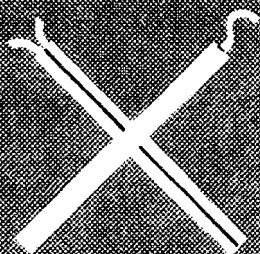
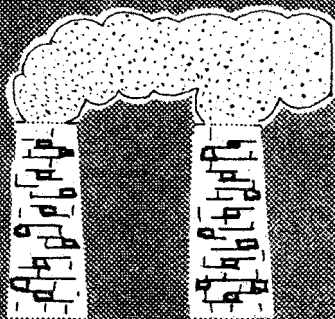
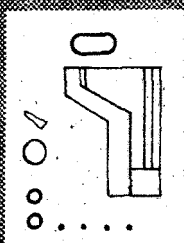
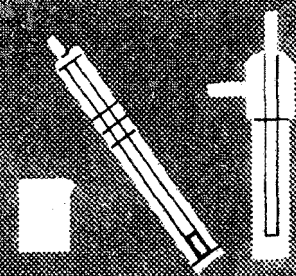


AIR POLLUTION EMISSION TEST

WEYERHAEUSER COMPANY

KRAFT MILL

EVERETT WASHINGTON



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Emission Measurement Branch
Research Triangle Park, North Carolina

PARTICULATE EMISSION MEASUREMENTS
FROM KRAFT PULP MILLS

EMB Projects Report No.
74-KPM-10

Plant Tested

Weyerhaeuser Company, Everett, Washington

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Emission Measurement Branch
Research Triangle Park
North Carolina 27711

by

W. R. Fearheller
D. L. Harris
M. T. Thalman

MONSANTO RESEARCH CORPORATION
DAYTON LABORATORY
1515 Nicholas Road
Dayton, Ohio 45407

Report Reviewed by Robert M. Martin

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I. INTRODUCTION

Under the Clean Air Act of 1970, the Environmental Protection Agency is given the responsibility of establishing performance standards for new installations or modifications to existing installations in stationary source categories. As a contractor, Monsanto Research Corporation (MRC), under the Environmental Protection Agency's "Field Sampling of Atmospheric Emissions" program, was asked to provide emission data from the Weyerhaeuser Company, Everett, Washington.

The field test work was directed by John Snyder, Field Testing Section, Emission Measurement Branch. The sampling was performed by Monsanto Research Corporation with Darrell L. Harris as Team Leader.

This report tabulates the data collected at the outlet of the wet scrubber system controlling the exhaust of the smelt tank. The smelt tank is part of the overall recovery system of the kraft pulp mill. Spent digestion chemicals (black liquor) are burned in a recovery furnace and smelt is formed in the bottom of the furnace. This smelt is continuously removed from the furnace and fed into the smelt dissolving tank where it is dissolved in scrubbing liquor or makeup water to make the uncausticized green liquor. Gaseous emissions from the smelt dissolving tank are scrubbed in a packed tower scrubber and emitted to the atmosphere.

Sampling was performed on the outlet of the packed tower scrubber. Particulate loadings were determined by Method 5, "Determination of Particulate Emissions from Stationary Sources." Other procedures that were required for the Method 5 tests were: Method 1, "Sample and Velocity Traverses for Stationary Sources;" Method 2, "Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube);" Method 3, "Gas Analysis for Carbon Dioxide, Excess Air and Dry Molecular Weight;" and Method 4, "Determination of Moisture in Stack Gases." All of the above methods are given in the Federal Register, Vol. 36, No. 247, Dec. 23, 1971.

The modification required at the sampling location was to provide a support surface for the sampling equipment.

This report presents a summary and discussion of sampling results, a description of the process, the location of sampling points and a description of the sampling and analytical procedures. Appendices contain all field and analytical data generated from this project.

II. SUMMARY AND DISCUSSION OF RESULTS

The outlet of the packed tower scrubber system of the smelt dissolving tank at the Weyerhaeuser Company's kraft pulp mill was sampled for particulate loading. An attempt was made to sample the inlet of this scrubber, but the flow was erratic and irregular at the only available sampling location. At some point locations flow direction was actually reversed. After discovering the flow discrepancies, the inlet sampling was aborted.

A total of six runs were attempted on the outlet, but only three of the six were valid runs. Prior to the first run a Method 4 moisture determination was performed, as well as a velocity traverse according to Methods 1 and 2. The moisture analysis indicated that the stack gases contained approximately 18.5% water by volume. This moisture value did not seem reasonable in view of the fact that the effluent was the outlet of a scrubber and saturated gas was expected. To recheck this calculation a wet bulb-dry bulb moisture check was made and it indicated that the moisture level was 17% by volume. Because of the agreement of the two methods, it was assumed that they were correct, and a value of 18% was used to calculate the nomograph factor. During the first half of the run the sampling train plugged several times and had to be shut down and restarted. At the half way shutdown for port change, the excess water was removed from the impingers, the silica gel replaced and the run continued.

