HISTORY OF THE FORT LEWIS
INCINERATOR: LESSONS LEARNED

Rudy M. Verzuh
Fort Lewis Public Works
Fort Lewis, WA
253-967-2763
FAX: 253-967-9333
Email: verzuhr@lewis.army.mil

William T. Morgan, P.E.
Lockwood Greene Technologies, Inc.
250 Williams Street, Suite 2350
Atlanta, GA 30303
404-654-4439
FAX: 404-654-4437
Email: bmorgan@lgt.lg.com`

Douglas C. Smith, P.E.
Bouillon, Inc.
700 5th Avenue, Suite 5800
Seattle, WA 98104
206-682-3910
FAX: 206-682-3916
Email: dcs@bouillon.com

ABSTRACT

The U.S. Army installation at Fort Lewis near Tacoma, Washington, completed in 1996 construction of a 163.3 Mg (180 ton) per day mass-burning, steam-generating incinerator. This plant was equipped with acid gas control equipment, but it was unable to consistently control acid gas emissions and flue gas temperatures. Design and equipment deficiencies included lack of independent control of acid gas emissions and flue gas temperature. The plant was also unable to deliver lime slurry at the proper concentration and rate. By retrofitting the acid gas control system with smaller lime slurry pumps and modified controls, The Fort Lewis Waste-to-Energy Plant was then able to consistently meet regulatory requirements for acid gas emissions and flue gas temperature.

INTRODUCTION

Plant Description

The Fort Lewis Waste-to-Energy Plant is located on the Fort Lewis Army installation near Tacoma, Washington. The plant burns solid waste generated from Fort Lewis, McChord Air Force Base, Bangor Submarine Base, Madigan Army Medical Center, and the Veterans Administration Hospital in Lakewood, Washington. It generates steam used for heat and hot water at Fort Lewis. It is owned and operated by the United States Army, Headquarters I Corps and Fort Lewis Public Works Directorate. The plant consists of three 54.4 Mg (60 ton) per day municipal waste, mass burn steam generating incinerator units. Each unit is equipped with a Keeler Dorr Oliver water wall boiler rated at 10,206 kg (22,500 lb) per hour of saturated steam at 7.73 kg/cm2 (110 lb/in2).

Trucks deliver refuse to the plant and dump it into the refuse pit. The refuse pit has a 1 to 3 day capacity depending on the number of units operating. Refuse is fed to the incinerators from the pit by an overhead crane equipped with a grapple. Emission controls include Selective Noncatalytic Reduction (SNCR) for NOX control, spray dryer scrubbers for acid gas control fabric filter pulse jet bag houses for particulate control, and powdered activated carbon injection for dioxin and mercury control.

Figure 1 shows a schematic cross section of the plant.

Plant History

The U.S. Army Corps of Engineers originally designed the Fort Lewis Waste-to-Energy Plant. in the 1980's. It was one of about several similar incinerators in the United States supplied by Keeler Dorr Oliver manufacturing during that time. Initial construction of the plant began in 1987 by the Texcel Corporation under contract to the Corps of Engineers. In August 1989, Texcel quit the project with construction 80 percent complete. In 1995, a contract was awarded by the Corps of Engineers to J.A. Jones and Lockwood Greene to complete the design, construction and startup of the waste-to-energy plant. In June 1996, the Fort Lewis Public Works Directorate assumed control of the plant startup.

During startup and initial operation of the plant, several performance problems were identified by the Public Works Directorate. One problem included inadequate control of acid gas emissions and inadequate control of flue gas temperature at the point it exited the spray dryer. These performance assessments were based upon data from plant instrumentation. No compliance tests were conducted until these problems were corrected.

In October 1996, the plant was shut down by the Public Works Directorate. Modifications were undertaken to correct these problems. Lockwood Greene Technologies, the environmental engineering subsidiary of Lockwood Greene Engineers, was contracted to design the modifications. J.A. Jones Construction Company was contracted to construct the modifications.

Emission Control Problems

The waste-to-energy plant has a spray dryer and fabric filter for each furnace unit. The original design of the spray dryer uses lime slurry for simultaneously controlling acid gas emissions and flue gas temperature. A lime storage silo, lime slaker, lime slurry recirculation system, and a lime slurry holding tank with mixer are common to all three spray dryers. Before the plant upgrade, the spray dryers were not consistently achieving the acid gas removal efficiencies required nor were they able to maintain flue gas temperatures in the desired range of 143^{0} C to 174^{0} C (290^{0}F to 350^{0}F).

A summary of the plant stack emission standards is listed in Table 1. The stack emission limit for SO2 is 30 ppmv for a 1-hour average using the continuous emission monitoring system (CEMS). The stack emission limit for HCl is 25 ppmv as measured by EPA reference method 26. (In a spray dryer, the reaction between Ca(OH)2 and acid gas proceeds to completion first with HCl, and then as much as possible to completion with SO2. [1] Thus the focus is on removal of SO2 in the flue gas.) Existing CEMS data indicated that peak stack SO2 emission on unit 2 was 160 ppmv. The 60-minute average ranged between 50 ppmv and 80 ppmv. This information is depicted in a typical CEMS SO2 concentration printout in Figure 2 for a 3-hour period for unit 2. The other two units had similar stack SO2 emission records.

The temperature of the flue gas entering the fabric filter baghouse from the spray dryer must be maintained below 174^{0} C (350^{0} F) for a 15-minute average to meet permit requirements. This flue gas temperature must also be maintained above 143^{0} F (290^{0} F) to prevent condensation in the baghouse and the exhaust stack and ductwork. (Condensation causes corrosion and turns the fly ash particles in the scrubber and baghouse into a black, sticky sludge). Actual temperature of gas exiting the scrubber before the upgrade, however, often fell

below 143° C (290° F) when the lime injection system was operating; it also regularly exceeded 174° C (350° F) when the lime injection system was turned off to prevent condensation.

SYSTEM INSPECTION

The first step in correcting the acid gas emission and flue gas temperature control problems was to inspect the system and identify the cause(s) of the problems.

