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PULP, PAPER, AND INSULATION MILL WASTE ANALYSIS

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ACKNOWLEDGMENT

This bulletin is the result of research conducted under a co-operative agreement between the Minnesota and Ontario Paper Company and the University of Minnesota on pulp, paper, and insulation mill waste analysis.

It would have been exceedingly difficult to conduct a project of this nature without the complete co-operation of the various members of the Minnesota and Ontario Paper Company organization. That such support and assistance was freely given has been most gratifying, and the members of the University of Minnesota Engineering Experiment Station staff who participated in conducting this project wish to take this opportunity of acknowledging their indebtedness. It would be difficult to mention the names of all those who aided us in this program, but we wish in particular to acknowledge the co-operation extended us by the research staff, of which Mr. M. S. Wunderlich is director, and by the heads and members of the various divisions at the International Falls plant, of which Mr. C. Larson is resident manager.

Pulp, Paper, and Insulation Mill Waste Analysis

INTRODUCTION

The losses encountered in the manufacture of pulp, paper, and insulation board are becoming increasingly important both from the standpoints of economy and of stream and atmospheric pollution. During these times of national peril it is especially necessary that all of our natural resources be utilized efficiently and to the fullest possible extent. In addition there is a growing understanding of the undesirable effects resulting from stream and atmospheric pollution in the vicinity of large manufacturing plants. In the pulp and paper industry the disposal of large volumes of waste products not only results in unsightly surroundings but also may, either directly or indirectly, cause conditions unhealthful to both human and aquatic life.

The first problem encountered in studying ways and means for the satisfactory utilization or disposal of waste products is to locate the various sources of waste and to make quantitative and qualitative measurements of them. This often becomes a major problem as the volumes handled are usually large. In addition, the measurements obtained must be typical even though the conditions under which the products are being manufactured may be constantly varying.

During the past year and a half the Engineering Experiment Station of the University of Minnesota, under a research agreement with the Minnesota and Ontario Paper Company, has been conducting measurements of all waste sources at the company's plant at International Falls, Minnesota. The processes conducted at this plant include the manufacture of sulphite, kraft, and groundwood pulp, and the manufacture of paper and insulation and building board. This project has afforded an excellent opportunity for studying and developing various means for making measurements of waste materials discharged from such plants.

In solving this problem, complete flow charts and sewer diagrams were first drawn up for the entire plant and the sources of waste located on these. Two approaches were then possible in the actual analyses of the waste sources. Either the composite losses could be measured at the points of common discharge from the mill, or the individual losses could be analyzed at the machine discharges. Although the latter procedure involved more work, it was adopted in these researches, as it enabled the analyses of the individual sources of waste as well as a later integration of the total losses.

In general, the objects of these researches were:

1. To develop satisfactory methods for the quantitative and qualitative measurements of all losses.
2. To locate and measure the major sources of waste and of stream and atmospheric pollution.

This bulletin presents a detailed description of the apparatus and methods used in these analyses made at the International Falls plant of the Minnesota and Ontario Paper Company and a brief summary of the results of these measurements.

SOURCES OF WASTE AT THE INTERNATIONAL FALLS PLANT OF THE MINNESOTA AND ONTARIO PAPER COMPANY

Sulphite, kraft, and groundwood pulp, various types of papers, and insulation and building board are all manufactured at the International Falls plant of the Minnesota and Ontario Paper Company. The processes encountered at this plant are thus greatly diversified and therefore afforded an excellent opportunity to investigate and develop means for measuring typical waste losses as encountered generally throughout the pulp, paper, and insulation board industry.

PROCESS FLOW CHARTS

At the beginning of the project, complete process flow charts were prepared for the International Falls sulphite, kraft, and Insulite mills, and the Fort Frances groundwood and paper mill, as shown in Figures 1, 2, 3, and 4. These flow charts show only the general flow of the stock in the screening system, since many different combinations may be used, depending upon operating conditions.

