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No testing data

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TESTING AND EVALUATION OF SEWAGE SLUDGE INCINERATOR AT FIELDS POINT WASTEWATER TREATMENT FACILITY PROVIDENCE, RHODE ISLAND

Phase I - Preliminary Review

August 1982

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SECTION 1

INTRODUCTION

The purpose of this preliminary engineering review is to evaluate the design and conditions of the Fields Point Wastewater Treatment Facility sewage sludge incinerator air pollution control system and determine if the system is capable of controlling emissions to the extent required to meet the cited regulations (40 CFR 60, Subpart O). Included in the evaluation is a review of the system design, previous problems with the system and test and operation reports. As a result of this review, conclusions and recommendations have been developed regarding the capabilities of the control system to meet the necessary emission limitations.

SECTION 2

SYSTEM DESCRIPTION

INCINERATOR

The sludge incinerator is multiple hearth with upper hearths used for drying of the sludge, middle hearths for incineration and lower hearths for cooling of the incinerator ash. The drying zone location varies as do the other two zones. The number of hearths required to dry the sludge is a function of feed rate, moisture content and combustibles content. The hearths used for incineration are in turn a function of the drying zone. Incineration should only take place on hearths 4,5 and 6[a]. Maintaining a consistent profile of drying, incinerating and cooling zones is crucial in reducing the amount of excess emissions from the incinerator.

Filter cake is charged to the top hearth and travels down toward the lowest hearth where it exits as ash. Assumptions used in the original design include:

- filter cake moisture content = 72-78%
- dry filter cake volatile content = 55-75%
- wet sludge firing capacity = 10 tons/hour
- equipment will perform satisfactorily between 60-100% of sludge firing capacity

Proper rates of excess air admitted to the incinerator are 50-125%. The rate is regulated by warm air recirculation ducts located at hearths 7 and 9. Based on observations of the hearth flame characteristics, an operator may either open or close these ducts to obtain optimum combustion conditions.

Exhaust gas from the incinerator passes out through the top hearth into the emission control system. An emergency bypass damper is located between the incinerator and afterburner. The purpose of the damper is to permit incinerator exhaust gas to bypass the scrubber system during startup, shutdown and system malfunction (e.g. high I.D. fan inlet temperatures, scrubber water pump failure, I.D. fan failure). The damper is automatically controlled with pneumatic pressure and also responds to a manual override procedure.

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[a] Source: Reference 1.

Pollution Control System

The pollution control system is comprised of a venturi scrubber and a perforated tray impingement tower (See Figure 1). Other components of the system include a flooded-weir gas precooling (quench) section upstream of the venturi, a flooded elbow immediately after the venturi and an induced draft fan after the tray tower. An afterburner is located in the system preceeding the quench section of the venturi.

Scrubber/Impinger System

The scrubber section of the control system is a variable throat, spray type venturi designed and supplied by AirPol. Table 1 contains design information for the scrubber.

Gas exiting the top of the incinerator is designed to pass through the afterburner where temperatures approaching 1400°F oxidize volatile, odorous compounds present in the vapor. As the hot gas exits the afterburner it enters the precooling quench section of the scrubber. Quench water at 75°F and 15 psig is sprayed from opposite sides of the duct by two non-clog type stainless steel nozzles. These nozzles are specified as Spraco No. 11152026 with a rated flow per nozzle of 76 gpm at 15 psig and a spray angle of 104°. The spray water cools the hot gas stream prior to the high energy venturi throat.

Venturi water at 75°F and 3 psig is pumped into an inlet weir above the quencher and through an expansion connection. The expansion connection consists of a weir and thimble to allow one inch of expansion in either the vertical or horizontal direction. The weir allows uniform distribution of venturi water across the area of the scrubber with no dead spots. Turbulence created by high gas velocity in the converging throat section deflects the water travelling down the wall into the gas stream. Particles carried along with the gas impact on the water wall and become entrained. The width of the rectangular orifice (throat) is controlled by two parallel hinged plates which are adjusted by manual chain drive. Restricting the throat area increases the linear gas velocity and subsequent pressure drop.