Control System

The original SO2 control consisted of a single control loop that responded only to flue gas temperature at the spray dryer outlet. This original control scheme is shown in Figure 3. No separate water injection to control flue gas temperature had been included in the design. Insufficient injection of lime slurry occurred when the flue gas temperature leaving the spray dryer was low. This was one reason for an excessive concentration of SO2 in the flue gas. The lime slurry injection rate into the spray dryer could also be controlled manually from the control room; however, this procedure presented the problem of controlling two independent variables (acid gas and flue gas temperature) with only one control input, i.e. the lime slurry.

Flue Gas Temperature

The flue gas temperature at the inlet to the spray dryer was consistently about 27° C (50° F) below the design temperature. Resolving actual operating conditions with the original design was outside the scope of this project. The impact of this on the spray dryer was to limit the available temperature drop in the spray dryer. Any modifications would have to accommodate this low temperature. It should also, theoretically at least, accommodate the original design termperature, in the event that later equipment or operational changes caused this to be realized.

Lime Slurry Injection Pump

The lime slurry injection pump was inspected by the authors. It was a progressive cavity pump provided with the original plant 10 years earlier. This particular pump was the object of plant operator's complaints because it was uncontrollable. An inspection of the pump curve revealed that with the existing controller, this pump was oversized. It would provide an estimated minimum flow of approximately 18.9 to 37.8 L/min (5 to 10 gpm). The actual pump rpms were measured in the field at approximately 30 rpm. This was the controller's lowest possible operating speed; however, at this speed it would stall and have to be manually restarted.

If the controller originally had been designed to cool the flue gas, it would have had to deliver approximately 11.4 L/min (3 gpm), corresponding to a pump speed of approximately 30 rpm. However, the controller was in fact designed to operate the pump at a speed of 100 to 1200 rpm. Flue gas temperature data from the spray dryer exit indicated that the controller delivered far too much lime slurry when it activated the pump.

The lime injection pump manufacturer was contacted about providing an alternate pump. The manufacturer indicated that the original pump would produce a predictable flow at even 1 rpm. But the manufacturer also had a smaller pump that would produce 0.95 to 11.4 L/min (0.25 to 3 gpm) over a speed range of 25 rpm to 1200 rpm.

Heaters

The spray dryer is cylindrically shaped. The bottom section terminates in a cone. This cone is the coolest part of the spray dryer. To prevent condensation and to control temperature of the gases residing in the cone, the equivalent of 0.083 Kw heaters per spray dryer were installed on the sides of each cone. Each cone was also insulated. The heaters were able to maintain temperatures of the spray dryer cone surface metal between 28^0 C to 35^0 C ($85°F$ - $95°$ F). This was insufficient heat to keep the spray dryer exit temperature in the desired range. Temperature indicators revealed that the cone gas temperature varied widely, apparently independent of the heaters. These gas temperatures were often as low as 60^0 C ($140°$ F), considerably below the spray dryer design exit temperature of 143^0 C ($290°$ F). The result was that particles of fly ash would accumulate in a moisture rich environment, creating a sticky black sludge. This black sludge would jam the fly ash drag conveyors. Further investigation of the heaters revealed that the original design for the spray dryers included 3.5 kW heaters for each spray dryer. This design would have maintained 121^0 C ($250°$ F) surface temperature if it had been installed. However, the heaters that were originally installed were only 0 0.83 kW per spray dryer.

Lime Slaking System

An inspection of the lime slaking, lime slurry storage and lime recirculation pumps revealed several problems. The lime slurry concentration was only 4 percent. This value was reported to vary from 3 to 20 percent. It was apparent the slaking system was not producing the required slurry consistently. Also, the mixer was located near the surface of the lime slurry storage tank rather than near the base of the tank, resulting in poor mixing.

ACID GAS EMISSION CONTROL PROCESS DESIGN

Once deficiencies in the acid gas control system were identified, it was necessary to review the system and redesign the inadequately performing system components.

Flue Gas Flow

It was necessary to estimate lime slurry requirements and the consequent lime slurry flows, as well as the effect on flue gas cooling by the addition of the water in the lime slurry. The original design documents indicated that the design flue gas flow was 21,846 kg/hr (48,170 lb/hr) at 100 percent excess air at the furnace outlet; this did not include steam suppression or lime injection. Since the manufacturer's documents were unavailable, combustion calculations were completed to verify this value. These calculations established this number to be 23,766 kg/hr (52,405 lb/hr). This number could vary, depending on excess air. Any modifications therefore would have to be designed to accommodate the excess air variations.

Composition of the waste was estimated from other work completed on this project. The waste contained 0.04% S, and 0.8 % Cl by weight. Subsequent check with a reference data shows these design values from the field were typical (typical MSW S is 0.01 to 0.40 %; Cl is 0.13 to 0.95 %) [2]. It was assumed that all of the S and Cl entered the flue gas as SO2 and HCl respectively.

Lime Slurry Requirements

A mass balance was prepared to determine the amount of lime required to remove the estimated acid gas content in the flue gas. This mass balance is presented in Table 2. Calculations results are shown in Figure 4. This figure illustrates the flue gas temperature drop in the spray dryer resulting from addition of water. Approximately 7.6 L/min (2 gpm) of water at 15^0 C (59^0 F) causes the flue gas temperature to drop 28^0 C (50^0 F), assuming that flue gas specific heat is 1.0 kJ/kg-^{0}C (0.24 Btu/lb-^{0}F) and that flue gas flow is as previously calculated. This temperature drop is termed "Delta T." The diagonal line in Figure 4 is a plot of

Delta T versus flow of water added to the flue gas. For example, if 7.57 L/min (2 gpm) of water is added, the Delta T is 55°C (100° F).

Figure 4 can be used to estimate the effect of water in lime slurry on the flue gas temperature. If a 4 percent lime slurry is used, the mass balance in Table 2 indicates that a lime slurry injection rate should be 39.4 L/min (10.4 gpm). This rate predicts that acid gas control would be effective. Figure 4 shows that 39.4 L/min (10.4 gpm) of 4 percent lime slurry will result in a Delta T of 294° C (530° F). Since the flue gas temperature entering the spray dryer is only 211° C to 222° C (380° F to 400° F), it can be seen that use of 4 percent lime slurry is unrealistic.

