based on theoretical calculations of fuel savings. Pulp percentages greater than 10% resulted in minimal improvement over the baseline fuel use.

Air Pollution Control

Using paper pulp and polymer as sludge conditioning agents had no negative effects on air emissions from the incinerator. With the exception of mercury, the concentrations of all metals and particulates in the flue gas decreased significantly when the sludge was conditioned with paper pulp and polymer instead of lime and ferric chloride. The levels of mercury in the flue gas increased somewhat, but were still less than one percent of the allowable emissions. The paper pulp and polymer had little, if any, effect on other miscellaneous parameters of the flue stack emissions.

Ash Quality/Quantity

When paper pulp and polymer were used as sludge conditioning agents instead of lime and ferric chloride, the amount of ash produced by incinerating the sludge was reduced by 76% to 87%. Lime and ferric chloride produced a large portion of the ash. The concentrations of metals in the ash increased when paper pulp and polymer were used, but were well below the toxicity limits (as determined by TCLP) for all analyses. The increase in the metals concentrations of the ash may be attributed to a smaller volume of ash. A significant increase in phosphorus concentrations was also observed. There was no noticeable difference in the handling characteristics of the ash.

Overall Incinerator Combustion Quality and Efficiency

When polymer was used for sludge conditioning, the optimal amount of added paper pulp was 5% of dry solids. Conditioning sludge this way would save about $91 per dry ton of sludge solids. Most of the savings would be in lower costs for fuel oil, conditioning chemicals, and ash disposal. The current cost for sludge processing is approximately $425 per dry ton of sludge, based only on operating costs. The total potential savings, based on the 1994 costs and quantities, was estimated to be $182,442. The estimated payback period for the installation of paper pulp and polymer conditioning is approximately 2 years.

AUTOMATIC INCINERATOR CONTROL

Fuel oil use and air emissions were monitored to check the automatic control of the incinerator. It was believed that by using automatic control to adjust parameters such as fuel oil use, air flow, and sludge feed rate, the incineration process could be adjusted faster and more often to react to changing conditions in the incinerator.

Fuel Oil Use

Automatic control of the incinerator during the project reduced fuel oil use by 6.6 gallons per dry ton of sludge solids (approximately 8%), for a savings of approximately $4 per ton. Fine-tuning the control system may yield additional savings. The data show that manual control can be fairly economical compared to automatic control.

Air Pollution Control

Based on data from the project, automatic control of the incinerators decreased the concentrations of most metals in the exhaust gas. How the metals concentrations were reduced is unknown.

HEAT BALANCES

Heat balances, determined for all the sludge mixtures evaluated, confirm that polymer and 5% by weight paper pulp was the optimal mix of sludge conditioning agents. The heat balances also indicate that evaporating water in the sludge accounts for approximately 40% of the heat required for incineration. Reducing the quantity of water in the sludge entering the incinerator would lead to a significant decrease in the amount of fuel oil required for incineration.

WASTE HEAT RECOVERY AND UTILIZATION STUDY

Using the information obtained from the Heat Balance calculations, a Waste Heat Recovery and Utilization Study was performed. The purpose of the study was to identify practicable opportunities for utilizing the heat generated by the sludge incineration process.

A survey of the incineration process and equipment identified three significant sources from which heat is available:

- Incinerator Exhaust Gas (approximately 1380°F, containing significant amounts of abrasive ash)
- Scrubber Water (a low level of heat, 150-180°F, contaminated with wet and sticky ash)
- Radiant Heat from the incinerator and the exhaust ducting (approximately 200°F and 1500°F, respectively)

It was determined that there is no practical method of utilizing the radiant heat from the incinerator shell or the exhaust stack for any purpose other than to continue the current practice of heating the sludge incineration room. The incinerator exhaust gas and the scrubber water were the only two sources of heat evaluated for recovery and utilization in the plant.

Numerous places to utilize the available heat from the two sources were then identified. However, only four of the heat sinks are of any significant magnitude. These four heat sinks are:

- Fluidizing Air Preheat
- Main Building Heat
- Heat for Sewer District #3 Building
- Sludge Preheat / Drying

Preheating the fluidizing air entering the incinerator is one practical option for using heat recovered from the incineration process. In fact, this option has already been implemented at the treatment facility with good results. The estimated payback period for preheating the fluidizing air is approximately 12.9 years. Heating of the main building and the Sewer District #3 Building have estimated payback periods of 15.4

years and 10.9 years respectively. Preheating the sludge feed into the incinerator would be cost effective but difficult to implement alone. As such, this option would probably be done in conjunction with one of the building heat options. The payback period for preheating the sludge, not including the primary costs for the building heat loop, is estimated to be 2.5 years. Drying the sludge would require significant changes in the sludge processing and handling equipment, and may also present additional problems with odors and/or air handling. The payback period for sludge drying was not evaluated as part of this study.

In addition, several smaller heat sinks were identified and evaluated. Because these options for heat utilization are not economical by themselves, they are assumed to be done in conjunction with one of the building heat options. These heat sinks include chlorine vaporization, fuel oil preheating, and scum tank preheating. The potential savings from these alternatives are relatively small, and largely depend upon the capital cost of the equipment that would need to be installed. The payback period determined for these options consider only the additional equipment that would be installed, and do not include the primary costs for the building heat loops. Preheating of the fuel oil is unattractive due to an estimated 109 years required for payback. Chlorine vaporization is estimated to have a payback period of 11.7 years, however, the actual savings may be lower due to the unknown frequency and duration of this heat requirement. Preheating the scum tank may be an attractive alternative due to its simplicity and a potential payback of as little as one year, assuming continuous use.

Cogeneration, using the incinerator exhaust gas to generate electricity, also was evaluated. This option was determined to be unattractive due to the cyclical nature of the incinerator operation.

1. INTRODUCTION

This report describes a project for Testing Fluidized Bed Incinerators for Energy Efficient Operation. This work was performed on a single incinerator process train at the Erie County Southtowns Sewage Treatment Plant in Hamburg, New York.

A large quantity of unwanted sludge is produced each year as a by-product of sewage treatment. Incineration is one viable alternative to reduce the quantity of sludge that ultimately requires disposal. The operating requirements for incinerators, especially for air emissions and ash disposal, can be relatively stringent. If not operated properly, incineration can be expensive compared to other disposal options. For these reasons, incinerators should be operated efficiently and economically.

The New York State Energy Research and Development Authority (NYSERDA) issued Program Opportunity Notice (PON) No. ER-145-89 to test and demonstrate new technologies for instrumentation and automation, heat recovery, ash management, and air pollution control that could lead to energy and other cost savings for incinerators at wastewater treatment plants (WWTPs).

Erie County evaluated its Southtowns treatment facility and determined that several areas of the incineration process could be upgraded. The process areas needing improvement, and new technologies to address them, were identified in a proposal to NYSERDA under the PON. Process areas that were identified included:

- Manual control of the fluidized bed incinerators and the overall sludge combustion process at the treatment plant;
- Only a small amount of the heat input to or generated by the incinerators is recovered;
- A large quantity of auxiliary fuel is used to evaporate the water in the feed sludge; and
- Lime and ferric chloride, used to condition the sludge before dewatering, constitute a large part of the ash material that must be disposed off site.

Erie County proposed that through automatic incinerator control, waste heat recovery, using alternative auxiliary fuels, and increasing dewatering efficiency, the costs of sludge management could be reduced significantly at the treatment plant. Based on the Erie County proposal, NYSERDA agreed to co-fund the demonstration project under the PON.

2. TREATMENT PLANT PROCESSES AND OPERATION

All work described in this report was performed at the Southtowns Sewage Treatment Plant in Hamburg, New York. The plant was constructed in 1981 by the Erie County Southtowns Sewage Treatment Agency, under an intermunicipal cooperative agreement. Agency members are Erie County, Town of Hamburg, Village of Hamburg, Mount Vernon Sewer District, and Wanakah Sewer District. The Agency, in turn, contracted with Erie County to be its fiscal and operating agent. The treatment facility, operated by the Erie County Department of Environment and Planning (ECDEP), is relatively new, well maintained, and in excellent condition.

The Southtowns Advanced Secondary Sewage Treatment Plant is an activated sludge plant with a design wastewater treatment capacity of 16 million gallons per day (MGD). The present operating rate for the plant is approximately 12 MGD. The principal wastewater treatment processes at the plant include: screening chambers, pure-oxygen activated sludge reactors, bioclarifiers, phosphorus removal, rapid sand filtration, and chlorination. Figure 2-1 shows a flow diagram of the wastewater treatment and sludge management system.

The PhoStrip process used for phosphorus removal normally would generate a chemical sludge; however, with phosphate banned from retail detergents, the plant can remove phosphorus in excess of the limitations without adding chemicals, and there is usually no phosphate sludge.

Biosludge is dewatered by plate and frame filter presses, and incinerated in two Dorr Oliver fluidized bed incinerators.

This demonstration project focused on four process areas of the treatment system that deal with waste activated sludge from the bioclarifiers: sludge processing; sludge incineration; air pollution control; and ash handling. Each of these is described in the following sections.

2.1 Sludge Processing

The excess sludge produced by the activated sludge reactors and collected from the bioclarifiers is subsequently incinerated. Before it can be efficiently incinerated, the sludge must be dewatered using three

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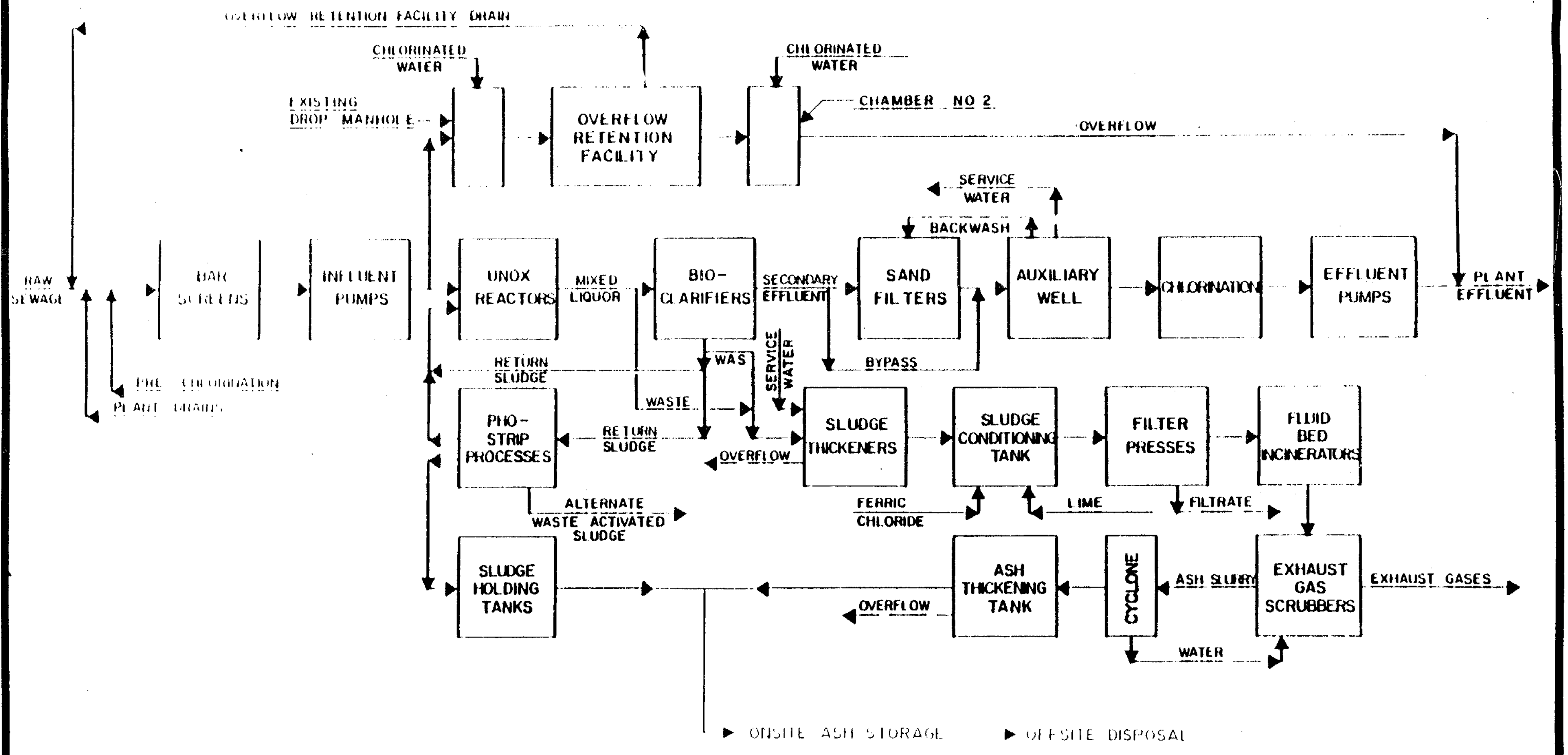

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WASTEWATER TREATMENT PROCESS

FIGURE 2-1

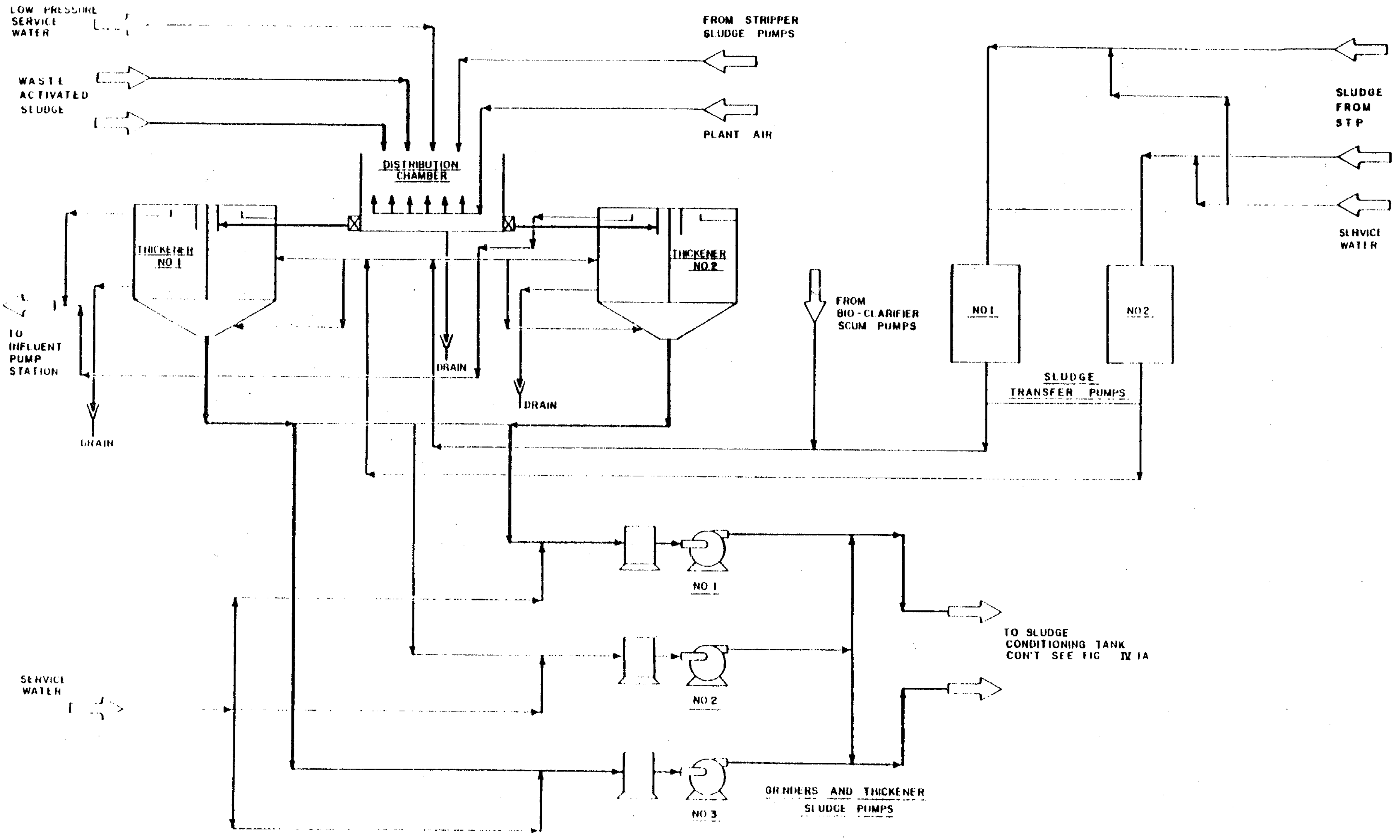
different steps: thickening; conditioning; and pressure filtration. Figures 2-2 and 2-3 illustrate the sludge treatment process. Thickening is done in large cylindrical tanks where solids in the wastewater are allowed to settle, forming a blanket of sludge on the bottom of the tank. Rotating rake arms slowly stir the sludge, pushing the solids toward a sludge hopper, where they are pumped through a grinder to a sludge-conditioning tank. In the next step, ferric chloride and lime are blended with the sludge to improve its dewaterability. Plate and frame filter presses are then used to dewater the sludge before incineration. When the sludge is removed from the activated sludge reactors, the sludge is only 0.1 to 0.5 percent solids. By the time the sludge is removed from the filter press, the solids content has been increased to between 25 and 30 percent solids.

2.2 Sludge Incineration

The dewatered biological sludge cake from the filter press is fed by a drag conveyor and screw feeder into the fluidized bed incinerators at the plant. Figure 2-4 illustrates the incineration process. The incinerators burn the sludge in a bed of sand that is fluidized or put into suspension by blowing combustion air through the unit. The agitation in the fluidized zone causes the sludge to be rapidly dispersed and provides optimum contact with the hot sand and combustion air. The organics from the sludge remain in the fluidized sand zone until they have been burned. The noncombustible materials are reduced to a fine ash by the agitation of the sand. When the ash has been reduced to a material lighter than the bed sand, it is carried out of the incinerator with the exhaust gas.

The reactor part of the incinerator is a cylindrical unit lined with refractory brick. The air for the combustion of the sludge enters the bottom of the reactor and is fed upward through a tweyre (orifice plate or diffuser between the windbox and fluidized bed), the sand supporting grid, and then into the sand bed. The sludge cake is fed to the incinerator through a screw conveyor. The exhaust air from the incinerator normally passes through a heat exchanger to preheat the combustion air fed into the incinerator. The heat exchanger was out of service during the demonstration project. The temperature of the combustion air and efficiency of the incinerator, therefore, would probably be higher than this project indicates.

In 1994, a total of 1,989 tons of sludge (dry weight) were incinerated. This is an average rate of just over 454 lbs. per hour. Although there are two sludge processing trains and fluidized bed incinerators at the



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WASTE ACTIVATED SLUDGE CONDITIONING SYSTEM

FIGURE 2-2

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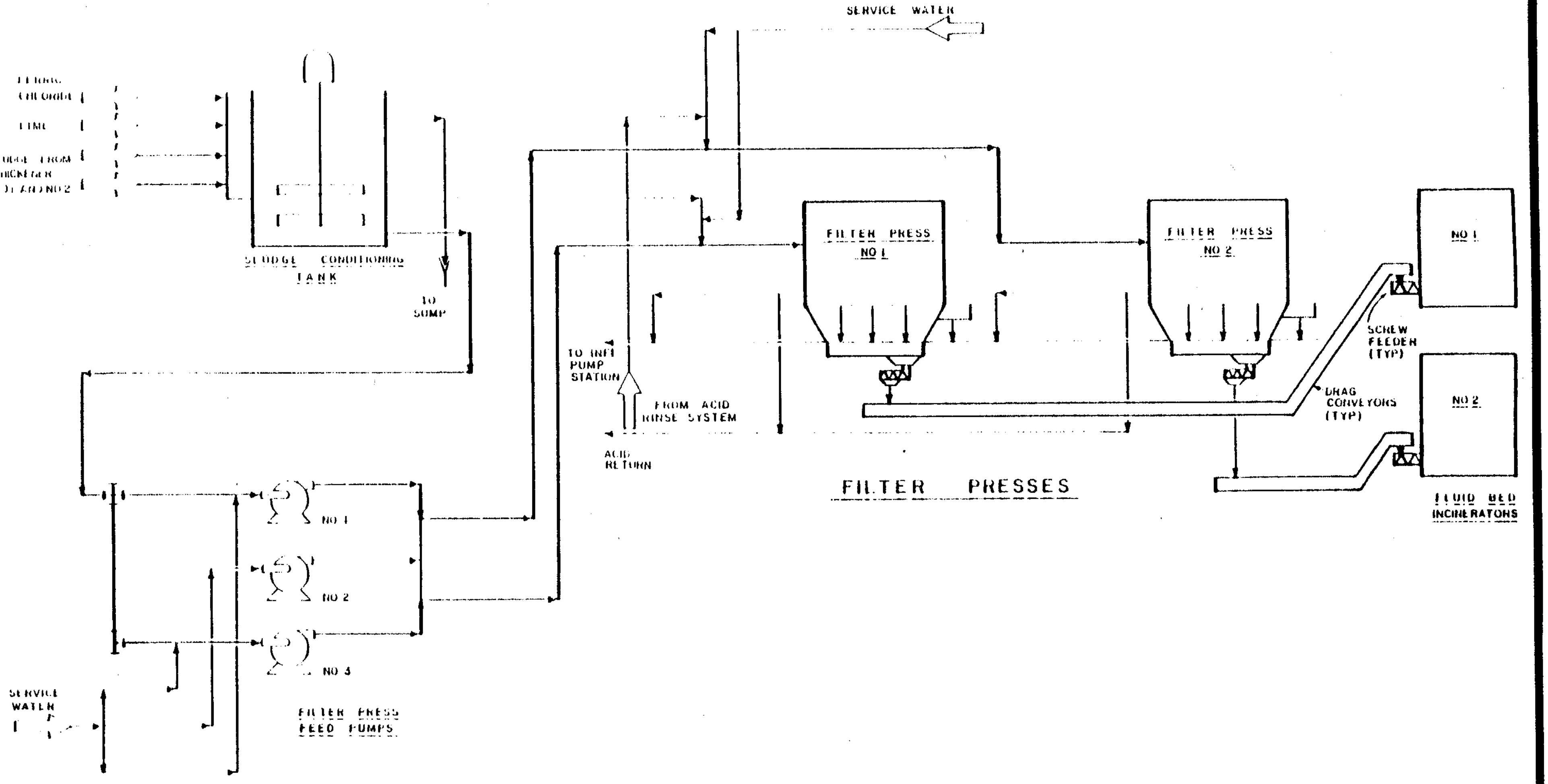

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WASTE ACTIVATED SLUDGE CONDITIONING SYSTEM

FIGURE 2-3

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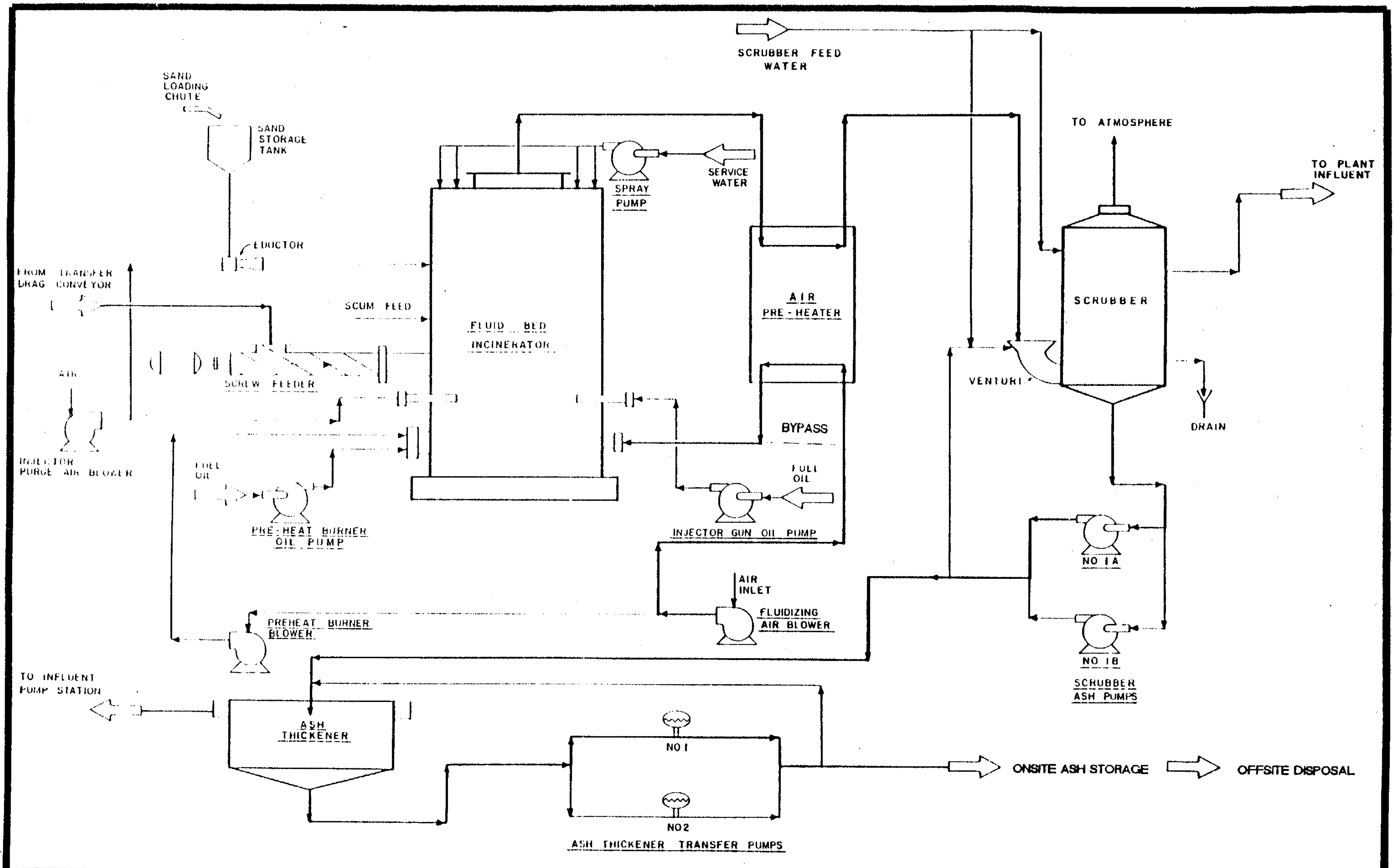

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SLUDGE AND SCUM INCINERATION PROCESS

FIGURE 2-4

plant, one unit is usually running at full capacity while the other unit is shutdown. The incinerators operate concurrently about 25 percent of the time.

2.3 Air Pollution Control

Before the exhaust gases generated by sludge incineration can be released into the atmosphere, ash residue must be removed. The ash-laden gases, after passing through the heat exchanger, are mixed with water and forced through a narrow venturi where intimate contact between the gases and water is achieved. The water not only removes the majority of the ash from the exhaust air, it also cools the exhaust air. Before the exhaust air exits the building stack, it is cleaned further in a tray scrubber and then passed through an entrainment separator to remove any water droplets. Figure 2-4 shows the air pollution control equipments.

2.4 Ash Handling

When the ash residue has been removed from the combustion exhaust gases using the venturi scrubber, the ash has to be removed from the scrubber water. The scrubber water is first passed through a cyclone that removes the ash and recycles part of the water back to the scrubber. The ash then goes to an ash thickener where water is drained. The concentrated ash and water mixture flows to an ash dumpster truck, where more excess water is decanted from the mixture. The ash dumpster truck takes the ash to a temporary onsite storage location where it is stockpiled to allow the ash to dry. Finally, the ash is disposed at an off-site location. Figure 2-4 shows ash handling equipment. The amount of ash produced in 1994 was 1,218 dry tons. A majority of the ash is produced from the inorganic ferric chloride and lime used for sludge processing.

3. SUMMARY OF PROJECT OBJECTIVES

Through automatic incinerator control, waste heat recovery, the use of auxiliary fuels, and improving dewatering efficiency, plant personnel believed the cost of operations and sludge incineration at the treatment plant could be significantly reduced.

The first objective was to determine the effect of adding paper pulp and polymer, instead of lime (calcium hydroxide) and ferric chloride, to condition the sludge before incineration. Operating the system with the modified sludge feed stream was compared to operating it under standard conditions. The system was monitored to determine the effect of adding pulp and polymer in these areas:

- sludge dewaterability;
- sludge cake release and feed characteristics;
- sludge moisture content and BTU value;
- auxiliary fuel consumption;
- incinerator combustion quality and efficiency;
- air pollution control equipment operation; and
- ash quality/quantity.

Five different mixtures of pulp and polymer were evaluated to determine their effect on sludge management operations and determine the optimum ratio for adding these to the sludge stream.

The second objective was to evaluate manual and automatic control of the incineration system. Automatic operation was evaluated for auxiliary fuel use and air pollution control.

The third objective was to calculate heat balances for the incineration system and evaluate waste heat recovery and use.

4. INSTRUMENTATION AND CONTROL EQUIPMENT

Of the many different components needed to control and monitor the incineration system, some existed and some had to be installed for this project. Presently, the incinerator is manually controlled. All incineration variables, including the air flow rates, sludge feed rates, and fuel oil feed rates are controlled manually. The only automatic controls are emergency safety shut-downs that eliminate possible damage to the incinerator and prevent hazards to those working in the plant. The emergency safety shut-downs, standard for the fluidized bed incinerator, were included at the time of purchase. These safety shut-downs cannot be removed or overridden, so they were left, unmodified, in place and are not discussed further in this report.

After the incinerators were installed, and before this project, additional monitoring and manually controlled instrumentation was purchased to log data and record incinerator operating conditions. Many instruments were connected to the annunciator panel in the incinerator control room, and were easily accessible for tie-in to the new data acquisition computer and system controller. Table 4-1 lists the existing and new instrumentation used in the project.

4.1 Existing Equipment

Thermocouples (T-1 through T-7)

The thermocouples (temperature transmitters) consist of a filled system with a temperature bulb and a force balance transmitter. The transmitters have an output of 4-20 mA.

Flow Meter - Electromagnetic (F-1)

This flowmeter measures the flow of fluidizing air into the incinerator. The magnetic flow meter senses the flow through a metering tube mounted in the fluidizing air line. The flowmeter transmits a millivolt signal linearly proportional to flow.