As the water carrying the entrained particles travels through the throat it passes into the flooded elbow section where the stream velocity decreases allowing the water and gas streams to separate. The gas stream passes through a horizontal connecting duct to the base of the impingement tower. Gas velocity is further reduced upon entry to the tower. The stream passes upward toward the perforated trays. The trays are each flooded with 600 gallons per minute per tray of 75°F water at 3 psig. Water enters the trays from inlet ports on opposite sides and flows across the tray due to the water pressure and bouyancy created by the upflowing gas. As gas passes through each perforation in the tray, it creates a jet which bubbles up the water and further entrains soild particles. At the top of the tower is a chevron overlapping vane mist eliminator to reduce the carryover of water dropets in the stack effluent gas.

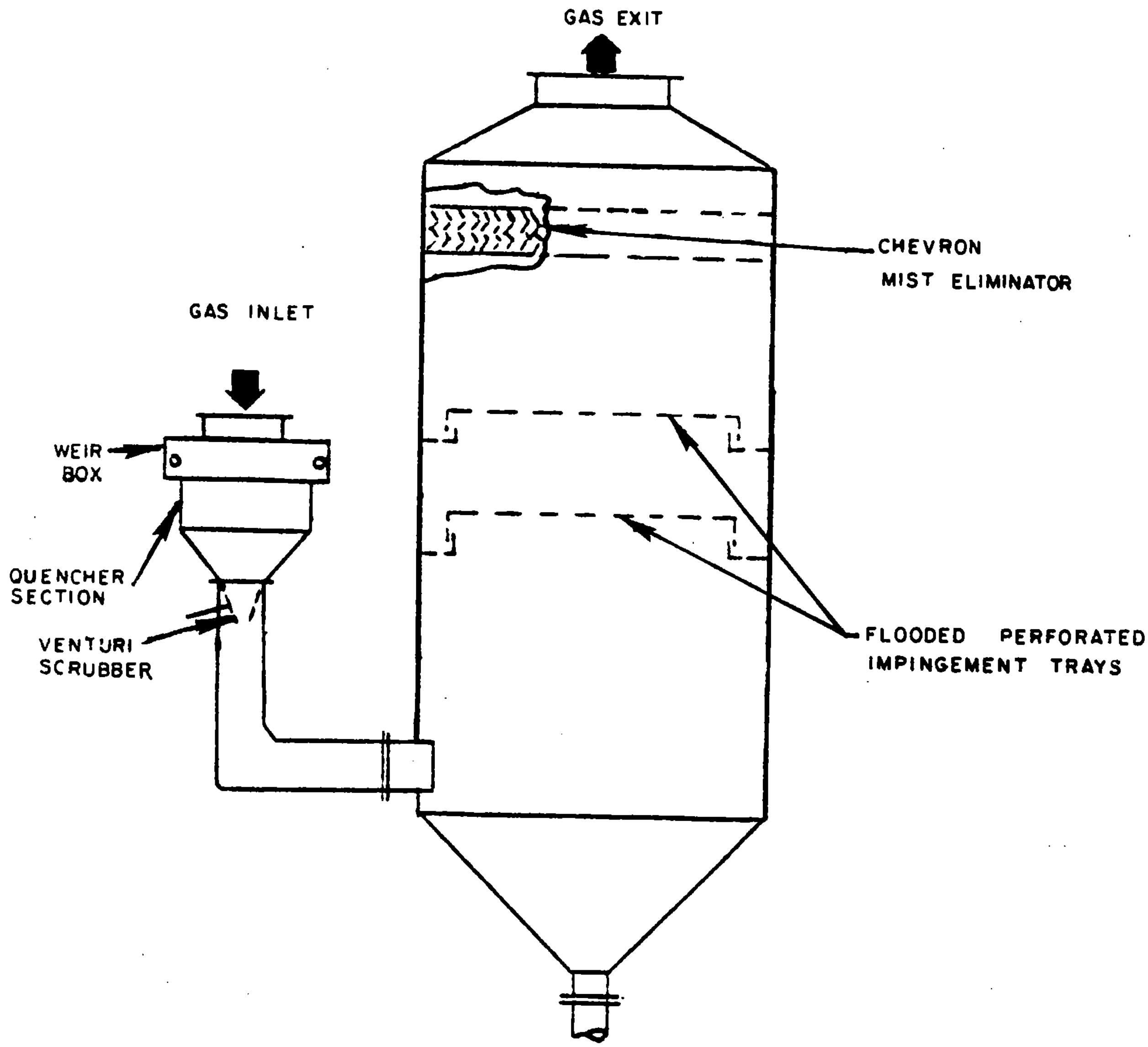

Figure 1. Venturi Scrubber and Perforated Tray Impinger Tower[1]

TABLE 1. SCRUBBER/IMPINGER DESIGN DATA[1]

Quencher Venturi Gas Volume	89,537 ACFM
Quencher Venturi Inlet Gas Temperature	1400°F
Inlet Pressure	- 2" w.c.
Quencher Pressure Drop	1 to 2" w.c.
Venturi Pressure Drop	23" w.c.
Separator Pressure Drop	8" w.c.
Spray Liquid Rate	220 GPM @ 15 psig, 75°F
Weir Liquid Rate	400 GPM @ 3 psig, 75°F
Cooler Liquid Rate	1200 GPM @ 3 psig, 75°F
Outlet Gas Volume @ .32" w.c.	24,737 ACFM
Outlet Gas Temperature	110°F
ID Fan	350 HP, 1750 RPM
Total System Pressure Drop	32" w.c.

Following the impingement tower is an induced draft (I.D.) fan. This fan is rated at 750 horsepower and 1750 rpm. The purpose of the fan is to provide a draft through the incinerator as well as creating the necessary pressure drops through the scrubber system. A conoflow damper is located in the duct immediately preceeding the I.D. fan. This damper regulates the volume of gas pulled by the fan.

Scrubber water consists of effluent from the water treatment plant. A concrete holding tank is used to store scrubber water prior to being pumped to the system. The solids content of the water depends on the characteristics of the plant effluent water. Design criteria for solids permissible in the scrubber water is 1-5 %.[a]