The Fort Frances pulp and paper mill is located at Fort Frances, Ontario, directly across the river from the International Falls plant. Although no actual waste measurements were made at the Fort Frances mill, some groundwood, as indicated on the flow charts, is piped across the river to the International Falls plant and there utilized in the manufacture of paper. All groundwood manufactured in the International Falls plant is used for making insulation and building board. The sulphite mill in the International Falls plant supplies most of the chemical pulp used in the manufacture of paper at both the International Falls plant and the Fort Frances mill. Sulphite pulp is sold in the form of lap to various paper manufacturing companies, and both the International Falls plant and the Fort Frances mill use sulphite pulp manufactured in the company's plant at Kenora, Ontario.

All sources of waste at the International Falls plant were located on the flow charts and numbered for identification.

SEWER DIAGRAMS

Before the actual analyses of any of the losses were started, complete sewer diagrams were drawn for all plants from which waste measurements were to be made. Figure 5 is a plan of the entire plant showing the main sewers connecting the various buildings with the river. The detailed sewer diagrams for the wood room, kraft mill, digester room, screen and machine rooms, and Insulite mill are shown in Figures 6, 7, 8, 9, and 10. The points of entrance of all losses to these sewers were located on these diagrams and cross-checked with all losses noted on the flow charts. The numbering system used to designate the losses on the flow charts was also used on these sewer diagrams.