Table 4-1

Summary of Control System Components

Southtowns Sewage Treatment Plant

Instrument Number	Instrument Type	Variable Monitored/Controlled	Instrument Purpose	Status	
				Existing	Installed for Project
T-1	Thermocouple	Air Preheater Outlet Temperature	Test Data	X	
T-2	Thermocouple	Wind Box Temperature	Test Data	X	
T-3	Thermocouple	Incinerator Bed Temperature	Monitoring for Control	X	
T-4	Thermocouple	Freeboard Temperature	Test Data	X	
T-5	Thermocouple	Incinerator Outlet Temperature	Test Data	X	
T-6	Thermocouple	Venturi Scrubber Flue Gas Inlet Temperature	Test Data	X	
T-7	Thermocouple	Venturi Scrubber Flue Gas Outlet Temperature	Test Data	X	
T-8	Thermocouple	Fluidizing Air Preheater Inlet Air Temperature	Test Data		X
T-9	Thermocouple	Fluidizing Air Preheater Flue Gas Inlet Temperature	Test Data		X
T-10	Thermocouple	Fluidizing Air Preheater Flue Gas Outlet Temperature	Test Data		X
T-11	Thermocouple	Purge Air Temperature	Test Data		X
F-1	Flow Meter - Electromagnetic	Fluidizing Air	Test Data	X	
F-2	Flow Meter - RPM Conversion	Fuel Oil	Test Data	X	
F-3	Flow Meter - RPM Conversion	Sludge Feed	Test Data	X	
F-4	Flow Meter - Electromagnetic	Purge Air	Test Data		X
FC-1	Flow Control - DC Motor Controller	Fluidizing Air	Test Data	X	
FC-2	Flow Control - DC Motor Controller	Fuel Oil	Test Data	X	
FC-3	Flow Control - Air Damper	Sludge Feed	Test Data	X	
P-1	U-tube Manometer	Wind Box	Test Data	X	
P-2	U-tube Manometer	Freeboard	Test Data	X	
P-3	Differential Pressure Manometer	Constriction Plate Pressure Drop	Test Data	X	
P-4	U-tube Manometer	Scrubber Inlet	Test Data	X	
P-5	U-tube Manometer	Heat Exchanger	Test Data	X	
L-1	Differential Pressure Manometer	Bed Level	Test Data	X	
FG-1	Gas Analyzers	Incinerator Stack Gas Composition	Test Data		X
PLC-1	Programmable Logic Controller	-	Monitoring for Control		X

Flow Meter - RPM Conversion (F-2, F-3)

The fuel oil feed rate and the sludge feed rate are measured with a RPM (revolution per minute) conversion flow meter, a calibrated rheostat. The revolutions per minute of the sludge feed screw and fuel oil feed are converted to a flow rate.

Flow Control - Air Damper (FC-1)

The fluidizing air flow is manually controlled from the instrument panel. This unit includes a fluidizing air flow butterfly control valve with cylinder operator and positioner, and current-to-pneumatic convertor.

Flow Control - DC Motor Controller (FC-2, FC-3)

The DC motor flow control unit consists of a variable rheostat that varies the current available to the direct current motor which drives the screw feeder, thus varying the speed of the screw.

Pressure Sensor/Transmitter (P-1, P-2, P-4, P-5)

Pressure sensors measure the pressure at various points in incinerator train including the wind box, freeboard, scrubber inlet, and the heat exchanger. The pressure sensors are the U-tube manometer type. The U-tube is open to the atmosphere to obtain a gauge pressure. The pressure transmitter is the strain-gauge type. The units have an actuation range of zero to 150 inches of water. The output of the transmitter is a 4-20 mA signal.

Bed Level Sensor/Transmitter (L-1)

The bed level sensor is the differential pressure manometer type. The pressure transmitter is the strain gauge type. The units have a range of actuation from zero to 150 inches of water. The output of the transmitter is a 4-20 mA signal.

Constriction Plate Pressure Drop Sensor (P-3)

The constriction plate pressure drop sensor is the differential pressure manometer type. The pressure difference is measured between the windbox pressure and bed pressure. The pressure transmitter is the strain gauge type. The units have a range of actuation from zero to 150 inches of water. The output of the transmitter is a 4-20 mA signal.

4.2 New Equipment

Several new monitoring systems were installed to provide complete monitoring and control of the incineration process. New thermocouples, a flow meter, and flue gas analyzers for oxygen, carbon monoxide, and total hydrocarbons were installed. A data acquisition system was then installed to automatically record all the monitored parameters in computerized format. Finally, a programmable logic controller (PLC) was installed to control and optimize the incineration process based on key system variables. Each of the new components is described in this section.

Oxygen Analyzer (FG-1)

The oxygen analyzer determines the concentration of oxygen in the flue gas exiting the incinerator stack. The incinerator controller then uses the oxygen level in the stack to determine the appropriate fluidizing air flow rate for the system.

The oxygen concentration in the flue gas is determined using a zirconia cell maintained at a temperature of approximately 1000°F. The zirconia cell is shaped like a cone and is coated with a layer of porous platinum that acts as a catalyst to promote the electrochemical reaction of electrons and oxygen molecules. The reaction permits mobility of the oxygen molecules within the zirconium lattice when the lattice is heated to 1000°F. The porous platinum coating is also an electrode. The open circuit voltage at the electrode is a function of the partial pressure of oxygen on both sides. The partial pressure on one side of the probe is maintained at a constant level, usually that of air. The electro-magnetic force that develops indicates oxygen concentration on the other side of the probe. The sensor is protected by a stainless steel sintered shield that allows the flue gas to enter the sensor but prevents particulates from entering. Output from the probe is a 4-20 mA DC signal.

Carbon Monoxide Analyzer (FG-1)

The carbon monoxide analyzer determines the concentration of carbon monoxide in the flue gas exiting the incinerator stack. The level of carbon monoxide does not control the incineration system; it indicates incinerator efficiency.

The analyzer operates on the non-dispersive infrared absorption principle using the single-beam method with an opto-pneumatic double-layer detector. A radiation spiral is heated to approximately 1112°F to emit infrared radiation. After the radiation has passed the analyzer cell, its intensity is measured selectively in a double-layer detector cell. The intensity of the radiation after passing through the analyzer cell indicates the carbon monoxide concentration. Output from the probe is a 4-20 mA lineal signal, proportional to the carbon monoxide concentration.

A portable stack sample conditioner was used with the carbon monoxide analyzer. The sample conditioner was placed before the gas analyzer to remove moisture from the sample without removing the gas components of interest. Removing moisture prevents water from condensing in sample filters, pumps, and gas analyzers. A gas sample pump pulls the sample from the stack, through a heated hose to the sample conditioning unit, and then into the gas analyzer. The maximum influent sample temperature allowable is 400°F. The heated hose between the flue stack and the sample conditioning unit keeps the sample from cooling and condensing before conditioning. According to the manufacturer, no carbon monoxide in the stack sample is lost due to sample conditioning.

Total Hydrocarbon Analyzer (FG-1)

The Total Hydrocarbon (THC) Analyzer determines the concentration of hydrocarbons in the incinerator flue gas. The level of THC in the flue gas indicates the efficiency of the incineration process. Ideally, if incineration is effective and complete, there should be relatively few hydrocarbons in the flue gas.

The THC analyzer uses Flame Ionization Detection (FID) based on measuring the current produced by ions through an electrostatic field caused by combustion and polarization. The instrument reports the response equivalent to a known response factor. To prevent condensation, all parts in contact with the sample are heated to 400°F. The flue gas sample from the incinerator stack is transported to the analyzer through a heated hose, similar to the carbon monoxide unit. Output from the unit is a 4-20 mA lineal signal, proportional to the level of hydrocarbons.

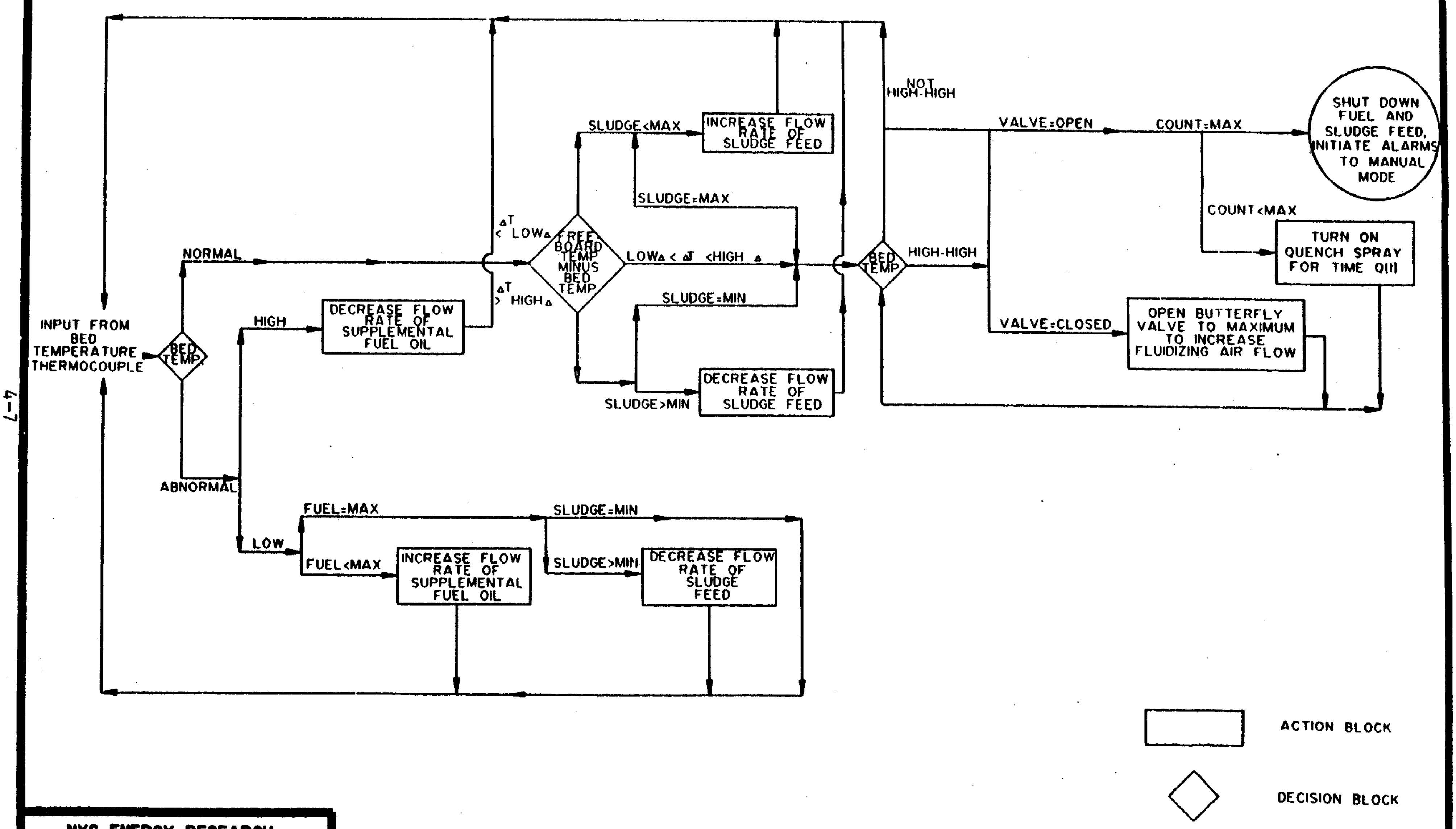
A sampling probe and filter are used to extract a sample from the exhaust stack. Filtration is done in the heated zone to prevent sample condensation that would corrode the equipment. Filtration removes fine ash that would plug the heated hose and hamper subsequent steps in the gas sample analysis. The filter is designed for continuous operation, with timed, periodic blow-back cycles that clean the system with blasts of clean air.

Mastermind Controller (PLC-1)

Figure 4-1 shows the flow diagram the Mastermind, a versatile combustion control and data acquisition system, uses to control the incineration system. Three control loops are programmed into the Mastermind controller. The first loop controls the fuel oil flow to the incinerator based on the bed temperature. The second loop controls the fluidizing air flow rate based on the oxygen sensor in the stack and data from the air flow transmitter. The sludge feed rate is controlled by the third loop in the control system. The freeboard temperature and the bed temperature transmitters determine the sludge feed rate to the incinerator. This control loop is active only when the bed temperature is normal, or when the bed temperature is high and the oil flow rate is at a minimum.

In addition to controlling the fuel oil flow, the fluidizing air flow, and the sludge flow rates, the Mastermind also monitors the incinerator bed temperature to be sure the incinerator operates within safe limits. If the bed temperature goes above the "High Bed Temp" setting, an alarm condition occurs, fluidizing air is maximized, and the sludge feed rate is decreased to a minimum. If these actions fail to lower the bed temperature, bed quench sprayers are activated. If the bed temperature is still too high, the system is shut down.

In addition to controlling the incinerator operation, the Mastermind collects data from 24 monitoring points that are sent to the Data Acquisition system.



NYS ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

ERIE COUNTY DEP

URS CONSULTANTS, INC.

SOUTHTOWNS ADVANCED SECONDARY SEWAGE TREATMENT PLANT
LOGIC CONTROL OF BED TEMPERATURE

FIGURE 4-1

Data Acquisition Unit (PLC-1)

The Data Acquisition system works in conjunction with the Mastermind controller. All monitoring points are sampled by the computer once per second. An average of each point is calculated once per minute, and this one minute average is stored in a computer database. The file is in an ASCII format so it may easily be imported into standard spreadsheet or database programs. Spreadsheet software was included in the computer system to allow the plant operator to observe and manipulate the data. Incineration variables monitored by the system are those in Table 4-1. The computer provides graphic user interface screens that represent the process being monitored and gives digital readouts of several key parameters. Four-hour trends and system setpoints are also indicated. The computer monitors the Mastermind controller and conveys actions being taken.

Thermocouples (T-8 through T-11)

The thermocouples/thermowells measure the purge air temperature, the temperature of the fluidizing air into the air preheater, and the temperature of the flue exhaust gas into and out of the air preheater.

Flowmeter - Electromagnetic (F-4)

The electromagnetic flow meter measures the flow rate of purge air into the incinerator using an annubar, a primary flow sensor designed to produce a differential pressure proportional to the air flow.

5. PROJECT HISTORY AND BACKGROUND

Work on the demonstration project began in March 1991. Most tasks proceeded according to the plans without problems. All control and monitoring equipment was installed and ready for startup by August 1992. However, before the demonstration and monitoring task could begin, the instrumentation and control system start-up and check-out tasks had to be finished. These tasks involved starting and operating all the equipment for two weeks, or until URS and the ECDEP were confident the equipment was ready for continuous use. This task was to ensure the demonstration project could proceed without interruptions caused by equipment problems. URS and its subcontractor, Automatic Firing, attempted to complete this task five times, beginning in September 1992. Most problems associated with completing this task were due to harsh conditions at the original flue gas sampling location.

The original flue gas sampling point was located in the main flue duct off the incinerator to keep the monitoring point as close as possible to the combustion source and for consistency with the sampling points on other incinerator demonstration projects. However, the conditions in the flue stack from a fluidized bed incinerator are much harsher than the conditions in other types of incinerators. The high temperature and acidic conditions of the flue gas damaged sample probes and lines. Additionally, transport of the ash and moisture-laden flue gas samples, coupled with the temperature-sensitive monitoring equipment, created a very difficult "materials handling" problem.

It was ultimately decided that sampling points for carbon monoxide and total hydrocarbons would be moved to a location after the exhaust gas scrubber. The decision to relocate the instruments was based on calculations and information that concluded moving the sample location would be in the best interest of the project, and should not significantly affect flue gas measurements. Problems encountered during attempts to startup the system monitoring components are summarized in chronological order below.

First Startup Attempt - September 1 through 4, 1992

Problems encountered during the first attempt to startup and operate the incinerator control and monitoring systems include:

1) Three thermocouples monitoring temperatures in the incinerator system failed. Two were damaged when incinerator flue gas reached normal operating temperatures. After examination by the manufacturer, it was determined the thermocouples had incorrect bore tolerances, so the thermocouples were damaged when the incinerator's heat caused them to expand more than their capacity. The third thermocouple gave questionable readings during system checkout. The manufacturer thoroughly inspected and tested this thermocouple but could find no deficiencies. Faulty thermocouples were repaired and reinstalled.

2) Another problem developed with the total hydrocarbon and the carbon monoxide analyzing systems. These two monitoring systems consist of sample probes located in the flue stack directly off the top of the incinerator, sample transfer lines, heated hoses to transport the sample at an acceptable temperature, a sample conditioning unit (carbon monoxide only), and the sample analyzers. While the analyzers for these two systems appeared to be operating correctly, problems were encountered in the connection between the sample probes and the sample transfer lines. The sample must be cooled from the flue gas temperature (1200°F - 1600°F) to a temperature less than 475°F, to avoid damaging the heated hoses. The samples have a high moisture content and must be kept at a temperature higher than 300°F to minimize the risk of hydrocarbon compounds condensing. Maintaining the temperature from 300°F to 475°F was difficult because the sample flow rates were too low. Periodic purging of the system sample lines with added to the problem. The purging cooled the lines between each sampling event, causing condensation when the warm, moist sample air reentered the cool lines. Condensation was also a problem during system startup when all system components were at ambient temperatures.

To maintain the temperature in the sample lines, several modifications were made. Heat tracing and additional insulation were added to the sample transfer lines and valves to keep the sample at an adequate temperature. The sample air purge lines also were insulated.

3) Ash in the flue gas blocked the sample transfer lines and probes, requiring periodic cleaning of the lines and probes. If allowed to accumulate, ash could plug the lines and valves, and damage the analyzers. Additional piping was installed to allow the use of high pressure (80 psi) air to periodically purge ash from the sample transfer lines and probes.

4) Minor problems discovered in the computer software used to control the incineration system and collect and store monitoring data included memory conflicts among software packages and a malfunctioning message box. The manufacturer corrected these problems.

5) Vibration of the flue gas sample lines was a significant problem during the first startup attempt. Under normal operation, the fluidized bed incinerators vibrate considerably. Because the sample probes and lines were mounted on the flue stack directly off the incinerators, these lines, which have small diameters, began to vibrate, loosen, and crack. To rectify the problem, isolators and additional pipe supports were installed on the sample collection and transfer lines.

Second Startup Attempt - September 28 through 30, 1992

Despite the modifications made to the system after the first attempt, problems related to the harsh conditions of the flue gas persisted during the second system startup and checkout. Problems encountered included:

1) The sample collection lines installed in the system were originally copper; however, due to the presence of chlorides and the elevated temperature of the flue gas, the copper lines were quickly destroyed by corrosion. The copper sample lines were replaced with stainless steel.

2) Despite using compressed air to periodically purge sample lines and probes, ash and particulates continued to build up in the sample lines and at the tip of the total hydrocarbon analyzer probe in the flue stack. In a further attempt to alleviate this

problem and to keep sample lines clean, the duration and frequency of the compressed air purges were increased and timers were added to control the purge air cycles.

3) Cooling of the flue gas samples, and condensation in the sample lines continued despite additional heat tracing and insulation added to the sample lines. In a second attempt to maintain the system's temperature, purge lines were relocated and heat tracing and insulation were added.

Third Startup Attempt - October 2, 1992

While the monitoring instrumentation and the data acquisition system were operational, condensation and buildup of solids in the lines of the total hydrocarbon analyzer continued to be a problem during the third attempt at startup and operation.

1) Due to sample cooling and condensation, the carbon monoxide analyzer failed. To rectify the situation the original heat tracing that was installed on the sample collection line after the first attempted startup was removed and replaced with heavy-duty industrial heat tracing. Insulation also was added to the sample acquisition lines and the purge air lines.

2) Despite the increased frequency and duration of the purge air cycles, ash particulates continued to clog the sample lines and probes for the oxygen and the total hydrocarbon analyzers. All piping and filters were cleaned, and purging the lines with high pressure air increased. In addition, a filter was placed on the line to the hydrocarbon analyzer to remove ash particulates.

3) The sample collection lines cracked. These lines, originally copper, had been changed to Type 304 stainless steel. However, this material still was not adequate to withstand conditions in the flue exhaust of the incinerator. To resolve this problem, the lines were replaced with Type 316L stainless steel flexible tubing.

Fourth Startup Attempt - November 2, 1992

As in the previous attempts, the conditions of the flue exhaust, especially the high concentrations of particulates, were the greatest challenge in trying to operate the system.

1) The total hydrocarbon analyzer was on line for less than 24 hours before the buildup of ash and particulates forced a shutdown of the test. The lines became clogged with particulates although several times during the 24-hour period they were manually purged and cleaned in addition to timed automatic purging.

2) The oxygen analyzer had been on-line and operating correctly for approximately one week before the test when a weld at the oxygen probe broke. A new oxygen probe was ordered and installed.

3) They were minor problems with the computer data acquisition software. The computer vendor was contacted to resolve them.

4) In attempting to eliminate condensation, insulation was added to the purge lines. Two heating units were also added to the total hydrocarbon analyzer system.

5) The Type 316L stainless steel flexible tubing, used for the sample transfer lines, failed after 48 hours due to the system's harsh conditions.

Fifth Startup Attempt - February 24 through March 1, 1993

During the fifth startup attempt, the oxygen and the carbon monoxide analyzers worked properly. However, problems with the total hydrocarbon analyzer could not be resolved. Ash and particulates continued to build up on the probe, filters, and lines. Cooling of the sampling system, which allowed condensation to form, damaged the sample piping and the analytical equipment.

Following the fifth attempt at startup and operation of the stack monitoring systems, URS and their subcontractor, Automatic Firing, reviewed the system. An exhaustive search for experts and people with experience in combustion and analytical testing was conducted. No supplier/manufacturer or engineering firm/expert could be found with experience in sampling high-temperature flue gases from the main exhaust of a fluidized bed incinerator burning sludge conditioned with lime and ferric chloride.

At this point, the only logical resolution to the problem was relocating the flue gas sampling point beyond the incinerator's Venturi scrubber. This sampling point would not have the severe conditions associated with sampling the main incinerator flue, yet it would provide adequate information to control and monitor the system. This was demonstrated by calculations based on actual conditions.

In November 1993, all parties decided that sampling locations for carbon monoxide (CO) and the THC monitors would be moved to a point after the incinerator exhaust scrubbers. This was thought to be the best way to alleviate the materials handling problems that plagued the project from the beginning. The location of the O_2 probe was not moved because problems with this probe had not involved materials handling. The O_2 analyzer is a probe in the flue stack and does not have sample lines to plug, whereas the THC and CO monitors have sample transfer lines and conditioning systems. The THC probe is the most complex due to its specific temperature requirements.

At the same time, the incinerator air preheater (heat exchanger) developed significant leakage, causing fluidizing air to short circuit into the exhaust. A new exchanger was ordered, but was not scheduled to be ready until early 1995. Thus, for the duration of the project, the fluidizing air was piped directly to the incinerator windbox without preheating. Although the overall incinerator efficiency would be lower, the impact on fuel oil use resulting from paper pulp and polymer sludge conditioning and automatic incinerator control should not be significant.

The demonstration and monitoring task began in March 1994, after relocating the CO and THC sampling locations, and the successful startup and check-out of incinerator control and monitoring equipment. Table 5-1 shows the actual dates when each baseline and sludge mixture test was performed. The first of the two baseline tests began March 10, 1994. Demonstration tests were hampered by several problems that developed after the beginning of the baseline testing.

Table 5-1

Dates of Analytical Testing and Monitoring - 1994

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			03/09	03/10 Baseline #1 Begins Baseline #1-1	03/11 A (2) D (1) Baseline #1-2	03/12 Baseline #1-3
03/13 Oxygen Probe Breaks	03/14	03/15	03/16	03/17	03/18	03/19
03/20	03/21	03/22	03/23 Monitoring Resumes Baseline #1-4	03/24 Baseline #1-5	03/25 A (2) D (1) Baseline #1-6	03/26 Baseline #1-7
03/27 Baseline #1-8	03/28 Baseline #1-9	03/29 Problems w/ Oxygen Probe Noted Baseline #1-10	03/30 A (2) D (1) Baseline #1-11	03/31 Baseline #1-12	04/01 Good Friday Baseline #1-13	04/02 Baseline #1-14
04/03 Easter Baseline #1-15	04/04	04/05	04/06	04/07	04/08	04/09
04/10	04/11	04/12	04/13	04/14	04/15	04/16
04/17	04/18	04/19 Assume Oxygen Probe Fixed	04/20 Test Run	04/21 Test Run	04/22 Test Run	04/23 Baseline #2-1
04/24 Baseline #2-2	04/25 Baseline #2-3	04/26 Baseline #2-4	04/27 A (2) A-MS,MSD (1) D (1) Baseline #2-5	04/28 Baseline #2-6	04/29 Baseline #2-7	04/30 Baseline #2-8

Table 5-1

Dates of Analytical Testing and Monitoring - 1994

<table>
<tr><th>Sunday</th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th><th>Saturday</th></tr>
<tr><td>05/01</td><td>05/02</td><td>05/03
A (2)
B (1)
B-MS (1)
D (1)</td><td>05/04</td><td>05/05
A (2)
D (1)</td><td>05/06</td><td>05/07</td></tr>
<tr><td>Baseline #2-9</td><td>Baseline #2-10</td><td>Baseline #2-11</td><td>Baseline #2-12</td><td>Baseline #2-13</td><td>Baseline #2-14</td><td>Baseline #2-15</td></tr>
<tr><td rowspan="2">05/08</td><td>05/09</td><td>05/10</td><td>05/11</td><td>05/12</td><td>05/13</td><td rowspan="2">05/14</td></tr>
<tr><td colspan="5">Fluidized Bed Incinerator Down for Maintenance and Oxygen Probe Repair</td></tr>
<tr><td rowspan="2">05/15</td><td>05/16</td><td>05/17</td><td>05/18</td><td>05/19</td><td>05/20</td><td rowspan="2">05/21</td></tr>
<tr><td colspan="5">Selection of Polymer/Pulp Mixtures for Testing</td></tr>
<tr><td rowspan="2">05/22</td><td>05/23</td><td>05/24</td><td>05/25</td><td>05/26</td><td>05/27</td><td rowspan="2">05/28</td></tr>
<tr><td colspan="5">Install Polymer Feed System</td></tr>
<tr><td rowspan="2">05/29</td><td>05/30</td><td>05/31</td><td>06/01</td><td>06/02</td><td>06/03</td><td rowspan="2">06/04</td></tr>
<tr><td colspan="5">Install Polymer Feed System</td></tr>
<tr><td rowspan="2">06/05</td><td>06/06</td><td>06/07</td><td>06/08</td><td>06/09</td><td>06/10</td><td rowspan="2">06/11</td></tr>
<tr><td colspan="5">Install Polymer Feed System</td></tr>
<tr><td rowspan="2">06/12</td><td>06/13</td><td>06/14</td><td>06/15</td><td>06/16</td><td>06/17</td><td rowspan="2">06/18</td></tr>
<tr><td colspan="5">Install Polymer Feed System</td></tr>
</table>

Table 5-1

Dates of Analytical Testing and Monitoring - 1994

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
06/19	06/20	06/21	06/22	06/23	06/24	06/25
	Install Polymer Feed System					
06/26	06/27	06/28	06/29	06/30	07/01	07/02
	Install Polymer Feed System					
07/03	07/04	07/05	07/06	07/07	07/08	07/09
	Repair Oxygen Probe					
07/10	07/11	07/12	07/13	07/14	07/15	07/16
	Misc. Scheduling Problems					
07/17	07/18	07/19	07/20	07/21	07/22	07/23
	Misc. Scheduling Problems					
07/24	07/25	07/26	07/27	07/28	07/29	07/30
	Misc. Scheduling Problems					
07/31	08/01 A (4) B (1) C (4) D (3)	08/02 A (4) B (1), C (4) C-MS,MSD (1) D (3)	08/03 A (4) B (1) C (4) D (3)	08/04 A (4) A-MS,MSD (1) B (1), C (4) D (3)	08/05 A (4) B (1) C (4) D (3)	08/06
	Mix #1-1, 1-2	Mix #2-1, 2-2	Mix #3-1, 3-2	Mix #4-1, 4-2	Mix #5-1, 5-2	

NOTES: Number of samples shown in ( ). Schedules A,B,C, and D shown on Table 5-2.
QA/QC samples matrix spike (MS) and matrix spike duplicates (MSD) as follows:
MS/MSD analyses performed on the SW-846 parameters only.
MS analyses only performed on the TCLP parameters.
Batch QC for all other parameters.

Table 5-2

ANALYTICAL TESTING SCHEDULES

Schedule A - Incinerator Ash

Heavy Metals	
Lead	SW-846, Method 7421
Cadmium	SW-846, Method 6010
Mercury	SW-846, Method 7471
Zinc	SW-846, Method 6010
Chromium	SW-846, Method 6010
Copper	SW-846, Method 6010
Chlorine	ASTM D-808
Sulfur	ASTM D-1552
Phosphorus	EPA 600/4-79-020, 365.2

Schedule B - Incinerator Ash

TCLP

Schedule C - Paper Pulp

Ultimate Analysis	
Percent Carbon	ASTM D-3178
Percent Hydrogen	ASTM D-3178
Percent Oxygen	ASTM D-3178
Percent Nitrogen	ASTM D-3179
Percent Sulfur	ASTM D-3239
Percent Ash	ASTM D-3174
Percent Water	ASTM D-3173
Heavy Metals	
Lead	SW-846, Method 7421
Cadmium	SW-846, Method 6010
Chlorine	ASTM D-808
Heat Content	ASTM D-2382

Schedule D - Sludge

Ultimate Analysis	
Percent Carbon	ASTM D-3178
Percent Hydrogen	ASTM D-3178
Percent Oxygen	ASTM D-3178
Percent Nitrogen	ASTM D-3179
Percent Sulfur	ASTM D-3239
Percent Ash	ASTM D-3174
Percent Water	ASTM D-3173
Heat Content	ASTM D-2382

Four times during the testing stage the oxygen probe broke, and the testing had to be suspended until the probe could be repaired, sometimes for several weeks. The probe supplier often was uncooperative in resolving problems with the equipment. Most problems resulted from damage due to harsh conditions in the incinerator stack. The other major problem that caused a long-term shut down was the lack of equipment to connect the polymer feed system to the sludge process units. Other minor delays were caused by the need to shut down the incinerator system for routine maintenance, and schedule conflicts that were created by vacations and the availability of subcontractors doing the stack analysis work. The last test of the pulp and polymer mixtures was August 9, 1994.

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6. SUMMARY OF RESULTS FOR PULP AND POLYMER ADDITION TRIALS (EXPERIMENTS)

Using polymer as a sludge conditioning agent had been previously tested at the treatment plant, while the outcome of adding paper pulp was an unknown factor. Therefore, the rate of polymer addition was held constant and only the concentration of paper pulp was varied in the mix tests. Thus, any observed change in the quality of the conditioned sludge between the mix tests would be due to the paper pulp, not the polymer. The compositions of the various sludge mixtures tested are summarized in Table 6-1.

A polymer dosage rate of 12 to 14 lbs per dry ton of sludge was selected using previous test results and bench-top trial experiments. To consider the potential benefits of sludge conditioning using a combination of paper pulp and polymer, the polymer addition rate was held constant at 12 lbs per dry ton of sludge and the amount of paper pulp added in the sludge mix tests varied from 0% to 20% of the dry weight of sludge.

Mix test #5-1, which consisted of 20% paper pulp, would not feed through the filter press. Therefore, the automatic portion of the mix test (Mix #5-2) was run with 15% pulp instead of 20%. This deviation was accounted for in the evaluation of the operational data for the incineration system.

The paper pulp was delivered by truck from the supplier, and pumped into a spare lime storage tank. From there, the paper pulp was pumped directly into the sludge conditioning tank using the lime feed pumps. The sludge and the paper pulp were mixed in the conditioning tank prior to being pumped into the filter press.

Polymer feed equipment consisted of a skid-mounted, variable speed, high pressure, polymer pump and a pipe mounted magnetic flowmeter. Neat polymer was pre-mixed with water in a polyethylene batch tank with a mixer. This mixture was then fed to the polymer feed pump. The polymer was added to the sludge stream after the filter press feed pumps and prior to the filter press, at which point the sludge had already been combined with the paper pulp solution.