During the second half of the run rough calculations were made for the first half, and they indicated a moisture content of approximately 40% and an isokinetic percentage of about 145%. This run was aborted and the sample was not saved.

Runs 2 and 3 were made the next day and both were calculated to be super isokinetic. It was determined that the stack gases were saturated, as suspected, and the stack temperature was changing during the run, causing wide variations in the moisture content. It was decided that an average stack temperature and average moisture content could not be used to set the nomograph for the run. Instead, the stack temperature would have to be closely monitored, and adjustments made in the nomograph calculation when a temperature change was noted. The nomograph was therefore adjusted to each new temperature for a moisture level equivalent to a saturated gas at the new temperature. The next three runs (Nos. 4, 5, and 6) were made using this procedure and turned out to be isokinetic within the $\pm 10\%$ requirement.

Table 1 summarizes the results of particulate sampling, giving particulate loadings and several of the more important variables. Run 1 is not listed since the partially collected sample was not saved. Runs 2 and 3, while not within the isokinetic specification, are given for reference. Runs 4, 5, and 6 are the acceptable runs.

Table 1
Summary of Particulate Results

Run Number:	2	3	4	5	6
Date:	10/10/73	10/10/73	10/11/73	10/12/73	10/12/73
Method Type:	EPA-5	EPA-5	EPA-5	EPA-5	EPA-5
Volume of gas sampled - (Nm ³) ^a - (DSCF) ¹	2.28 (80.5)	2.10 (74.2)	1.93 (68.2)	1.95 (69.0)	1.79 (63.2)
Percent Moisture by Volume	43.5	47.6	44.8	47.4	47.8
Average Stack Temperature - °C - (°F)	80.6 (177)	81.7 (179)	78.9 (174)	82.2 (180)	80.6 (177)
Stack Volumetric Flow Rate - Nm ³ /sec - (DSCFM) ²	6590 (3880)	5790 (3410)	6300 (3710)	6120 (3600)	5810 (3420)
Stack Volumetric Flow Rate - m ³ /sec - (ACFM) ³	13800 (8140)	13200 (7750)	13600 (8020)	14000 (8220)	13300 (7840)
Percent Isokinetic	116.5	121.9	104.2	108.4	104.6
Feed Rate - M tons/hr of Equivalent Pulp Production - (tons/hr)	14.3 (15.8)	17.0 (18.7)	15.9 (17.5)	17.1 (18.8)	17.3 (19.1)
Duration of Run - Minutes	220	220	220	220	220
<u>Particulates</u>					
Probe, Cyclone, and Filter Catch, mg	559.6	628.8	503.4	631.4	530.1
mg/Nm ³ - (grains/DSCF) ⁶	245 (0.107)	300 (0.131)	261 (0.114)	323 (0.141)	295 (0.129)
Kg/hr - (lb/hr)	1.61 (3.56)	1.73 (3.820)	1.64 (3.610)	1.97 (4.350)	1.72 (3.780)
Kg/M ton of Equivalent Pulp Production - (lb/ton)	0.113 (0.225)	0.102 (0.204)	0.103 (0.206)	0.115 (0.231)	0.0994 (0.198)
Total Catch - mg	613.6	678.5	533.3	664.9	556.2
mg/Nm ³ - (grains/DSCF) ⁶	270 (0.118)	323 (0.141)	277 (0.121)	341 (0.149)	311 (0.136)
Kg/hr - (lb/hr)	1.77 (3.900)	1.87 (4.120)	1.73 (3.820)	2.08 (4.580)	1.80 (3.970)
Kg/ M ton of Equivalent Pulp Production - (lb/ton)	0.124 (0.247)	0.110 (0.220)	0.109 (0.218)	0.122 (0.244)	0.104 (0.208)
Percent Impinger Catch	8.8	7.3	5.6	5.0	4.7

¹Dry Standard Cubic Feet @ 70°F, 29.92 in Hg

²Dry Standard Cubic Feet per Minute @ 70°F, 29.92 in Hg

³Actual Cubic Feet per Minute - Stack Conditions

⁴Normal Cubic Meters at 21.1°C, 760 mm Hg

⁵Metric Tons per Hour (1 metric ton - 1000 Kg)

⁶Grains per Dry Standard Cubic Feet

III. PROCESS DESCRIPTION AND OPERATION

PROCESS DESCRIPTION

A. General

Kraft pulp is produced from wood as shown in Figure 1. In the process, wood is chipped into small pieces and then cooked (digested) under pressure at elevated temperatures in "white liquor"--a water solution of sodium hydroxide and sodium sulfide. The white liquor chemically dissolves lignin, leaving wood cellulose (pulp) which is filtered from the spent liquor and washed. The pulp produced is usually made into paper.