Controls and Instrumentation

Controls and instrumentation on the incinerator and scrubber systems include a variety of items. Operating parameters are monitored from the control panel with log entries made once per hour. A multipoint temperature recording chart was installed to monitor temperatures in the incinerator as well as temperatures in the afterburner, quencher and I.D. fan exhaust. A position indicator is provided for the emergency bypass damper. This allows the operator to determine damper position. Other parameters monitored at the control panel include:

- afterburner outlet pressure
- venturi/quencher differential pressure
- I.D. fan discharge pressure.

Parameters monitored in other locations include:

- sludge feed rate (by weight)
- weir water flow rate
- weir/spray water flow rate
- impinger water flow rate
- impinger tower pressure drop.

[a] Source: Reference 1.

SECTION 3

INITIAL TESTING

The system was originally tested by Recon Systems, Inc. on September 30, 1980 and October 1, 1980 in order to determine compliance status with respect to 40 CFR 60, Subpart O - Standards of Performance for Sewage Treatment Plants. All tests were performed in accordance with U.S. EPA Methods 1-5. EPA personnel were present through the duration of testing and EPA reviewed the test report and determined that the emission rates stated therein were representative of actual rates. Reported emission rates for three runs were 2.43 lb/dry ton, 4.12 lb/dry ton and 3.04 lb/dry ton. The average rates used to determine compliance was 3.20 lb/dry ton which is 146% over the NSPS emission limit of 1.30 lb/dry ton.[a]

Operating conditions during the test were as follows; average dry sludge firing rate was 1.79 tons per hour (tph) based on a wet sludge rate of 7.59 tph and 23.6% average solids contents; average oxygen concentration in stack exhaust gas ranged from 14.0% to 14.8% during the test; venturi pressure drop ranged from 25 to 27 inches of water.