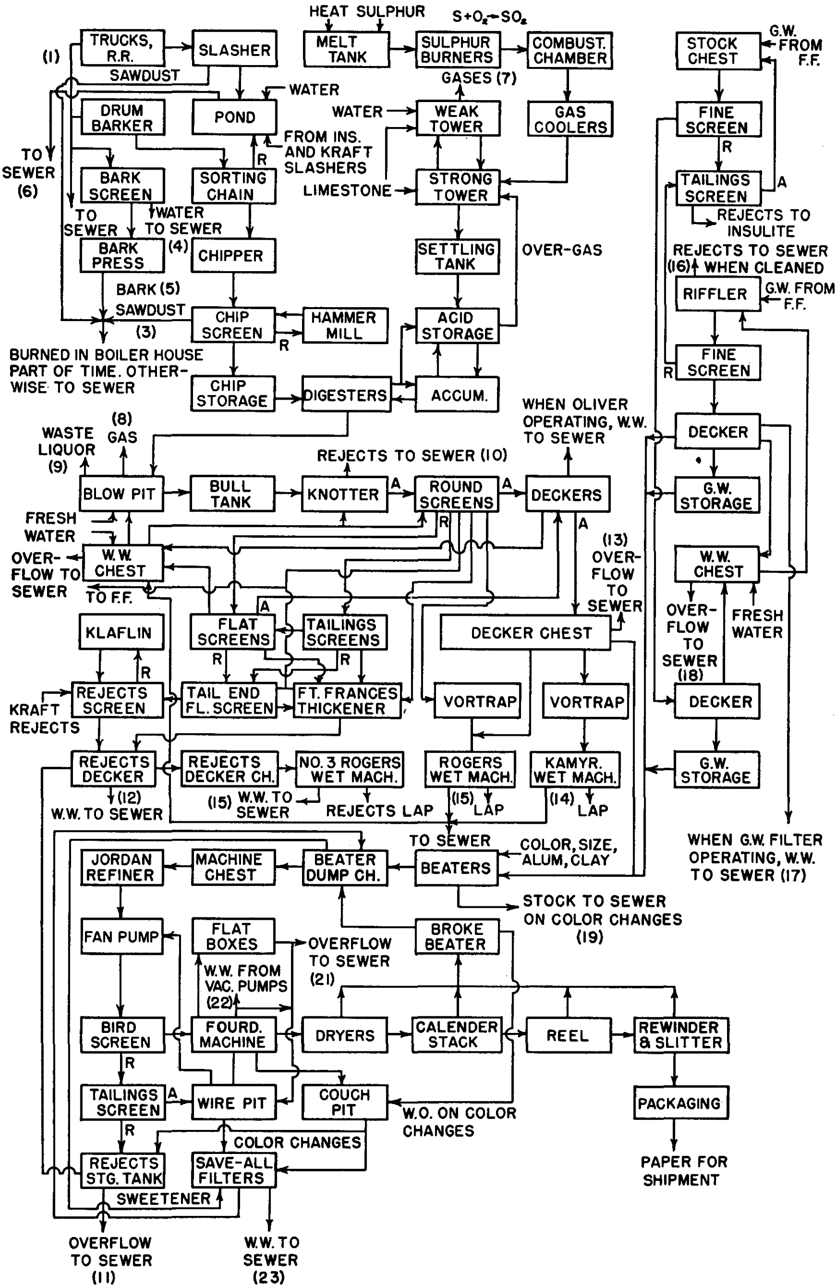


FIG. 1. SULPHITE PULP AND PAPER FLOW CHART

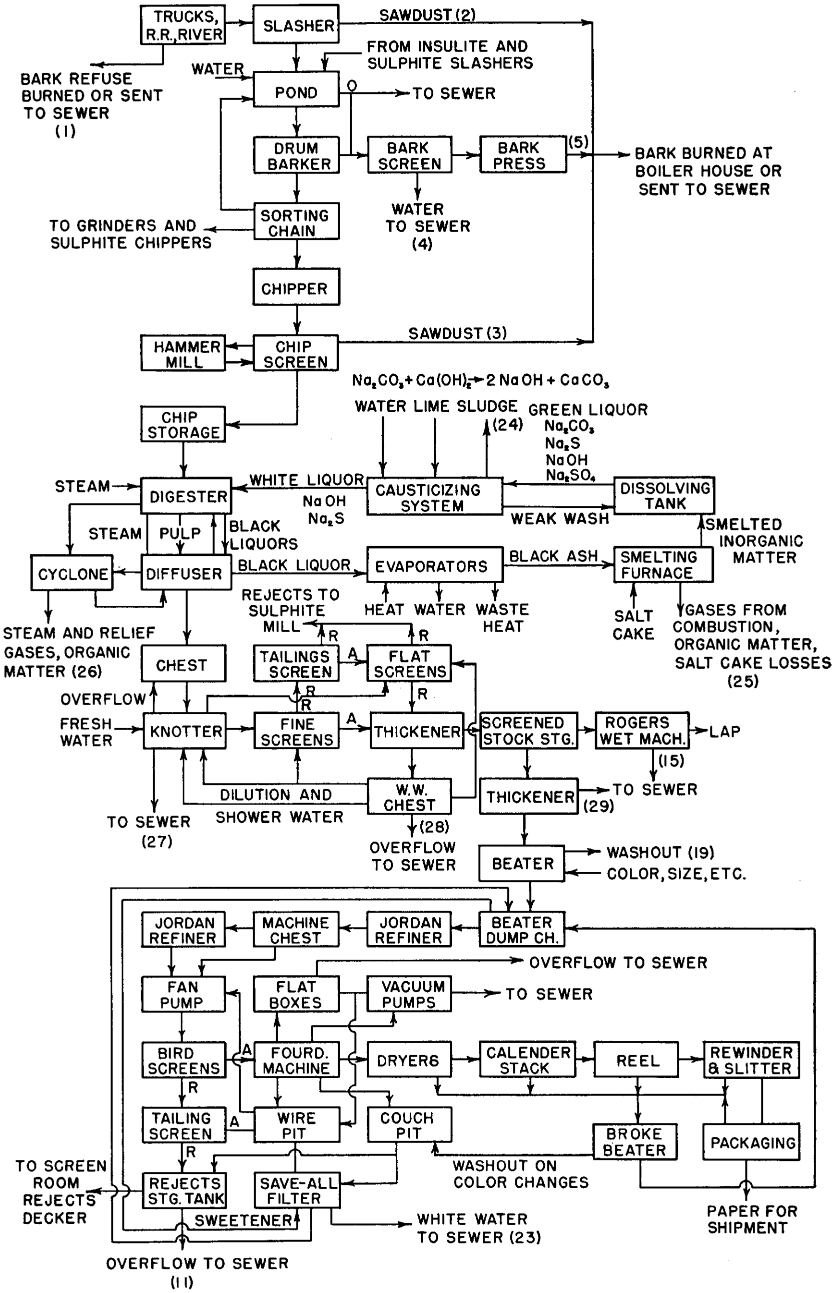