The balance of the process is designed to recover the cooking chemicals. Spent cooking liquor and the pulp wash water are combined for treatment to recover cooking chemicals. The combined streams, called weak black liquor, are normally concentrated to 60-65% solids in evaporators and then fired in a recovery furnace. Combustion of the organics in the black liquor provides a significant portion of the heat required for generating process steam. Inorganic chemicals from the black liquor are recovered as a molten smelt from the bottom of the furnace. The smelt, consisting of sodium carbonate and sodium sulfide, is dissolved in water and transferred to a causticizing tank. Lime added to the tank converts sodium carbonate to sodium hydroxide, completing

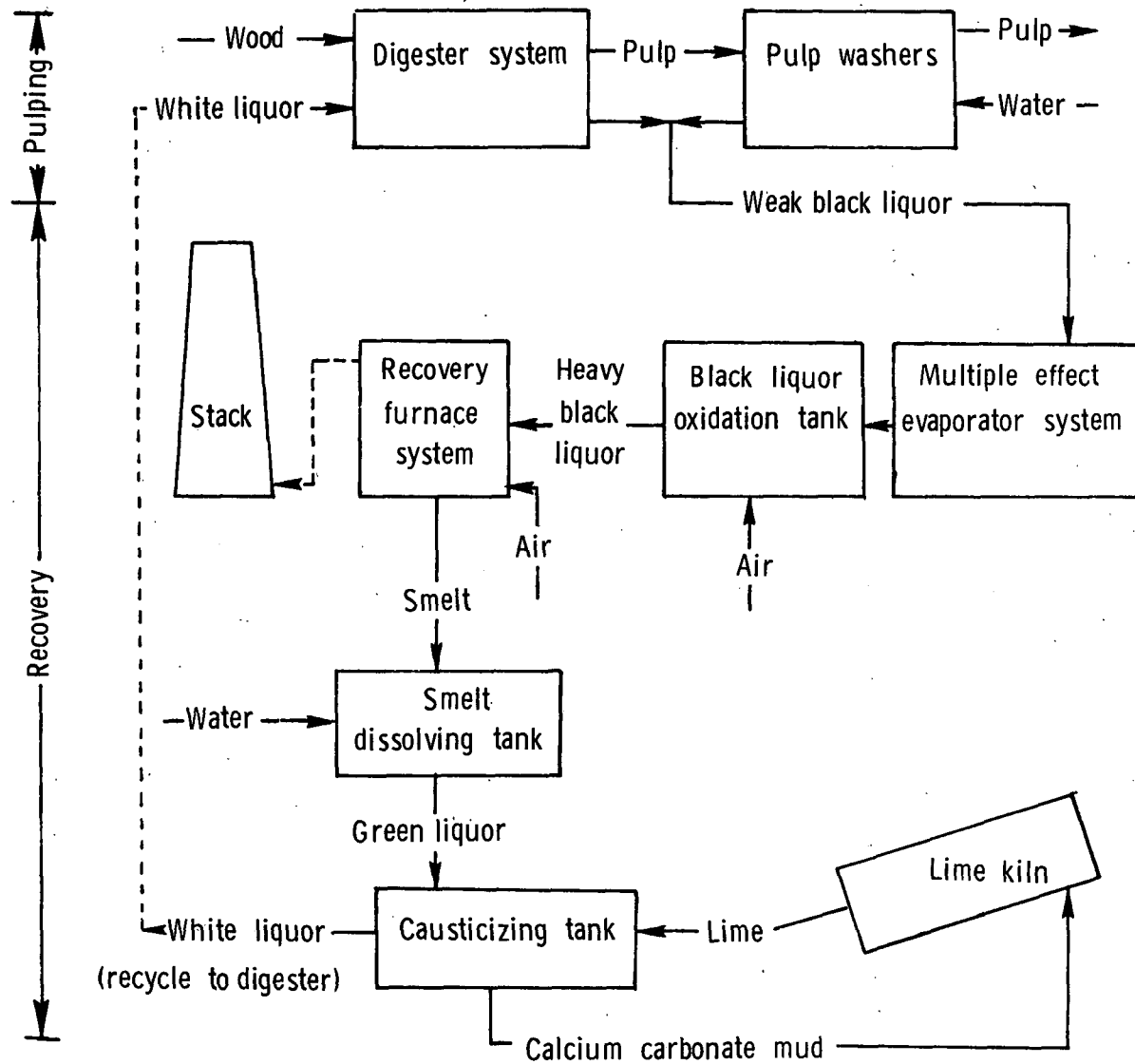


Figure 1. The Kraft Pulping Process

the regeneration of white liquor, which is then recycled to the digesters. The calcium carbonate mud which precipitates from the causticizing tank is recycled to a kiln to regenerate lime.

B. Smelt Dissolving Tank

The smelt dissolving tank receives a stream of molten smelt which is continuously tapped from the bottom of the recovery furnace. The molten smelt is subsequently dissolved in the smelt dissolving tank to form "green liquor"--a water solution of sodium sulfide and sodium carbonate. The green liquor is then sent to the causticizing department for further processing. Weak wash is used as the dissolving liquid in the smelt tank. Weak wash is the liquid stream that results from washing the lime mud.