However, it is also known that the lime slurry pump that Texcel provided (the contractor who quit the project) could not operate below about 15.1 L/min (4 gpm); this is equivalent to a Delta T of 111° C (200° F). This Delta T results in a flue gas temperature of 82° C to 93° C (180° F to 200° F) which is too cool, but it is close to operating data prior to the fix.

If a 16 percent lime slurry is used (see the mass balance in Table 2), a lime slurry injection rate of 9.8 L/min (2.6 gpm) should be used. This rate is necessary to control acid gas. Referring again to Figure 4, this would result in a Delta T of 72° C (130° F). This Delta T will produce a flue gas temperature of 121° C (250° F) to 132° C (270° F), which is much closer to the desired temperature range. Figure 4 also shows the expected injection rate range of the 16 percent lime slurry is 5.3 L/min to 9.8 L/min (1.4 to 2.6 gpm). This corresponds to a range of Delta T's of 39° C to 72° C (70°F to 130° F), and a corresponding spray dryer flue gas exit temperature of 121° C to 177° C (250° F to 330° F). A higher percent lime concentration would result in a lower amount of water introduced, a lower Delta T and a higher spray dryer exit temperature. The 16 percent lime slurry was a suitable design goal, considering the fact that the spray dryer entering flue gas temperature, while at times as low as 193° C (380° F), was also periodically around 128° C (425° F).

An independent water injection system is required if flue gas inlet temperature is raised (it is theorized) due to different operating procedures or new plant modifications, or if it fluctuates independently of SO2 concentration.

Water Injection Requirements

Figure 4 can be used to estimate how much water over and above the water in the lime slurry is required for temperature control of the flue gas. As can be seen, the desired outlet temperature of the spray dryer is 143° C (290° F). However, the inlet temperature sometimes fluctuates around the original design point of 232° C (450° F), but it usually was found to be 193° C to 204° C (380° F to 400° F). This is lower than the original design point. These data indicated that a lime slurry injection system should operate at a high percent lime to prevent excessive flue gas temperature drop. Also, the water injection system would need to be sized to handle the design temperature of the entering flue gas as well as any normal excursions above the design temperature. Figure 4 shows if 3.9 L/min (1 gpm) of water were added as part of the lime slurry, only 2.3 L/min (0.62 gpm) additional water from the would be needed from the water injection system to achieve a Delta T of 45° C (80° F); this would cool the incoming flue gas from 193° C to 148° C (380° F to 290° F).

Heater Requirements

The requirement was to maintain a cone surface temperature of 143° C (290° F). The redesign required new heaters with an output of 3.6 kW per spray dryer.

RECOMMENDED UPGRADES

The problems noted previously in this paper compounded each other. Simultaneous acid gas and flue gas temperature control were not possible with the existing equipment. The authors prepared the design for the following equipment upgrades. The contractor subsequently installed these designs.

Lime Slurry Injection Pump

The authors recommended installation of a smaller capacity pump from the original pump manufacturer. This pump could be installed in place of each over capacity pump. Adequate space and easily matched fittings made this a good solution. The smaller pump operates at 100 to 1,200 rpm. The control range between 100 rpm (0.94 L/min (.25 gpm) of lime slurry) up to 1,200 rpm (18.9 L/min (5 gpm) of 16 percent lime slurry) provides more precise control of lime slurry injection rate and therefore of acid gas emissions. A new drive reduction gear was also required to operate with the existing pump motor.

Lime Slaker System Upgrade

The authors recommended that the slaker supplier train the plant staff in proper slaking to maintain a 16 percent or higher lime concentration in the slurry. This then would allow the new slurry injection pump to operate in the desired control range. A longer mixing shaft was installed in the lime slurry storage tank. More powerful lime slurry recirculation pump motors were installed because the specific gravity of the 16 percent lime was higher than that of 4 percent lime.

Water Injection System

A separate water injection system was installed. This consisted of water injection pumps, relief valves, and a control valve with associated piping changes. The existing flue gas temperature detector on the spray dryer exit controlled the control valve. Figure 5 shows the revised control system.

Cost of Upgrades

Cost of the upgrades was relatively modest. For example, equipment costs were $20,000 per train. Installation costs exceeded the equipment costs and were approximately $150,000 for all three trains.

RESULTS OF THE ACID GAS CONTROL UPGRADES

It can be readily seen how each problem with the equipment compounded the previous problem. In short, the acid gas control was nonfunctional. The acid gas control was found to be quite good after the modifications were made. A chart of CEMS data is shown in Figure 6. These data include SO2 emissions as well as the activity of the lime slurry injection pump. These data represent all three incinerator units. SO2 emissions average about 10 ppmv with short term peaks that near 30 ppmv and minimum values of about 4 ppmv. Activity of the lime slurry injection pump is noteworthy. The SO2 concentration peaks, the lime slurry injection pump speed increases to remove the SO2. The speed range from 20 percent to 80 percent indicates that the choice of pump size and lime slurry concentration were correct.

The activity of the water injection pump is shown in Figure 6. This pump provides a small but steady flow of water to keep the spray dryer within its optimum temperature range. The control valve range shown on Figure 6 is approximately 1 to 2 percent. The control valve has a characteristic curve, and this represents 1 to 2 percent of the design flow at a given pressure. Each percentage represents approximately 1.9 L/min (0.5 gpm). There is a fluctuation of up to about 3 percent. At the same point in time, the outlet temperature of the spray dryer is very stable. This indicates the temperature control is working well.

Table 3 displays the results of the annual compliance test for SO2, HCl, and other parameters. These tests were conducted approximately 2 months after the upgrades were installed. Data show the plant emissions are well within the Puget Sound Air Pollution Control Agency requirements. Compliance tests confirm the CEMS data. In particular, dioxin values are well within the established limits. CO is considered a surrogate for dioxin. The CO value can exceed the permit limit, as in the case of unit 3, although dioxin emissions are well below the permit limit and the lowest of all three units. These compliance tests were conducted before startup of the carbon injection system. The 1998 compliance test report, which should portray the effect of carbon injection, was not available at the time of this paper.