FIG. 2. KRAFT PULP AND PAPER FLOW CHART

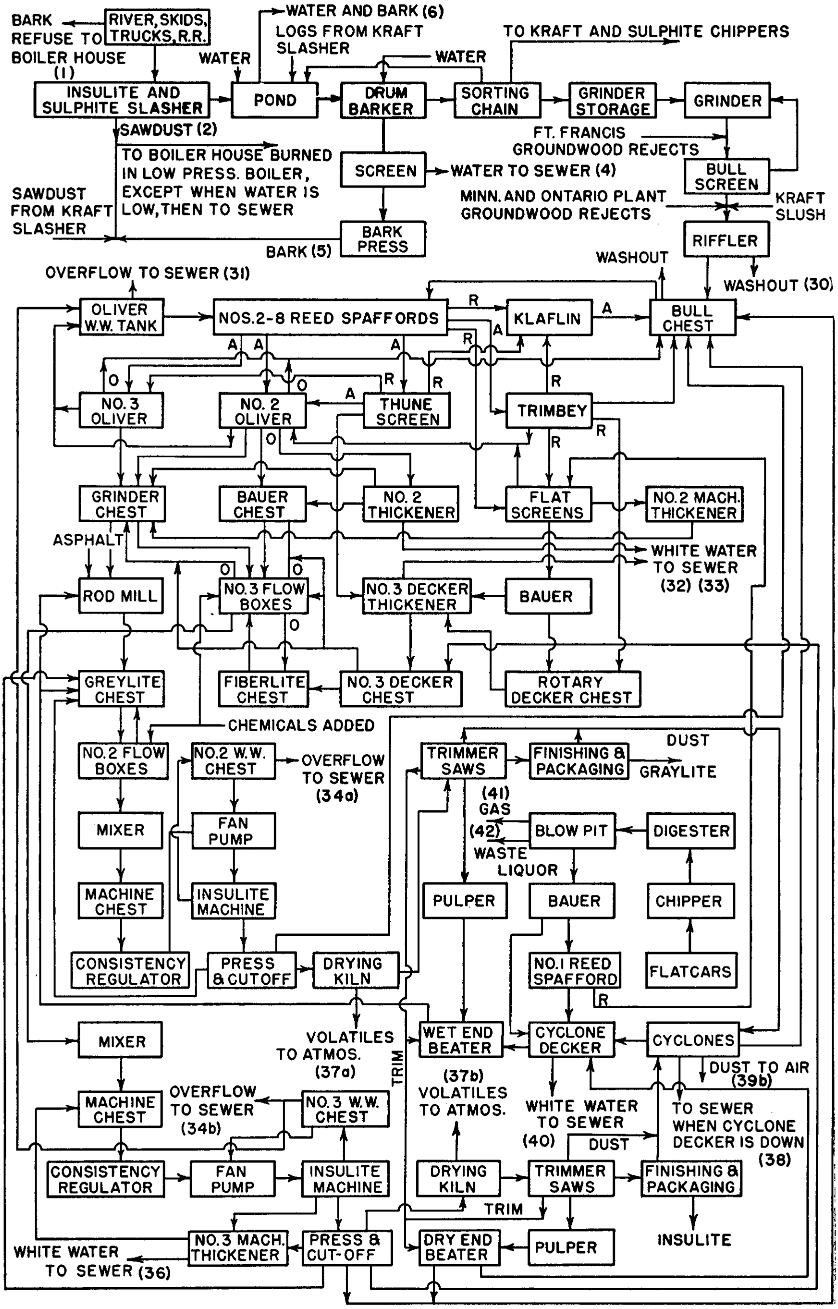


FIG. 3. INSULITE FLOW CHART

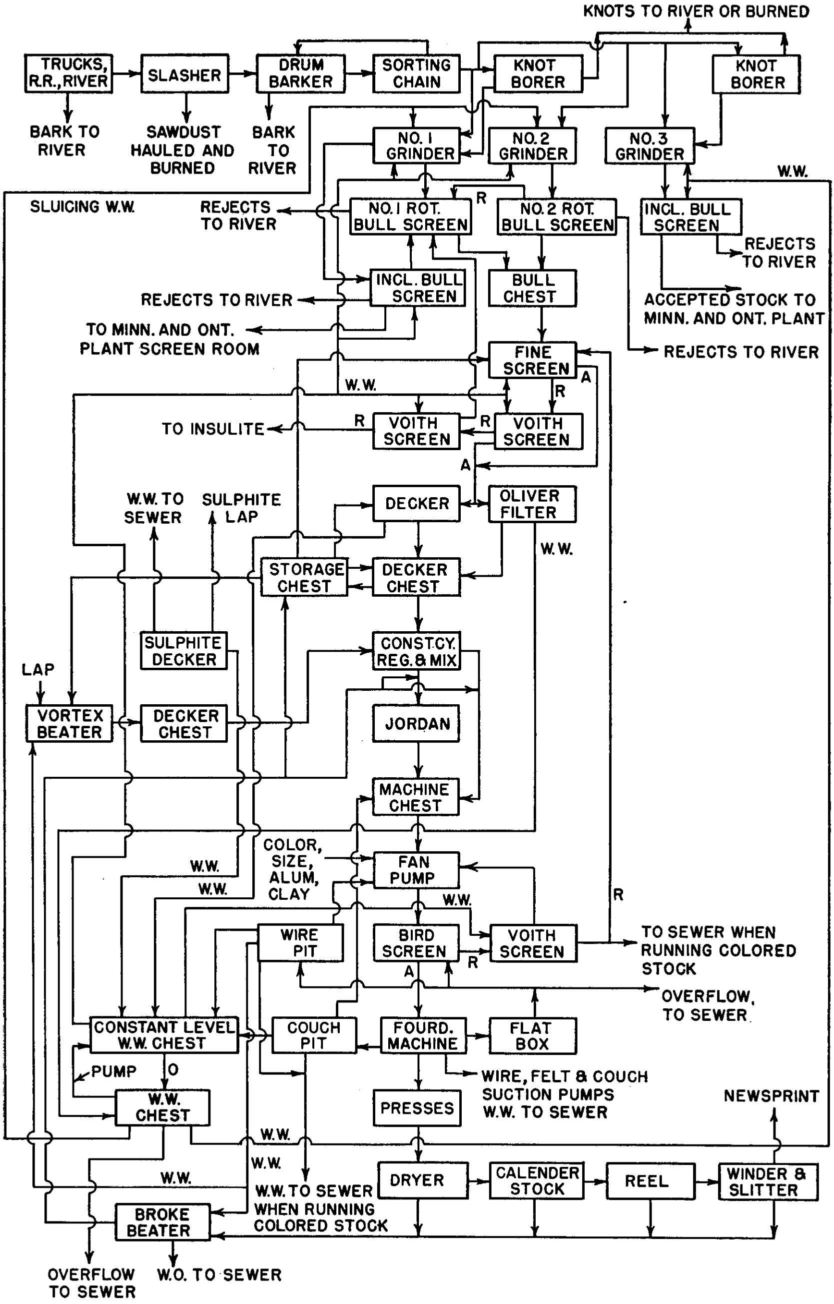