To make a fair comparison of the sludge mix tests conditioned with paper pulp, it was hoped the quality of the paper pulp would be consistent throughout the test period. However, as shown on Table 6-2, some pulp parameters such as ash content and heat content varied considerably. The paper pulp was obtained

Table 6-1

Sludge Mix Test Concentrations

Mix Test	Date	Polymer (lbs/ton of dry sludge)	Paper Pulp % of Conditioned Sludge (dry weight)
Mix #3-1	8/3/94	12	0
Mix #3-2	8/3/94	12	0
Mix #1-1	8/1/94	12	5
Mix #1-2	8/1/94	12	5
Mix #2-1	8/2/94	12	7.5
Mix #2-2	8/2/94	12	7.5
Mix #4-1	8/4/94	12	10
Mix #4-2	8/4/94	12	10
Mix #5-2	8/9/94	12	15
Mix #5-1	8/5/94	12	20

Table 6-2

Paper Pulp Analysis

Sample I.D.	PULP #1-1	PULP #1-1 DUP	PULP #1-2	PULP #1-2 DUP	PULP #2-1	PULP #2-2	PULP #2-2 DUP	PULP #4-1
Date collected	08/01/94	08/01/94	08/01/94	08/01/94	08/02/94	08/02/94	08/02/94	08/04/94
Parameter								
Chlorine	0.56%	0.50%	0.58%	<0.2%	0.57%	0.89%	1.37%	0.14%
Carbon	42.71%	30.03%	42.42%	37.54%	41.75%	32.46%	40.06%	28.95%
Hydrogen	6.05%	3.94%	6.03%	5.14%	6.05%	4.42%	5.64%	4.94%
Nitrogen	0.085%	0.25%	0.23%	0.16%	0.12%	0.30%	0.15%	0.10%
Sulfur	0.15%	0.18%	0.13%	0.17%	0.20%	0.16%	0.21%	0.029%
Ash	7.51%	7.09%	7.92%	7.79%	7.67%	8.30%	8.63%	30.14%
Gross heat of Combustion (BTU/lb)	7,137	7,078	7,169	7,018	6,907	7,171	6,966	4,883
Water/Loss on Drying	98.71%	98.10%	98.10%	98.14%	98.77%	98.78%	98.76%	96.32%

NOTE: DUP - Duplicate

Table 6-2 (Cont'd)

Paper Pulp Analysis

Sample I.D.	PULP #4-1 DUP	PULP #4-2	PULP #4-2 DUP	PULP #5-1	PULP #5-1 DUP	PULP #5-2	PULP #5-2 DUP	Average	Sample Standard Deviation
Date collected	08/04/94	08/04/94	08/04/94	08/05/94	08/05/94	08/09/94	08/09/94		
Parameter									
Chlorine	<0.1%	0.12%	<0.1%	0.27%	<0.1%	<0.1%	<0.1%	0.33%	0.41%
Carbon	25.12%	29.65%	29.92%	40.26%	38.15%	35.42%	34.61%	35.27%	5.66%
Hydrogen	4.00%	4.90%	4.76%	5.92%	5.31%	5.08%	4.96%	5.14%	0.70%
Nitrogen	0.10%	<0.1%	<0.1%	0.051%	<0.1%	<0.1%	<0.1%	0.10%	0.10%
Sulfur	0.03%	0.04%	0.074%	0.12%	0.071%	0.045%	0.035%	0.11%	0.07%
Ash	30.51%	30.84%	29.64%	10.61%	11.44%	22.32%	22.69%	16.21%	10.06%
Gross heat of Combustion (BTU/lb)	4,847	4,925	4,761	6,737	6,518	5,155	5,386	6,177	1,024
Water/Loss on Drying	96.27%	96.64%	96.26%	97.09%	97.10%	97.14%	96.87%	97.54%	0.98%

NOTE: DUP - Duplicate

from a local paperboard manufacturer; therefore, it was not possible to control the production or quality of the pulp.

The BTU value of the pulp for the duration of the mix tests ranged from 4800 to 7200 BTU/lb dry weight. During Mix test #4 and #5 the heat content of the pulp was nearly 2000 BTU lower than pulp used during the first mix tests. The variability of the pulp parameters could account for some of the observed changes in the conditioned sludge mixtures such as the decrease in BTU value of the sludge as the amount of pulp increased. Wherever possible, the analytical data was corrected for the error caused by the variation in the quality of the paper pulp. However, for many of the analyses, this was simply not possible.

There was no attempt to optimize the lime and ferric chloride addition rate during the baseline testing since these were optimized previously. It may have been possible to improve the quality of the sludge conditioned with lime and ferric chloride; however, the sludge was handled using the same procedures normally followed in the treatment plant. Each sludge dewatering and incineration train is independent. The two filter presses and two incinerators are not interconnected. Based on the operating history of the treatment plant, the plate and frame filter press is the rate-limiting step in the entire sludge dewatering and incineration process train. Even if the filter press is operating continuously, the incinerator is able to burn all the sludge produced. Because the filter press is presently the rate-limiting step in the sludge treatment and incineration process, the effect of the conditioned sludge on the filter press cycle time is important. Any increase in the sludge throughput of the filter press would allow more sludge to be processed at the facility.

Naming Conventions

Two baseline tests, each with a duration of 15 days, were conducted on the incineration process. The incinerator was under manual control for Baseline #1 and under automatic control for Baseline #2. The six sludge, air, or ash samples taken during the baseline period were designated as -1, -2, and -3 for the manual baseline, and -4, -5, and -6 for the automatic baseline (e.g. Sludge-1).

Five ratios of paper pulp and polymer were evaluated in the mix tests, each designated #1 through #5. Each mix test was run under manual (-1) and automatic (-2) control, for a total of ten tests. Whenever the text refers to Mix Test #1, for example, it refers to both the manual and the automatic tests of mix ratio #1 (5% paper pulp). Whenever the results of the mix tests are specific to either the manual or automatic phase, it will be designated as Mix Test #1-1 or Mix Test #1-2 respectively.

6.1 **Sludge Dewaterability**

6.1.1 Objectives

The water content of the conditioned sludge fed into the incinerator is important when trying the operate the incinerator economically. Sludge with higher water content requires more auxiliary fuel to evaporate the water before it can be burned. Improving the dewaterability of the sludge will lead to less auxiliary fuel use, that in turn lowers incinerator operating costs. As shown in the heat balance calculations, Section 8, converting the water in the sludge to steam uses the largest part of the energy.

6.1.2 Data Collection and Analysis

The total solids of the sludge after dewatering was measured by the lab at the Southtowns Treatment Plant daily during the baseline tests, and once per load during each of the individual mix tests. Table 6-3 summarizes the solids analyses done. Due to an oversight, total solids was not determined during several days of baselines #1 and #2; however, this should not affect the conclusions. Because there is no difference in the sludge quality whether the incinerator is under manual or automatic control, data from both baseline tests were averaged to get a baseline solids content for the dewatered sludge conditioned with lime and ferric chloride. Table 6-3 shows the average solids content in the sludge feed to the incinerator for the period of the baseline testing was 26.3%.

The solids content of dewatered sludge also was determined as part of the analytical work performed by IEA, Inc., the laboratory subcontractor to URS. The results of are summarized in the Table. The results of the analyses performed by IEA, Inc. closely agree with the analyses performed by the laboratory at Southtowns. The average for all these analyses was 26.4% solids.

Each dewatered sludge test mixture was analyzed for total solids by the Southtowns laboratory. Table 6-4 shows the amount of paper pulp added to each mixture and the results of the solids analyses. Because the same sludge test mixture was used for the automatic and manual phase of each test, an average result for each sludge test mixture was determined and then compared to the average baseline value for sludge conditioned with lime and ferric chloride which had a higher solids content than any of the dewatered sludge mixtures conditioned with paper pulp and polymer.

Table 6-3

Total Sludge Solids (Lime and Ferric Chloride Conditioned)

Test	Date Of Sample	Paper Pulp % of Sludge	Percent Total Solids by Southtowns Lab	Percent Total Solids by IEA, Inc.
Baseline #1	3/10/94			
Baseline #1	3/11/94		26	25.2
Baseline #1	3/12/94		31.2	
Baseline #1	3/23/94		21.5	
Baseline #1	3/24/94		19.8	
Baseline #1	3/25/94		27.2	26.73
Baseline #1	3/26/94		28.2	
Baseline #1	3/27/94		23.6	
Baseline #1	3/28/94		26.2	
Baseline #1	3/29/94		20.7	
Baseline #1	3/30/94		25.6	24.94
Baseline #1	3/31/94		28.5	
Baseline #1	4/1/94		26.8	
Baseline #1	4/2/94		30.8	
Baseline #1	4/3/94		25.1	
Baseline #2	4/23/94			
Baseline #2	4/24/94			
Baseline #2	4/25/94			
Baseline #2	4/26/94			
Baseline #2	4/27/94		28.1	27.5
Baseline #2	4/28/94		26.8	
Baseline #2	4/29/94			
Baseline #2	4/30/94		25.2	
Baseline #2	5/1/94		24.5	
Baseline #2	5/2/94		28.8	
Baseline #2	5/3/94		27.4	27.66
Baseline #2	5/4/94			
Baseline #2	5/5/94		26	26.65
Baseline #2	5/6/94		25.6	
Baseline #2	5/7/94		31.5	
Average			26.3	26.4
Sample Standard Deviation			3.0	1.1

Baseline #1 - Manual Control
Baseline #2 - Automatic Control

Table 6-4

Total Sludge Solids (Paper Pulp and Polymer Conditioned)

Test	Date Of Sample	Paper Pulp % of Sludge	Percent Total Solids by Southtowns Lab	Percent Total Solids by IEA, Inc.
#3-1	8/3/94	0	22.0	20.8
#3-2	8/3/94	0	21.4	20.6
Average			21.7	20.7
Percent Change from Baseline			-17.5%	-21.7%
#1-1	8/1/94	5	24.0	23.7
#1-2	8/1/94	5	25.9	23.7
Average			25.0	23.7
Percent Change from Baseline			-5.2%	-10.3%
#2-1	8/2/94	7.5	25.1	23.1
#2-2	8/2/94	7.5	22.8	22.7
Average			24.0	22.9
Percent Change from Baseline			-9.0%	-13.4%
#4-1	8/4/94	10	24.3	23.4
#4-2	8/4/94	10	21.3	20.7
Average			22.8	22.1
Percent Change from Baseline			-13.3%	-16.5%
#5-2	8/9/94	15	18.5	18.5
Percent Change from Baseline			-29.7%	-30.0%
#5-1	8/5/94	20	22.4	21.5
Percent Change from Baseline			-14.9%	-18.9%

The solids content of the dewatered sludge conditioned with paper pulp and polymer did not appear to correlate directly to the amount of paper pulp in the mixture. However, the data showed that those mixtures containing less paper pulp showed higher levels of total solids. The total solids content of Mix #1 (5% pulp and 25% total solids) and Mix #2 (7.5% pulp and 24% total solids) were both within the normal range of the baseline values for total solids. Mix #5-2 (15% pulp) had the lowest total solids content of 18.5%. Mixes #3 (0% pulp), #4 (10% pulp), #5-1 (20% pulp), and #5-2 (15% pulp) all had total solids content well below the normal range of the baseline values.

6.1.3 Conclusions

Based on data summarized in Tables 6-3 and 6-4, there is no improvement in the dewaterability of sludge using paper pulp and polymer as conditioning agents. The data correlates with the wastewater treatment industry's view that ferric chloride and lime conditioning will produce higher sludge cake solids than polymer. It was initially thought that there was no improvement in dewaterability due to the additional water that was being added to the sludge with the paper pulp. Analysis of the paper pulp solution added to the sludge showed only 1.3% to 3.2% solids (96.8% to 98.7% water). The high water content was due to dilution of the pulp slurry (4% as received) to facilitate pumping and handling by the WWTP feed system. However it was determined that the lack of improvement in sludge dewaterability is due to the tendency of paper pulp to bind water and the difficulty in separating the pulp from the water using a conventional sludge filter press.

The paper pulp will bind a certain quantity of water, regardless of the amount of water initially added to the paper pulp. This conclusion is supported by the fact that the sludge conditioned with higher quantities of paper pulp also generally had higher quantities of water at the end of the filter press cycle.

Using liquid sludge to prepare the pulp mixture instead of water was considered but was rejected for several reasons. The liquid sludge could:

- Create septic conditions in the paper pulp storage tank and promote anaerobic biological activity because the sludge is not yet stabilized.

- Create odor and venting problems for the paper pulp production/storage areas.

- React with the paper pulp prior to dewatering. This could adversely affect the dewaterability or binding effects of the pulp compared to pulp that is mixed with the sludge and promptly dewatered.

The quantity of water used to make the paper pulp slurry is very small compared to the water content of the sludge prior to dewatering. At the projected pulp use rate (5% by weight of dry sludge solids), about 1,410 gallons of water are added per day to approximately 20,000 gallons of liquid sludge.

6.2 Sludge Cake Release and Feed Characteristics

6.2.1 Objectives

Sludge cake release is the ease with which the sludge filter cake can be removed from the filter press at the end of a cycle. If the conditioned sludge has good release characteristics, the sludge will fall out of the press when the automatic plate shifter moves the individual plates. In automatic mode, the filter press can be unloaded in 15 to 20 minutes. If the sludge is sticky, the automatic plate shifter may not be able to pull the plates apart. The press must then be switched to manual mode, and plant operating personnel may have to move the plates, and physically scrape and clean the filter cloth. If personnel need to scrape and clean the sludge cake from the filter press, the time to unload the filter press increases considerably. To be successful, the sludge mixture must be dewatered and the resultant cake must be released from the filter cloth with minimal scraping and cleaning.

Another important factor regarding the quality of the sludge fed into the filter press is how often the press must be shut down for cleaning. After an extended period of use, the filter cloth can become blinded and ineffective in dewatering the sludge. When blinding occurs, the filter press is shut down and the filter cloths are cleaned with a muriatic acid solution. The entire cleaning process takes the filter press out of service for approximately 16 hours. Dewatering sludge conditioned with paper pulp and polymer may affect the length of time between filter press shutdowns. However, the long-term effects of using paper pulp and polymer on filter press runs were beyond the scope of this project.

The dewatered sludge cake must be capable of easily passing through the existing screw feeder. While certain cake consistencies may release easily from the filter press, some consistencies tend to knead like bread dough in the screw feeder, and lack sufficient body to feed properly into the incinerator.

The two sludge dewatering and incineration trains are independent of each other. The two filter presses and two incinerators are not interconnected. Based on the operating history of the treatment plant, the plate and frame filter press is the rate-limiting step in the entire sludge dewatering and incineration operation. Even if the filter press is operating continuously, the incinerator is able to burn all the sludge produced. Therefore, the effect of the conditioned sludge on the filter press cycle time is an important factor. Any increase in the sludge throughput of the filter press would allow more sludge to be processed at the facility.

6.2.2 Data Collection and Analysis

Evaluation of the sludge cake release and feed characteristics was based on operator observations and cycle times. No sampling or analysis was performed. The filter press cycle consists of two phases, the press load step and the filter cake release step. The time to fill and release each filter press load was recorded separately by a plant operator. The total time for the filter press fill and release cycle was calculated by adding the two numbers.

The filter press load and unload times may be somewhat subjective, as there are factors that could have had an effect on the times. The variability of the data is "built-in" and cannot be removed. The end of the filter press load cycle is determined manually, when the plant operator observes that the filtrate effluent from the filter press has dropped to approximately 25% full flow. Because the end of the filter load time is not exact, there would be some variability in the observed times, particularly during pulp and polymer mix tests, when only two loads for each mix ratio were run.

Because the sludge cake release is not affected if the incinerator system is under manual or automatic control, the average baseline cake feed and release characteristics were determined using observations from both baseline tests. The press load and unload times for all the baseline tests (sludge conditioned with lime and ferric chloride) are summarized in Table 6-5. The load and unload cycle times for the paper pulp and polymer mix tests are summarized in Table 6-6.

Filter Press Cycle Time - The average baseline filter press cycle time, including the press load and unload, was slightly more than four hours. Of the test mixtures, the shortest cycle times were obtained for Mix tests #5-1 (20% pulp), #3 (0% pulp) and #4 (10% pulp), all of which were approximately three hours, 10 minutes. The press load cycle times for all the paper pulp and polymer mix tests were shorter than the average baseline cycle time, by anywhere from seven to 64 minutes. Thus, it appears that adding polymer and paper pulp may significantly decrease filter press load cycle time and increase filter press sludge throughput, depending on the amount of paper pulp added.

Filter Press Dry Solids Throughput - To compare the various mix tests on an equal basis, the actual rate at which the sludge is being processed must be calculated. The rate at which total dry sludge solids were processed for each of the test conditions was calculated in Table 6-6. The filter press cycle time was first converted to a volumetric throughput by estimating the volumetric capacity of the filter press at 125 ft^3.

Table 6-5

Filter Press Cycle Times
Sludge Conditioned with Lime and Ferric Chloride

Day	Date	Press Load			Press Unload	Total
		Start	End	Elapsed Time Hr:Min	Elapsed Time Hr:Min	Cycle time Hr:Min
Baseline #1-1	03/10/94	10:30 PM	02:15 AM	03:45	00:10	03:55
Baseline #1-2	03/11/94	04:45 AM	07:45 AM	03:00	00:08	03:08
		10:00 AM	01:15 PM	03:15	00:08	03:23
		02:20 PM	05:25 PM	03:05	00:10	03:15
Baseline #1-3	03/12/94	11:20 PM	02:50 AM	03:30	00:15	03:45
		05:35 AM	08:25 AM	02:50	00:10	03:00
		09:21 AM	12:45 PM	03:24	00:08	03:32
		01:55 PM	05:00 PM	03:05	00:10	03:15
		06:20 PM	09:25 PM	03:05	00:10	03:15
Baseline #1-4	03/23/94	03:55 AM	07:00 AM	03:05	00:15	03:20
		05:30 PM	10:15 PM	04:45	00:15	05:00
Baseline #1-5	03/24/94	10:30 AM	02:15 PM	03:45	00:10	03:55
		02:30 AM	06:00 AM	03:30	00:10	03:40
		07:35 PM	10:55 PM	03:20	00:08	03:28
Baseline #1-6	03/25/94	11:05 PM	02:50 AM	03:45	00:10	03:55
		03:30 AM	06:00 AM	02:30	00:15	02:45
		07:40 AM	11:10 AM	03:30	00:10	03:40
		01:45 PM	06:05 PM	04:20	00:10	04:30
		07:30 PM	10:30 PM	03:00	00:10	03:10
Baseline #1-7	03/26/94	01:35 AM	05:15 AM	03:40	00:10	03:50
		07:35 AM	10:30 AM	02:55	00:10	03:05
		06:30 PM	10:00 PM	03:30	00:10	03:40
Baseline #1-8	03/27/94	10:40 PM	02:05 AM	03:25	00:10	03:35
		04:35 AM	07:30 AM	02:55	00:10	03:05
		10:45 AM	01:15 PM	02:30	00:10	02:40
		01:40 PM	04:40 PM	03:00	00:15	03:15
		05:00 PM	08:30 PM	03:30	00:10	03:40
Baseline #1-9	03/28/94	09:30 PM	12:55 AM	03:25	00:10	03:35
		03:30 AM	06:30 AM	03:00	00:08	03:08
		07:10 AM	10:15 AM	03:05	00:10	03:15
		11:30 AM	02:45 PM	03:15	00:10	03:25
		07:30 PM	10:50 PM	03:20	00:08	03:28
Baseline #1-10	03/29/94	04:20 AM	08:30 AM	04:10	00:10	04:20
		08:40 AM	11:55 AM	03:15	00:10	03:25
		12:55 PM	04:30 PM	03:35	00:10	03:45
		05:10 PM	08:50 PM	03:40	00:15	03:55
Baseline #1-11	03/30/94	09:10 PM	12:20 AM	03:10	00:10	03:20
		01:33 AM	05:30 AM	03:57	00:10	04:07
		06:40 AM	10:15 AM	03:35	00:10	03:45
		10:55 AM	03:00 PM	04:05	00:12	04:17
		03:20 PM	07:30 PM	04:10	00:15	04:25
		09:30 PM	12:35 AM	03:05	00:10	03:15
Baseline #1-12	03/31/94	09:25 AM	01:30 PM	04:05	00:10	04:15

Table 6-5 (cont'd)

Filter Press Cycle Times
Sludge Conditioned with Lime and Ferric Chloride

Day	Date	Press Load			Press Unload Elapsed Time Hr:Min	Total Cycle time Hr:Min
		Start	End	Elapsed Time Hr:Min		
Baseline #1-13	04/01/94	06:10 AM	10:15 AM	04:05	00:10	04:15
		11:20 AM	03:00 PM	03:40	00:15	03:55
		03:30 PM	07:00 PM	03:30	00:10	03:40
		09:35 PM	12:15 AM	02:40	00:10	02:50
Baseline #1-14	04/02/94	10:25 AM	01:30 PM	03:05	00:10	03:15
		03:15 PM	06:30 PM	03:15	00:10	03:25
		07:00 PM	11:00 PM	04:00	00:10	04:10
Baseline #1-15	04/03/94	11:30 PM	03:00 AM	03:30	00:10	03:40
		05:30 AM	09:00 AM	03:30	00:10	03:40
		09:25 AM	01:10 PM	03:45	00:10	03:55
		01:30 PM	04:30 PM	03:00	00:10	03:10
		05:20 PM	08:35 PM	03:15	00:10	03:25
Baseline #2-1	04/23/94	09:00 PM	01:35 AM	04:35	00:10	04:45
		01:50 AM	07:00 AM	05:10	00:10	05:20
		07:20 AM	11:25 AM	04:05	00:10	04:15
		11:50 AM	04:15 PM	04:25	00:10	04:35
		05:30 PM	10:05 PM	04:35	00:10	04:45
Baseline #2-2	04/24/94	10:30 PM	02:00 AM	03:30	00:10	03:40
		04:30 AM	09:10 AM	04:40	00:10	04:50
		09:20 AM	02:50 PM	05:30	00:10	05:40
		05:40 PM	09:00 PM	03:20	00:10	03:30
Baseline #2-3	04/25/94	09:45 PM	02:00 AM	04:15	00:10	04:25
		02:15 AM	07:00 AM	04:45	00:10	04:55
		07:30 AM	12:05 PM	04:35	00:10	04:45
		12:15 PM	04:15 PM	04:00	00:15	04:15
		05:30 PM	10:00 PM	04:30	00:15	04:45
Baseline #2-4	04/26/94	10:35 PM	03:00 AM	04:25	00:10	04:35
		03:10 AM	07:40 AM	04:30	00:10	04:40
		09:00 AM	12:45 PM	03:45	00:10	03:55
		03:15 PM	07:20 PM	04:05	00:10	04:15
Baseline #2-5	04/27/94	09:00 PM	01:15 AM	04:15	00:10	04:25
		01:40 AM	06:00 AM	04:20	00:10	04:30
		06:40 AM	10:50 AM	04:10	00:10	04:20
		11:45 AM	04:20 PM	04:35	00:10	04:45
		04:40 PM	08:20 PM	03:40	00:08	03:48
		08:30 PM	01:00 AM	04:30	00:10	04:40
Baseline #2-6	04/28/94	01:20 AM	05:45 AM	04:25	00:15	04:40
Baseline #2-7	04/29/94	10:30 PM	02:00 AM	03:30	00:10	03:40
		02:35 AM	06:45 AM	04:10	00:15	04:25
		07:00 AM	11:25 AM	04:25	00:10	04:35
		11:35 AM	04:20 PM	04:45	00:08	04:53
		04:30 PM	08:00 PM	03:30	00:15	03:45
		08:50 PM	12:25 AM	03:35	00:10	03:45

Table 6-5 (cont'd)

Filter Press Cycle Times
Sludge Conditioned with Lime and Ferric Chloride

Day	Date	Press Load			Press Unload	Total
		Start	End	Elapsed Time Hr:Min	Elapsed Time Hr:Min	Cycle time Hr:Min
Baseline #2-8	04/30/94	12:35 AM	05:25 AM	04:50	00:10	05:00
		05:35 AM	10:20 AM	04:45	00:10	04:55
		10:20 AM	03:00 PM	04:40	00:10	04:50
		03:20 PM	06:50 PM	03:30	00:15	03:45
		07:15 PM	11:25 PM	04:10	00:10	04:20
Baseline #2-9	05/01/94	11:35 PM	03:50 AM	04:15	00:10	04:25
		04:35 AM	09:00 AM	04:25	00:10	04:35
		09:15 AM	01:25 PM	04:10	00:10	04:20
		02:00 PM	06:30 PM	04:30	00:15	04:45
Baseline #2-10	05/02/94	01:15 AM	05:40 AM	04:25	00:10	04:35
		06:10 AM	10:30 AM	04:20	00:10	04:30
		11:30 AM	04:25 PM	04:55	00:14	05:09
		04:40 PM	08:50 PM	04:10	00:15	04:25
Baseline #2-11	05/03/94	09:15 PM	01:05 AM	03:50	00:10	04:00
		03:05 AM	07:25 AM	04:20	00:10	04:30
		07:40 AM	11:30 AM	03:50	00:10	04:00
		01:00 PM	05:15 PM	04:15	00:15	04:30
		06:15 PM	10:45 PM	04:30	00:11	04:41
Baseline #2-12	05/04/94	11:15 PM	03:50 AM	04:35	00:10	04:45
		05:00 AM	09:20 AM	04:20	00:12	04:32
		04:38 PM	08:30 PM	03:52	00:15	04:07
Baseline #2-13	05/05/94	09:35 PM	02:05 AM	04:30	00:15	04:45
		02:55 AM	07:10 AM	04:15	00:10	04:25
		07:30 AM	11:00 AM	03:30	00:10	03:40
		12:15 PM	03:30 PM	03:15	00:15	03:30
		05:30 PM	09:30 PM	04:00	00:10	04:10
		09:45 PM	02:20 AM	04:35	00:15	04:50
Baseline #2-14	05/06/94	02:40 AM	06:55 AM	04:15	00:10	04:25
		07:10 AM	11:45 AM	04:35	00:10	04:45
		11:55 AM	03:35 PM	03:40	00:10	03:50
		03:45 PM	07:45 PM	04:00	00:10	04:10
		08:00 PM	12:45 AM	04:45	00:10	04:55
Baseline #2-15	05/07/94	01:55 AM	06:25 AM	04:30	00:10	04:40
		06:40 AM	11:45 AM	05:05	00:10	05:15
		12:00 PM	04:20 PM	04:20	00:15	04:35
		05:20 PM	09:10 PM	03:50	00:15	04:05
		09:20 PM	02:05 AM	04:45	00:10	04:55
Average Cycle Time				**03:53**	**00:10**	**04:04**

Table 6-6

Filter Press Load/Unload Cycle Times
Paper Pulp and Polymer Mix Tests

	Date	Paper pulp % of sludge	Press Load			Press Unload Elapsed Time Hr:Min	Total Cycle time Hr:Min	Volumetric[2] Throughput ft^3/hr	Sludge Density g/L	Conditioned Sludge Thruput lb/hr	Correction Factor[1]	Sludge Throughput lb/hr	Total Solids %	Dry Solids Throughput lb/hr	Press condition (Operator observation)
			Start	End	Elapsed Time Hr:Min										
Baseline															
Average Cycle Time					03:53	00:10	04:04	30.7	1098	2,105	0.745	1,568	26.30%	412	
#3-1	08/03/94	0	06:45 AM	09:25 AM	02:40	00:25	03:05		1075						Very sticky
#3-2	08/03/94	0	10:30 AM	01:15 PM	02:45	00:30	03:15		1035						Very sticky
Average Cycle Time					02:42	00:27	03:10	39.5	1055	2,597	1	2,597	21.70%	564	
#1-1	08/01/94	5	07:15 AM	11:15 AM	04:00	00:15	04:15		1063						Wet-OK
#1-2	08/01/94	5	11:40 AM	03:05 PM	03:25	00:15	03:40		1045						Better
Average Cycle Time					03:42	00:15	03:57	31.6	1054	2,080	0.95	1,976	25.00%	494	
#2-1	08/02/94	7.5	07:10 AM	10:30 AM	03:20	00:20	03:40		1050						Good
#2-2	08/02/94	7.5	12:10 PM	03:30 PM	03:20	00:20	03:40		1050						Good
Average Cycle Time					03:20	00:20	03:40	34.1	1050	2,233	0.92	2,054	24.00%	493	
#4-1	08/04/94	10	06:15 AM	09:15 AM	03:00	00:15	03:15		1058						Very good
#4-2	08/04/94	10	10:15 AM	01:10 PM	02:55	00:10	03:05		1042						Very good
Average Cycle Time					02:57	00:12	03:10	39.5	1050	2,585	0.89	2,301	22.80%	525	
#5-2	08/09/94	15	11:15 AM	02:25 PM	03:10	00:15	03:25	36.6	1025	2,339	0.82	1,926	18.50%	356	Good
#5-1	08/05/94	20	06:15 AM	09:00 AM	02:45	00:15	03:00	41.7	1061	2,757	0.75	2,068	22.40%	463	Good

NOTE: 1 - Correction factor for baseline based on ratio: (sludge + ferric chloride + lime)/sludge.
Correction factor for mixtures based on : Correction Factor = 1 - [X/(100-X)], where X = % paper pulp.
2 - Assumes a total volumetric capacity of 125 ft^3.

Next, the volumetric throughput rate was converted to pounds of dry sludge solids based on the conditioned sludge density, total solids, and the percentage of conditioners added to the sludge.