Several reasons have been cited for the failure of the system to meet the required emission limits; improper sludge feed rate, improper sludge quality, dirty scrubber water, and flaking in the test stack. Sludge was fed at a rate of 7.59 wet tons per hour versus 10 wet tons per hour rated capacity.[b] The system was originally designed to operate in a range 60% to 100% of the rated design capacity (e.g. 6-10 wet tons per hour feed rate). Sludge quality was in the range of 50-55% volatiles, slightly lower than the design value of 55 - 75% volatiles. An agreement reached prior to testing stated that sludge quality during the test was to be unspecified.[b] Possible causes of dirty inlet scrubber water could have been exceptionally high solids content in the treatment plant effluent, dirty scrubber water strainer.[c] Apparently, no quantitative measurements of scrubber water solids content were made at the time of the test. The interior of the stack in which the initial tests were conducted was

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[a] Written correspondence from John Carlson, U.S. EPA Air Section Sampling and Analysis Division to Ray DiNardo, U.S. EPA Air Compliance Section, Enforcement Division, December 16, 1981.

[b] Written correspondence from Harshad Modi, Nichols Engineering to Ken Klipper, Hart Engineering, November 17, 1980

[c] Written correspondence from Paul Sylvia, Castellucci, Galli Associates, to Anthony Autiello, Charles Krasnoff and Associates, December 2, 1980.

reported to be " flaking."[b] The paint originally used to coat the stack interior was peeling off and collecting in the sample train. Also, particulate matter in the scrubber effluent gas had collected on the interior surface which may have added to the flaking. This condition may have resulted in the dislodging of material which was not actually being emitted in the scrubber effluent but which may have been collected in the sampling train.

The combustion profile of the incinerator was somewhat low during the test. Incineration was occuring below the specified range of #4 to #6 hearth which may have affected emission characteristics.

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[b] Written correspondence from Harshad Modi, Nichols Engineering to Ken Klipper, Hart Engineering, November 17, 1980.

SECTION 4

SYSTEM RECONDITION

The sludge incinerator and scrubber system had to be extensively reconditioned after approximately 18 months of being inoperative. Some of the more pertinent items covered in the reconditioning program included; draining and cleaning the scrubber water holding tank and strainer; lubricating the I.D. Fan including the damper linkages and having the motor checked by an electrician; checking and cleaning the impingement tower seive trays; checking and replacing all water pump seals where necessary; manometers were cleaned and filled with fluid; sludge totallizer was repaired and calibrated.

A start-up schedule was then developed to bring the system up to full scale operation. Start-up and dry out of the incinerator was performed according to procedures listed in the Operation and Maintenance Manual. Internal inspections of both the incinerator and scrubber systems were conducted to determine the integrity of the system. Precooler quenching water was observed to be flowing from the weir down the interior walls of the quench section resulting in sufficient flooding. Venturi water spray nozzles were also observed to be operational.[a] Impinger tower tray water was observed flowing onto the two sieve trays. The water was guaged at 800 gpm according to the flow meter. Measurements were subsequently taken of water levels in the scrubber water holding tank and the guage calibrated accordingly.[b] Tray water was observed to flow part way across the tray and fall through without reaching the center and flooding the entire tray. Operation of the system with gas flowing upward through the sieve trays should provide the holdup necessary for the tray water to flood the entire tray (See Calculations, Appendix A). Initial burning of sludge was originally intended to commence on June 15, 1982. Several problems arose with the operation of the system causing initial sludge firing to be delayed until July 1, 1982. Some problems encountered included; leaks developed in the control air lines causing the emergency bypass damper to open; scrubber effluent water tank developed a leak in the basement causing the scrubber system to be placed on standby; the main coil filter was taken out of service due to mechanical problems and sludge was being dried by standby filters with limited capacity; manometer fluid evaporates from manometer tubes daily; the I.D. Fan damper was put in the manual mode because when in the automatic mode it oscillated excessively.