No instances of excessive cooling or condensation in the scrubber cone have occurred since the upgrade to the scrubber heaters was performed

CONCLUSIONS

The Fort Lewis Waste-to-Energy Plant upgrades are successful. The plant is now able to consistently control acid gas emissions and flue gas temperatures. The solution to the problem was simply a close look at the various components of the spray dryer system and replacement of some relatively inexpensive equipment and/or a change in operating procedures. The plant now easily meets acid gas emission standards and also fulfills its responsibility to dispose of waste and provide a reliable supply of steam for Fort Lewis.

REFERENCES

1. Personal conversation with Owen F. Fortune, General Electric Environmental Services Company, 1986.
2. ASME Research Committee on Industrial and Municipal Wastes, <u>Thermodynamic Data for Waste Incineration,</u> United Engineering Center, New York, 1979; page 100.
3. Fort Lewis Waste-To-Energy Plant Compliance Test Report, Fort Lewis Public Works Directorate, Fort Lewis, Washington, October 1997.

TABLE 1
PUGET SOUND AIR POLLUTION CONTROL AGENCY
SUMMARY OF FORT LEWIS INCINERATOR EMISSION LIMITS

CRITERIA	LIMIT
Carbon Monoxide, CO	50 ppmv for a 4-hour average 140 ppmv for a 1-hour average as measured by CEMS and any 12 consecutive months; total from all three incinerators cannot exceed 37.2 Mg (41 ton)
Particulate matter, PM	0.14 dscm (0.007 grains/dscf with back half*)
Sulfur dioxide, SO2	30 ppmv for a 1-hour average as measured by CEMS
Hydrogen chloride, HCl	25 ppmv
SO2 + HCl	Any 12 consecutive months: total from all three incinerators must not exceed 31.7 Mg (35 ton*)
Nitrogen oxides, NOx	180 ppmv for a 12-hour average by CEMS; and any 12 consecutive months: total from all three incinerators cannot exceed 35.4 Mg (39 ton*)
Total hydrocarbons	70 ppmv for a 1-hour average by compliance test
Cadmium, Cd	101 g/million dscm (4.4 grains/million dscf*) by compliance test
Lead, Pb	1,007 g/million dscm (44 grains/million dscf*) by compliance test
Mercury, Hg	801 g/million dscm (35 grains/million dscf *) by compliance test
Dioxins/furans	13 ng/dscm total mass or 0.20 ng/dscm diosin/furan toxic equivalency of 2,3,7,8 - TCDD (TEQ); any 12 consecutive months, total dioxin/furan from all three incinerators cannot exceed 3.1 grams
Opacity	5 %, 6 minutes in any 1 hour by compliance test; 10 % by CEMS
Inlet temperature to baghouse	Maximum 350^0 F
Pressure drop across baghouse	0.0076 kg/cm2 (3 to 6 inches water column*), maximum
Combustion temperature	871^0 C (1600° F*) minimum; 982^0 C (1800° F*) 15 minute average

*Puget Sound Air Pollution Control Agency units
All emission limits corrected to 7 % oxygen, dry basis

TABLE 2
MASS BALANCE TO DETERMINE LIME REQUIREMENTS
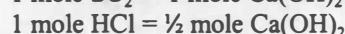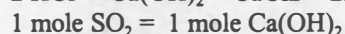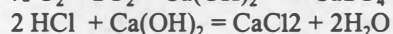
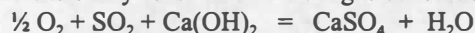1. Determine moles of CaO per 45.35 kg (100 lb) of refuse:

   For Sulfur, S = 0.4366% of refuse; therefore 0.0043 x 45.43 kg (100 lb) = 0.19 kg (.43 lb) S/45.42 kg (100 lb) refuse; thus the amount of S per mole is 0.19 kg (.43 lb)/32.07 kg/kg moles (32.07 lb/lb mole) S

   For Chlorine, Cl = 0.789778% of refuse; therefore 0.0079 x 45.43 kg (100 lb) = 0.36 kg(0.79 lb) Cl/45.43 kg(100 lb) refuse; thus the amount of Cl per mole is 0.36 kg (0.79 lb)/35.5 kg/kgmoles (35.5 lb/lb mole) Cl
   Moles of Sulfur /45.34 kg (100 lb) refuse = 0.013 moles S
   Moles Chlorine/45.35 kg (100 lb) refuse = 0.022 moles Cl

   Lime slurry reaction with acid gas constituents:
   $\frac{1}{2} O_2 + SO_2 + Ca(OH)_2 = CaSO_4 + H_2O$
   $2 HCl + Ca(OH)_2 = CaCl2 + 2H_2O$
   1 mole SO_2 = 1 mole $Ca(OH)_2$
   1 mole HCl = $\frac{1}{2}$ mole $Ca(OH)_2$

   Amount of lime required to react with amount of acid gas in flue gas:
   For 45.35 kg (100 lb) refuse: 0.013 moles S requires 0.013 moles $Ca(OH)_2$, which is equivalent to 0.013 moles CaO
   Similarly for Cl: 0.022 moles Cl requires ½ (0.022) moles $Ca(OH)_2$, which is equivalent to 0.011 moles CaO
   The sum of the moles of CaO required per 45.35 kg (100 lb) of refuse is 0.013 + 0.011 =
   0.024 moles/45.35 kg (100 lb) refuse;
   since the CaO is only95 % pure: CaO required = 0.024/0.95 = 0.025 moles CaO/45.35 kg (100 lb) refuse
   On a mole basis: 25.44 kg (56.1 lb)/mole CaO x 0.025 moles/45.35 kg (100 lb) refuse =
   0.63 kg (1.4 lb) CaO /45.35 kg (100 lb) refuse

2. Amount of CaO per hour of CaO per incinerator:

   2267 kg (5000 lb) refuse/hr/incinerator x 0.63 kg (1.4 lb) CaO/45.35 kg (100 lb) refuse = 31.7 kg (70 lb) CaO/hr on a stoichiometric basis;
   Assume that twice the stoichiometric amount of lime is necessary to insure a complete reaction: 2 x 31.7kg (70lb) = 63.5 kg (140 lb/hr) CaO