The recovery furnace in which the smelt is formed was manufactured by the Babcock and Wilcox Company. This furnace is designed to operate at an equivalent pulp production of 318 air dried metric tons (350 air dried tons) per day, but it is presently operating around 363 to 408 air dried metric tons (400 to 450 air dried tons) tons per day. Hot black liquor is sprayed into the furnace through a nozzle near the furnace bottom. Occasionally, when extra heat is needed or when the black liquor supply is temporarily interrupted, natural gas or oil is burned.

The smelt dissolving system consists of a smelt spout, a dissolving tank, agitators, circulating pumps, and a system of pumps and piping for transferring the green liquor to the causticizing department. The smelt dissolving tank is normally supplied with a closed top, a vent pipe and steel housing which enclose the smelt spouts projecting from the front of the furnace hearth.

A smelt spout is basically a water cooled trough. It is necessary to disperse or otherwise break up the stream of smelt before it hits the surface of the liquor in the tank. This is accomplished by discharging a heavy stream of recirculated green liquor into the stream of molten smelt through nozzles located behind and slightly below the smelt spout.

Breaking up the smelt stream before it hits the liquor surface in the tank prevents serious explosions which might be caused by the reaction between the hot smelt, consisting primarily of sodium sulfide and sodium carbonate, and the green liquor in which it is to be dissolved. In effect, there is a continual series of small explosions taking place at the contact point of the molten smelt and the recirculated green liquor. This contact with the hot smelt thoroughly agitates the receiving water, and causes the formation of large amounts of steam. The steam is vented to the atmosphere through a scrubber to remove particulates. The smelt dissolving tank and scrubber are shown in Figure 2.

C. Air Pollution Control System

The particulate emissions from the smelt tank are controlled by a packed tower scrubber. This scrubber is designed to handle 50,900 m³/sec (30,000 acfm). The scrubber is a 2.4 meter (8 foot) diameter steel tank 6.7 meters (22 feet) high containing a scrubbing section in the bottom packed with 7.6 centimeter (3 inch) polypropylene intalox saddles, and an entrainment separator (demister) in the top packed with 5.1 centimeter (2 inch) polypropylene intalox saddles. Between sections weak wash is sprayed downward through a distributor to contact the gases which are drawn up through