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[a] Personal communication between Brian Hobbs, GCA Technology Division and Al Verdouw, Indianapolis Center for Advanced Research, July 15, 1982.

[b] Personal communication between Brian Hobbs, GCA Technology Division and Paul Pinault, NBWQMDC, June 11, 1982.

Operation of the afterburner will be suspended during the compliance test and in subsequent operation.

SECTION 5

EVALUATION

A review of standard venturi scrubber and impingement separator design methods was conducted. Twelve other sludge incinerators operating in the U.S. use venturi scrubber/impingement separator emission control systems. Pressure drop in these units range from 9" w.c. to 32" w.c. with an average pressure drop of approximately 20" w.c.[2] Typical liquid to gas ratios (L/G's) for venturi scrubbers and impingement separators are 2-15 gal/1000 acfm and 1 gal/1000 acfm respectively.[3]

An inspection of the facility prior to pretesting revealed certain aspects of the operation which deviated from procedures listed in the operation and maintenance manual. Operating variables monitored during the evaluation and their values are listed in Table 2. Temperatures for the gas stream entering the quench section of the venturi range from 700-800°F without operating the afterburner. Temperatures of the quenched gas should be effectively the same as if the afterburner were operating. The volume of gas flowing into the venturi will therefore also remain constant at approximately 30,800 acfm (See Appendix A - Calculations). Pressure drop through the scrubber can be maintained by adjusting the throat orifice width and water flow rate. Pressure drop through the scrubber was initially registering 40 inches of water, well above the specified 23 inches listed as the design value. Due to this excessive pressure drop, the afterburner breech door was opened to allow infiltration of dilution air and a subsequent reduced pressure drop to 28 inches water. The throat orifice was maintained in a fully open position at all times in order to reduce the pressure developed in the scrubber.

The weir water flow guage was inoperative during the inspection. Flow rates were determined to be below the design value of 400 gpm[a]. Feeling for flow through the weir by sticking my hand to the base of the weir water trough resulted in only a slight sensation of suction. The weir water inlet flow also felt low. A combination weir and spray water flow meter registered 300-350 gpm. Most of the manometers connected to the quencher/venturi section of the system were inoperative. According to the incinerator/scrubber system operating logs, the weir water flow guage has worked intermittently since restarting. Hourly readings of flow rates were recorded on July 3,4,5,8 and 12.

Other observations made during the inspection include significant visible fugitive emissions escaping from the top of the incinerator. These emissions are probably a result of sludge burning in the upper hearths rather than the middle ones. Possible reasons for this include the fact that the sludge was only being fed at two tons per hour (due to the inoperative coil filter) and the sludge was very dry. The sludge totalizer was operating. Visible emissions consisting of a yellow plume were also noticeable exiting from the sampling stack. The scrubber water holding tank was observed to be full. The water contained in the tank appeared to have a high solids content.

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[a] Conversation between Brian Hobbs, GCA Technology Division and Al Verdouw, IARC, July 19, 1982.

TABLE 2. SYSTEM OPERATION VALUES DURING INSPECTION

Variable	Value
Spray water pressure	14-17 psig
Tray water flow rate	1320 gpm
Weir and spray water flow rate	300-350 gpm
Venturi pressure drop	28" w.c.
Separator pressure drop	4-5" w.c.
Weir water flow rate	(inoperative)
Temperature of gas stream entering quencher	750°F
Temperature of gas stream exiting stack	90°F

SECTION 6

CONCLUSIONS

The following conclusions were reached based on the preceeding evaluation of the emission control system:

1) Quench water design flow rate is 220 gpm, which is twice the adiabatic saturation demand of the incinerator flue gas stream at 1400°F. Assuming that the temperature of the gas stream is approximately 700°F without the operation of the afterburner, the adiabatic saturation demand should be approximately exceeded by a factor of four.