3. Determine feed rate of 16% lime slurry:
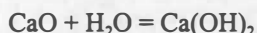
   $CaO + H_2O = Ca(OH)_2$
   1 mole CaO @ 56 kg/kg-mole (lb/lb-mole) = 1 mole $Ca(OH)_2$ @ 33.6 kg/kg-mole (74 lb/lb-mole)
   63.5 kg (140 lb)/hr CaO x 33.6/25.4 (74/56) = 83.9 kg (185 lb) $Ca(OH)_2$
   % lime slurry = weight of $Ca(OH)_2$/water + CaO
   16 % lime slurry = 0.69 kg (1.53 lb) $Ca(OH)_2$/3.8 kg (8.34 lb) water + 0.52 kg (1.16 lb) CaO
   Weight of 3.8 L (1 gal) of 16% lime slurry = 3.8 kg (8.34 lb) + 0.52 kg (1.16) = 4.3 kg (9.5 lb)/ L(gal)
   L/hr (gal/hr) of 16 % lime slurry = 83.9 kg (185 lb)/hr CaO/0.52 kg (1.16 lb) CaO/gallon = 601.8 L (159 gal)/hr
   L/min (gpm) of 16% lime slurry = 601.8 L (159 gal) /60 min per hr = 9.8 L/min (2.6 gpm) of 16% lime slurry

4. Operating range required for lime injection pump at two slurries (instantaneous peak) :

	Theoretical Slurry Requirement Per Incinerator	
Refuse Firing Rate	4%	16%
27.21 Mg (30 Ton) Per Hour	19.7 L/min(5.2 gpm)	4.9 L/min (1.3 gpm)
54.4Mg (60 Ton Per Hour)	39.4 L/min(10.4 gpm)	9.9 L/min (2.6 gpm
81.6Mg (90 Ton Per Hour)	59.0 L/min(15.6 gpm	14.8 L/min (3.9 gpm)
108.8 Mg (180Ton Per Hour)	78.7 L/min (20.8 gpm	19.7 L/min (5.2 gpm)

Note: Metric units may vary slightly due to rounding.

TABLE 3
COMPLIANCE TEST RESULTS
JULY 1997 (PRIOR TO STARTUP OF CARBON INJECTION)

Parameter	Unit 1	Unit 2	Unit 3	Permit Limit
Temperature, ^{0}C	146	152	153	177
(°F)	(295)	(305)	(307)	(350)
Particulate matter, g/dscm	0.23	1.37	1.37	0.16
(gr/dscf)	(0.01)	(0.06)	(0.06)	(0.007)
SO2, ppm as C @ 7% O2	15	14	5.8	30
HCl, ppm as C @ 7% O2	23	13	11	25
Dioxin/furans, ng/dscm	2.8	2.3	1.2	13 total mass or 0.20 TEQ
Carbon monoxide, CO, ppm	24	48	82	50
Cadmium, Cd, g/million dscm	12.4	1.8	4.8	101
(gr/million scf)	(0.54)	(0.08)	(0.21)	(4.4)
Lead, Pb, g/million dscm	8.9	2.9	2.3	1010
(gr/million dscf)	(0.39)	(0.13)	(0.1)	(44)
Mercury, Hg, g/million dscm	97.1	131	31.9	804
(gr/million dscf)	(4.23)	(5.7)	(1.39)	(35)
Total hydrocarbon, ppmd as C @ 7% O2	3.8	3.2	3.2	70
NOx, ppm as C @ 7% O2	148	114	121	180