FIG. 4. FORT FRANCES GROUNDWOOD PULP AND PAPER FLOW CHART

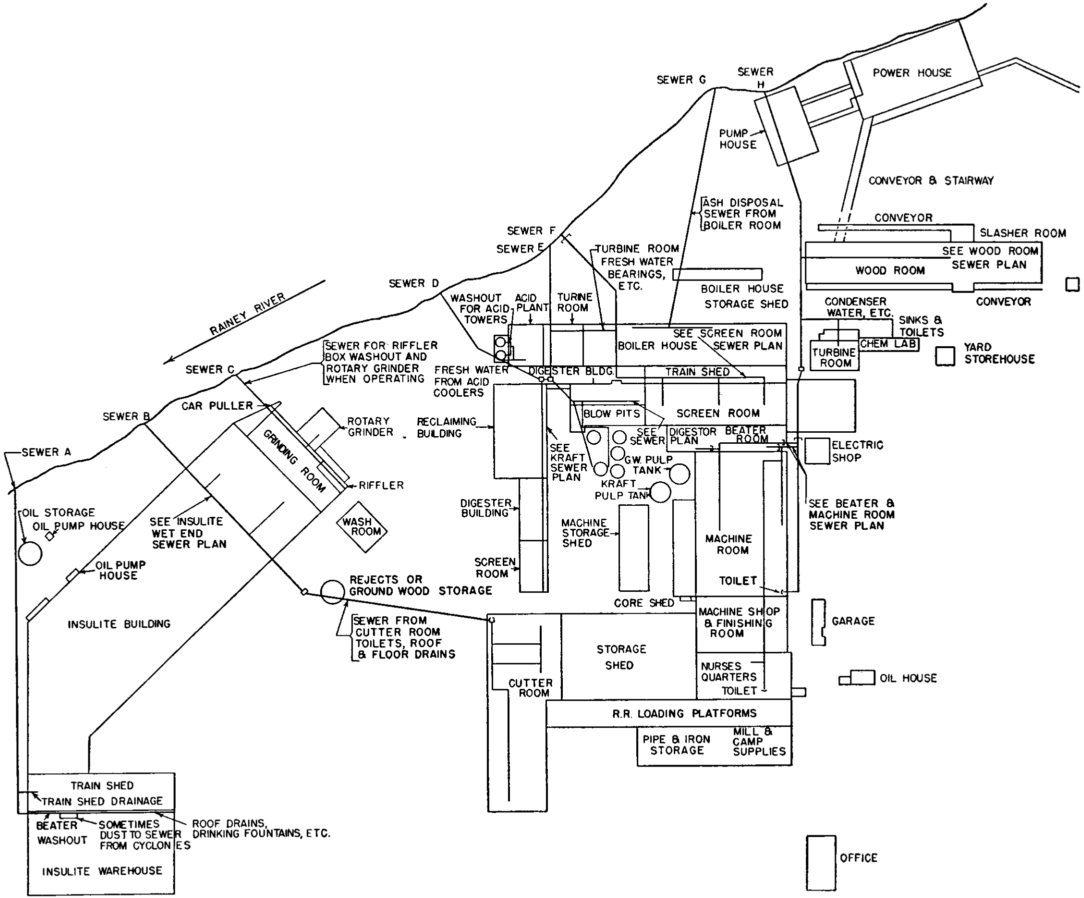