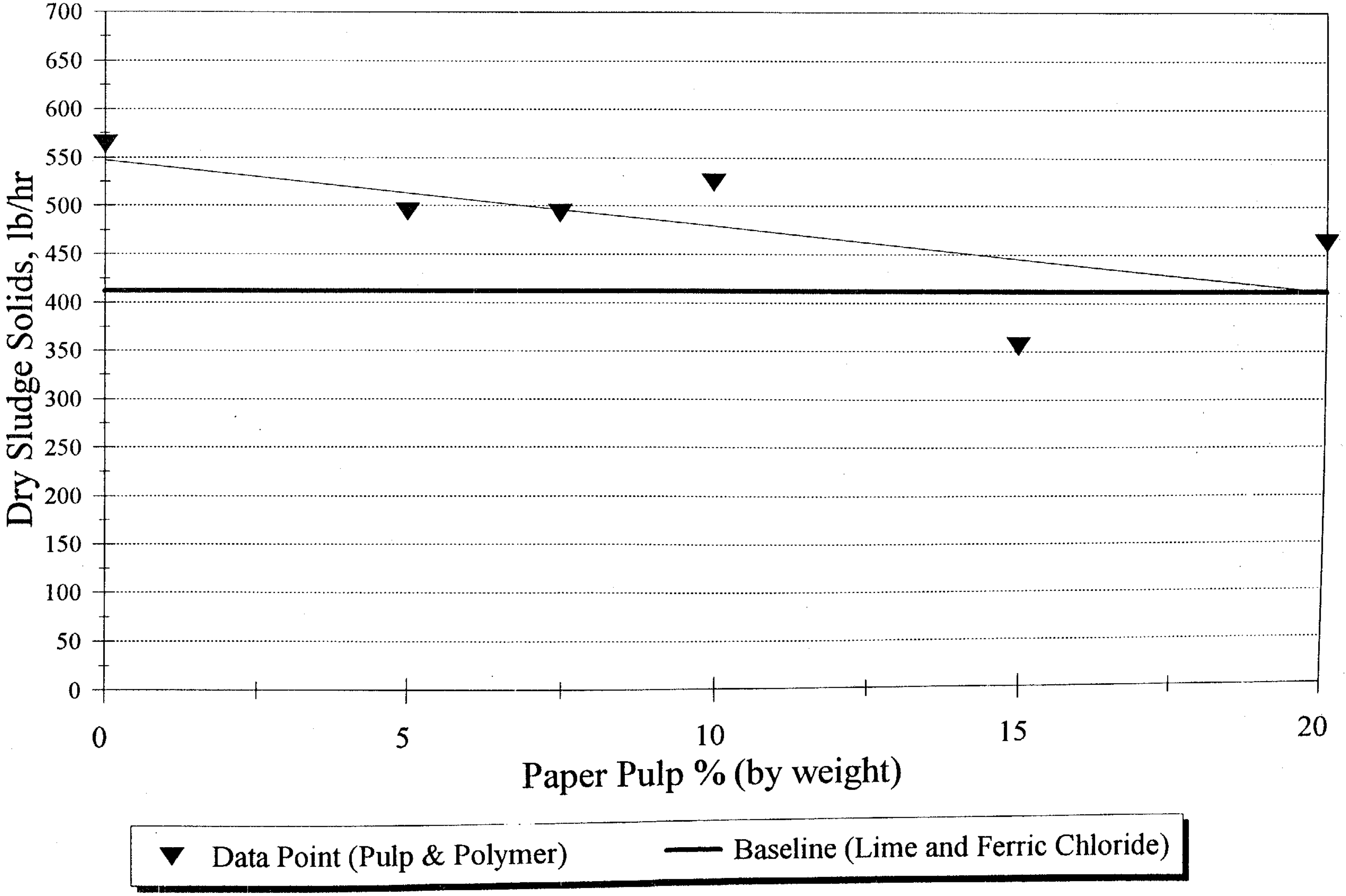
The dry sludge solids throughput rates were plotted against the percentage of paper pulp used in the corresponding sludge mixtures. This is shown on the graph in Figure 6-1. Under the baseline conditions, using lime and ferric chloride for sludge conditioning, an average of 412 lbs/hr of dry sludge solids were dewatered. As shown by the graph, with no paper pulp, nearly 550 lbs/hr of dry sludge solids could be dewatered. Increasing the amount of pulp leads to a corresponding decrease in the throughput of dry sludge solids but, using the line of best linear fit, all test conditions have a corresponding sludge throughput greater than the baseline condition. At approximately 20% paper pulp, the dry sludge solids throughput is equivalent to the baseline conditions. Based on the limited data of this experiment, adding paper pulp in excess of 20% by weight of sludge would lower the dewatered sludge solids throughput rate below the rate for sludge conditioned with lime and ferric chloride.

<u>Sludge Release Characteristics</u> - The unloading characteristics for all the mix tests were slightly longer but comparable to the conditions when using lime and ferric chloride, with the exception of Mix test #3. The sludge from Mix test #3, which did not contain any paper pulp, was described by the operators as being very sticky and difficult to remove from the filter cloth. This mixture was judged to be below standard by plant personnel. The sludge release seemed to improve with the addition of up to 10% paper pulp. Mix #4 containing 10% paper pulp was described as having very good sludge release characteristics. Adding more than 10% pulp did not provide any added benefit to the release of the sludge.

<u>Sludge Feed Characteristics</u> - According to the plant personnel, feed characteristics of the sludge from the mix tests were acceptable. There were no difficulties feeding any of the conditioned sludge test mixtures through the conveyors or the screw feeder. There was no noticeable difference in the feed characteristics of the sludge from the mix tests compared to the baseline sludge conditioned with lime and ferric chloride.

Figure 6 - 1

Filter Press Sludge Throughput



6.2.3 Conclusions

Based on the data and previous discussion, these conclusions were drawn:

- The use of paper pulp and polymer significantly reduced the sludge filter press cycle time compared to the average cycle time when processing sludge conditioned with lime and ferric chloride;

- As the percentage of paper pulp was increased, the throughput of dry sludge solids decreased. Until approximately 20% pulp by weight was added to the sludge, paper-pulp conditioned sludge showed better throughput of dry sludge solids than the sludge conditioned with lime and ferric chloride.

- The release characteristics of the sludge mix conditioned with polymer but no paper pulp (Mix #3) were sticky and unacceptable. The lack of paper pulp also may lead to more frequent filter cloth blinding, requiring more frequent dewatering press shutdowns for cleaning.

- There was no noticeable difference in the feed characteristics of sludge conditioned with paper pulp and polymer compared to sludge conditioned with lime and ferric chloride.

Based on the limited data gathered, there appear to be no negative impacts on sludge dewatering due to the use paper pulp and polymer for sludge conditioning; however, polymer alone would be unacceptable. Conditioning the sludge using paper pulp and polymer compared to lime and ferric chloride increased the sludge throughput of the filter press. Further optimization trials would lead to the pulp and polymer ratio providing the most improved sludge dewatering and handling characteristics.

6.3 Sludge BTU Value

6.3.1 Objectives

The moisture content (evaluated in Section 6.1) and BTU value of the conditioned sludge affect the amount of auxiliary fuel required for effective incineration. The overall heat content of the conditioned sludge is determined by the BTU value of the dry solids and percentage of water in the sludge. Water and other noncombustible materials, such as lime and ferric chloride, do not contribute to the heat content of the sludge. Just as the overall heat content of the sludge can be increased by reducing its water content, the heat content also can be improved by decreasing the quantity of noncombustible solids in the sludge. By determining the heat content of the dry solids in its sludge, and knowing its moisture content, the overall BTU value can be determined.

6.3.2 Data Collection and Analysis

Twenty-one samples were taken for BTU value (gross heat of combustion) during the demonstration project. Samples were collected three times during each baseline test with lime and ferric chloride, and once during each run of the pulp and polymer test mixtures. Five additional QA/QC duplicate samples were collected during the paper pulp and polymer mix tests. All the results for BTU value analyses are summarized in Table 6-7. Due to the high moisture content of the conditioned sludge, it was not possible to determine the BTU value of the sludge "as received". The conditioned sludge had to be dried to measure the BTU value of the dry solids.

Because the BTU value of the conditioned sludge would not be affected if the incinerator system is under manual or automatic control, the BTU value of the sludge conditioned with lime and ferric chloride was determined using the data collected during both the manual and automatic portions of the baseline tests. The overall average BTU value of the sludge conditioned with lime and ferric chloride on a dry weight basis was 5517 BTU/lb.

The BTU value of the pulp and polymer mixtures was determined and compared to the baseline values. Although the BTU value does not directly correspond to the percentage of pulp in the mixture, results indicate that at the lower pulp concentrations (0-7.5%) the BTU value of the dry sludge was approximately 7900 BTU/lb. At higher pulp concentrations (10-20%), the BTU value of the dry sludge was lower, in

Table 6-7

Sludge Moisture Content and BTU Value

Sample I.D.	Paper Pulp % of Sludge	Dry Solids Gross Heat of Combustion (BTU/lb)	Moisture (%)	Calculated Wet Sludge Gross Heat of Combustion (BTU/lb)	Percent Change in BTU Value from Baseline
SLUDGE-1		5273	74.8	1328.8	
SLUDGE-2		5556	73.27	1485.12	
SLUDGE-3		5428	75.06	1353.74	
BASELINE #1 - Average		5419	74.38	1389.22	
SLUDGE-4		5486	72.5	1508.65	
SLUDGE-5		5551	72.34	1535.41	
SLUDGE-6		5805	73.35	1547.03	
BASELINE #2 - Average		5614	72.73	1530.36	
BASELINE - Average		**5517**	**73.55**	**1459.79**	
SL #3-1 *	0	7439	79.18	1548.8	
SL #3-2	0	8306	79.39	1711.87	
MIX #3 - Average		**7873**	**79.29**	**1630.34**	**12**
SL #1-1*	5	7734	76.26	1836.05	
SL #1-2	5	8029	76.28	1904.48	
MIX #1 - Average		**7882**	**76.27**	**1870.27**	**28**
SL #2-1*	7.5	7687	76.91	1774.93	
SL #2-2	7.5	8204	77.31	1861.49	
MIX #2 - Average		**7946**	**77.11**	**1818.21**	**25**
SL #4-1*	10	6829	76.57	1600.03	
SL #4-2	10	7454	79.28	1544.47	
MIX #4 - Average		**7142**	**77.93**	**1572.25**	**8**
SL #5-2	15	**7056**	**81.48**	**1306.77**	**-10**
SL #5-1*	20	**7080**	**78.54**	**1519.37**	**4**

NOTE: * - Average of the result for the sample and duplicate analysis.

- 1= Manual Control

- 2 = Automatic Control

the range of 7100 BTU/lb. However, the decrease in the heat content of the sludge could be due to the higher percentage of water in the mixture from the pulp additive, as discussed in Section 6.1.

Overall Sludge BTU Value - To determine the net change in the BTU value of the sludge due to adding paper pulp and polymer, the overall (or "as received") BTU value of the paper pulp and polymer sludge mixtures was calculated. This allows the mixtures to be compared equally by accounting for the effects of both the change in heat content of the dry solids, and the change in moisture content of the sludge mixtures. The overall BTU value of the conditioned sludge was determined using this formula:

$$\text{Overall BTU value} = \frac{100 - \%\ \text{Moisture}}{100} \times \frac{\text{BTU}}{\text{lb dry solids}}$$

This evaluation only adjusts the heat content of the sludge for the percent total solids, and ignores the heat required to evaporate the water in the sludge. A more detailed evaluation is included with heat balance calculations in Section 8.

As shown in Table 6-7, the average overall BTU value of the sludge conditioned with lime and ferric chloride was 1460 BTU/lb. The best overall BTU value from the mix tests was obtained for Mix #1 (5% pulp), which with 1870 BTU/lb, was 28% higher than the baseline value. Mix #5-2 (15% pulp) actually had a heat content 10% lower than the baseline value. The lack of correlation between the heat content of the sludge compared to pulp is most likely due to variability in the pulp quality. Analysis of the paper pulp is summarized in Table 6-2.

6.3.3 Conclusions

Based on the analytical data and previous discussions, these conclusions were made about the effect of adding pulp and polymer on the moisture content and the BTU value of the conditioned sludge:

- Adding paper pulp and polymer increased the overall BTU value of the sludge, primarily by reducing the quantity of noncombustible material (lime and ferric chloride) in the conditioned sludge. The heat content of the pulp is very similar to the heat content of the dry sludge solids.

- The benefit of additional paper pulp, above 10% by dry weight of sludge, appeared to be minimal. However, the exact increase, or the optimum dose of paper pulp and polymer, could not be quantified due to the variability of the heat content of the pulp used in the mix tests.

Apparently, using paper pulp and polymer increases the sludge's overall heat content.

6.4 Auxiliary Fuel Consumption

6.4.1 Objectives

Due to the increase in the overall BTU value of the sludge conditioned with paper pulp and polymer described in Section 6.3, there should be a corresponding drop in the use of auxiliary fuel oil. Although there are several other factors that may affect fuel oil use, this section describes only the overall reduction in fuel oil use, if any. A more detailed analysis is given in Section 8.1.

6.4.2 Data Collection and Analysis

Fuel oil use was one of the parameters recorded as one minute averages by the data acquisition system throughout the demonstration project. The conditioned sludge feed rate also was recorded. Thus, it was possible to determine the quantity of fuel required to incinerate the sludge. To deal with the voluminous quantity of data recorded, a daily data graph was developed. The sludge feed rate was recorded as feet per minute based on conveyer speed; however, to compare the various mix test ratios these numbers were converted to lb per minute, based on analytical data and a conversion factor of 1.8 ft^3/ft for the conveyor.

Because operating the incinerator under manual or automatic control could affect fuel oil use, the two baseline tests are evaluated separately. The data from the manual sludge mix tests will be compared only to the data from the manual baseline; data from the automatic mix tests will be compared to the data from the automatic baseline test.

There were times when information collected by the data acquisition system was unusable. These times include incinerator down time, instrument malfunctions, sludge feed problems, and other situations when the data would not represent usual operating conditions. All the unusable data were deleted from the spreadsheet before the development of graphs. Graphs of the fuel-to-conditioned-sludge ratio for each day of incinerator operation are included in Appendix B. Also shown on the graphs are the periods of time when unusable data was removed from the database, as well as the statistical analysis of the useable data.

Manual Tests - The average fuel oil to dry sludge ratio was developed for each day of the manual baseline test period (sludge conditioned with lime and ferric chloride). The results of these daily fuel usage rates for the baseline testing are summarized in Table 6-8. The average of fuel use rates was 0.074 gallons per pound of dry sludge solids.

The fuel oil to sludge ratio also was recorded for each of the paper pulp and polymer mix tests, and summarized in Table 6-9. As shown, four of the five sludge mixtures containing paper pulp and polymer required significantly less fuel oil than the amount of fuel oil required to incinerate the sludge conditioned with lime and ferric chloride. The decrease in fuel use ranged from 25% to 54%. Mix test #1 (5% pulp) showed the best improvement with a 54% decrease in fuel usage. Mix test #5 (20% pulp) showed a 4% increase in the fuel oil use.

Because the fuel oil use rate primarily depends on the BTU value of the sludge, these values also were reported in Table 6-9 for comparison. The decrease in fuel use predictably corresponds to the increase in BTU value of the sludge incinerated. Figure 6-2 is a graph of the fuel oil necessary to incinerate the dry sludge solids compared to the BTU value of the wet conditioned sludge for the manual mix tests.

Automatic Tests - The average fuel oil-to-dry-sludge ratio was developed for each day of the automatic baseline test period (sludge conditioned with lime and ferric chloride). Results of baseline daily fuel use rates are summarized in Table 6-8. The average of the fuel use rates was 0.071 gallons per pound of dry sludge solids (about 4% less than during the manual baseline tests.)

The fuel use rates from each of the paper pulp and polymer mix tests under automatic operation were compared to results of the automatic baseline test. As Table 6-10 shows, the fuel use rates varied significantly. Mix #1 (5% pulp) resulted in a 70% reduction in the fuel use rates. This mix also showed the best improvement during the manual baseline tests. The decrease in the fuel use for the mix tests generally corresponded to the increase in BTU value of the sludge incinerated, with the exception of Mix #4. The incineration of Mix #4 (10% pulp) resulted in an 80% increase in the fuel use rate compared to the sludge conditioned with lime and ferric chloride despite the fact that the BTU value of the sludge was slightly higher than the BTU value of the sludge conditioned with lime and ferric chloride. Operational problems with the automatic control probably caused the increase in fuel oil consumption for this particular mix test. Figure 6-3 is a graph of the fuel oil required to incinerate the dry sludge solids compared to BTU value of the wet conditioned sludge for the automatic mix tests.

Table 6-8

Fuel /Sludge Ratio
Sludge Conditioned with Lime and Ferric Chloride

Day	MANUAL CONTROL (Baseline #1)							AUTOMATIC CONTROL (Baseline #2)							
	Date	Average Fuel to Sludge Ratio (gpm/fpm)	Sludge Density (g/L)	Correction Factor from Table 6-6	% Total Solids[1]	Gal Fuel Oil Per Pound of Dry Activated Sludge	Gal Fuel Oil Per Ton of Dry Activated Sludge	Date	Average Fuel to Sludge Ratio (gpm/fpm)	Sludge Density (g/L)	Correction Factor from Table 6-6	% Total Solids[1]	Gal Fuel Oil Per Pound of Dry Activated Sludge	Gal Fuel Oil Per Ton of Dry Activated Sludge	Sample Standard Deviation
1	03/10/94	1.682	1089	0.745	26.3	0.070	140	04/23/94	1.618	1112	0.745	26.3	0.066	132	0.426
2	03/11/94	1.81	1080	0.745	26	0.077	154	04/24/94	1.699	1112	0.745	26.3	0.069	139	0.425
3	03/12/94	1.759	1124	0.745	31.2	0.060	120	04/25/94	1.793	1112	0.745	26.3	0.073	147	0.407
4	03/23/94	2.272	1032	0.745	21.5	0.122	245	04/26/94	1.704	1112	0.745	26.3	0.070	139	0.475
5	03/24/94	1.787	1056	0.745	19.8	0.102	204	04/27/94	1.598	1104	0.745	28.1	0.062	123	0.426
6	03/25/94	1.528	1087	0.745	27.2	0.062	124	04/28/94	1.671	1132	0.745	26.8	0.066	132	0.425
7	03/26/94	1.765	1098	0.745	28.2	0.068	136	04/29/94	1.647	1112	0.745	16.3	0.109	217	0.417
8	03/27/94	1.608	1084	0.745	23.6	0.075	150	04/30/94	1.704	1131	0.745	25.2	0.071	143	0.332
9	03/28/94	1.588	1090	0.745	26.2	0.066	133	05/01/94	1.622	1090	0.745	24.5	0.073	145	0.368
10	03/29/94	1.505	1103	0.745	20.7	0.079	158	05/02/94	1.578	1034	0.745	28.8	0.063	127	0.426
11	03/30/94	1.653	1074	0.745	25.6	0.072	144	05/03/94	1.537	1151	0.745	27.4	0.058	117	0.439
12	03/31/94	1.568	1129	0.745	28.5	0.058	117	05/04/94	1.49	1112	0.745	26.3	0.061	122	0.811
13	04/01/94	1.591	1094	0.745	26.8	0.065	130	05/05/94	1.782	1165	0.745	26	0.070	141	0.625
14	04/02/94	1.765	1142	0.745	30.8	0.060	120	05/06/94	2.022	1032	0.745	25.6	0.091	183	1.401
15	04/03/94	1.597	1055	0.745	25.1	0.072	144	05/07/94	1.715	1167	0.745	31.5	0.056	112	0.424
AVERAGE		1.699	1089			0.074	148		1.679	1112			0.071	141	0.522

NOTE: 1. % Total solids was not analyzed for several days of the baseline tests. For these days, the % total solids was assumed to be the average value determined for the entire baseline test period.

Table 6-9

Fuel Oil to Sludge Ratio

Paper Pulp and Polymer Mix Tests
Manual Operation

Mix Tests	Paper Pulp % of Sludge	Date	Average Fuel to Sludge Ratio (gpm/fpm)	Sludge Density (g/L)	Correction Factor from Table 6-6	% Total Solids	Gal Fuel Oil Per Pound of Dry Activated Sludge	Percent Change from Baseline	Heat Content "as received" (BTU/lb wet sludge)	Percent Change from Baseline
Average Manual Baseline							0.0739		1389	
Mix #3-1	0	8/3/94	1.260	1075	1	22	0.0474	-36%	1549	12%
Mix #1-1	5	8/1/94	0.931	1063	0.95	24	0.0342	-54%	1836	32%
Mix #2-1	7.5	8/2/94	1.134	1050	0.92	25.1	0.0417	-44%	1775	28%
Mix #4-1	10	8/4/94	1.419	1058	0.89	24.3	0.0552	-25%	1600	15%
Mix #5-1	20	8/5/94	1.536	1061	0.75	22.4	0.0767	4%	1519	9%

Figure 6-2

Fuel Oil Use - Manual Tests

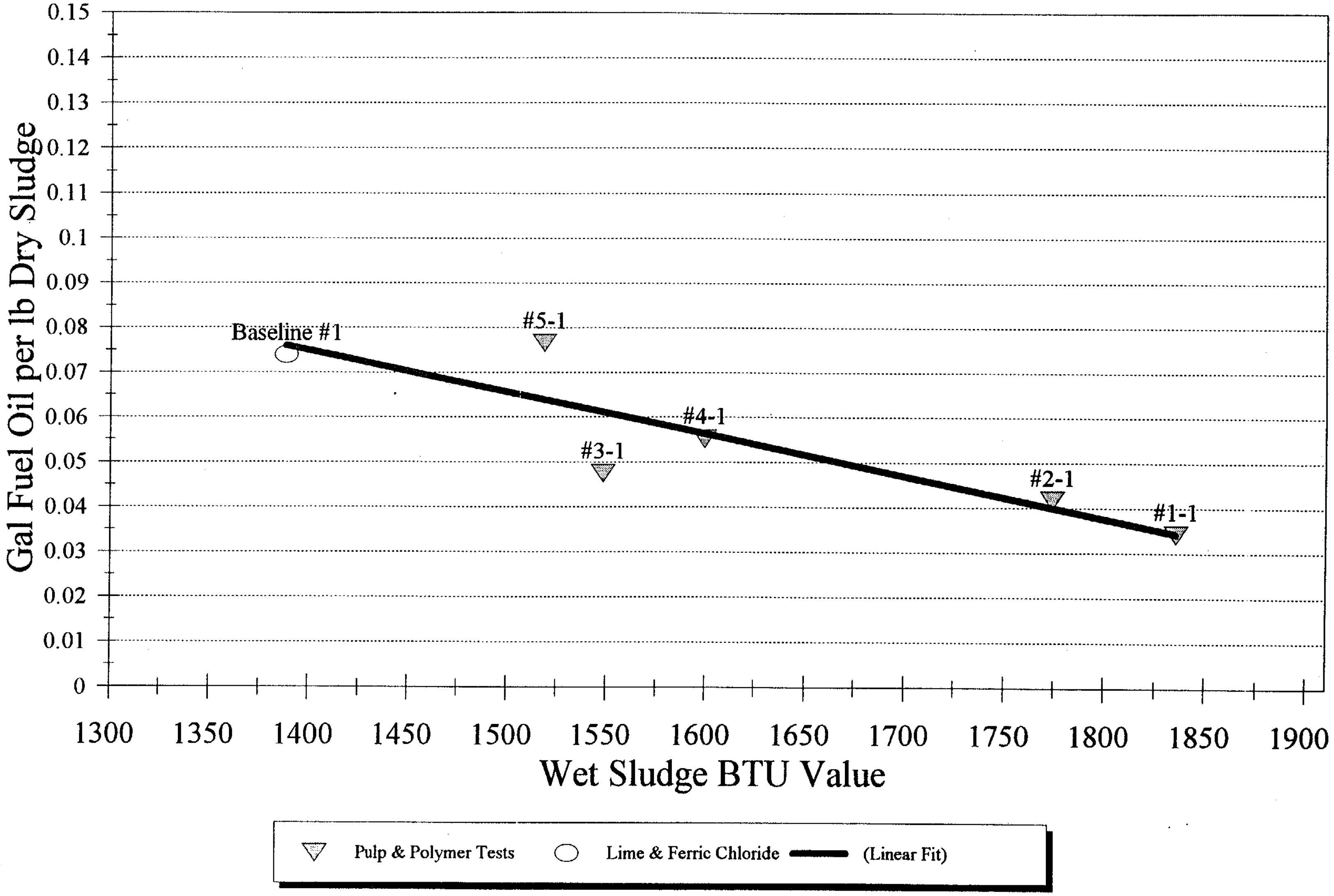


Table 6-10

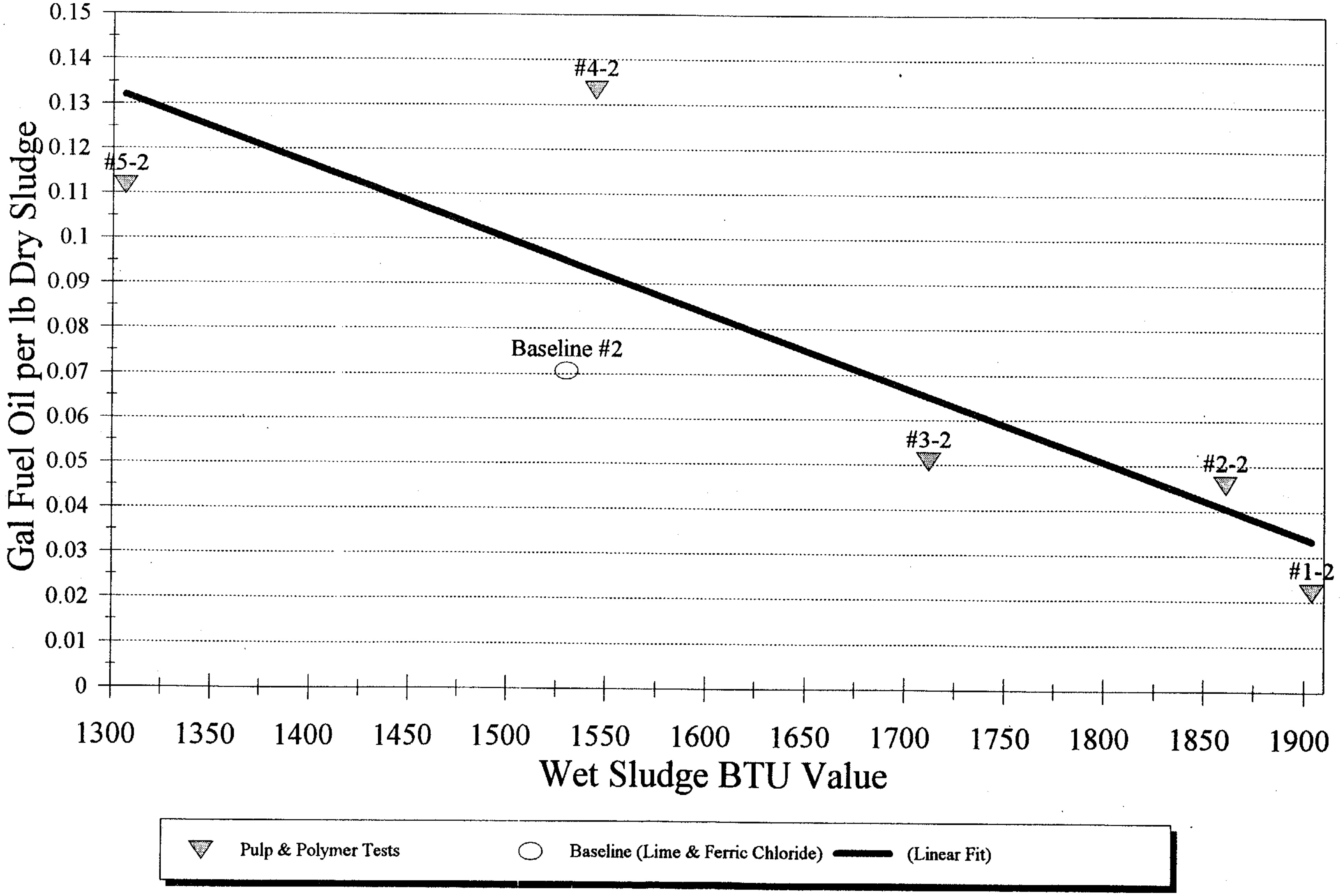
Fuel Oil to Sludge Ratio

Paper Pulp and Polymer Mix Tests
Automatic Operation

Mix Tests	Paper Pulp % of Sludge	Date	Average Fuel to Sludge Ratio (gpm/fpm)	Sludge Density (g/L)	Correction Factor from Table 6-6	% Total Solids	Gal Fuel Oil Per Pound of Dry Activated Sludge	% Change from Baseline	Heat Content "as received" (BTU/lb wet sludge)	% Change from Baseline
Average Automatic Baseline							0.0706		1530	
Mix #3-2	0	8/3/94	1.263	1035	1	21.4	0.0508	-31%	1712	23%
Mix #1-2	5	8/1/94	0.639	1045	0.95	25.9	0.0221	-70%	1904	37%
Mix #2-2	7.5	8/2/94	1.132	1050	0.92	22.8	0.0458	-38%	1861	34%
Mix #4-2	10	8/4/94	2.957	1042	0.89	21.3	0.1333	80%	1544	11%
Mix #5-2	15	8/9/94	1.783	1025	0.75	18.5	0.1117	51%	1307	-6%

Figure 6-3

Fuel Oil Use - Automatic Tests



6.4.3 Conclusions

Based on the analytical data and previous discussion, these conclusions were drawn about the effect of paper pulp and polymer addition on the use of auxiliary fuel oil in the incinerator:

- Several conditioned sludge mixtures resulted in a significant decrease in the amount of auxiliary fuel required.
- The best mixture for improved fuel oil use was Mix #1, conditioned with polymer and 5% paper pulp. This mixture showed a 54% reduction in fuel oil use for the tests under manual control and a 70% reduction for the tests under automatic control.
- Pulp percentages greater than 10% resulted in minimal improvement over baseline fuel use.

Based on the limited analytical data obtained for this project, significant savings (30%+) in auxiliary fuel costs could be realized using paper pulp and polymer as conditioning agents. This conclusion is supported by theoretical calculations (Appendix G) based on the relative heat contents of the sludge conditioned with paper pulp and polymer compared to sludge conditioned with ferric chloride and lime. Section 7 evaluates the effect of automatic compared to manual control on the fuel oil use rates.

6.5 **Air Pollution Control**

6.5.1 Objectives

Several parameters of flue gas exhaust from the incinerator were monitored, including the concentrations of metals, particulates, carbon monoxide, total hydrocarbons, and oxygen, to determine if the flue gas will exceed any of the appropriate emissions criteria for sewage sludge incinerators.

6.5.2 Data Collection and Analysis

Metals Emissions - It was initially believed that the method of incinerator control would not affect the concentration of metals in the incinerator's flue gas. However, according to analytical data, there may be some correlation between the metals emissions and the mode of incinerator control. This will be evaluated further in Section 7.2.

To evaluate using pulp and polymer as sludge-conditioning agents, manual test runs are compared to the manual baseline, and the automatic test runs to the automatic baseline to eliminate any effects on emissions due to the operating mode of the incinerator. Flue gas samples for metals emissions were taken from the stack of the incinerator located on the roof of the treatment facility.

Metals Emissions - Manual Tests - Flue gas from the incinerator was analyzed for six metals: cadmium, chromium, copper, lead, zinc, and mercury. The metal emissions for the manual sludge baseline conditioned with lime and ferric chloride, and the manual mix tests for sludge conditioned with paper pulp and polymer, are compared in Table 6-11. The results, arranged in order of increasing pulp content in the sludge, show that although the level of metals decreased significantly from the baseline tests, there does not appear to be any correlation between the specific quantity of paper pulp in the sludge and metals emissions in the flue gas. However, the test data are very limited and represent short duration of time. During baseline tests, when the composition of the conditioned sludge is relatively "consistent," the concentration of metals detected in the various samples varied significantly. Therefore, it is hard to quantify if the change in the metals concentration between the pulp mix tests is due to the change in the pulp concentration, or it is simply due to normal variation in the metals content of the in-coming sludge. Figure 6-4 shows a graph of the specific metals concentration in the flue exhaust compared to the concentration of paper pulp in the sludge mixture.