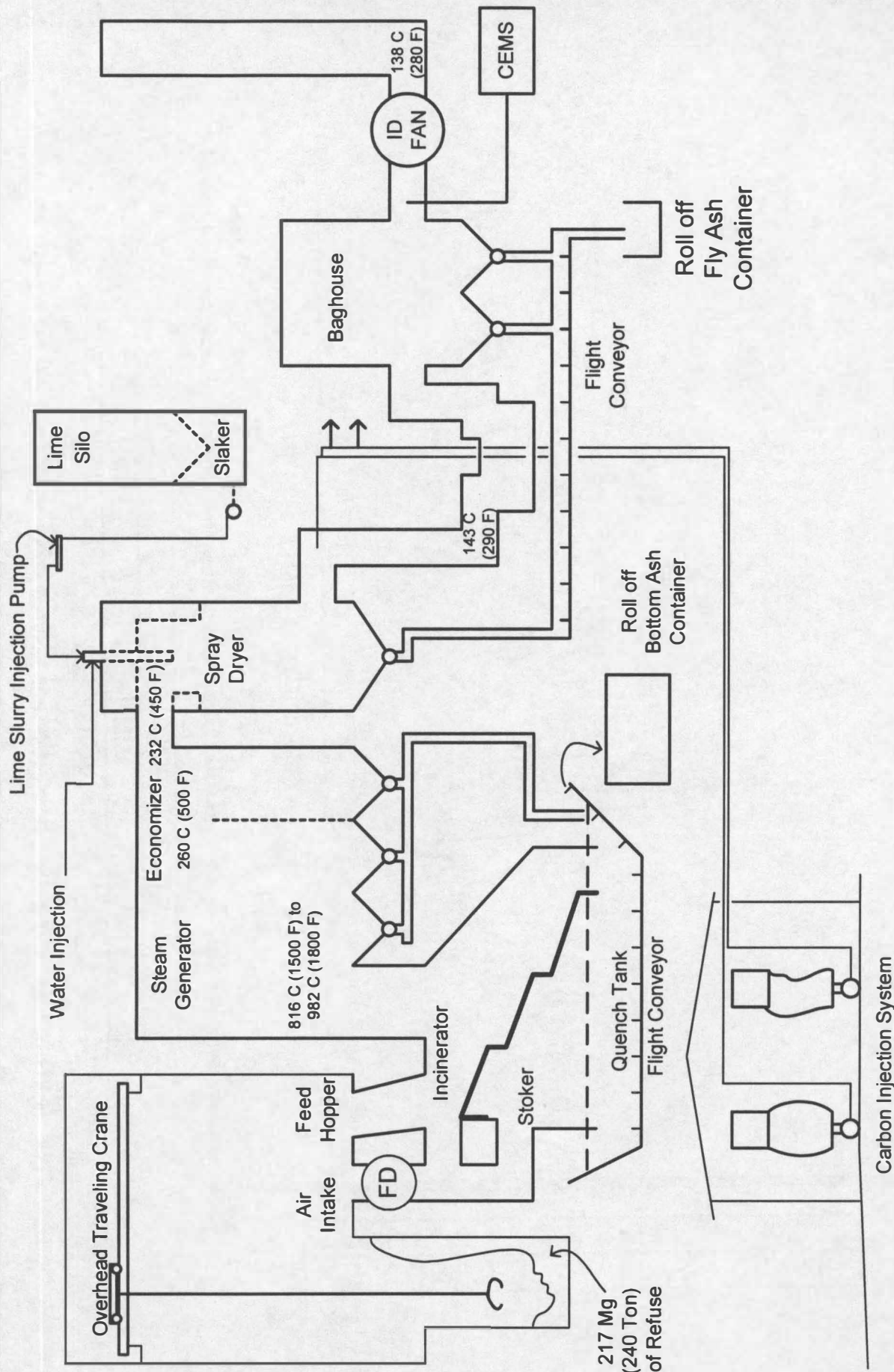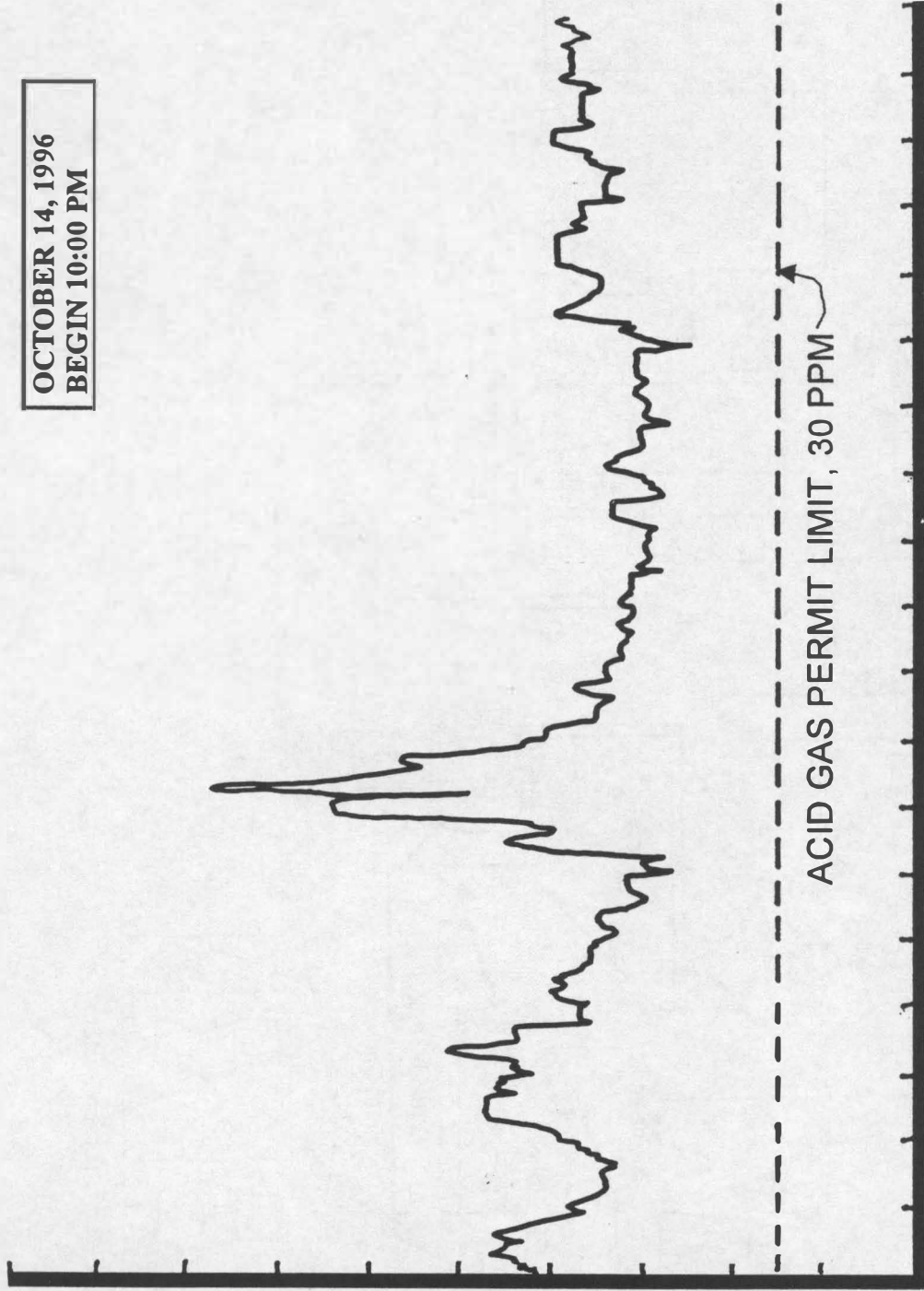Note: Compliance test data reported in English units except for dioxin

FIGURE 1

SCHEMATIC CROSS SECTION OF FORT LEWIS INCINERATOR

(Drawing and data from U.S. Army Corps of Engineers drawing)