FIG 5. GENERAL SEWER DIAGRAM FOR INTERNATIONAL FALLS PLANT OF MINNESOTA AND ONTARIO PAPER COMPANY

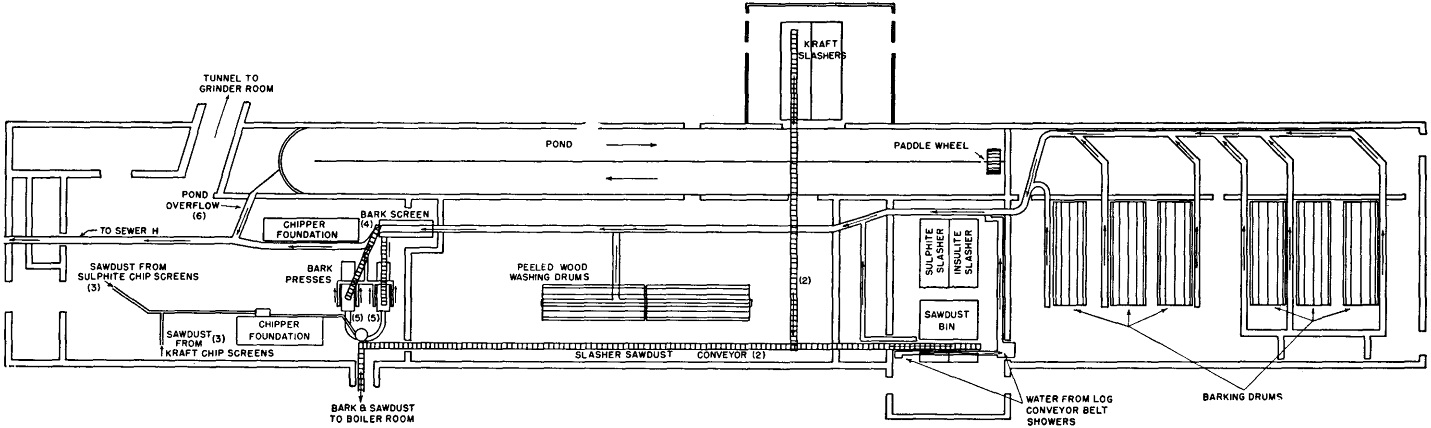