Table 6-11

Incinerator Flue Stack Metal Emissions - Manual Tests

Test	Paper Pulp % of Sludge	Cadmium lb/h	Chromium lb/h	Copper lb/h	Lead lb/h	Zinc lb/h	Mercury lb/h	Particulates lb/h
BASELINE #1		0.0000255	0.0000234	0.0027500	0.0022400	0.0012400	0.0002050	0.3000000
BASELINE #1		0.0000270	0.0000073	0.0008640	0.0052100	0.0002190	0.0000233	0.2500000
BASELINE #1		0.0000031	0.0000058	0.0016700	0.0026300	0.0004800	0.0003400	0.3100000
	Average	0.0000185	0.0000122	0.0017613	0.0033600	0.0006463	0.0001894	0.2866667

#3-1	0	0.0000067	0.0000134	0.0002070	0.0009670	0.0001090	0.0006520	0.0560000
Percent Change		-64%	10%	-88%	-71%	-83%	244%	-80%

#1-1	5	0.0000074	0.0000132	0.0004240	0.0005600	0.0000883	0.0006970	0.0450000
Percent Change		-60%	8%	-76%	-83%	-86%	268%	-84%

#2-1	7.5	0.0000025	0.0000073	0.0000152	0.0000405	0.0000288	0.0013500	0.0150000
Percent Change		-87%	-40%	-99%	-99%	-96%	613%	-95%

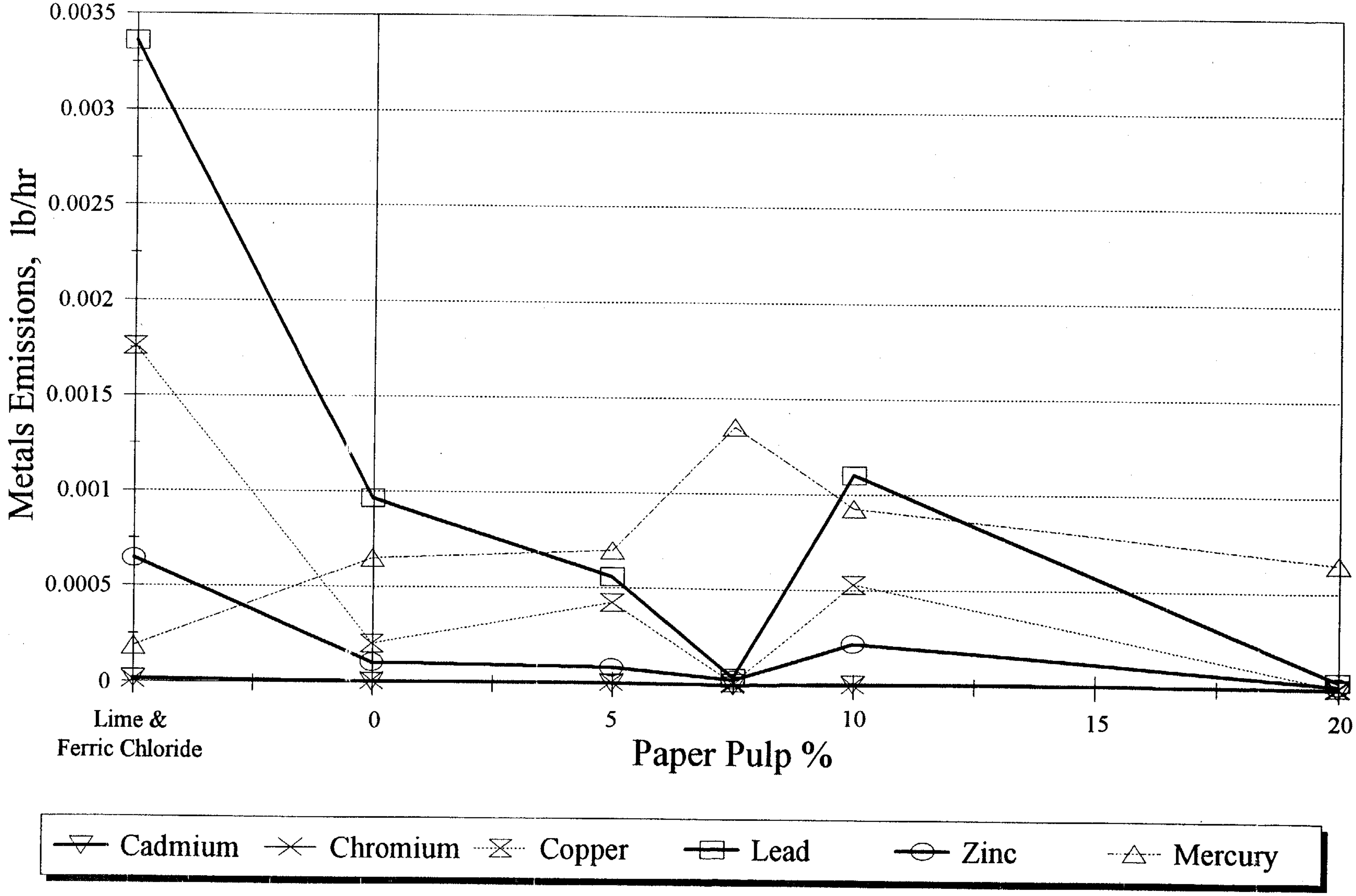
#4-1	10	0.0000125	0.0000109	0.0005320	0.0011000	0.0002240	0.0009280	0.0780000
Percent Change		-33%	-10%	-70%	-67%	-65%	390%	-73%

#5-1	20	0.0000025	0.0000045	0.0000106	0.0000406	0.0000187	0.0006500	0.0160000
Percent Change		-87%	-63%	-99%	-99%	-97%	243%	-94%

All emissions are in lb/h.

Figure 6-4

Metal Emissions - Manual Tests



Despite data limitations, several observations can be made about the concentration of metals in the flue gas. With the exception of mercury, the concentrations of nearly all metals decreased significantly between the manual baseline tests and the manual mix tests. Mercury emissions during the manual mix tests increased from 243% to 613% over the manual baseline tests. Even the highest mercury emissions (1.35×10^{-3} lb/hour, from Mix #2-1), were only 0.46% of the allowable mercury emissions (3200 grams per 24-hour period or 0.294 lb/h). Mercury is the only metal analyzed for which there presently is an emission limitation.

Two possible sources of the metals in the flue gas during the mix tests are the paper pulp and the sludge. Because no metals analysis was performed on the sludge and the pulp was analyzed only for cadmium and lead, it is not possible to determine whether one of these sources was responsible for the increase in mercury concentration. It is possible that the change in the concentration of mercury and the other metals is due to a change in the concentration of metals in the sludge. Three months passed between the last round of baseline tests and the first round of the sludge mix tests. Over this time period, the quality of the sludge could have changed due to seasonal or other variations in the plant wastewater influent. Previous analysis of the sludge has shown that the metals concentrations can vary significantly from month to month. It is also possible the different conditioning agents cause the composition of the sludge and/or ash to change the way that certain metals behave in the system. The pH and temperature of the system are other factors that could affect the behavior of the metals. There is also a remote possibility that either the fuel oil or the polymer contained mercury during the mix tests. Based on the data collected for this project, it is only possible to speculate on the source of the mercury.

Particulates were monitored as part of flue stack testing. As shown in Table 6-11, the concentration of particulates in the manual mix tests decreased from 73 to 95% compared to manual baseline tests. This decrease in particulates may be due to the changed quality of the sludge and ash, and how the sludge behaves in the incineration and flue gas treatment processes (i.e. venturi scrubber). The decrease in particulates also may be due to the fact that sludge conditioned with paper pulp and polymer contains significantly less noncombustible material than sludge conditioned with lime and ferric chloride.

<u>Metals Emissions - Automatic Tests</u> - The results of the automatic tests showed the same general results as the manual tests. The results of automatic tests are shown Table 6-12. As with the manual tests, all metals and particulate showed a significant reduction from the baseline emissions with the exception of mercury. The increase in mercury concentrations in the automatic test ranged from 61 to 337% over the

Table 6-12

Incinerator Flue Stack Metal Emissions - Automatic Tests

Test	Paper Pulp % of Sludge	Cadmium lb/h	Chromium lb/h	Copper lb/h	Lead lb/h	Zinc lb/h	Mercury lb/h	Particulate lb/h
BASELINE #2		0.0000115	0.0000732	0.0002940	0.0001760	0.0000901	0.0003340	0.1200000
BASELINE #2		0.0000146	0.0000177	0.0004220	0.0025000	0.0000999	0.0003020	0.1400000
BASELINE #2		0.0000125	0.0000012	0.0002930	0.0022100	0.0000723	0.0003600	0.1300000
	Average	0.0000129	0.0000307	0.0003363	0.0016287	0.0000874	0.0003320	0.1300000
#3-2	0	0.0000025	0.0000098	0.0000111	0.0000124	0.0000340	0.0005890	0.0270000
Percent Change		-81%	-68%	-97%	-99%	-61%	77%	-79%
#1-2	5	0.0000025	0.0000066	0.0000108	0.0000122	0.0000306	0.0014500	0.0210000
Percent Change		-81%	-78%	-97%	-99%	-65%	337%	-84%
#2-2	7.5	0.0000025	0.0000056	0.0000084	0.0000124	0.0000208	0.0009430	0.0150000
Percent Change		-81%	-82%	-98%	-99%	-76%	184%	-88%
#4-2	10	0.0000025	0.0000055	0.0000096	0.0000124	0.0002440	0.0005350	0.0290000
Percent Change		-81%	-82%	-97%	-99%	179%	61%	-78%
#5-2	15	0.0000025	0.0000113	0.0000237	0.0000537	0.0000455	0.0012500	0.0240000
Percent Change		-81%	-63%	-93%	-97%	-48%	277%	-82%

All emissions are in lb/h.

baseline concentrations during the automatic test. However, even at the highest emissions of mercury ($1.45x10^{-3}$ lb/hour) the level is only 0.049% of the total allowable mercury emissions.

As shown in Figure 6-5, although the level of metals decreased significantly from the baseline tests, there seems to be no correlation between the specific quantity of paper pulp in the sludge and the resultant metals emissions in the flue gas. Several metals concentrations were relatively consistent in all the test mixtures. Compared to the baseline values, cadmium emissions were consistently 81% lower, copper emissions were 93 to 98% lower, and lead emissions were 97 to 99% lower. The manual tests did not exhibit this consistency in metals concentrations in the exhaust gas.

Flue Gas Concentrations - Flue gas emissions were monitored for oxygen, carbon monoxide and total hydrocarbons. The results are shown in Tables 6-13, 6-14, and 6-15. Because the incinerator control mode may affect flue gas concentrations, the manual and the automatic monitoring events were considered separately in the data analysis.

The flue stack concentrations of carbon monoxide appear to be independent of the agents used to condition the activated sludge. In manual and automatic tests, concentrations of carbon monoxide were sometimes higher and sometimes lower than baseline values.

With the exception of sludge Mix #3-2 (0% paper pulp), the concentration of total hydrocarbons in the flue stack was lower than the respective baseline value for all the sludge mix tests. Reductions ranged from 2% to 65%. There does not appear to be, however, any significant correlation between the actual quantity of paper pulp in the sludge and the subsequent reduction in total hydrocarbons. All hydrocarbon concentrations were below the regulatory limit of 100 ppm monthly average. The highest average concentration of hydrocarbons was approximately 20 ppm.

Miscellaneous Stack Parameters - In addition to metals, exhaust from the treatment facility stack was analyzed for several miscellaneous parameters. The results are summarized in Table 6-16. As shown, adding paper pulp and polymer had little if any effect on the quality of the exhaust gases. The only factors with any significant change were temperature and moisture; however, these increases are most likely due to the seasonal difference in temperature between the baseline tests done from March to May, and actual mix tests done in August.

Figure 6-5

Metal Emissions - Automatic Tests

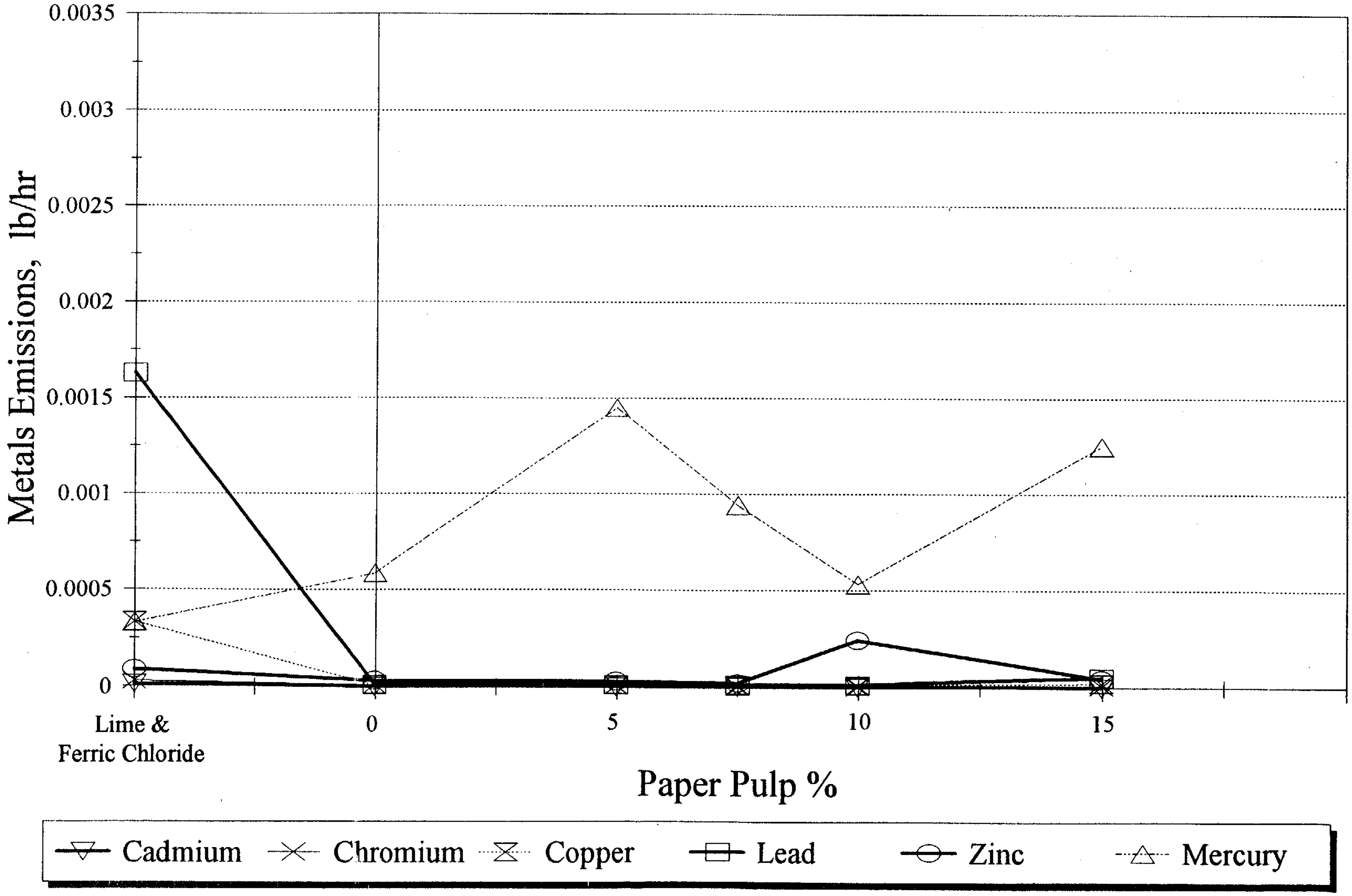


Table 6-13

Comparison of Automatic vs. Manual Flue Gas Concentrations of Oxygen, Total Hydrocarbons, and Carbon Monoxide

Date	Test	O2 %	Normalized to 7% Oxygen	
			CO (ppm)	THC (ppm)
MANUAL CONTROL				
03/10/94	Baseline #1-1	4.41	99.31	8.68
03/11/94	Baseline #1-2	6.1	90.64	19.90
03/12/94	Baseline #1-3	4.71	22.07	7.89
03/23/94	Baseline #1-4	8.16	52.94	12.32
03/24/94	Baseline #1-5	5.17	67.46	8.80
03/25/94	Baseline #1-6	4.75	29.56	7.44
03/26/94	Baseline #1-7	5.2	10.03	7.41
03/27/94	Baseline #1-8	4.06	12.91	6.98
03/28/94	Baseline #1-9	4.32	10.97	7.08
03/29/94	Baseline #1-10	4.12	12.53	7.34
03/30/94	Baseline #1-11	Oxygen analyzer was not working properly		
03/31/94	Baseline #1-12	Oxygen analyzer was not working properly		
04/01/94	Baseline #1-13	6.99	13.64	11.55
04/02/94	Baseline #1-14	4.55	6.11	10.32
04/03/94	Baseline #1-15	1.5	6.84	6.59
AVERAGE		4.93	33.462	9.407
AVERAGE MOISTURE (%)			2.361	
NORMALIZED TO 0% MOISTURE			**34.271**	**9.634**
AUTOMATIC CONTROL				
04/23/94	Baseline #2-1	4.86	18.02	1.53
04/24/94	Baseline #2-2	5.25	17.74	1.95
04/25/94	Baseline #2-3	4.69	15.41	1.49
04/26/94	Baseline #2-4	5.25	15.99	3.22
04/27/94	Baseline #2-5	4.66	24.33	2.73
04/28/94	Baseline #2-6	7.23	16.23	13.01
04/29/94	Baseline #2-7	6.78	31.13	2.67
04/30/94	Baseline #2-8	14.56	66.00	5.95
05/01/94	Baseline #2-9	16.04	67.54	7.40
05/02/94	Baseline #2-10	16.12	65.03	8.93
05/03/94	Baseline #2-11	16.59	81.37	11.90
05/04/94	Baseline #2-12	Oxygen analyzer was not working properly		
05/05/94	Baseline #2-13	Oxygen analyzer was not working properly		
05/06/94	Baseline #2-14	Oxygen analyzer was not working properly		
05/07/94	Baseline #2-15	Oxygen analyzer was not working properly		
AVERAGE		10.21	42.559	6.368
AVERAGE MOISTURE (%)			2.618	
NORMALIZED TO 0% MOISTURE			**43.703**	**6.539**

NORMALIZED AVERAGE FOR BASELINE RUNS	**38.99**	**8.09**

Table 6-14

Manual Tests
Flue Gas Concentrations of Oxygen, Total Hydrocarbons, and Carbon Monoxide

Date	Test	Paper Pulp % of Sludge	O2 %	Moisture %	Normalised to 7% O2 & 0% Moisture	
					CO (ppm)	THC (ppm)
	Manual Baseline Avg.			2.361	34.27	9.63
8/3/94	Mix #3-1	0	5.02	5.694	17.51	5.09
	% Change				-49%	-47%
8/1/94	Mix #1-1	5	Oxygen analyzer was not working properly			
8/2/94	Mix #2-1	7.5	Oxygen analyzer was not working properly			
8/4/94	Mix #4-1	10	2.68	6.071	43.19	6.28
	% Change				26%	-35%
8/5/94	Mix #5-1	20	3.81	3.658	32.03	5.12
	% Change				-7%	-47%

Table 6-15

Automatic Tests
Flue Gas Concentrations of Oxygen, Total Hydrocarbons, and Carbon Monoxide

Date	Test	Paper Pulp % of Sludge	O2 %	Moisture %	Normalized to 7% O2 & 0% Moisture	
					CO (ppm)	THC (ppm)
	Automatic Baseline Avg.			2.618	43.70	6.54
8/3/94	Mix #3-2	0	4.39	5.023	39.01	7.01
	% Change				-11%	7%
8/1/94	Mix #1-2	5	4.1	4.740	51.22	5.09
	% Change				17%	-22%
8/2/94	Mix #2-2	7.5	4.44	4.570	44.13	6.40
	% Change				1%	-2%
8/4/94	Mix #4-2	10	5.35	5.198	35.42	5.52
	% Change				-19%	-16%
8/9/94	Mix #5-2	15	4.55	4.567	44.33	2.30
	% Change				1%	-65%

Table 6-16

Incinerator Flue Gas Miscellaneous Parameters

Test	Paper Pulp % of Sludge	Stack Flow ACFM	Stack Temp °F	Moisture %	CO2 %	O2 %	CO %	N2 %
#1 (Manual)		1,804	74	2.655	8.0	14.0	0.0	78.0
#1 (Manual)		1,869	68	2.174	8.3	11.3	0.0	80.3
#1 (Manual)		1,992	69	2.253	7.9	8.6	0.0	83.5
Average (Manual)		1,888	70	2.361	8.1	11.3	0.0	80.6
#2 (Auto)		1,610	82	3.537	8.0	12.7	0.0	79.3
#2 (Auto)		1,800	80	3.253	8.3	14.0	0.0	77.8
#2 (Auto)		1,892	65	1.985	8.1	13.3	0.0	78.4
Average (Auto)		1,767	76	2.925	8.1	13.3	0.0	78.5
Overall Average		1,828	73	2.643	8.1	12.3	0.0	79.6
Auto vs. Manual		-6%	8%	24%	1%	18%	0%	-3%
#3-1	0	1,928	97	5.694	8.0	10.5	0.0	81.5
#3-2	0	1,744	93	5.023	6.0	12.5	0.0	81.5
Average		1,836	95	5.359	7.0	11.5	0.0	81.5
Percent Change [1]		2%	38%	141%	-1%	-7%		1%
Percent Change [2]		-1%	23%	72%	-26%	-6%		4%
Avg. % Change		0%	30%	106%	-14%	-7%		2%
Auto vs. Manual		-10%	-4%	-12%	-25%	19%		0%
#1-1	5	1,903	95	5.311	8.0	8.0	0.0	84.0
#1-2	5	1,756	91	4.470	8.0	8.0	0.0	84.0
Average		1,830	93	4.891	8.0	8.0	0.0	84.0
Percent Change [1]		1%	35%	125%	-1%	-29%		4%
Percent Change [2]		-1%	20%	53%	-2%	-40%		7%
Avg. % Change		0%	28%	89%	-1%	-35%		6%
Auto vs. Manual		-8%	-4%	-16%	0%	0%		0%
#2-1	7.5	1,834	88	4.287	7.5	11.0	0.0	81.5
#2-2	7.5	1,771	90	4.570	7.0	8.5	0.0	84.5
Average		1,803	89	4.429	7.3	9.8	0.0	83.0
Percent Change [1]		-3%	25%	82%	-7%	-3%		1%
Percent Change [2]		0%	19%	56%	-14%	-36%		8%
Avg. % Change		-1%	22%	69%	-10%	-19%		4%
Auto vs. Manual		-3%	2%	7%	-7%	-23%		4%
#4-1	10	1,885	99	6.071	9.0	8.5	0.0	82.5
#4-2	10	2,064	94	5.198	7.0	11.0	0.0	82.0
Average		1,975	97	5.635	8.0	9.8	0.0	82.3
Percent Change [1]		-0%	41%	157%	12%	-25%		2%
Percent Change [2]		17%	24%	78%	-14%	-18%		4%
Avg. % Change		8%	32%	117%	-1%	-21%		3%
Auto vs. Manual		9%	-5%	-14%	-22%	29%		-1%
#5-2	15	1,855	90	4.567	8.0	12.0	0.0	80.0
Percent Change [2]		5%	19%	56%	-2%	-10%		2%
#5-1	20	1,883	83	3.658	8.0	11.5	0.0	80.5
Percent Change [1]		-0%	18%	55%	-1%	2%		-0%

NOTE:

1. Percent Change is based on the manual baseline metals concentration.
2. Percent Change is based on the automatic baseline metals concentration.

6.5.3 Conclusions

Based on the analytical data and the previous discussion, these conclusions were drawn about the effect of paper pulp and polymer on air emissions:

- Mercury emissions appear to have increased significantly, but are still less than 1% of the total allowable mercury emissions.
- Emissions of cadmium, chromium, copper, lead, and zinc in the flue gas decreased significantly.
- Emissions of particulates decreased significantly.
- There was little, if any, effect on other miscellaneous parameters of the flue stack emissions.
- Emissions of carbon monoxide do not appear to be affected by the sludge conditioning agents.
- The emissions of total hydrocarbons may be slightly reduced.

Based limited analytical data, there appeared to be significant improvement in the air emissions from the treatment facility from using paper pulp and polymer for sludge conditioning. Benefits may include reduced emissions of most metals and particulates.

6.6 Ash Quality/Quantity

6.6.1 Objectives

The quality and quantity of the ash were characterized to measure the effects from the sludge conditioned with paper pulp and polymer. Using combustible sludge conditioners like paper pulp and polymer, instead of the noncombustible lime and ferric chloride presently used, was expected to reduce the quantity of ash produced from the sludge incinerators. However, because the ash must be disposed in an offsite landfill, its quality was also a concern. If the modified sludge conditioning process causes the ash to contain concentrations of leachable organics or metals that exceed limitations, it may be necessary to pay a higher cost to dispose of the ash. Such costs must be factored into the overall economic analysis.

6.6.2 Data Collection and Analysis

Ash Quantity - Due to the method used to handle ash from the incinerator, it is not possible to accurately determine the amount of ash actually produced, especially over the relatively short duration of the sludge mix tests. The measure of the difference in the quantity of ash was determined based on analysis of the conditioned sludge for ash content as summarized in Table 6-17. As this table shows, the sludge conditioned with lime and ferric chloride had an average ash content of 38.4% of total dry solids.

Each of the paper pulp and polymer sludge test mixtures also were analyzed for ash content as shown in Table 6-17. As the table shows, the content of the ash in the sludge conditioned with paper pulp and polymer was significantly less than the value of 38.4% ash, determined for the sludge conditioned with lime and ferric chloride. The percent ash in the sludge mixtures was essentially constant among the various paper pulp and polymer mixtures, ranging from 4.9% to 9.2%. The significant difference in ash quantity between the baseline tests and the mix tests is primarily due to eliminating the noncombustible lime and ferric chloride conditioning agents, major constituents of the ash.

Ash Quality, Physical Parameters - The effect of the paper pulp and polymer addition on ash quality was determined as part of the demonstration project. The physical and chemical parameters of the ash were determined. Physical parameters included the ash density, total solids, and total volatile solids. The results are summarized in Table 6-17.

Table 6-17

Ash Physical Parameters

Test	Date Of Sample	Paper Pulp % of Sludge	Sludge % Ash[1]	Ash Density g/L[1]	Ash % Total Solids[1]	Ash % Total Vol Solids[1]
Baseline #1	3/10/94					
Baseline #1	3/11/94		43.01	1647	52.1	1.4
Baseline #1	3/12/94			1570	45.9	1.8
Baseline #1	3/23/94			1455	51.3	1.9
Baseline #1	3/24/94			1485	44.9	2.0
Baseline #1	3/25/94		39.39	1577	55.0	1.6
Baseline #1	3/26/94			1538	47.4	1.4
Baseline #1	3/27/94			1532	52.8	1.2
Baseline #1	3/28/94			1484	47.2	1.6
Baseline #1	3/29/94			1517	46.9	0.9
Baseline #1	3/30/94		40.00	1521	52.8	1.4
Baseline #1	3/31/94			1609	47.0	2.1
Baseline #1	4/1/94			1499	48.5	1.7
Baseline #1	4/2/94			1372	39.6	
Baseline #1	4/3/94			1456	39.3	2.0
Baseline 1 Average (Manual)			40.8	1518.7	47.9	1.6
Sample Standard Deviation			1.9	69.9	4.7	0.4

Baseline #2	4/23/94					
Baseline #2	4/24/94					
Baseline #2	4/25/94					
Baseline #2	4/26/94					
Baseline #2	4/27/94		32.22	1677	62.0	0.9
Baseline #2	4/28/94			1462	45.9	1.1
Baseline #2	4/29/94					
Baseline #2	4/30/94			1434	42.7	0.0
Baseline #2	5/1/94			1250	45.3	1.3
Baseline #2	5/2/94			1529	54.3	1.6
Baseline #2	5/3/94		38.83	1780	58.8	0.9
Baseline #2	5/4/94					
Baseline #2	5/5/94		37.13	1648	55.3	1.4
Baseline #2	5/6/94			1649	55.6	1.3
Baseline #2	5/7/94			1520	49.3	1.3
Baseline 2 Average (Auto)			36.1	1549.9	52.1	1.1
Sample Standard Deviation			3.4	158.5	6.6	0.5

Overall Average	38.4	1530.9	49.6	1.4
Sample Standard Deviation	3.6	110.7	5.8	0.5

Table 6-17 (Cont'd)

Ash Physical Parameters

#3-1[2] #3-2	8/3/94 8/3/94	0 0	6.3 5.4	1543.0 1412.0	53.4 43.1	1.2 1.2
Average			5.8	1477.5	48.3	1.2
Percent Change Over Baseline			-84.8%	-3.5%	-2.6%	-11.7%
#1-1[2] #1-2	8/1/94 8/1/94	5 5	5.9 6.0	1418.0 1399.0	44.5 41.0	1.6 1.5
Average			5.9	1408.5	42.8	1.5
Percent Change Over Baseline			-84.6%	-8.0%	-13.7%	10.9%
#2-1[2] #2-2	8/2/94 8/2/94	7.5 7.5	6.2 5.5	1381.0 1329.0	41.2 39.2	1.4 1.3
Average			5.9	1355.0	40.2	1.4
Percent Change Over Baseline			-84.7%	-11.5%	-18.9%	-2.0%
#4-1[2] #4-2	8/4/94 8/4/94	10 10	7.0 5.6	1372.0 1438.0	42.1 44.5	1.6 1.5
Average			6.3	1405.0	43.3	1.6
Percent Change Over Baseline			-83.6%	-8.2%	-12.6%	12.7%
#5-2	8/9/94	15	4.9			
Average						
Percent Change Over Baseline			-87.2%			
#5-1[2]	8/5/94	20	9.2	1326.0	38.2	1.3
Average						
Percent Change Over Baseline			-75.9%	-13.4%	-22.9%	-6.0%

NOTE: 1 - If no result is shown in the table, a sample was not analyzed.
2 - An average of the values obtained for the sample and the duplicate sample.

When comparing data from the manual and the automatic tests of the sludge conditioned with lime and ferric chloride, automatic operation of the system apparently had some effect on the ash physical parameters. However, the amount of ash in the sludge between the two tests also varied, and this parameter would not be expected to vary with the mode of the system operation. Therefore, it was assumed that the relatively small variations in the other ash parameters are due to variations in the quantity and/or quality of the sludge during the baseline testing, and not to the mode of operation. The average baseline concentrations of the sludge conditioned with lime and ferric chloride, for comparison to the paper pulp and polymer mix tests, was determined based on the average of values from the manual and automatic baselines.

<u>Ash Density</u> - The average density of the ash from the sludge conditioned with lime and ferric chloride was 1531 g/L. The densities of the ash from the sludge conditioned with paper pulp and polymer were all lower, ranging from 1326 to 1478 g/L. However, the density of the ash still is significantly higher than the density of water (1000 g/L). This is important because to decant excess water from the ash, the ash must be denser than water so it will settle quickly to the bottom of the ash thickener. The staff reported no noticeable difference in the quality or handling of the ash during the mix tests.

<u>Ash Total Solids</u> - The wet ash produced from the sludge conditioned with lime and ferric chloride was 49.6% total solids. The total solids content of the ash produced from sludge mixtures conditioned with paper pulp and polymer ranged from 38.2% to 48.3%.

<u>Ash Total Volatile Solids</u> - The total volatile solids content of the ash during the baseline tests was 1.4%. The total volatile solids content of the ash during the mix tests ranged from 1.2% to 1.6%. From this data, the change in the sludge mixtures apparently did not have a significant effect on the percent of combustible material remaining in the ash exiting the incinerator emission controls.

The change in density and total solids content of the ash may be inversely proportional to the concentrations of paper pulp in the sludge mixture. As more paper pulp was included in the sludge, the resultant ash had a lower density and a lower total solids content. Conversely, as the amount of paper pulp was decreased, the density and total solids content of the ash increased. Over the ranges observed, neither the ash density nor total solids content are expected to significantly affect the incinerator operation or ash-handling characteristics.

Ash Quality, Chemical Parameters - The ash samples from the demonstration project were analyzed for metals, phosphorus, chlorine, sulfur, and full TCLP (both metal and organic compounds). The results of the ash analyses for metals are given in Table 6-18 and TCLP in Table 6-19.