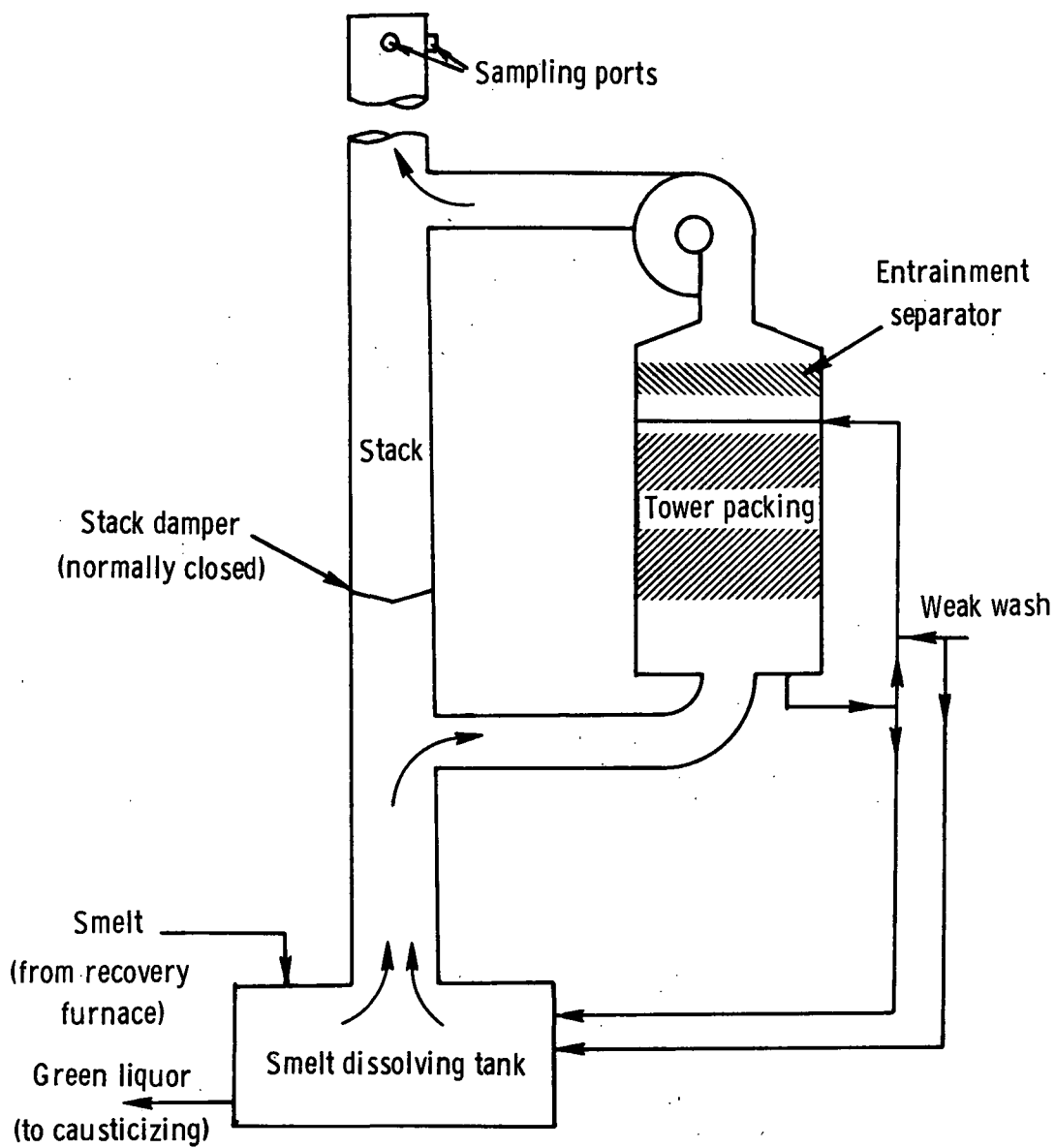


Figure 2. Smelt Dissolving Tank and Scrubber
at the Weyerhaeuser Mill at
Everett, Washington

the packing by an induced draft fan. One stream of water leaves the scrubber. A portion of this stream is bled off and drained to the smelt dissolving tank. The rest of the water is recycled and blended with the incoming makeup water (weak wash).

PROCESS OPERATION

A. General

The purpose of the tests was to measure emission levels during normal mill operation. Process conditions were carefully observed, and testing was done only when the test facility appeared to be operating normally.

During the tests, important process conditions were monitored and recorded on data sheets. Readings were taken about once every half-hour. These data, and a key to the entries, are given in Appendix B and summarized below.

B. Smelt Dissolving Tank - Recovery Furnace

As far as can be determined from the process data (Appendix B) and conversations with the operators, the equipment operated normally during the tests. The observed ranges of major operating conditions during the tests are summarized in Table 2. Black liquor flow rate varied between 606 and 772 liters (160 and 204 gallons) per minute; the normal rate is approximately 720 liters (190 gallons) per minute. The solids contents in the black liquor during these tests range between 59.4 and 64.4%.

The recovery furnace operation was steady throughout the tests. The black liquor flow rate did change, however,

Table 2

Summary of the Recovery Furnace and Packed Tower Process Data

Operation condition	Units	<u>Range during test</u>					
		#1	#2	#3	#4	#5	#6
Black liquor feed rate	lpm	757-776	606	719	606-719	704-731	712-719
	gpm	200-205	160	190	160-190	186-193	188-190
Black liquor solids content	%	59.4-61.8	60.6-62.6	60.2-62.0	60.6-62.2	60.8-62.8	61.0-64.4
Steam production	1000 kg/hr	57-64	64-68	64-68	57-64	64-67	64
	1000 lb/hr	126-141	140-150	140-150	125-140	142-148	140-142
Total recirculation rate to packed tower	lpm	1018-1136	1124-1143	1113-1154	1090-1168	1101-1136	1113-1136
	gpm	269-300	297-302	294-305	288-308	291-300	294-300
Makeup water to packed tower	lpm	303	299	299	299	299-303	303
	gpm	80	79	79	79	79-80	80

toward the end of Test No. 4. A larger size nozzle was substituted so that a greater black liquor flow could be accommodated. The changeover only required about one minute and, according to the operators, did not interrupt the smelt flow to the smelt dissolving tank. Once the nozzle was changed the black liquor flow and other furnace parameters were steady.

During the last test (No. 6) there was a problem with the ash return system from the furnace's precipitator. The ash is dissolved and ducted to the black liquor system prior to the furnace. This duct became plugged and had to be washed out, with the result that only water entered the black liquor system and diluted the black liquor. This was indicated by the reduced black liquor density as recorded by the meter in the control room.

However, according to the operators, this did not have an affect on the total solids flow to the recovery furnace since they were adding extra salt cake makeup to compensate for the loss in ash normally returned to the black liquor system. Analyses of the black liquor during this period indicated solids contents of 61 and 64.4%.

C. Air Pollution Control System

The total liquid recirculation flow rate to the scrubber's sprays ranged between 1018 and 1166 liters (269 and 308 gallons) per minute during the tests.

The scrubber bypass damper was closed throughout the testing. The damper did open slightly several times because of large eruptions in the smelt dissolving tank. These eruptions are typical of smelt dissolving operation, and cause a buildup

of pressure in the system. The bypass damper is designed to open when necessary to relieve the pressure. These openings, however, lasted only a few seconds.

The gases from the black liquor oxidation (BLO) system at this mill are vented to the smelt dissolving tank stack. This BLO system was shutdown during our testing, however, so that the BLO gases would not dilute the controlled emissions from the smelt dissolving tank. The BLO gases are normally added between the packed tower scrubber and the outlet sampling location.