2) Typical liquid to gas ratios (L/G's) for Venturi scrubbers and perforated tray impinger columns are 2-15 gal/1000 acfm and 1 gal/1000 acfm (per tray) respectively.[a] At flow rates of 30,800 acfm, 620 gpm (scrubber/quencher) and 24,400 acfm, 1200 gpm (impinger), L/G's are 20.1 and 49.2 respectively (See Calculations, Appendix A). These L/G's are above standard design specifications.

3) Reductions in weir water flow rates may be caused by insufficient expansion of the weir joint caused by lower precooler temperatures than the design value. An excessively low water flow rate in the scrubber would create fewer water droplets available for impingement and smaller average diameter droplets. This could result in lower particulate collection efficiency. Since the L/G is approximately 20 gal/1000 acfm and well above typical design rates, reduced L/G would begin to affect particle penetration at approximately 300 gallons per minute.

4) Scrubber water solids content should be between 1-5% as per the Operation and Maintenance Manual. Higher scrubber water solids content (dissolved and suspended) would reduce the capacity of the water to further absorb solid particles. Should the solids content of the scrubber water become high enough, retrainment of particles from the perforated sieve trays may occur. Also, the system will experience more rapid deterioration (eroision) due to the abrasive characterisitcs of the slurry.

5) Due to the fact that the incinerator and scrubber system have been idle for an extended period of time, maintenance problems such as corrosion, leaking pump seals, glands, flanges, piping, etc., will occur as evidenced in the problems experienced in the restart of the system. System downtime may therefore be above normal until the system is "debugged."

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[a] Source: Reference # 3.

6) Running the scrubber system without the afterburner may lead to an increase in emissions of combustibles such as hydrocarbons, oils, fats and some solids. This increase will depend on the quality of the sludge and the operation of the incinerator. If the incinerator burning profile is kept in the correct hearth sequence as per the operation instructions, most volatiles should be sufficiently oxidized.

7) Use of specified Spraco nozzles number 1152026 in the venturi procooling section will result in a maximum spray water rate of 152 gpm (at a per nozzle rate of 76 gpm). System design calls for total spray water rate of 220 gpm.

8) The design of the air pollution control system is consistent with units installed on other sewage sludge incinerators that are meeting the 40 CFR 60, Subpart O emission standard. If the air pollution control system and the incinerator are properly maintained and operated according to the design specifications, then the system should meet the required emission standard.

SECTION 7

RECOMMENDATIONS

Based on the preceeding conclusions, the following recommendations have been developed:

1) Scrubber water solids content should be measured for both the inlet and outlet scrubber water during testing.

2) Sludge feed rate should be in the design range of 6-10 wet tons per hour during testing.

3) Data sampling and analysis of operating conditions during the test should include:

a. temperatures indicated on strip chart recorder

b. feed rate (tons per hour) from the scale totalizer every 15 minutes

c. location of burning zone

d. scrubber water flow rates (weir, spray, and tray)

e. sludge quality (percent volatiles, moisture content) from laboratory

f. pressure drops across air pollution control devices.

4) Combustion profiles in the incinerator should be maintained as per the Operation and Maintenance Manual.

REFERENCES

1 Process Operation and Maintenance Manual for Nichols-Herreshoff Sludge Furnace Installation. Project No. CE-1271. Nichols Engineering and Research Corporation. Belle Meade, NJ. August 1979. 210 pp.

2 A Review of Standards of Performance for New Stationary Sources - Sewage Sludge Incinerators, EPA-450/3-79-010. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, March, 1979.