While it was thought that operating the incinerator in automatic or manual control may have had some effect on the metals content of the ash, a review of the data showed that the metals content can vary from sample to sample. While the concentrations of some metals increased, others decreased, making it difficult to quantify any effect due to the incinerator control. It was decided to combine the data from the manual and the automatic baseline tests. The manual and automatic test data to each sludge mixture were combined to compare to baseline values.

Ash Metals - The incinerator ash was analyzed for total cadmium, chromium, copper, lead, mercury and zinc. The results of these analyses are given in Table 6-18. The percent change in the concentrations of each of the metals for each of the paper pulp and polymer mix tests compared to the sludge conditioned with lime and ferric chloride, is also shown. Figure 6-6 graphically represents metal concentrations in the ash.

As seen in the graph, the level of metals in the ash from sludge conditioned with paper pulp and polymer remained relatively consistent, or were somewhat higher, than the ash from the sludge conditioned with lime and ferric chloride. Some of the variation is likely due to the natural variability of the metal concentration in the sludge. Some of the increase in metals concentration of the ash may be related to the decrease of metals in the flue stack exhaust. If the venturi scrubber is able to remove more of the metal-containing particulate from the incinerator exhaust gas, the metals concentration of the ash may increase.

Mercury was not detected in the ash of any of the baseline analyses or mix tests.

Miscellaneous Analyses - Phosphorus, chlorine, and sulfur analyses are summarized in Table 6-18.

The concentrations of phosphorus in the ash increased by three orders of magnitude due to using polymer instead of the lime and ferric chloride. The phosphorus concentrations increased from an average of 32 ppm in the baseline analyses to a range of 29,000 to 58,000 ppm for the sludge mix tests.

Possible sources or reasons for the significant increase in phosphorus concentrations are only speculation based on the information that was collected for this project. Obvious potential sources such as the polymer

TABLE 6-18

Ash Chemical Parameters

PARAMETER SAMPLE I.D.	Paper Pulp % of Sludge	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	Phosphorus (mg/kg)	Chlorine (%)	Sulfur (%)
ASH-1		10.9	714	626	218	ND	3070	80.7	0.10	0.33
ASH-1 DUP		10.2	718	633	218	ND	3060	141.0	0.10	0.32
ASH-2		4.1	654	372	117	ND	2310	10.1	0.10	0.17
ASH-2 DUP		5.0	699	433	124	ND	2510	14.2	0.13	0.13
ASH-3		5.3	556	376	132	ND	1970	15.3	0.22	0.23
ASH-3 DUP		3.6	565	371	114	ND	1930	11.1	0.14	0.11
ASH-4		6.4	584	524	127	ND	2610	15.9	0.22	0.24
ASH-4 DUP		6.6	522	446	115	ND	2190	13.6	0.24	0.21
ASH-5		4.0	475	392	81	ND	1850	23.4	0.15	0.47
ASH-5 DUP		5.8	496	524	52	ND	2220	19.3	0.12	0.52
ASH-6		4.6	610	538	121	ND	2430	20.2	0.31	0.23
ASH-6 DUP		3.2	486	410	128	ND	1920	19.1	0.25	0.28
Baseline Arithmetic Mean		5.8	590	470	129	—	2339	32.0	0.17	0.27
Sample Standard Deviation		2.5	89	96	47	—	418	39.2	0.07	0.13
ASH #3-1	0	10.0	619	1140	268	ND	3670	41200	0.14	0.32
ASH #3-1 DUP	0	10.1	622	1180	272	ND	3670	39400	0.11	0.20
ASH #3-2	0	9.5	650	1490	260	ND	3920	54100	0.10	0.18
ASH #3-2 DUP	0	9.0	691	1560	273	ND	4180	50100	0.10	0.11
Arithmetic Mean		9.7	646	1343	268	—	3860	46200	0.11	0.20
Percent Change Over Baseline		66%	9%	185%	108%		65%	144313%	-36%	-25%
ASH #1-1	5	11.6	601	1840	260	ND	3930	54800	0.09	0.13
ASH #1-1 DUP	5	5.4	268	861	122	ND	1780	54800	0.10	0.10
ASH #1-2	5	11.7	623	1700	263	ND	4350	53100	0.10	0.15
ASH #1-2 DUP	5	4.7	254	701	115	ND	1780	59700	0.10	0.11
Arithmetic Mean		8.4	437	1276	190	—	2960	55600	0.10	0.12
Percent Change Over Baseline		44%	-26%	171%	47%		27%	173695%	-43%	-55%
ASH #2-1	7.5	8.1	642	1220	234	ND	3620	55700	0.11	0.15
ASH #2-1 DUP	7.5	4.2	291	595	115	ND	1620	53800	0.09	0.11
ASH #2-2	7.5	9.5	609	1250	284	ND	3970	63400	0.08	0.14
ASH #2-2 DUP	7.5	8.4	583	1190	261	ND	3770	60300	0.07	0.01
Arithmetic Mean		7.6	531	1064	224	—	3245	58300	0.09	0.10
Percent Change Over Baseline		30%	-10%	126%	73%		39%	182135%	-49%	-61%
ASH #4-1	10	5.8	567	1430	194	ND	3650	14900	0.07	0.09
ASH #4-1 DUP	10	6.0	553	1370	187	ND	3550	17500	0.06	0.06
ASH #4-2	10	5.3	523	1150	189	ND	3370	54100	0.04	0.08
Arithmetic Mean		5.7	548	1317	190	—	3523	28833	0.06	0.07
Percent Change Over Baseline		-2%	-7%	180%	47%		51%	90028%	-67%	-73%
ASH #5-1	20	6.2	512	1010	206.0	ND	3170	46800	0.06	0.18
ASH #5-1 DUP	20	5.4	485	950	194.0	ND	2980	44100	0.06	0.11
Arithmetic Mean		5.8	499	980	200.0	—	3075	45450	0.06	0.15
Percent Change Over Baseline		-0%	-15%	108%	55%		31%	141968%	-67%	-46%

Table 6-19

Ash TCLP Results

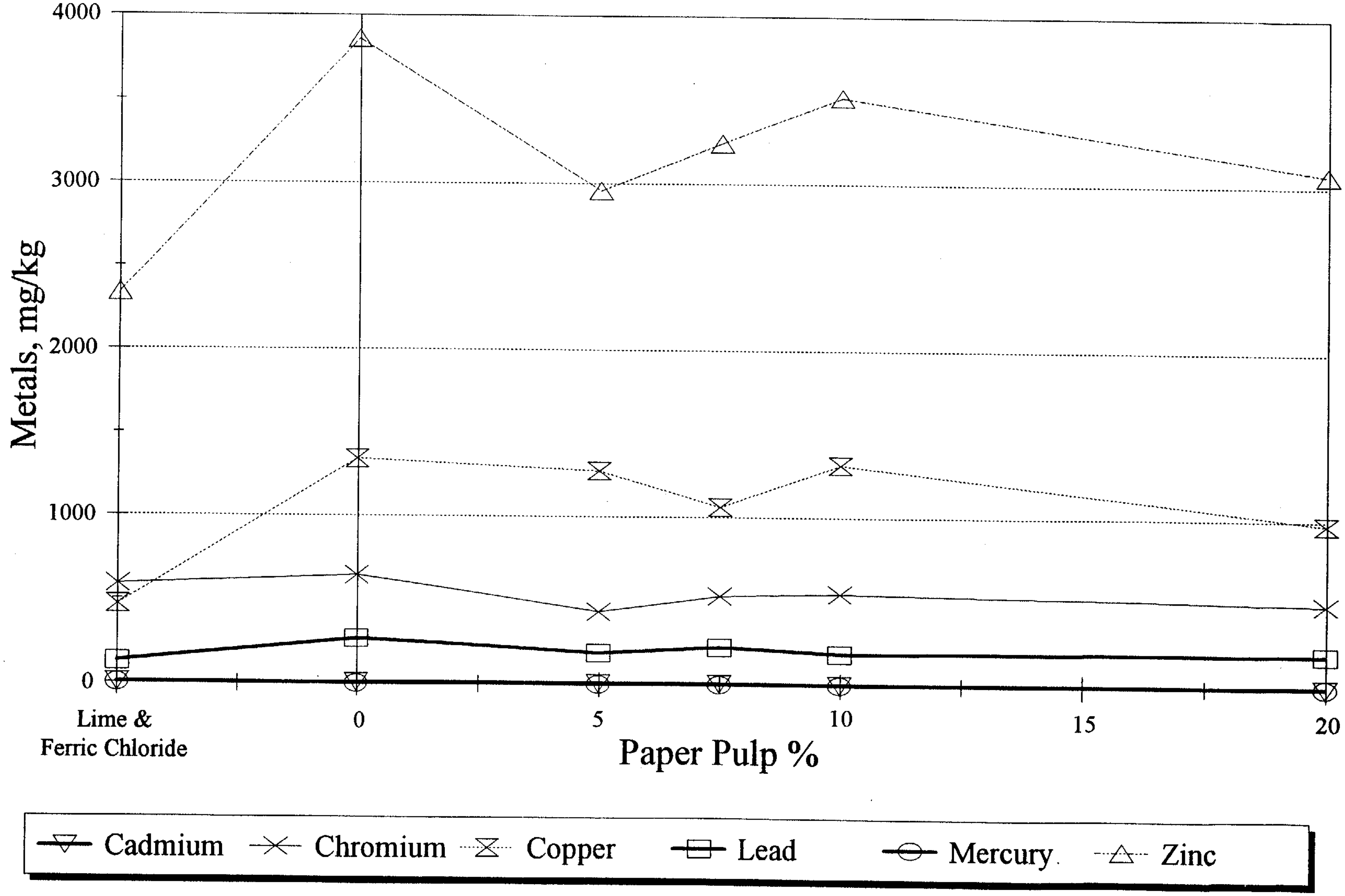
Parameters	Baseline	Ash #1-1	Ash #1-2	Ash #1-3	Ash #1-4	Ash #1-5	Regulatory Limit
Benzene							0.5
Carbon Tetrachloride							0.5
Chlorobenzene							100
Chloroform							6
2-Butanone							200
Tetrachloroethylene							0.7
Trichloroethylene							0.5
Vinyl Chloride							0.2
1,2-Dichloroethane							0.5
1,1-Dichloroethene							0.7
1,4-Dichlorobenzene							7.5
Hexachloroethane							3
Nitrobenzene							2
Hexachlorobutadiene							0.5
2,4,6-Trichlorophenol							2
2,4,5-Trichlorophenol							400
2,4-Dinitrotoluene							0.13
Hexachlorobenzene							0.13
Pentachlorophenol							100
2-Methylphenol							200
3 & 4-Methylphenol							200
Pyridine							5
Chlordane							0.03
Endrin							0.02
Heptachlor							0.008
Heptachlor Epoxide							0.008
Lindane							0.4
Methoxychlor							10
Toxaphene							0.5
2,4-D							10
Silvex							1
Arsenic							5
Barium	0.46		0.3	0.29	0.75	0.36	100
Cadmium		0.007					1
Chromium	0.802	1.11	0.99	1.22	0.57	0.74	5
Lead							5
Mercury							0.2
Selenium							1
Silver							5

All units are in mg/L

NOTE: Only detected values are reported.

Figure 6-6

Ash Metals Concentrations



conditioning agents and the paper pulp were not analyzed for phosphorus. Although the composition of the polymer is unknown, the Material Safety Data Sheet (MSDS) gave no indication that it contained phosphorus. There was no correlation between the phosphorus levels in the ash and the quantity of paper pulp used for conditioning. The change in phosphorus levels of the ash also occurred when only polymer was used for sludge conditioning. It is possible that the conditioning agents affect the way the phosphorus reacts in the sludge conditioning and incineration processes. Conditioning with polymer may cause the phosphorus to remain in the sludge/ash, whereas conditioning with lime and ferric chloride may cause the phosphorus to be dissolved and recycled back to the head of the plant in the filtrate or scrubber water recycle streams. However, without an analysis of all the process streams for phosphorus, the reason for the increase is unknown.

The capture of phosphorus in the ash associated with polymer conditioning would prove beneficial to the overall removal of phosphorus in the plant. This would warrant further study due to the potential benefits associated with phosphorus removal.

The elimination of ferric chloride also caused a decrease in the percentage of chorine in the ash with concentrations ranging from 36 to 67% lower. A reduction in the chlorine level in the ash may result in less damage to the incinerator and scrubber equipment. Chlorine at the extremely high temperatures of the exhaust gas can be very corrosive.

Sulfur concentrations also decreased from 25% to 73%, but with no apparent correlation to the concentrations of paper pulp added to the sludge.

Ash TCLP - While the concentration of metals in the incinerator ash is important, ash disposal depends on the TCLP analysis of the ash. The TCLP concentrations for organics and metals are presented in Table 6-19. As this table shows, there were no leachable organics detected in the incinerator ash. The only leachable metals detected were barium, cadmium, and chromium. No concentration was close to regulatory limits for hazardous waste.

6.6.3 Conclusions

Based on analytical data and the previous discussion, these conclusions about the effect of pulp and polymer addition on the quality and quantity of the incinerator ash compared to the traditional sludge stream were drawn:.

- The quantity of the ash produced decreased significantly (76 to 87% reduction in ash content of the sludge).
- There was no noticeable difference in the handling characteristics of the ash.
- While the concentrations of most metals in the ash increased, the TCLP analyses for the ash were well below the TCLP limit for all compounds.
- Phosphorus concentrations in the ash increased by three orders of magnitude.
- Chlorine levels in the ash were reduced 36% to 67%.

Based on limited analytical data, there appeared to be no negative impacts to the ash due to using paper pulp and polymer for sludge conditioning. Benefits include the reduced quantity of ash that must be disposed off- site, and reduction in the levels of corrosive chlorine.

6.7 **Overall Incinerator Combustion Quality and Efficiency**

6.7.1 Optimum Ratio of Pulp and Polymer

The objectives for the addition of paper pulp and polymer to the sludge feed stream were outlined and evaluated in previous sections. These objectives are summarized on Table 6-20 along with the pulp mix ratio(s) that best met the particular objective.

As shown on the table, Mix #1 (containing 5% paper pulp) best met the objectives of the demonstration project. Mix #2 (containing 7.5% pulp) gave results very similar to, but not quite as good as Mix #1. Mix #3 (containing 0% pulp) was unacceptable on the criteria of cake release, and showed only marginal improvement in the remaining study objectives. Therefore, it is assumed that the optimum pulp addition ratio is in the range of 5%. The optimum ratio would have to be determined through long-term monitoring of the incineration process and use of paper pulp and polymer conditioning agents. To evaluate the cost of implementing pulp addition, it will be assumed that 5% pulp would be added to the sludge mixture.

6.7.2 Cost Analysis of Pulp and Polymer Addition

The purpose of this cost analysis is to determine whether or not it is cost effective to use paper pulp and polymer for sludge conditioning. Several factors need to be considered in evaluating the cost of implementation including:

- Personnel requirements;
- Maintenance requirements;
- Auxiliary fuel use;
- Sludge conditioning chemicals;
- Ash disposal costs;
- Air emissions costs; and
- Overall system operation.

Table 6-20

Summary of Pulp Mix Test Results

Objective	Best Pulp Mix Ratio*	% Paper Pulp	Comments
Sludge Dewaterability	Mix #1	5%	No mixes improved the sludge dewaterability.
Cake Release and Feed Characteristics	Mix #5	15-20%	Mix #3, containing no paper pulp, was too sticky. Release and feed of all other mixes was acceptable.
BTU Value	Mix #1, #2	5-7.5%	Mixes #3, #4, and #5 showed only marginal improvement.
Auxiliary Fuel Consumption	Mix #1, #2	5-7.5%	Mixes #3 and #4 showed only marginal improvement. Mix #5-2 increased fuel use.
Air Pollution Control			All mixtures had similar characteristics. No unfavorable mixes.
Ash Quality/Quantity			All mixtures had similar characteristics. No unfavorable mixes.

* The Mix Ratios consider the manual (-1) and the automatic (-2) test of each sludge mixture.

Each of these factors will be determined on a per ton of sludge basis. Costs were determined based on the 1994 Sludge Processing and Chemical Feed costs that were provided by Erie County, shown in Appendix E. In 1994, 2821 dry tons of conditioned sludge were incinerated at the facility. From the operating data, it was estimated that 1989 tons of the 2821 tons of conditioned sludge solids were actual sludge solids; (i.e., 832 tons of conditioning chemicals were incinerated).

Paper Pulp Supply Assumptions - How the paper pulp is supplied to the treatment facility may have a significant impact on the costs of implementation. For the project, the paper pulp was purchased by the truckload from a local paperboard manufacturer for $250 per 3,200 gallons of 4% pulp solids, or approximately $468 per ton of dry solids. If pulp is purchased for long-term operation, a lower price could probably be negotiated.

As an alternative to purchasing paper pulp, the treatment plant could purchase equipment and produce their own supply of paper pulp slurry. As shown in the memo presented in Appendix F, the capital cost to install pulping equipment would range from $150,000 to $250,000. The capital cost of the equipment is not considered in the determination of the overall sludge processing costs. However, the capital costs are compared to the estimated annual savings, to determine the costs versus the benefits of implementing paper pulp and polymer conditioning, and to determine the approximate pay back time on the initial capital costs.

The heat content of the paper pulp is an important factor affecting the heat content of the conditioned sludge, and savings in fuel oil use. Therefore, it is very important to use only high quality paper in the pulping process. Low heat content materials such as magazines, glossy paper, and brown paper would have to be removed before pulping the paper. For this estimate, it was asumed that a no cost a source of paper, such as wastepaper collection at County buildings or some other source, could be arranged. However, if insufficient wastepaper is available, old newspapers could be purchased for $10 to $30 per ton.

Personnel Requirements - It is expected that there would be some increase in the manpower requirements if paper pulping activities were to be implemented at the treatment plant. Little time and manpower is presently required for preparing and handling lime and ferric chloride. However, if paper pulp is produced, a conservative estimate shows one additional employee, working 8 hours per day, 5 days per week, would be required. It is assumed that this employee would cost approximately $20 per hour, or $41,600 annually. The duties of this person would include the following;

- Collecting waste paper from County facilities and transporting it to the treatment plant;
- Sorting and removing magazines, glossy paper, brown paper, and other low heat content materials; and
- Preparing the pulp solution.

Based on a pulp use rate of 5%, an average daily sludge production rate of 6.5 dry tons, and an assumed pulping capacity of 750 lbs dry paper solids per batch, only one batch of pulp per day would be required.

Equipment maintenance requirements also would be expected to remain nearly constant. The only additional equipment that would be required would be the paper pulper, a transfer pump, transfer lines, and possibly some batch storage tanks. The maintenance for these items is expected to be similar to that of the existing equipment which would no longer be used.

Fuel Oil - The 1994 fuel oil use rate was 102.3 gallons per ton of dry conditioned sludge (145 gallons per dry ton of sludge solids) at a cost of $0.607 per gallon of fuel oil. Based on the information presented in Section 6.4, the fuel oil consumption rate, using 5% paper pulp, was from 54% to 70% less than the baseline conditions. To be conservative, it is assumed that there would theoretically be at least a 30% reduction in fuel oil use. Based on 1994 data, this would equate to a fuel oil use rate of (145 gallons x 0.70) = 101.50 gallons per dry ton of sludge, at a cost of (101.50 gallon x $0.607 per gallon) = $61.61 per dry ton of solids.

Electricity - Because electricity use is not directly related to the incineration process, and should not be affected significantly by the use of paper pulp and polymer, it is assumed the electricity cost per dry ton of sludge will remain constant.

Conditioning Chemicals - Chemicals presently used in conditioning the sludge include lime, ferric chloride, polymer, muriatic acid, and sludge additive.

- Lime - The lime dosage rate in 1994 was 567 lbs per ton of dry sludge. With a lime cost of $0.03668 per pound, the cost to treat a ton of dry sludge would be $20.80. No lime would be required if pulp and polymer conditioning were implemented.

- Ferric Chloride - The ferric chloride dosage rate in 1994 was 270 lbs per ton of dry sludge. With a cost of $0.093 per pound of ferric chloride, the cost to treat a ton of dry sludge would be

$25.11. It is assumed that no ferric chloride would be required if pulp and polymer were implemented for conditioning the sludge. Ferric chloride still would be used for phosphorus removal.

- Muriatic Acid - Muriatic acid is used to clean the filter press cloths whenever the cloths are blinded. Although using paper pulp and polymer may have a long-term effect on the frequency of filter cloth cleaning, this was not determined by the project. Therefore, it is assumed muriatic acid use would remain constant.

- Sludge Additive - The sludge additive, consisting of kaolin clay, is used to reduce fouling of the heat exchanger. If conditioning the sludge using paper pulp and polymer were implemented, it is assumed that the sludge additive would no longer be required. This would have to be verified through long-term operation and monitoring the system. However, because the heat exchanger was not in use for the duration of 1994, there was no cost for sludge additive.

- Polymer - A small quantity of polymer is used in the ash thickening and dewatering process. Polymer use for ash-thickening and dewatering is assumed to remain constant with the use of paper pulp and polymer for sludge conditioning.

While several of the conditioning chemicals would be eliminated, paper pulp and polymer would be additional costs.

- Paper Pulp - Based on the 5% dosage rate, the paper pulp requirement would be 100 lbs of dry pulp per dry ton of sludge. Assuming that arrangements can be made to collect wastepaper from County facilities, there would be no cost for the paper. The pulp production costs are included in the personnel costs. The approximate cost that was paid to treat a ton of sludge during the demonstration was $23.

- Polymer - The polymer used in the demonstration project was Percol 778 FS 40. The polymer dosage rate was 12 lbs per dry ton of sludge. Assuming a cost of $1.45 per lb of polymer, the cost to treating a ton of sludge would be $17.40.

<u>Repair and Maintenance</u> - It is assumed that the costs to repair and maintain the sludge conditioning and incineration process would be constant despite of the sludge conditioning agents used. In actuality,

eliminating ferric chloride would reduce the concentration of chlorides in the incinerator and the incinerator's flue-gas. Chlorides can be very damaging and corrosive, especially when coupled with conditions in the incinerator exhaust. Reducing the chloride concentration may produce less corrosion and longer equipment life. The effects of using paper pulp and polymer over an extended time would have to be determined through long-term use and evaluation.

Reactor Sand - The costs for reactor sand are expected to remain constant regardless of the sludge conditioning process.

Ash Disposal - The 1994 costs for ash disposal were $55 per wet ton of ash. The total quantity of ash disposed was 1217.9 dry tons or 2521 wet tons. Based on the information in Section 6.6, it was demonstrated that the quantity of ash could be reduced from 76 to 87%. To be conservative, it is assumed that the quantity of ash for disposal, while using paper pulp and polymer, would be 75% less than at present. Thus the amount of ash requiring disposal would be approximately 630 wet tons at a cost of $55 per ton.

Overall System Operation - Several cost factors previously evaluated, while not affected on a daily basis, could be affected as a result of overall incinerator operation. If the incinerator could process the sludge in less time, due to increased sludge throughput, the personnel and electricity costs would be reduced.

It is presently necessary to run one incinerator continuously, with a second one operating approximately 25% of the time to process all the sludge. Operating the second incinerator requires adding a person to the shift to run the facility. As shown in Figure 6-1, the dry sludge solids throughput rate, when using sludge conditioned with lime and ferric chloride, is approximately 412 lb/hr. The dry sludge solids throughput rate, when using sludge conditioned with 5% paper pulp and polymer, was approximately 515 lb/hr. This is a 25% increase in the system's sludge throughput. Based on these numbers, it appears possible to operate the system year round using only one incinerator. This would have a beneficial impact on manpower and electricity use. A 25% increase in sludge throughput would equate to a 20% reduction in the overall operation of the incinerator. Therefore a 20% reduction in the electricity costs will be assumed. Because manpower is not as directly related to the incineration process as electricity use, no change in the manpower requirements will be assumed.

One advantage of the fluidized bed incinerators is that they can quickly be started up or shut down as required for sludge processing. Other types of incinerators have to be operated continuously and do not have such flexibility in operation.

Because the incinerator is presently the limiting step in the capacity of the treatment facility, increased throughput of the incinerators would also allow the total treatment capacity of the plant to be increased.
Summary - Based on information previously presented the total operating cost to treat sludge conditioned with paper pulp and polymer would be $332.97 per dry ton of sludge. This compares to the 1994 operating cost of $424.70 per dry ton of sludge, to treat sludge conditioned with lime and ferric chloride.
Table 6-21 compares the 1994 treatment costs and estimated costs if paper pulp and polymer had been used as conditioning agents. It is important to note that these costs are based on the information from the demonstration project. If the heat exchanger had been in operation during the demonstration project, the actual fuel oil use would have been lower. The heat exchanger was not in operation for the duration of 1994.

6.7.3 Conclusions

As seen in Table 6-21, the estimated savings based on 1994 quantities would have been $182,442, which proves that significant savings could be made by implementing sludge conditioning with paper pulp and polymer. Based on capital costs of $150,000 to $250,000 for paper pulping equipment, and an estimated installed cost of $400,000 including buildings and appurtenances, the pulping system would pay for itself in approximately 2 years.

Added savings due to decreased manpower are not included in this estimate, nor are savings from increased efficiency if the heat exchanger were in operation. Further optimization of the paper pulp and polymer dosage rates also could produce additional savings. The estimated potential savings also do not consider the long-term effects of pulp and polymer addition on sludge management operations that are presently unknown.

Table 6-21

Cost Analysis of Pulp and Polymer Addition
Processing Costs

	1994 Costs	Pulp/Polymer Addition
Personnel (Operations)	$298,792.51	$340,392.51
Personnel (Maintenance)	$17,324.31	$17,324.31
Fuel Oil	$175,162.60	$122,613.82
Electricity	$54,311.23	$43,448.98
Conditioning Chemicals		
Lime	$41,382.85	—
Ferric Chloride	$49,838.89	—
Polymer	$5,691.60	$5,691.60
Muriatic Acid	$1,745.28	$1,745.28
Sludge Additive	—	—
Polymer (Percol FS 778 FS 40)	—	$34,608.60
Pulp	—	$0.00
Repair and Maintenance	$56,778.65	$56,778.65
Reactor Sand	$5,001.20	$5,001.20
Ash Removal to Landfill	$138,690.75	$34,672.69
Total Cost	$844,719.87	$662,277.64
Total Dry Sludge Incinerated	1,989 TONS	1,989 TONS
Equivalent Conditioned Sludge	2,821 TONS	2,088 TONS
Operational Cost per Ton Sludge	$424.70	$332.97

7. SUMMARY OF RESULTS FOR AUTOMATIC INCINERATOR CONTROL

It was expected that automatic operation might provide better control of the system than with manual control. Parameters, such as the air flow rate and the fuel oil flow rate, could be adjusted faster and more often to react to changing conditions in the incinerator. Various parameters of the incineration process that may be affected by the mode of incineration control were analyzed. Due to the massive amount of data collected for this project, each of the project objectives was analyzed separately. A general assessment of automatic control of the incineration system appears in Section 7.3.

7.1 Auxiliary Fuel Consumption

7.1.1 Objectives

One objective of this project was to determine the effect of automatic control of the incineration system on auxiliary fuel requirements. By quickly adjusting the auxiliary fuel oil flow rate to react to system changes, such as an increase in the BTU value of the sludge, it was assumed that excess fuel oil used in the incineration process would be eliminated.

7.1.2 Data Collection and Analysis

The most important data collected regarding the control of the incinerator are the manual and the automatic baseline tests. Although paper pulp and polymer mix tests were run in manual and automatic mode, these tests were very short (less than 4 hours) compared to baseline tests for which data were collected 24 hours a day for 15 days. Therefore, the results of baseline tests are much more important to determine the benefits, if any, to implement automatic control of the incineration system.

Baseline Tests - To allow data to be compared on an equal basis, fuel oil use rates were determined based on the feed rate of sludge into the system, as presented in Section 6.4.2. The average fuel oil use rate during the manual baseline test was 0.0739 gallons per pound of dry sludge incinerated (0.0136 gallon per 1000 BTU of sludge). As shown in Table 7-1, the average fuel oil use rate during the automatic baseline test was 0.0706 gallons per pound of dry sludge incinerated (0.0126 gallons per 1000 BTU of sludge). Thus, there apparently was an estimated 7.9% decrease in the use of auxiliary fuel oil, as a result of automatic control of the system.

Table 7-1

Fuel Oil to BTU Ratio

Manual vs. Automatic Operation

Mix Test	Percent Paper Pulp	Control	Average Fuel Use*	Heat Content	Fuel Oil to BTU Ratio	Percent Change Man vs. Auto
			gal/lb dry sludge	BTU/lb dry solids	gal. oil per 1000 sludge BTU	%
Baseline	Lime & Ferric Chloride	Man	0.0739	5,419	0.0136	-7.9%
		Auto	0.0706	5,614	0.0126	
Mix Test #3	0	Man	0.0474	7,439	0.0064	-4.1%
		Auto	0.0508	8,306	0.0061	
Mix Test #1	5	Man	0.0342	7,734	0.0044	-37.7%
		Auto	0.0221	8,029	0.0028	
Mix Test #2	7.5	Man	0.0417	7,687	0.0054	3.0%
		Auto	0.0458	8,204	0.0056	
Mix Test #4	10	Man	0.0552	6,829	0.0081	121.1%
		Auto	0.1333	7,454	0.0179	
Mix Test #5		Not applicable due to different pulp ratios for manual and automatic.				

NOTE: * - Average Fuel Use from Table 6-9 for manual control and 6-10 for automatic control.

Another important factor is a change in the fuel use rate between the two tests. When the data for the daily fuel/sludge ratios are graphed, as shown in Figure 7-1 and 7-2, it is apparent there is a distinct difference between the two control methods. Data for the manually controlled test are more constant and fall over a smaller range of values, with occasional spikes outside the normal range. When the incinerator is controlled automatically, the data fluctuate from one to two gpm/fpm with a consistent pattern.

The difference in control methods also is apparent when comparing the standard deviations for the data. The standard deviation indicates the sample data consistency. The average standard deviation for the manual baseline condition was calculated to be 0.277 gpm while the average standard deviation from the automatic baseline condition was 0.522 gpm; almost twice as high.