FIG. 6. WOOD-ROOM SEWER DIAGRAM

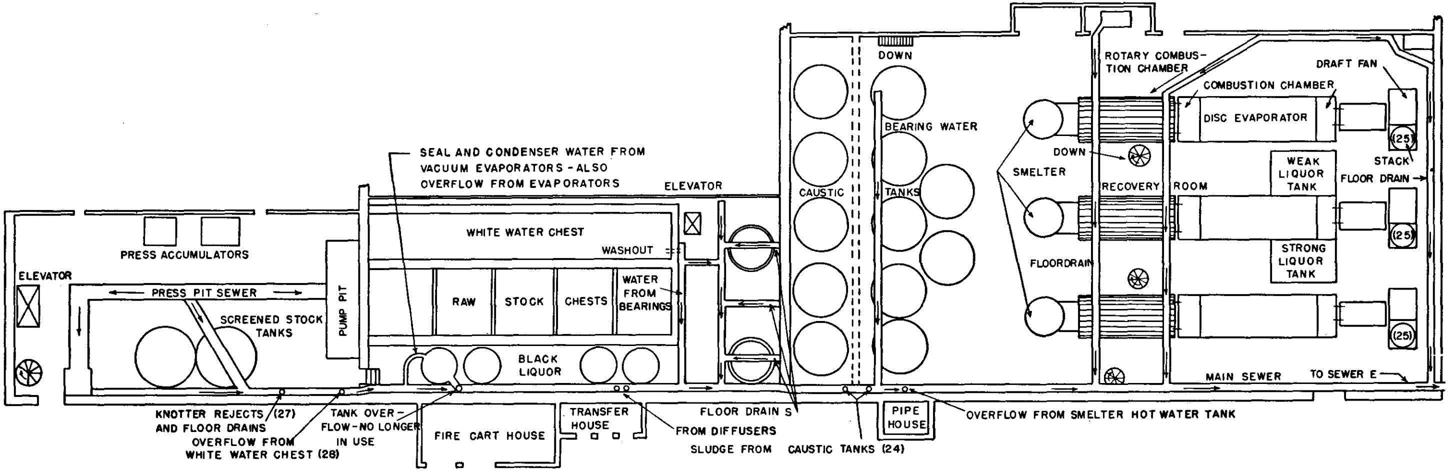


FIG. 7. KRAFT MILL SEWER DIAGRAM

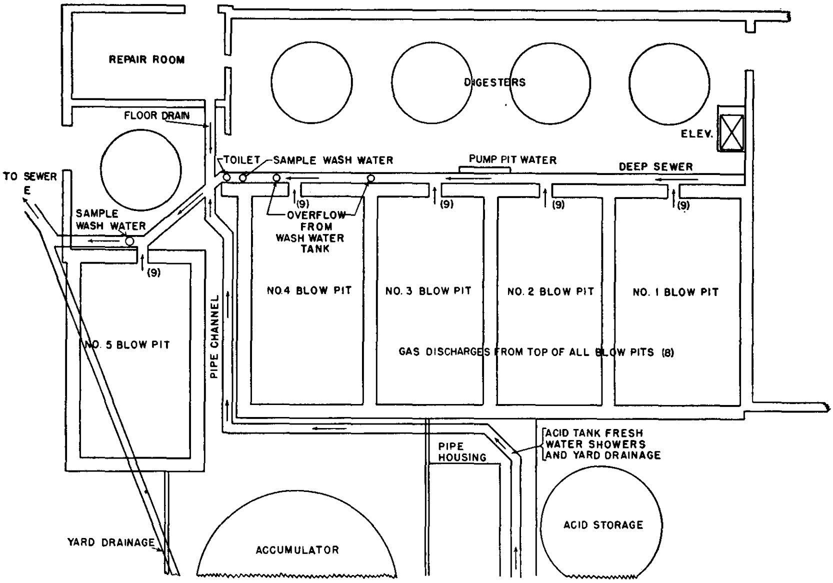