ftlew600b.vsd

331

FIGURE 2

UNIT TWO ACID GAS (SO₂) EMISSIONS PRIOR TO FIX

PARAMETER	UNITS	SCALE
TIME	MINUTES	0 to 180

ACID GAS PERMIT LIMIT, 30 PPM

OCTOBER 14, 1996
BEGIN 10:00 PM

PARAMETER	UNITS	SCALE
ACID GAS, SO2	PPM	0 to 200
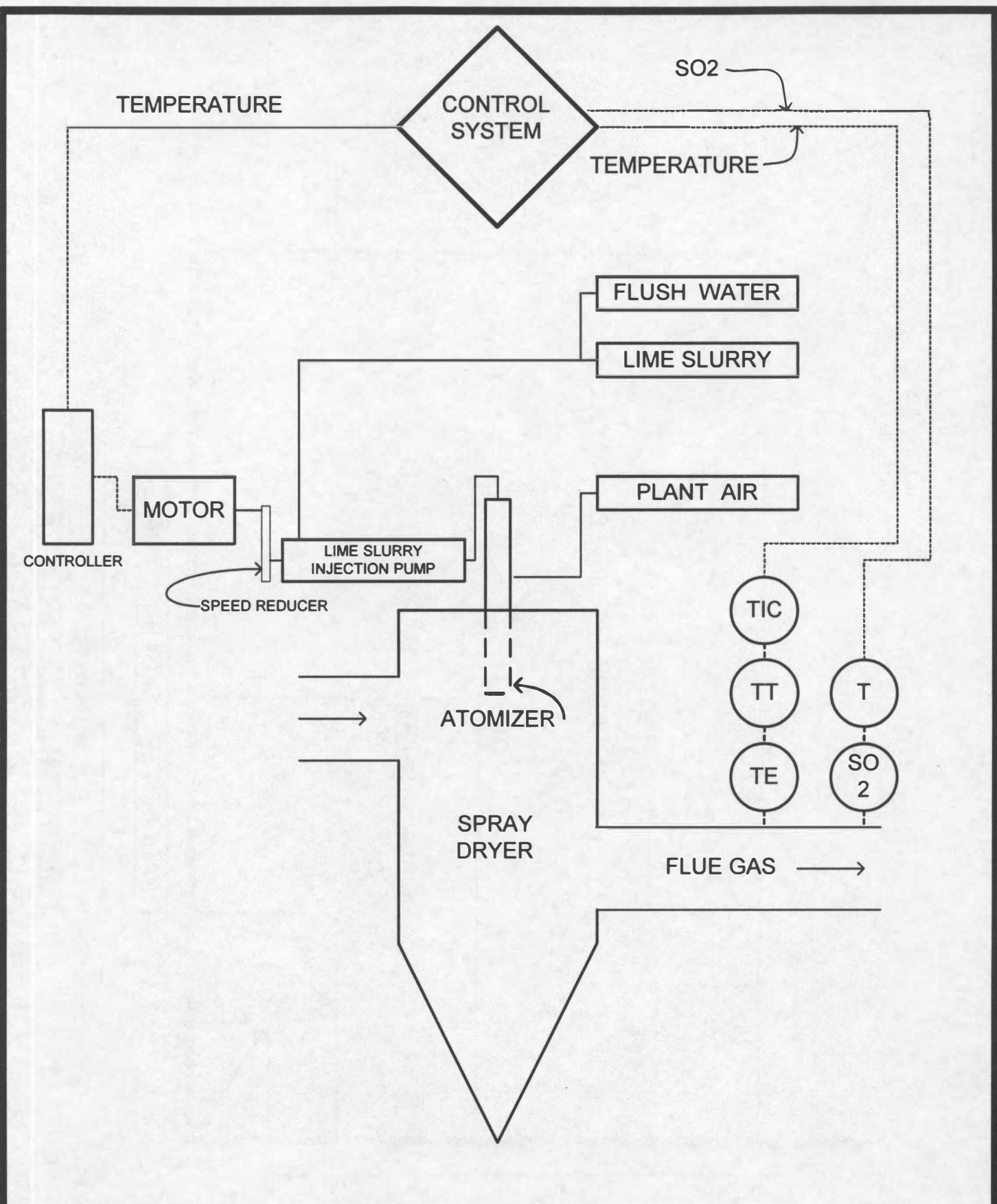
FIGURE 3
ORIGINAL CONTROL SCHEME
LIME INJECTION CONTROLLED BY TEMPERATURE
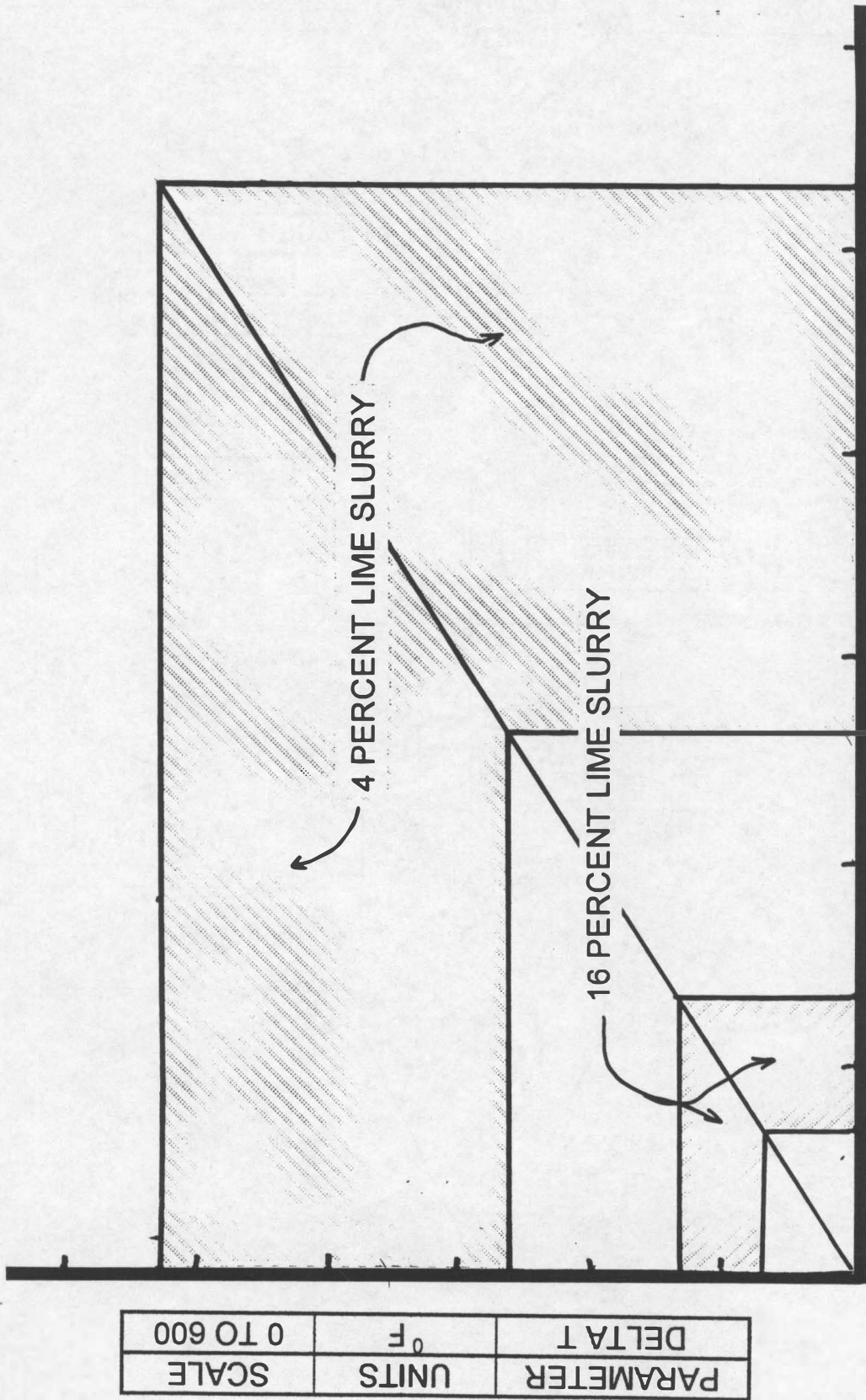
PARAMETER	UNITS	SCALE
FLOW	GPM	0 TO 12