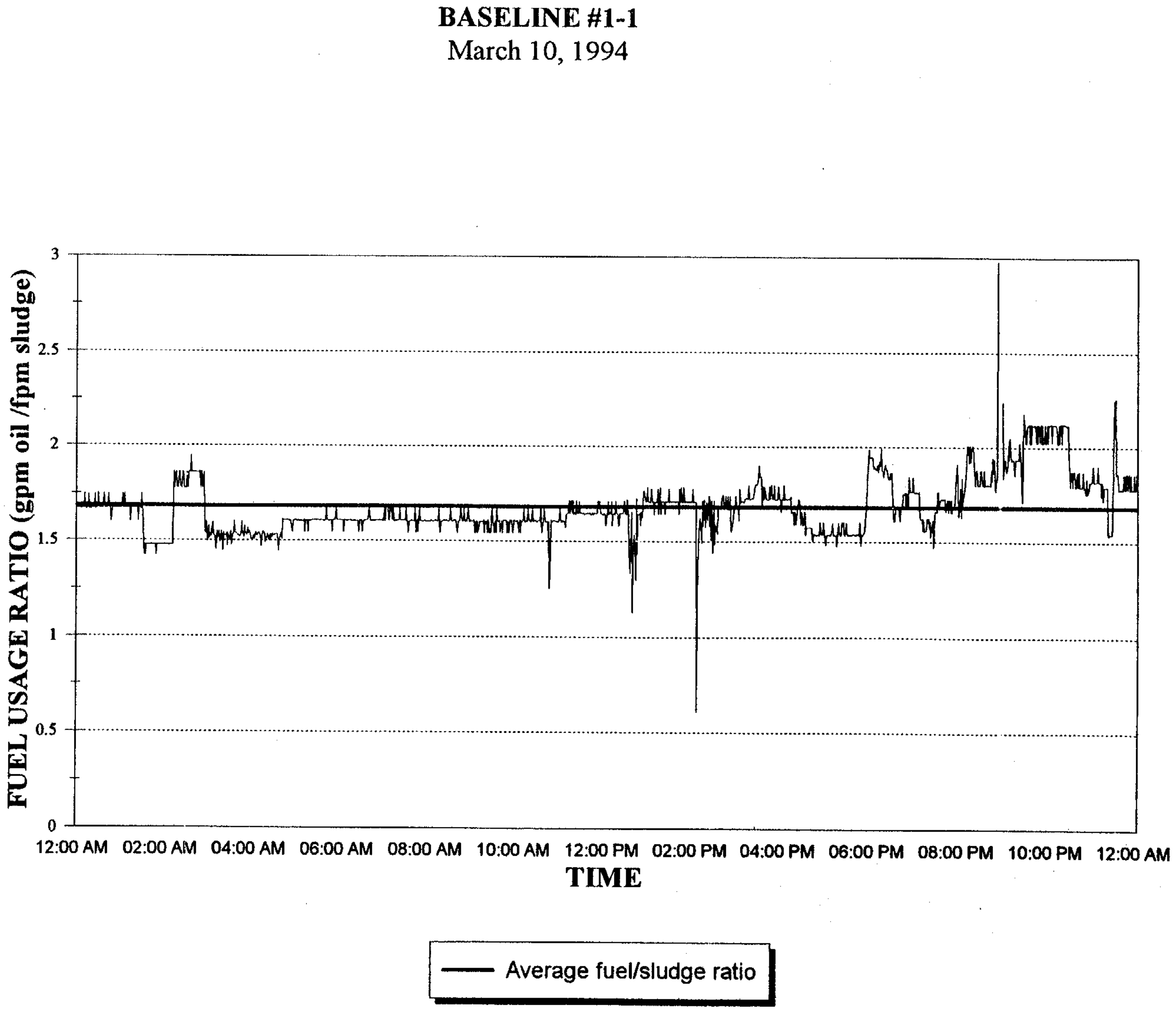
Based on the graphic representation of the data, it is apparent automatic control of the fuel oil and sludge flow rates may need to be adjusted (fine-tuned) or modified for better control of the incineration system. The control of the two flow rates is based on the temperature in the incinerator. By adjusting how the control system reacts to changes in the incinerator temperature, it may be possible to reduce fluctuations in fuel oil use and keep the rates constant. Modifications could include using a rolling average to smooth out peaks and the rapid response of the system. The control based on the oxygen analysis also could be connected to the control for temperature. If it is possible to improve the control system, there may be additional savings in fuel use; although it is not possible to quantify such savings. Because all control systems are connected to the Programmable Logic Controller (PLC), it is relatively easy to adjust system setpoints and other parameters.

Mix Tests - Results of fuel oil use rates are summarized in Table 7-1. As can be seen in this table, there is no definitive correlation between automatic and manual control and the amount of fuel oil used. Mix test #1 showed a 37.7% drop in fuel oil use from manual to automatic control, while Mix test #4 showed a 121% increase in fuel oil use from manual to automatic control. Fuel oil use rates in Mixes #2 and #3 remained relatively consistent from manual to automatic control. However, due to their short duration, the data from the mix tests are not very reliable. Additionally, as can be seen by looking at a graph of the data from Mix test #4 (Figure 7-3), one or more of the parameters in the incineration system was not operating under normal conditions, as wide fluctuations during the automatic control period indicate.

Figure 7-1
Sample Data for Manual Incinerator Control

Fuel / Sludge ratio	
Arithmetic Mean	1.682
Standard Deviation	0.155

NOTES:
Problems with sludge feed:
08:52 PM - 08:56 PM



BASELINE #1-1
March 10, 1994

Figure 7-2
Sample Data for Automatic Incinerator Control

Fuel / Sludge ratio	
Arithmetic Mean	1.618
Standard Deviation	0.426

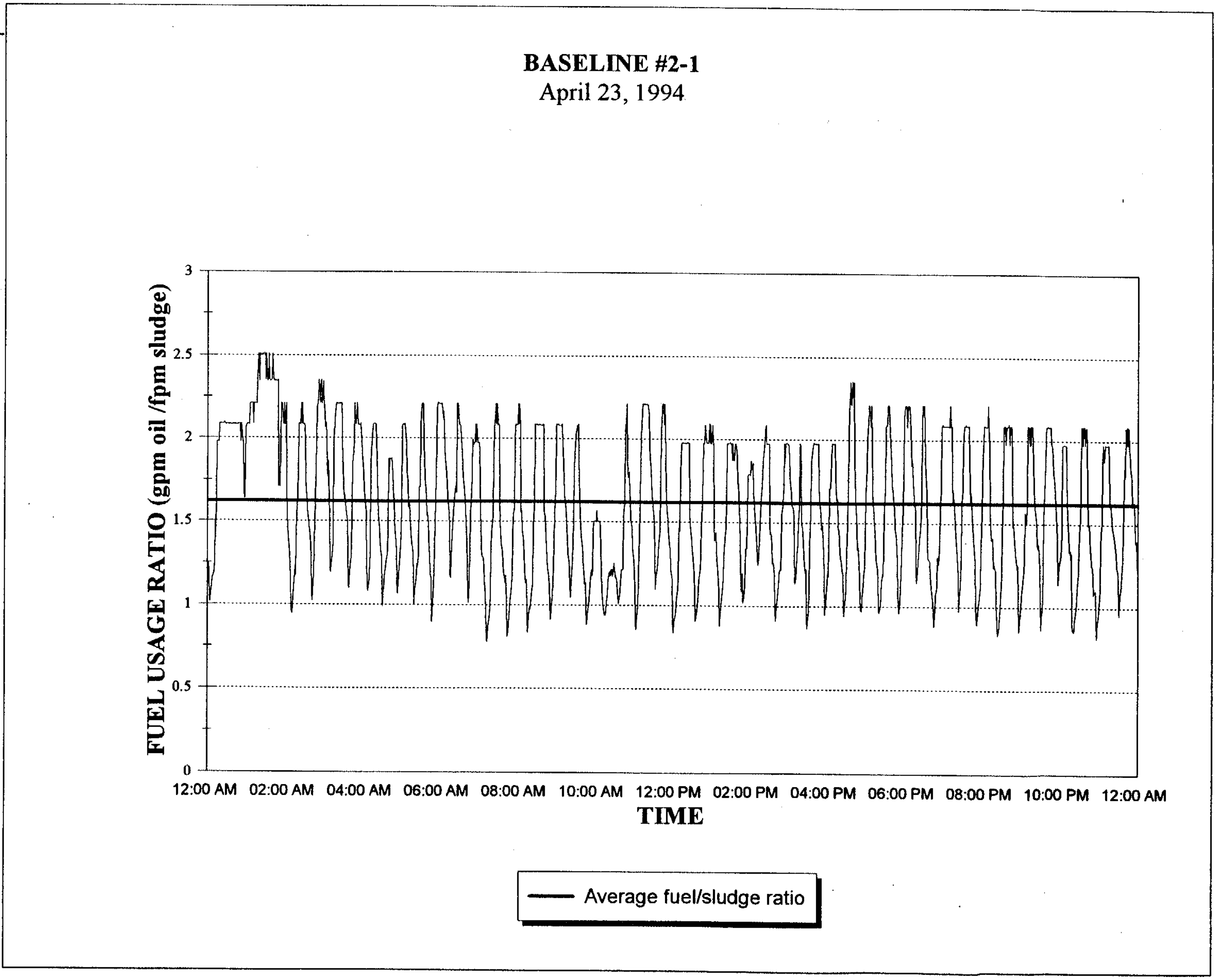


Figure 7-3
Mix Test #4

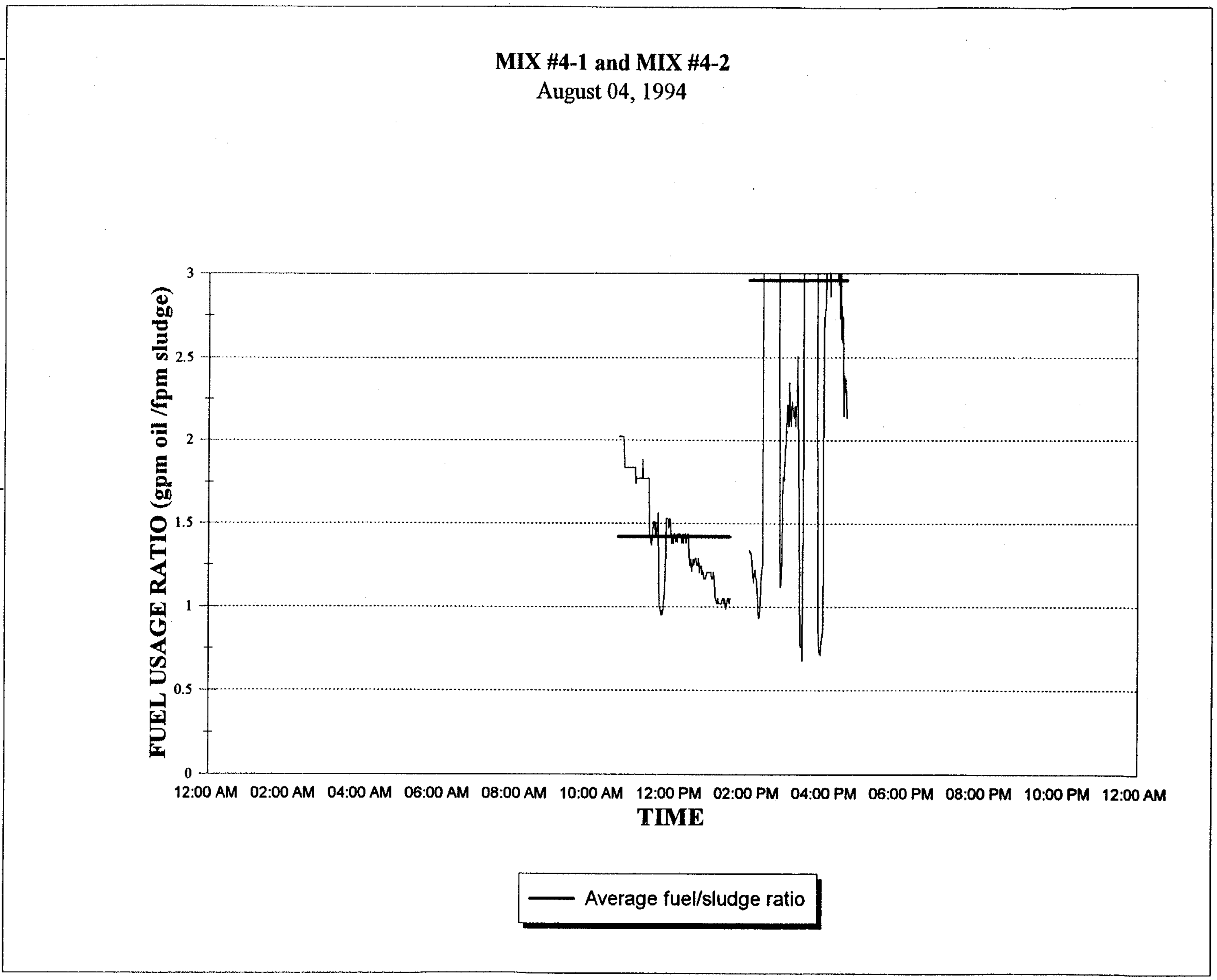
Fuel / Sludge ratio (Mix #4-1)
10:37 AM-01:30 PM

Arithmetic Mean	1.419
Standard Deviation	0.309

Fuel / Sludge ratio (Mix #4-2)
02:00 PM-04:30 PM

Arithmetic Mean	2.957
Standard Deviation	1.799

Notes:
03:20 PM - 03:22 PM - Out of test.



7.1.3 Conclusions

Based on the analytical data and the previous discussion, it does not appear that automatic control of the incineration system produced significant savings in auxiliary fuel oil use. Based on baseline tests, an improvement of only 6.6 gallons per dry ton of sludge was realized. Additionally, the data indicate that control of the system is more steady under manual control, while the parameters fluctuate significantly under automatic control.

It should be possible to adjust the characteristics of the incinerator controller to reduce fluctuations in the fuel oil rate. However, eliminating fluctuations in the control may not result in significant savings in auxiliary fuel oil use. The PLC should be fine-tuned so control is as consistent as manual control before comparing fuel use rates.

7.2 Air Pollution Control

7.2.1 Objectives

An objective of this project was to determine if automatic control of the incineration operation affected air emissions from the incineration system. Several parameters of the flue gas exhaust were monitored including the emissions of metals, particulates, carbon monoxide, total hydrocarbons, and oxygen.

7.2.2 Data Collection and Analysis

The flue stack sampling and monitoring data used in this section are the same as data that were analyzed in Section 6.5. In this section, data collected while the system was under manual control will be compared to data when the system was under automatic control.

Metals Emissions - The flue gas from the incinerator was analyzed for six metals: cadmium, chromium, copper, lead, zinc, and mercury. The metals emissions results for the baseline and mix tests are summarized in Table 7-2. Due to the short duration of the analytical tests, and the limited amount of data collected, it is difficult to quantify whether the change in the metals concentration is due to the change in the incinerator control, the natural variability in the metals concentrations in the feed stream, or if other factors affected the metals concentrations. It is assumed that data from comparing the two baseline tests would be the most reliable, because three flue stack samples were taken from each baseline test, whereas only one sample was taken during each test batch.

The baseline test data revealed the effect of operating the incinerator under automatic control on the metals concentrations. Decreased concentrations of cadmium, copper, lead, and zinc ranged from 31 to 86% in automatic control compared to the manual runs; however, concentrations of two metals increased. The concentrations of chromium rose an average of 152%; concentrations of mercury rose 75%.

The apparent effects of automatic control could be discounted because there were almost three months between the manual and automatic baseline tests, and the concentrations of metals in the sludge can vary, especially over a long period of time. However, when data from the mix tests were evaluated, a similar decrease in the concentrations of nearly all metals was apparent. The only metal concentration to increase

Table 7-2

Incinerator Flue Stack Metal Emissions - Automatic vs. Manual Control

Test	Paper Pulp % of Sludge	Cadmium lb/h	Chromium lb/h	Copper lb/h	Lead lb/h	Zinc lb/h	Mercury lb/h	Particulate lb/h
Manual Control								
Baseline #1		0.0000255	0.0000234	0.0027500	0.0022400	0.0012400	0.0002050	0.3000000
Baseline #1		0.0000270	0.0000073	0.0008640	0.0052100	0.0002190	0.0000233	0.2500000
Baseline #1		0.0000031	0.0000058	0.0016700	0.0026300	0.0004800	0.0003400	0.3100000
Average		0.0000185	0.0000122	0.0017613	0.0033600	0.0006463	0.0001894	0.2866667
Automatic Control								
Baseline #2		0.0000115	0.0000732	0.0002940	0.0001760	0.0000901	0.0003340	0.1200000
Baseline #2		0.0000146	0.0000177	0.0004220	0.0025000	0.0000999	0.0003020	0.1400000
Baseline #2		0.0000125	0.0000012	0.0002930	0.0022100	0.0000723	0.0003600	0.1300000
Average		0.0000129	0.0000307	0.0003363	0.0016287	0.0000874	0.0003320	0.1300000
Auto vs. Manual		-31%	152%	-81%	-52%	-86%	75%	-55%
#3-1 (Manual Control)	0	0.0000067	0.0000134	0.0002070	0.0009670	0.0001090	0.0006520	0.0560000
#3-2 (Automatic Control)	0	0.0000025	0.0000098	0.0000111	0.0000124	0.0000340	0.0005890	0.0270000
Auto vs. Manual		-63%	-27%	-95%	-99%	-69%	-10%	-52%
#1-1 (Manual Control)	5	0.0000074	0.0000132	0.0004240	0.0005600	0.0000883	0.0006970	0.0450000
#1-2 (Automatic Control)	5	0.0000025	0.0000066	0.0000108	0.0000122	0.0000306	0.0014500	0.0210000
Auto vs. Manual		-67%	-50%	-97%	-98%	-65%	108%	-53%
#2-1 (Manual Control)	7.5	0.0000025	0.0000073	0.0000152	0.0000405	0.0000288	0.0013500	0.0150000
#2-2 (Automatic Control)	7.5	0.0000025	0.0000056	0.0000084	0.0000124	0.0000208	0.0009430	0.0150000
Auto vs. Manual		-0%	-24%	-45%	-69%	-28%	-30%	0%
#4-1 (Manual Control)	10	0.0000125	0.0000109	0.0005320	0.0011000	0.0002240	0.0009280	0.0780000
#4-2 (Automatic Control)	10	0.0000025	0.0000055	0.0000096	0.0000124	0.0002440	0.0005350	0.0290000
Auto vs. Manual		-80%	-50%	-98%	-99%	9%	-42%	-63%
#5-2	15	0.0000025	0.0000113	0.0000237	0.0000537	0.0000455	0.0012500	0.0240000
#5-1	20	0.0000025	0.0000045	0.0000106	0.0000406	0.0000187	0.0006500	0.0160000

All emissions are in lb/h.

significantly (108%) was mercury in Mix test #1. Because each phase of the mix tests was performed on sequential batches of sludge, the concentrations of metals in the sludge samples would have been fairly consistent; that is, the reduction in the concentrations of metals was probably due to automatic operation of the incinerator. However, because the sludge was not analyzed for metals, it is not possible to confirm this.

The sludge feed rate could also have affected the metals concentrations in the exhaust gas. The feed rate for manual tests was usually higher than the automatic tests and would account for some of the difference. The efficiency of the scrubber may also be affected by the flow rate of sludge, causing additional emissions when the amount of sludge is increased.

Additional evidence that automatic operation of the incinerator may reduce the metals emissions is the fact that the magnitude of the reduction among the four tests was usually consistent for at least three of the four mix tests for all metals except zinc and mercury. Cadmium concentrations dropped from 63 to 80%; chromium concentrations from 27% to 50%; copper concentrations from 95% to 98%; and lead concentrations from 98% to 99%. The results from Mix test #2 do not correspond to the reductions observed in other tests.

Particulates were also monitored as part of the flue stack analysis. As Table 7-2 shows, concentrations of particulates were reduced from 52 to 63%; with the exception of Mix test #2 when the concentration remained constant.

Flue Gas Concentrations - The flue gas was continuously monitored for concentrations of oxygen, carbon monoxide, and total hydrocarbons to determine if automatic operation affected their levels. The results are shown in Table 7-3. Due to problems with the oxygen analyzer, a comparison between two of the four applicable mix tests could not be performed. The results of the remaining two mix tests showed widely conflicting results; therefore, only data from the two baseline tests were analyzed. These would be the most accurate data because they were collected for 15 days, 24 hours a day. As shown in the table, carbon monoxide concentrations increased an average of 28% and the concentration of total hydrocarbons dropped 32% when the incinerator was under automatic control. This appears to indicate that more hydrocarbons were incinerated, but the combustion was not as complete as under manual control. Since the concentrations

Table 7-3

Comparison of Automatic vs. Manual Mix Tests
Flue Gas Concentrations of Oxygen, Total Hydrocarbons, and Carbon Monoxide

Test	Date	Paper Pulp % of Sludge	O2 %	Moisture %	Normalized to 7% O2 & 0% Moisture	
					CO (ppm)	THC (ppm)
Manual Avg.				2.361	34.27	9.63
Automatic Avg.				2.618	43.70	6.54
Auto vs. Manual					28%	-32%
Mix #3-1	8/3/94	0	5.02	5.694	17.51	5.09
Mix #3-2	8/3/94	0	4.39	5.023	39.01	7.01
Auto vs. Manual					123%	38%
Mix #1-1	8/1/94	5	Oxygen Analyzer was not Working Properly			
Mix #1-2	8/1/94	5	4.1	4.740	51.22	5.09
Mix #2-1	8/2/94	7.5	Oxygen Analyzer was not Working Properly			
Mix #2-2	8/2/94	7.5	4.44	4.570	44.13	6.40
Mix #4-1	8/4/94	10	2.68	6.071	43.19	6.28
Mix #4-2	8/4/94	10	5.35	5.198	35.42	5.52
Auto vs. Manual					-18%	-12%
Mix #5-2	8/9/94	15	Not Applicable Due to Differing Concentrations			
Mix #5-1	8/5/94	20				

were low under both conditions, the increase is not believed to be a significant issue. Operating the incinerator under automatic control is not expected to raise incinerator emissions above present permit limits.

Miscellaneous Stack Parameters - When exhaust from the incinerator stack was analyzed for metals, several miscellaneous parameters were monitored. The results appear in Table 6-16. Whether the incinerator was under manual or automatic control had little, if any, effect on the exhaust gas quality. Observed changes are probably due to seasonal differences in temperature or ambient conditions.

7.2.3 Conclusions

Based on the previous information, automatic operation of the incinerator apparently had a positive effect on metals concentrations in the flue stack exhaust. How the metals were reduced, however, is unknown. The metals content of the sludge is also unknown; therefore, it is impossible to confirm that metals concentrations were constant between mix tests.

In regards to other stack parameters, there is evidence that automatic control may have decreased concentrations of total hydrocarbons, but increased the concentrations of carbon monoxide in the incinerator's exhaust. Operating the incinerator under automatic control is not expected to cause the incinerator emissions to exceed present permit limits.

While there is no conclusive evidence that automatic control of the incinerator affected incinerator exhaust, there is a possibility the emissions of metals and total hydrocarbons could be reduced. This should be tested after control of the incinerator is optimized as described in Section 7.1.

7.3 Incinerator Combustion Quality and Efficiency

7.3.1 Cost Analysis of Automatic Incinerator Control

The purpose of this analysis is to determine if it is cost effective to implement automatic incinerator control. It was determined in the previous section that automatic control of the incinerator should not have a significant impact on either air emissions or ash disposal costs. Only two major costs associated with sludge incineration, manpower and fuel oil use, would potentially be affected.

This cost analysis does not consider initial capital and installation costs of the control equipment because the equipment has been purchased as part of the demonstration project. Capital costs to implement long-term automatic operation would include modifications or additions to the existing equipment.

Personnel Requirements - It is assumed that automatic control of the incineration system would have little effect on the manpower requirements for sludge processing. Although the controller would replace the operators' responsibility for adjusting fuel oil and air flow rates, an operator is still required to monitor the system to assure that the controller is functioning properly.

Several times during the demonstration project, it was necessary to take the incinerator out of automatic mode due to problems associated with failures in one or more of the instruments measuring key system control parameters such as the oxygen meter. It was difficult to complete the baseline tests on 30 consecutive days due to problems with the system monitors. To consider a reduction in the manpower associated with control of the incinerator, the reliability of the instruments needs to be improved.

However, even if the automatic controller was reliable, some manpower is still necessary for normal maintenance and cleaning sample probes, to calibrate the measuring equipment, and to periodically change the gas supply cylinders required to operate some of the instruments. It was assumed there would be no reduction of manpower requirements under automatic control.

Fuel Oil - An additional objective for the automatic controller was to reduce the auxiliary fuel required to incinerate the sludge. Section 7.1 describes a fuel oil savings of 6.6 gallons per dry ton of sludge incinerated during the automatic control phase of the baseline tests compared to the manual operating phase.

Based on the 1994 fuel oil cost of $0.607 per gallon of fuel oil, the total annual savings would have been approximately $7,968.

7.3.2 Conclusions

Further analysis or testing the automatic controller may determine the system's full potential.

Based on information obtained for this project, the estimated annual savings from implementing automatic incinerator control was only $4 per dry ton of sludge, for an annual savings of approximately $7,968. These costs do not include operating costs that would be incurred by the automatic controller. These operating costs would include the gas supply cylinders and instrument calibration gases. The cost savings may not be adequate to justify the initial costs to implement automatic control.

8. HEAT BALANCES AND WASTE HEAT RECOVERY

8.1 Heat Balances

Heat balances were calculated for twelve different operating conditions. The heat balance provides a detailed account of all sources of heat into and from the incinerator. The heat balances were calculated for the baseline or present operating conditions; operating the present system with the control system in automatic mode; five paper pulp and polymer mix tests with the incinerator in manual mode; and five paper pulp and polymer mix tests with the incinerator in automatic mode. An example of the heat balance calculations, as well as a spreadsheet showing the heat balance calculations for all twelve of the operating conditions are included in Appendix G. Several graphs summarizing the heat balances for the various mix tests are also included in Appendix G.

Heat In: Sources of heat into the incinerator include No. 2 fuel oil; conditioned sludge; fluidizing air; and purge air. Figure 8-1 summarizes the results of the calculations for total heat in and total heat out. Figures 8-2, 8-3, 8-4, and 8-5 summarize the individual percentages of heat in and heat out for the various paper pulp and polymer mix tests, and for the baseline sludge conditioned with lime and ferric chloride. Fuel oil and dry sludge solids are the major contributors of heat into the incinerator.

When burning sludge conditioned with lime and ferric chloride, about 50% of the heat into the incinerator was from fuel oil. One of the objectives for conditioning the sludge with paper pulp and polymer was to maximize the heat into the system as sludge, and minimize the heat going into the system as fuel oil. Sludge mixtures #1-1 and #1-2, conditioned with polymer and 5% paper pulp, could meet this objective. For this sludge mixture, from 26% to 32% of the heat into the incinerator was from fuel oil and 58% to 64% of the heat was from the sludge.

The heat exchanger takes heat from incinerator exhaust gas and recycles it back into the system with the fluidizing air. If the heat exchanger had been in place during the project, more heat would have come into the system as fluidizing air, and less fuel oil would have been required. Based on the initial heat balance calculations performed when the incinerator was installed, the fuel oil rates would be approximately 25% lower than was determined during the demonstration project.

Figure 8-1

Heat Balance Summary

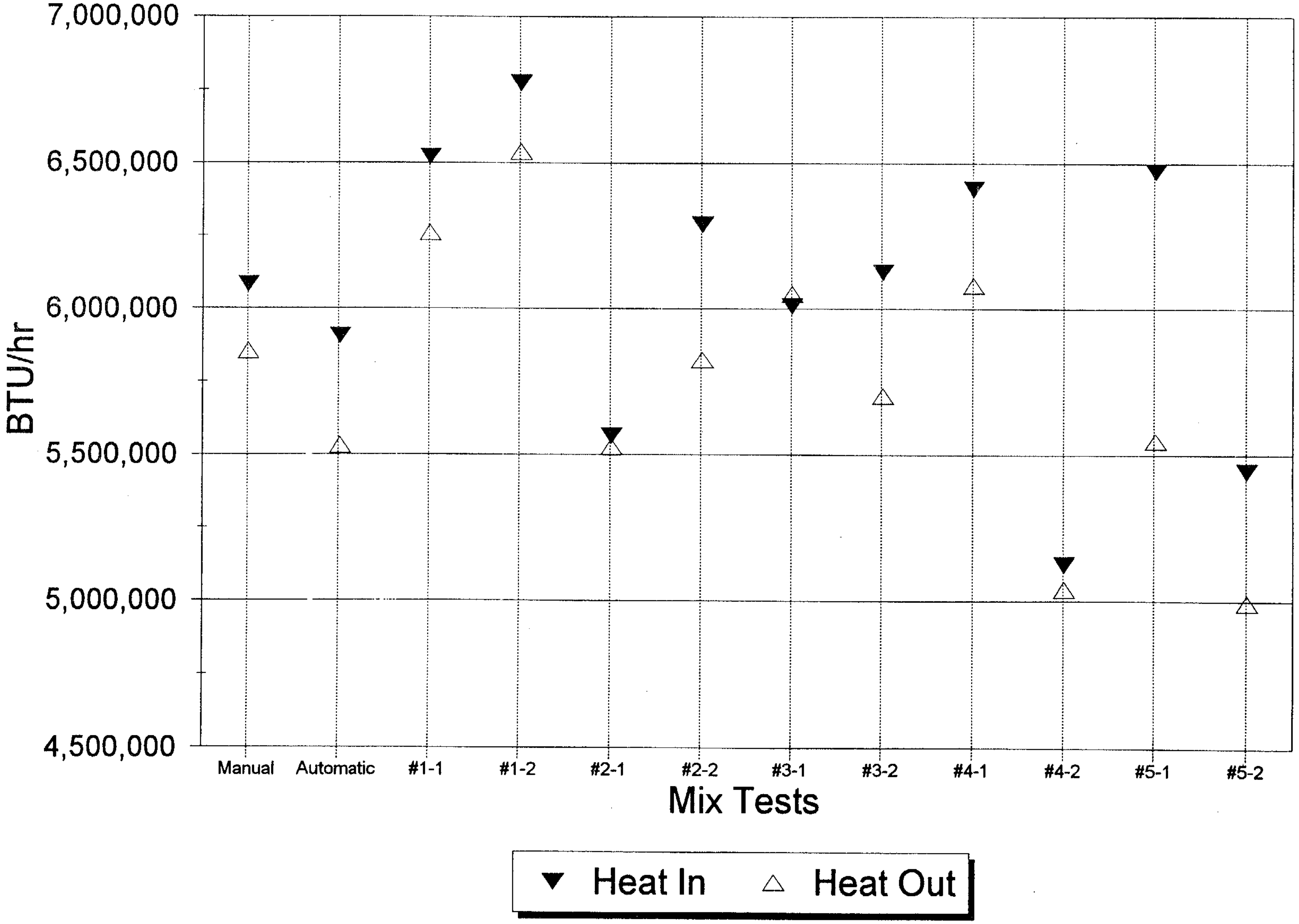
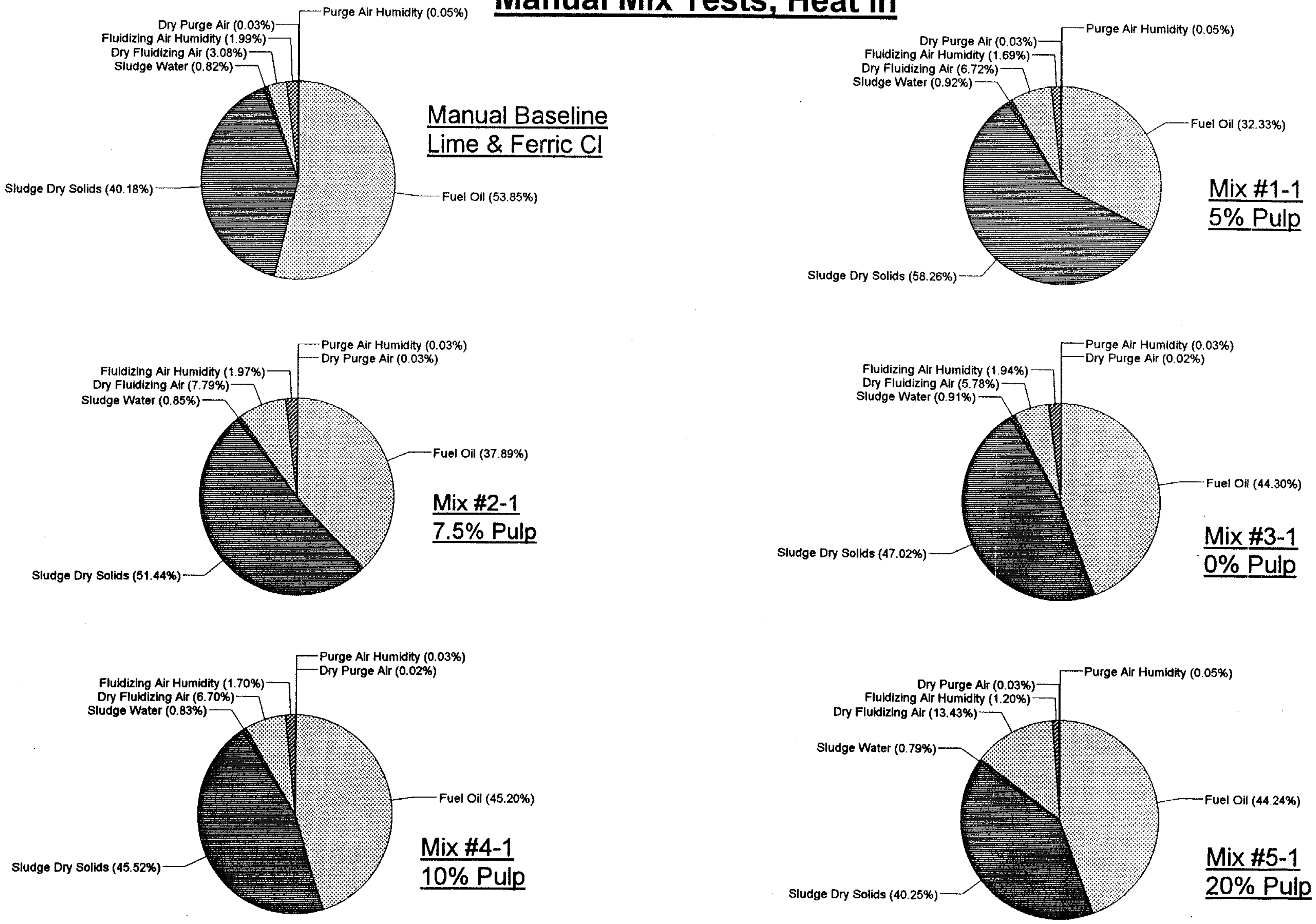