3 McIlvaine Scrubber Manual, The McIlvaine Co. Northbrook, Illinois.

APPENDIX A: CALCULATIONS

- Volume of gas stream entering quencher:

assume: ideal gas law, PV = nRT

$T_1 = 1400^\circ F\ (1860^\circ R)$

$V_1 = 89{,}500$ acfm

$T_2 = 180^\circ F\ (640^\circ R)$

$V_2 = ?$

$$\frac{V_1}{T_1} = \frac{nR}{P} = \frac{V_2}{T_2}$$ (assuming constant pressure and molar flow rate)

$$V_2 = \left(\frac{V_1}{T_1}\right) T_2 = \frac{89{,}500}{1860}\ 640^\circ R = 30{,}800 \text{ acfm}$$

- Liquid to Gas ratios based on design rates:

venturi: liquid rate = (220 gpm) + (400 gpm) = 620 gpm

gas rate = 30,800 acfm

$$\therefore L/G = \frac{620}{30.8 \times (1000 \text{ acfm})} = \frac{20.1 \text{ gallons}}{1000 \text{ cubic feet}}$$

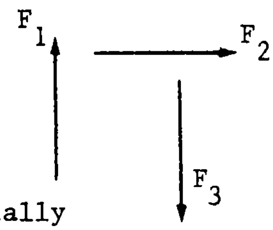
impinger: liquid rate = 1200 gpm

gas rate = 24,400 acfm

$$\therefore L/G = \frac{1200}{24.4 \times (1000 \text{ acfm})} = \frac{49.2 \text{ gallons}}{1000 \text{ cubic feet}}$$

(continued)

- Force balance on impinger water:



F_1 = force of gas flowing upward

F_2 = force of water horizontally

F_3 = gravitational force on water, vertically

tray diameter = 9'-6" (2.9m)

tray inlet pipe diameter = 6" (0.15m)

tray water flow rate = 1200 gal/min (4.56 m^3/min)

aasume: 2" pressure drop per sieve tray

$$2'' \; H_2O \;\; x \left[\frac{1.87 \text{ mm Hg}}{\text{inch water}}\right] = 3.74 \text{ mm Hg} = 498.7 \; \frac{kg}{m\text{-}s^2}$$

$$\text{water pressure} = 3 \text{ psi} \left[\frac{10^5 \; kg/m\text{-}s^2}{14.5038 \text{ psi}}\right] = 20{,}684 \; \frac{kg}{m\text{-}s^2}$$

$$\therefore F_2 = 20{,}684 \; \frac{kg}{m\text{-}s^2} \; (0.018 \; m^2) = 372.3 \; \frac{kg\text{-}m}{s^2}$$

$$\therefore F_1 = \left(498.7 \; \frac{kg}{m\text{-}s^2}\right)\left(\frac{2.9m}{2}\right)^2 \pi = 3296 \; \frac{kg\text{-}m}{s^2}$$

$$\therefore F_3 = \left(18.9 \; \frac{kg}{sec}\right)\left(9.78 \; \frac{m}{sec^2}\right) = 184.6 \; \frac{kg\text{-}m}{s^2}$$

Enclosure 2

(X) We do not have data of the types requested.
except for municipal sewage sludge incinerator - 2 source test reports enclosed

( ) We do have data of the types requested, but we do not believe the data will be useful to EPA, because

____

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____

( ) We only have partial data of the type(s) requested.

( ) We are restricted from providing the data requested because of agency policy.

( ) We cannot provide the data requested because of confidentiality agreements with the sources or other originators of the data.

( ) We cannot provide the data requested for the following other reason(s):

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( ) Our agency chooses not to provide the data requested.

Please return the completed form to:

E. L. Martinez, Chief
Criteria Emissions Section/AMTB (MD-14)
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

THANK YOU FOR YOUR COOPERATION

Agency: Alaska Dept of Environmental Conservation

Agency Contact and Telephone Number: Tom Chapple
(907) 465-2666