FIGURE 4

THEORETICAL EFFECT OF LIME SLURRY ON FLUE GAS TEMPERATURE

4 PERCENT LIME SLURRY

16 PERCENT LIME SLURRY

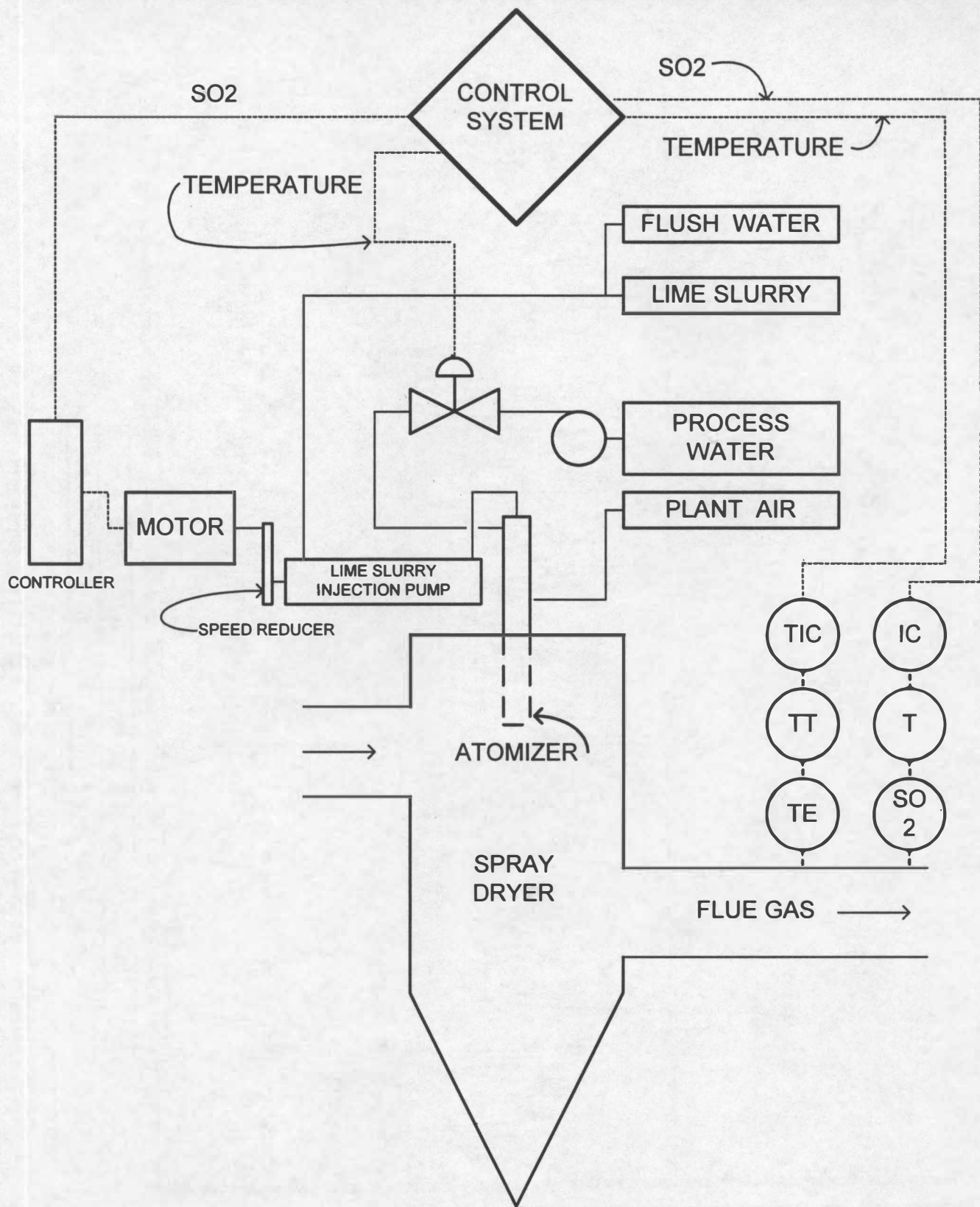| PARAMETER	UNITS	SCALE
DELTA T	°F	0 TO 600

FIGURE 5
REVISED CONTROL SCHEME
WITH LIME INJECTION CONTROLLED BY SO2 CONCENTRATION
AND WITH WATER INJECTION CONTROLLED BY TEMPERATURE

FIGURE 6

UNIT TWO HISTORICAL TRENDS AFTER FIX

PARAMETER	UNITS	SCALE
TIME	MINUTES	0 TO 900

PARAMETER	UNITS	SCALE
SPRAY DRYER EXIT TEMPERATURE	°C (°F)	0 TO 278 (0 TO 500)
WATER INJECTION CONTROL VALVE	%	0 TO 100
LIME SLURRY	%	0 TO 100
ACID GAS	PPM	0 TO 200

MAY 18, 1998
BEGIN 4:00 PM

FLUE GAS TEMPERATURE
EXITING SPRAY DRYER

TEMPERATURE PERMIT LIMIT
177° C (350° F)

LIME SLURRY INJECTION

ACID GAS

ACID GAS PERMIT LIMIT, 30 PPM

WATER INJECTION

336