Figure 8-2
Manual Mix Tests, Heat In



Manual Baseline
Lime & Ferric Cl

Mix #1-1
5% Pulp

Mix #2-1
7.5% Pulp

Mix #3-1
0% Pulp

Mix #4-1
10% Pulp

Mix #5-1
20% Pulp

Figure 8-3
Manual Mix Tests, Heat Out

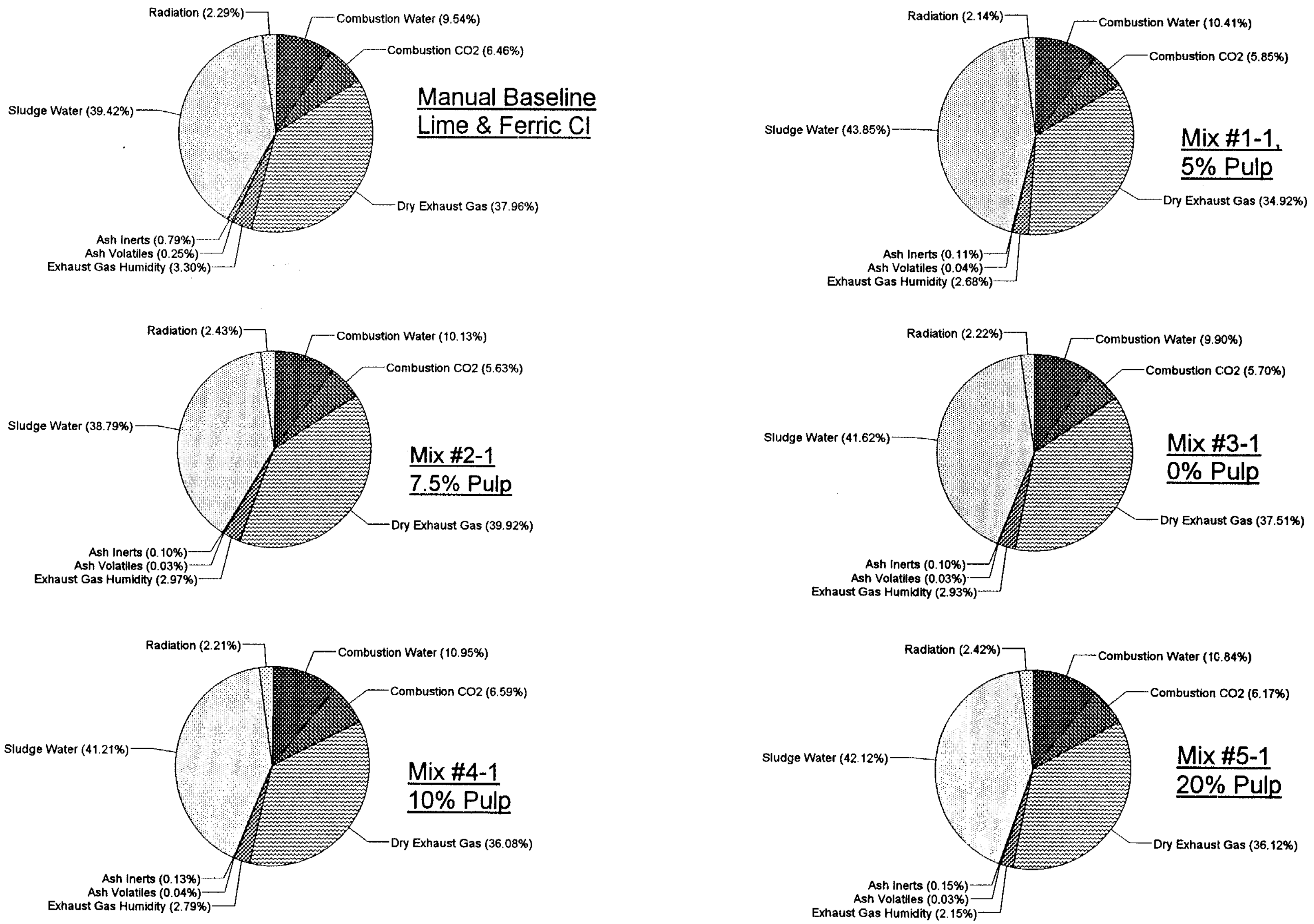


Figure 8-4
Automatic Mix Tests, Heat In

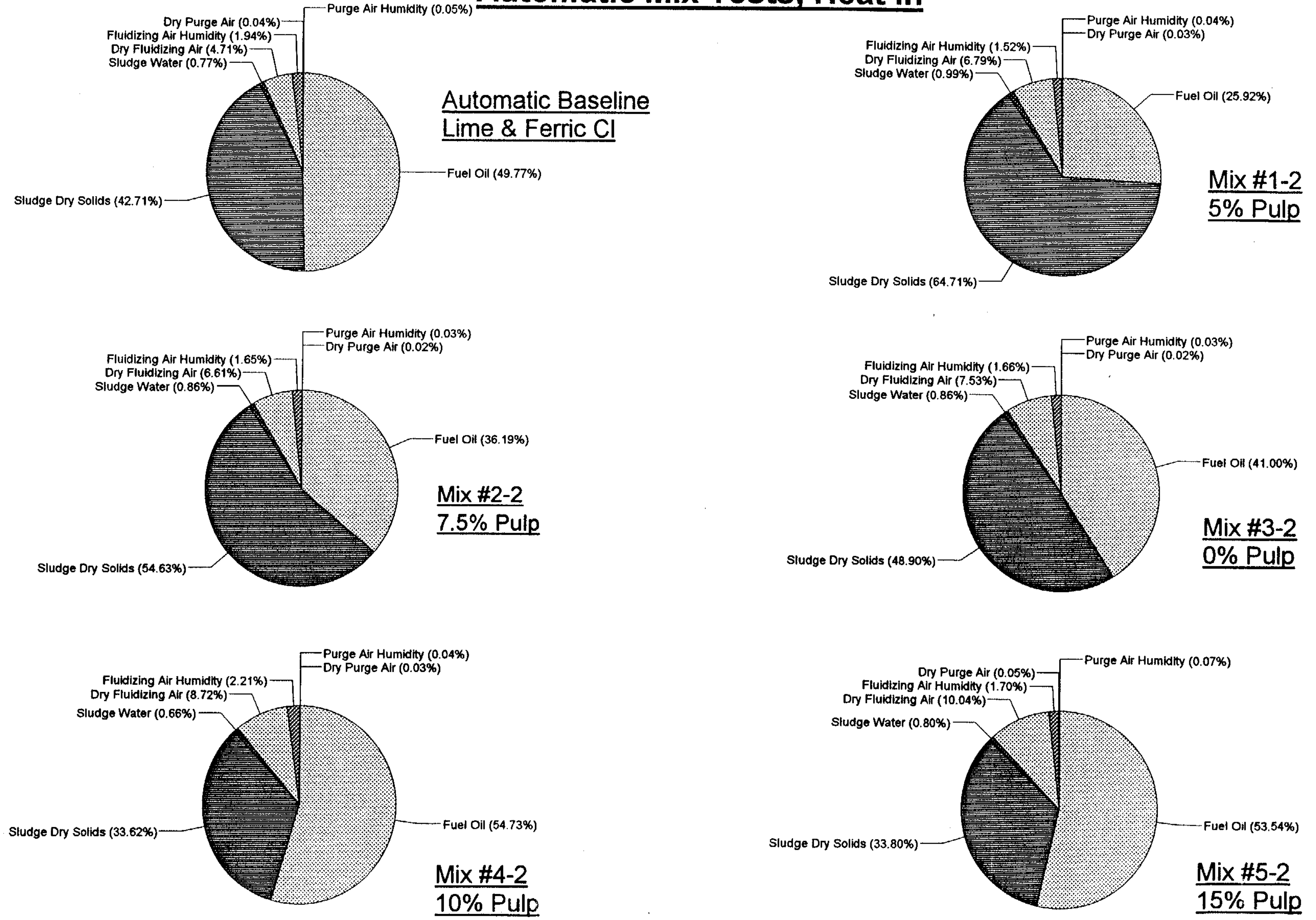
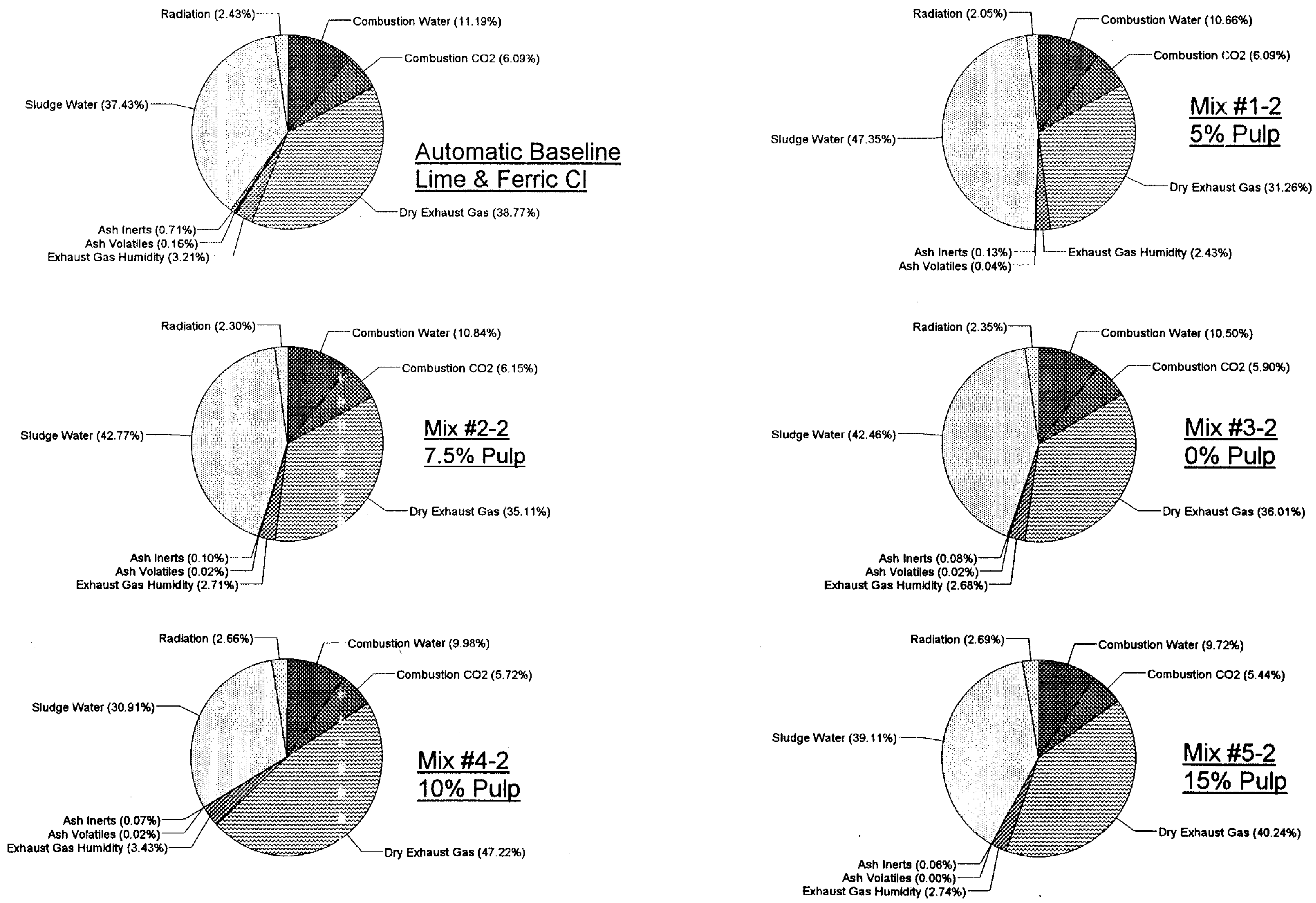


Figure 8-5
Automatic Mix Tests, Heat Out



Heat Out: The heat from the incinerator had relatively the same composition for all the mix tests, regardless of the heat into the system. The two main sources of heat from the incinerator are the exhaust gas and water from the sludge that is converted to steam. The exhaust gases comprised from 35% to 40% of the heat out, and the sludge water converted to steam comprised from 38% to 43% of the heat out.

Minimizing the quantity of water going into the system with the sludge would greatly reduce the total quantity of heat required for incineration. The water passing through the system serves no purpose in the incineration process. All the water fed into the incinerator is heated to the temperature of the incinerator, requiring a large quantity of heat. The water exits the incineration system as superheated steam, taking with it a large fraction of the total energy of the system.

Autogenous Operation: If it were possible to minimize the heat out of the system as steam, there eventually would be a point where no fuel oil would be required to sustain the incineration process. The system should be able to support the incineration process using only the heat value of the conditioned sludge without any auxiliary fuel. The point at which the incineration process is self supporting is known as **autogenous** operation.

Based on the information from the heat balances, the point where the incinerator could theoretically become autogenous was determined for each sludge mixture. For some of the mixtures, the calculations indicated that autogenous operation may not be possible. This is most likely due to errors or problems in system control over the short duration of each test. All of the sludge mixtures conditioned with paper pulp and polymer should be autogenous at some point. Only the sludge conditioned with lime and ferric chloride may not be capable of autogenous operation. This is because the BTU value of this dry conditioned sludge is not adequate to sustain the incineration process due to the high quantity of inerts.

All the sludge mixtures conditioned with paper pulp and polymer theoretically should be autogenous at 100% solids. However, due to inconsistency in the pulp and other factors, the data did not support this conclusion.

Sludge mixtures #1-1 and #1-2, conditioned with polymer and 5% paper pulp, theoretically would become autogenous if the mixtures could be dewatered to somewhere between 37% to 47% total solids. Producing a sludge cake containing such a high solids content is unlikely using the existing sludge conditioning equipment. The total solids obtained for mixtures #1-1 and #1-2 was only 24%. However, when it was assumed that the air preheater was operating, the calculations indicate that Mix #1 would be autogenous at approximately 37% solids.

Analysis of the heat balance calculations for all sludge mixtures supports the conclusion drawn in Section 6, that sludge Mix #1, conditioned with polymer and 5% paper pulp, is the optimum ratio of sludge mixtures evaluated.

8.2 Waste Heat Recovery

Using the information obtained from the Heat Balance calculations, a Waste Heat Recovery and Utilization Study was performed. The purpose of the study was to identify practicable opportunities for utilizing the heat generated by the sludge incineration process.

8.2.1 Heat Sources and Utilization Opportunities

The following were identified as being the primary heat sources:

- Incinerator Exhaust Gas - The exhaust gas contains a very high level of heat (1,380°F); however, it is contaminated with significant amounts of abrasive ash that frequently coats heat exchanger surfaces.

- Scrubber Water - The scrubber water contains a relatively low level of heat (150 to 180°F) and also is contaminated with wet and sticky ash.

- Radiant Heat - Radiant heat is primarily available at the incinerator shell surface and at the exhaust ducting (approximately 200°F and 1,500°F respectively). However, there is no practicable method to recover and use this heat. Therefore, radiant energy will heat the incinerator room as is current practice (this often results in uncomfortably high temperatures during the summer).

Several additional heat sources, unrelated to the incineration process, were identified in performing the Waste Heat Recovery and Utilization Study. These additional sources of heat include:

- Cooling water for the oxygen skid air compressors
- Cooling water for the various process air compressors
- Cooling water for the various hydraulic systems
- Lime Slaking

Utilization of these heat sources was outside the scope of this study. The incinerator exhaust gas and the scrubber water were the only two sources of heat evaluated for utilization in the plant.

Possible uses for the available heat were then identified. However, only four of the opportunities identified for heat utilization are of any significant magnitude. These uses include the following:

- Fluidizing Air Preheat - The present design of the incinerator includes a heat exchanger that uses incinerator exhaust to preheat the fluidizing air. This design has been proven to result in significant fuel oil savings. Also, the heat exchanger was out of service for the duration of the project, though only one of the two incinerators is equipped with such a device. Installing a larger preheater, for recovering more heat from the incinerator exhaust, is an additional option.

- Main Building Heat - Heating the main building using waste heat from the incineration process would utilize a large quantity of available waste heat. However, this would be only a seasonal use for waste heat. Natural gas presently is used to heat the main building.

- Sewer District #3 Building - Heating this building, although smaller than the main building, also would represent a significant heat sink during the winter months. However, an efficient radiant heat system was recently installed in this building.

- Sludge Drying - Preheating or drying sludge would utilize a large quantity of available waste heat and lower fuel oil use in the incinerators.

In addition to the four major heat utilization opportunities, several smaller opportunities were also identified. These opportunities include:

- Chlorine Vaporization - Two electric vaporizers provide standby capability to vaporize chlorine should demand and/or conditions require that the liquid chlorine be vaporized by heating. The proposed system would utilize hot water instead of electric heating to vaporize the liquid chlorine.

- Fuel Oil Preheating - Preheating the fuel oil prior to injection into the fluidized bed incinerator would utilize a small quantity of heat.

- Scum Tank Preheating - Before it can be incinerated, the scum that has been stored in the scum tanks must be heated. The present electric heating system would be replaced with a hot water heating system.

Cogeneration, using the incinerator exhaust gas to generate electricity, also was evaluated as an option for heat recovery. This option was determined to be unattractive due to the cyclical nature of the operation of each incinerator bed and the detrimental effect that this would have on steam/power generation.

8.2.2 Technical and Economic Feasibility

A conceptual design and associated cost estimate was developed in order to evaluate each of the heat recovery alternatives. There are two heat sources that were examined -- the high-temperature incinerator off-gas, and the low-temperature scrubber water. The technical difficulty with the alternatives is due mostly to the harsh conditions and the ash that is present in the two heat sources. The following sections briefly present the conceptual design for each of the alternatives, analyze the technical feasibility of the alternative, and then present the estimated costs and savings associated with each alternative.

Preheater, Larger Preheater - This option utilizes an air-to-air heat exchanger to preheat the incinerator fluidizing air using heat recovered from the exhaust gas. Increasing the temperature of the fluidizing air results in a decrease in the auxiliary fuel use. An air preheater has been part of the incineration process since the original construction of the plant. However, the air preheater was not in use for the duration of the demonstration project. Technical problems with this alternative are due to ash plugging the heat exchanger and the corrosive effects of the exhaust gas. Periodic shut-downs are required to clean the exchanger. A new heat exchanger is being fabricated and will be installed at the plant. The estimated capital costs and annual savings for this alternative are $184,186 and $14,288 respectively, for an estimated 12.9 year payback period. Installing a larger heat exchanger to preheat the fluidizing air to a higher temperature has estimated capital costs and annual savings of $259,786 and $26,508 respectively, and thus, an estimated payback period of 9.8 years.

Main Building Heat - This option utilizes an air-to-water heat exchanger or "economizer" to heat water using heat recovered from the exhaust gas. The hot water is then used to heat the main building of the treatment plant. The economizer would provide a significant portion of the heat during the winter months. Most of the heat recovered by the economizer during the summer months would not be used. Technical problems associated with this alternative are due to the harsh conditions of the exhaust gas. This option previously was attempted when the plant originally was constructed; however, there were many difficulties with the system including blowing of relief valves, pump and seal failure, tube bundle fouling, and leaks in the heat exchanger. The harsh operating conditions most likely led to the failure of the economizer. The proposed system would constantly circulate water through the economizer, regardless of whether it was needed for plant heat. Any excess hot water, especially during the summer months, would be recycled to the head of the treatment plant. The estimated capital costs and annual savings for this option are $381,015 and $24,739 respectively, for an estimated payback period of 15.4 years. Due to the marginal annual savings, this option might not be attractive, especially when the difficulties with the harsh operating conditions are considered.

Sewer District #3 Building Heat - This option uses the water from the scrubbers directly for providing heat to the Sewer District #3 Building. The technical problem with this alternative is the fine, sticky ash in the water. Before the scrubber water is used, ash will be removed using sophisticated, backwashable, strainers, and then the water will be filtered. Excess water will be recycled to the head of the treatment plant. The estimated capital costs and annual savings for this option are $81,640 and $7,497 respectively, for an estimated payback period of 10.9 years.

Sludge Preheat - This option would use heat from either the economizer or the scrubber water loop for the preheating of the sludge influent to the incinerator. The system most likely would consist of a water flooded jacket around the barrel of the screw feeders. Preheating the sludge would result in a direct reduction in the quantity of auxiliary fuel required. The only limitation to the amount of heat added to the sludge would be vaporization of the water, which could create feed problems. Due to the low annual cost savings, this system would not be economical by itself, and is assumed to be done in conjunction with one of building heating loops. The estimated capital costs and annual savings for this option, not including the costs for the economizer or scrubber water loops, are $5,825 and $2,353 respectively, for an estimated 2.5 year payback period.

Sludge Drying - If dried, the sewage sludge would make a very good fuel for the operation of the incinerators, although handling of the wet and sticky sludge would be problematic. In order to accomplish sludge drying, equipment capable of handling wet sludge, yet able to inject greater than 50% solids sludge into the incinerator would have to be identified. Due to the unique characteristics of the sludge, it is not possible to identify such equipment without further investigation and pilot studies. No costs were developed for this option.

Chlorine Vaporization - Chlorine vaporization is another option that is only economically viable if it is done in conjunction with one of the building heating loops. Hot water heating, as opposed to electric heating, would be used to periodically vaporize liquid chorine as necessary. The estimated capital costs and annual savings for this option, not including the costs for the economizer or scrubber water loops, are $19,150 and $1,643 respectively, for an estimated 11.7 year payback period. The actual annual savings may be lower because the frequency and duration at which vaporization is required has not been determined.

Fuel Oil Preheat - Preheating the fuel oil is another option that could be done in conjunction with one of the building heating loops. Preheating the fuel oil would lead to some decrease in the amount of auxiliary fuel that would be required. However, due to the relatively low quantity of fuel that is added, the potential annual savings are small. This option is not recommended.

Scum Tank Preheat - Heating the scum tank is a viable option if it can be piggybacked off of one of the building heating loops. The system would circulate hot water through the tank instead of electric heat that currently is used. Due to its relative simplicity and the fact that expensive electric heating is being eliminated, the potential payback as little as 1 year on this option is very attractive. The estimated capital costs and annual savings for this option, not including the costs for the economizer or scrubber water loops, are \$3,599 and \$2,523 respectively, for a 1.4 year payback period.

Table 8-1 summarizes the estimated capital cost, projected savings, and payback period for the various heat utilization opportunities.

Table 8-1

Waste Heat Recovery
Capital Costs, Projected Savings, and Return on Investment

Primary Heat Recovery Options	Estimated Capital Costs	Annual Projected Savings	Payback Period (Years)
Preheater[1]	$184,186	$14,288	12.9
Larger Preheater	$259,786	$26,508	9.8
Main Building Heat	$381,015	$24,739	15.4
Sewer District #3 Building Heat	$81,640	$7,497	10.9

Secondary Heat Recovery Options[3]			
Sludge Preheat	$5,825	$2,353	2.5
Sludge Drying[2]	-	-	-
Chlorine Vaporization	$19,150	$1,643	11.7
Fuel Oil Preheat	$8,392	$77	109.0
Scum Tank Preheat	$3,599	$2,523	1.4
Co-Generation[2]	-	-	-

NOTE:
1. A preheater has been successfully used since the construction of the plant. The preheater was out of service for the duration of the demonstration project.
2. Option could not be evaluated due to a lack of information and the complexity of the system.
3. By themselves, these secondary options are not cost effective. Options are assumed to piggyback off one of the building heat alternatives. Capital costs include only the additional equipment that would be required.

9. CONCLUSIONS

9.1 Effect of Pulp and Polymer Use on Plant Operations

Based on the analysis in the previous sections, using paper pulp and polymer as conditioning agents should have a beneficial effect on operations of the treatment facility. The two most obvious benefits are the potential for cost savings, and the possibility for increased plant capacity.

Cost Savings: Cost savings from using paper pulp and polymer as conditioning agents were estimated to be approximately $91.73 per dry ton of sludge solids. The cost savings would be realized in three incinerator operating costs: conditioning chemicals, fuel oil, and ash disposal. The cost for conditioning chemicals is approximately half as much when 5% paper pulp and polymer is used rather than lime and ferric chloride. Cost savings also would be realized from an estimated 30% decrease in fuel oil requirements due to the higher heat content of the sludge. Additionally, eliminating the inert (lime and ferric chloride) sludge conditioning agents would significantly reduce the quantity of ash produced. It is estimated that ash production would be reduced approximately 75%. All the ancillary costs associated with incineration such as personnel and maintenance would remain relatively unchanged.

Increased Capacity: The optimum ratio for paper pulp addition with the polymer was approximately 5% by weight of conditioned sludge. Lime and ferric chloride are currently added at a rate of approximately 25% by weight of conditioned sludge. More sludge would be processed in each load of the filter press when using paper pulp and polymer. Based on the analytical data, an increased sludge throughput of approximately 25% could be realized.

The filter press is presently the rate limiting step in the incineration process. Both incinerator process trains must be run concurrently for approximately 25% of the time to process all the sludge being produced. Increasing the throughput of the filter press will increase the rate that sludge can be incinerated. If the throughput can be increased sufficiently (from 20 to 25%), it would be possible to incinerate all the sludge with only one incinerator operating at a time.

Other Effects: Using paper pulp and polymer as sludge conditioning agents would have relatively little effect on day-to-day operations of the treatment facility. Time previously spent in handling lime and ferric chloride would be spent in preparing and handling the paper pulp. The most important part of pulp preparation would be quality control. Operators would have to sort the raw paper stock to assure that low heat content paper, such as magazines and brown paper, did not get into the pulp mixture. At a dosage rate of 5%, it is estimated that total pulp preparation would require less than two hours per day. Additional time would be required for collecting, sorting, and handling the paper.

It also may be necessary for operators to more closely monitor the quality of the conditioned sludge, and to adjust the rates of paper pulp and polymer addition. When using lime and ferric chloride, if the sludge quality is not adequate, simply adding more lime will increase the quality of the sludge cake. Adding too much lime will not have a negative effect on the sludge quality. However with the paper pulp and polymer, there is an optimal range for operation. Either too much or too little paper pulp or polymer could produce a sludge cake that would be sticky and unacceptable. It is presently unknown if the addition rates will remain relatively constant, or if periodic adjustment would be required. No short-term disadvantages for using paper pulp and polymer were identified.

9.2 Long-Term Effect of Pulp and Polymer Use on Plant Operations

It was not possible to determine the long-term effects of paper pulp and polymer use; however, these process areas should be monitored.

Lime and Ferric Chloride Elimination: The elimination of lime and ferric chloride conditioning chemicals is expected to have a long-term beneficial effect on the operation of the treatment plant. Both lime and ferric chloride are fairly corrosive chemicals. Eliminating these chemicals may reduce some of the long-term damage to the equipment used in their handling. Reducing the chlorides in the exhaust gas may be especially beneficial. Chlorides, combined with the moisture and high temperature of the exhaust gas, create an extremely corrosive mixture that damages the heat exchanger and other equipment located on the stack exhaust.

Filter Press Cleaning Cycles: Under the present operations, using lime and ferric chloride to condition the sludge, it is periodically necessary to shut down the filter press due to plugging or blinding of the filter cloths that cover the plates of the filter press. All the filter cloths must be cleaned with a muriatic acid solution; this removes the press from service for approximately 16 hours. It is unknown if alternative sludge conditioning agents will affect the frequency or extent of shutdowns and cleanings.

Heat Exchanger Plugging: Under present conditions, the ash in the exhaust stream builds up inside the heat exchanger which eventually becomes plugged and must be taken out of service for cleaning. Using paper pulp and polymer as sludge conditioning agents will result in less ash in the exhaust gas stream. The ash would have a different chemical composition than the ash currently produced. The effect of the modified ash on the heat exchanger and other components of the incinerator exhaust would have to be monitored.

10. RECOMMENDATIONS

Due to the overall cost savings and benefits outlined in this report, plant personnel should consider using paper pulp and polymer as conditioning agents at the Southtowns Sewage Treatment Plant. Before full implementation, it may be prudent to do long-term testing and monitor paper pulp and polymer sludge conditioning to assess any negative effects on the system's operation.

Additional studies before full implementation may include optimizing the paper pulp and polymer dosage rates, especially dewaterability of the sludge and long-term monitoring of the incineration system's operation. A study could determine if precoating the filter cloths with the paper pulp would provide an advantage compared to adding the pulp to the sludge mixture. An adequate, consistent, and economical source of paper suitable to produce pulp must be identified, as well as a suitable location for bulk paper storage and pulp production.

Operating the incinerator's automatic control system also should be considered for long-term use. An attempt should be made to fine-tune the parameters of the controllers so control is more consistent and less prone to cyclical fluctuations. Although the potential cost savings appear to be relatively small, the equipment installed during the project should not require significant capital costs to place in full-time operation. The automatic controller also may allow personnel to perform tasks other than monitoring the system.