D. Equivalent Pulp Production Rates

The operations of the smelt dissolving tank and recovery furnace are quantitatively related to the pulp production rate in the digesters. As a result, pollutant emission rate can be expressed on the basis of equivalent pulp production, as shown below:

$$\left(\begin{array}{c} \text{Emission rate,} \\ \text{kg/ton pulp} \end{array} \right) = \left(\begin{array}{c} \text{Emission rate,} \\ \text{kg/hr} \end{array} \right) \cdot \left(\begin{array}{c} \text{Equivalent pulp} \\ \text{production rate} \\ \text{tons/hr} \end{array} \right) \quad (1)$$

To use Equation 1, the equivalent pulp production was calculated from the black liquor charged during the tests, as shown below:

$$\left[\begin{array}{c} \text{Equivalent pulp} \\ \text{production,} \\ \text{M. tons} \end{array} \right] = \left[\begin{array}{c} \text{Black} \\ \text{liquor} \\ \text{charged,} \\ \text{liters} \end{array} \right] \left[\begin{array}{c} \text{Pulp-to-liquor ratio} \\ \text{at avg. \% solids} \\ \text{M tons/liter} \end{array} \right] \left[\begin{array}{c} \% \text{ Solids} \\ \text{(test avg.)} \\ \hline \% \text{ Solids} \\ \text{(base avg.)} \end{array} \right] \quad (2)$$

The last term in Equation 2 corrects for the actual percent solids (in the black liquor charged) compared to the average percent solids on which the pulp-to-liquor ratio is based.

The pulp-to-liquor ratio in the above equation was determined from mill records for the month of September 1973. The total pulp production during this time was 10,626 unbleached air dried metric tons (11.713 tons). Flow meter readings showed that 26,925,400 liters (7,113,700 gallons) of black liquor were charged during the same period. By division, the pulp-to liquor ratio was found to be 0.0004 M ton per liter (0.00165 ton per gallon).

The average solids content of the black liquor charged during the same time period (base average) was determined from the furnace operator's two-hourly records of solids content. The average of all the readings was found to be 61.4%.

Substitution of the above determined values into Equation 2 gives:

$$\left[\begin{array}{c} \text{Equivalent pulp} \\ \text{production,} \\ \text{M tons} \end{array} \right] = \left[\begin{array}{c} \text{Black liquor} \\ \text{charged,} \\ \text{liters} \end{array} \right] \left[\begin{array}{c} 0.0004 \\ \text{M tons/liter} \end{array} \right] \left[\begin{array}{c} \% \text{ Solids} \\ \text{(test avg.)} \\ 61.4 \end{array} \right] \quad (3)$$

Equation 3 was used to calculate the equivalent pulp production rate during each test on the smelt dissolving tank. The calculations are summarized in Table 3.

In summary, emission rates in units of kg per metric ton (pounds per ton) of pulp are calculated from Equation 1. Equivalent pulp production rates to use in this equation are also given in Table 3.

Table 3
Summary of Calculations of Equivalent Pulp Production Rate

Date-1973	Average black liquor flow rate during test,		Test Time, min	Avg. % Solids	Black liquor charged		Equivalent ^(a) pulp production		Equivalent pulp ^(b) production rate,	
	lpm.	(gpm)			liters $\times 10^3$	(gallons)	M ton	(tons)	M ton/hr	(tons/hr)
Oct. 10	606	(160)	220	61.7	1.33	(35,200)	52.5	(57.9)	14.3	(15.8)
Oct. 10	719	(190)	220	61.1	1.58	(41,800)	62.2	(68.6)	17.0	(18.7)
Oct. 11	666	(176)	220	62.2	1.47	(38,720)	58.2	(64.2)	15.9	(17.5)
Oct. 12	715	(189)	220	61.8	1.57	(41,580)	62.6	(69.0)	17.1	(18.8)
Oct. 12	715	(189)	220	62.7	1.57	(41,580)	63.6	(70.1)	17.3	(19.1)

^aCalculated from Equation 2.

^bCalculated by dividing equivalent pulp production by test time.

IV. LOCATION OF SAMPLING POINTS

INLET TO SCRUBBER

The ports for the scrubber inlet sampling were located in the original vertical stack at a distance of 4.17 m (164 in.) from the smelt tank outlet and 0.97 m (31 in.) from the junction of the scrubber inlet pipe and original stack. A damper was located in the stack downstream from the scrubber take-off line and could be opened if necessary to bypass the scrubber. The ports in the 1.37 m (54 in.) stack were 5.1 cm (2 in.) diameter flanged half unions covered with a blank flange.

OUTLET OF SCRUBBER

The scrubber outlet sampling location was in the original 1.37 m (54 in.) diameter stack at a point 3.73 m (147 in.) from the junction of the stack and scrubber fan outlet line and 1.73 m (68 in.) from the stack outlet. This was the center line location of one port, and the other port was 7.6 cm (3 in.) higher or 1.65 m (65 in.) from the atmospheric outlet. Ports were 10.2 cm (4 in.) ID flanged half unions with a blank flange for closing. The critical dimension in terms of diameters was 2.72 diameters downstream from the nearest upstream disturbance (the fan outlet). The dimensions required a 44 point traverse (22 points per direction).

A diagram of the total scrubber system showing the location of the sampling ports is given in Figure 3. Figure 4 shows the location of the traverse points at both the inlet and outlet ducts.

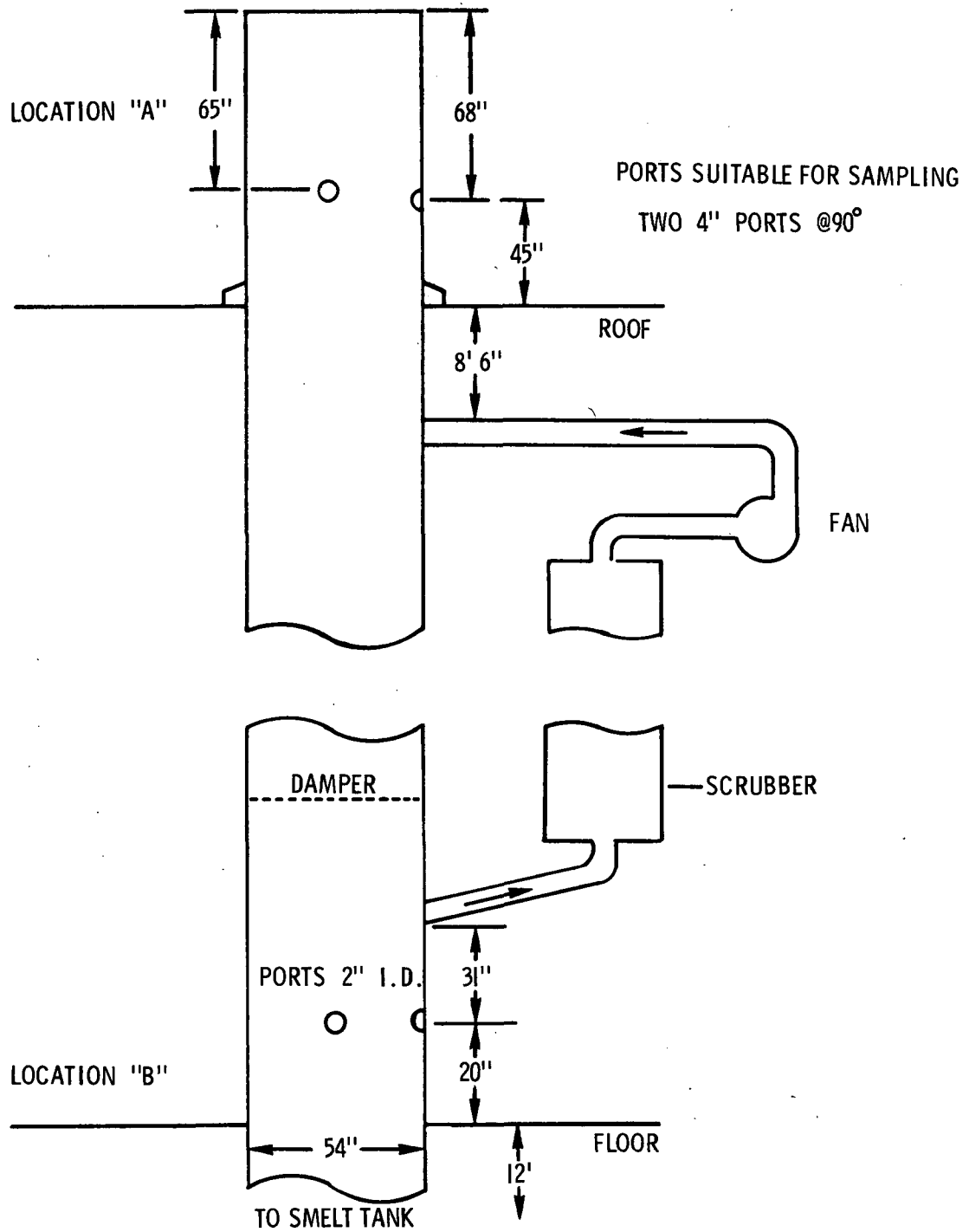


Figure 3. Inlet and Outlet of Weyerhaeuser Company Scrubber

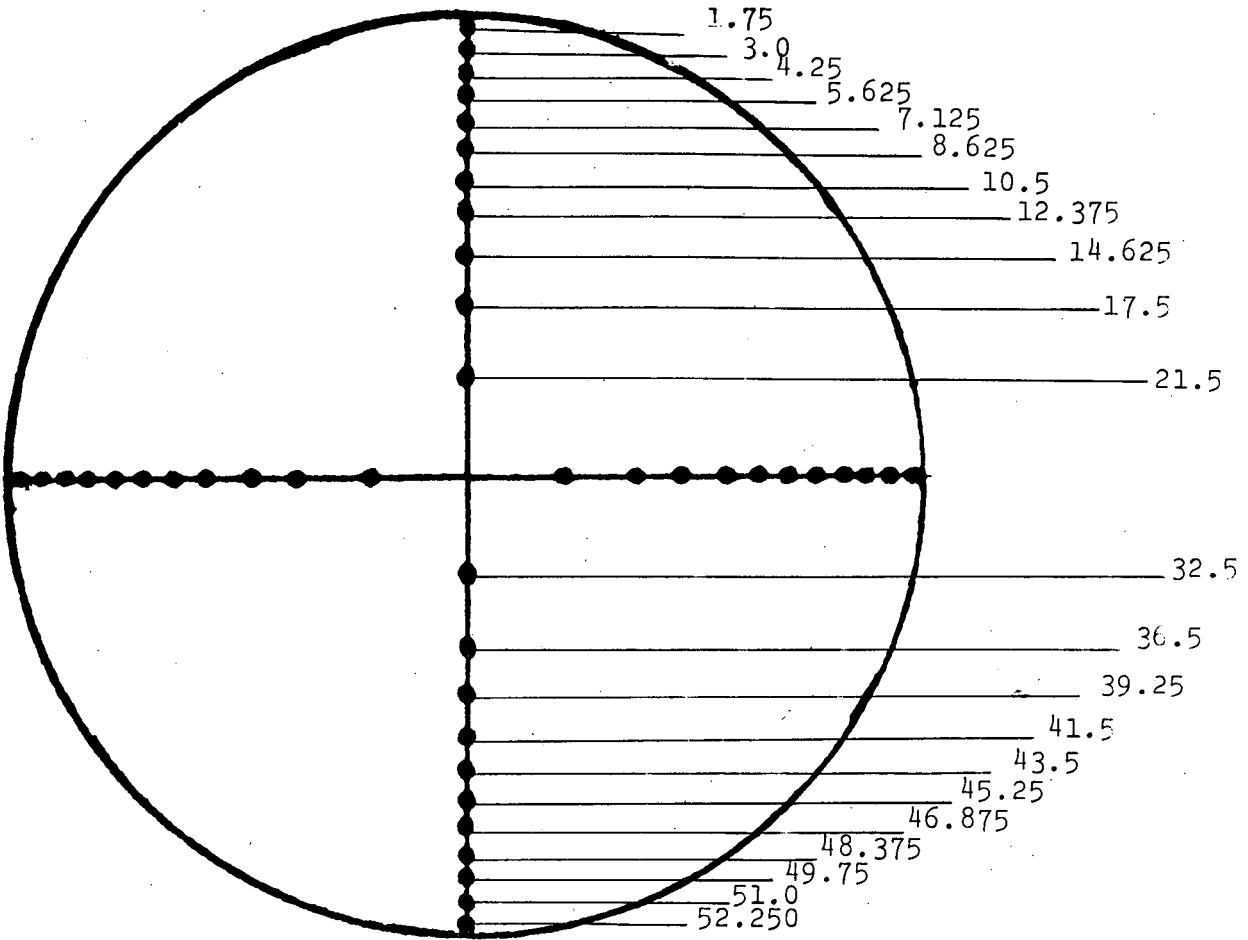


Figure 4. Traverse Point Locations

V. SAMPLING AND ANALYTICAL PROCEDURES

SAMPLING PROCEDURES

The outlet of the scrubber was sampled generally in accordance with Federal Register methods. Some exceptions to the methods are listed below.

1. The required number of traverse points for this sampling location was 44 according to Method 1. However, when these were calculated, the 4 points nearest the wall were within 1 inch. The calculation for 48 points was used and the 4 extreme points omitted resulting in a complete 44 point traverse.
2. Method 4 and the wet bulb-dry bulb moisture technique were used to determine initial moisture content.
3. The nomograph calculations were changed during the Method 5 runs to compensate for the change in moisture content as the stack gas temperature changed. Also, due to the high moisture content of the stack gas, the excess water in the impingers was removed and the silica gel replaced during the port change of each run.

4. Method 5 procedures were modified to collect "back half" samples as well as the standard filter and probe samples as described in the section below.

ANALYTICAL PROCEDURES

Analytical procedures for the Method 5 samples followed the Federal Register guidelines, with one exception. Container No. 3 as indicated in the method contains water from the impingers and washing of the glassware of the train. The solution was extracted with chloroform and ether, and then the extracted portion was dried to constant weight, as specified. In addition, the water remaining after extraction was evaporated to dryness at 100°C to constant weight.¹ Both weights were included in the total mass of particulate. Sample weight from the Method 5 samples were reported as "front half" (probe washings and filter collection weights) and "total" (front half plus water, chloroform-ether extract and impinger acetone washing weights).

¹See "Specifications for Incinerator Testing at Federal Facilities," U.S. Department of Health, Education, and Welfare publication, October 1967, page 31.