FIG. 8. DIGESTER-ROOM SEWER DIAGRAM

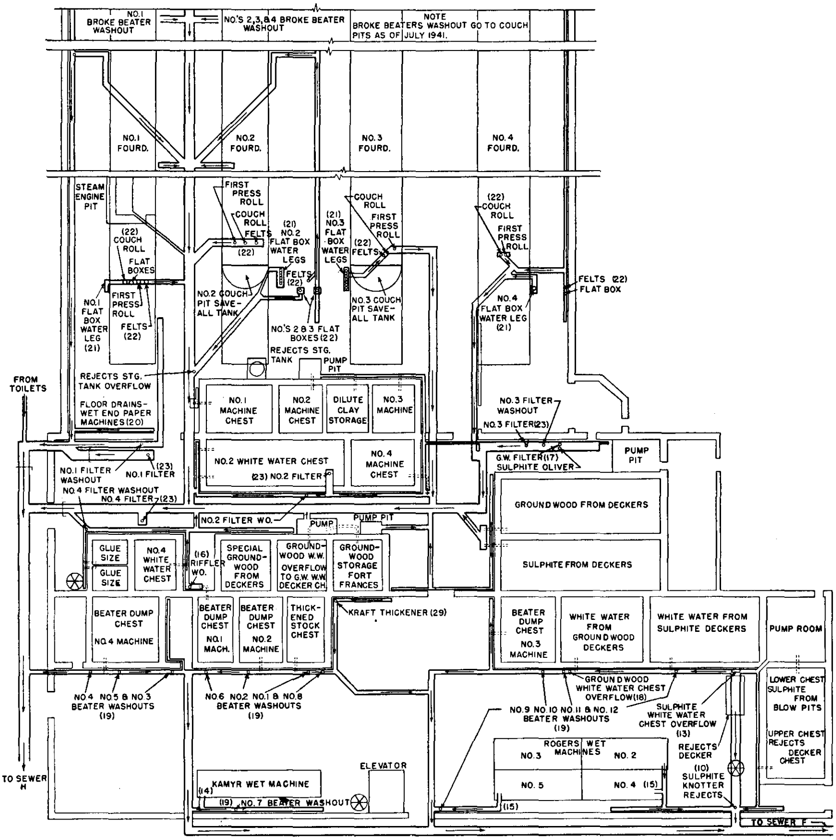


FIG. 9. SCREEN AND MACHINE-ROOM SEWER DIAGRAM

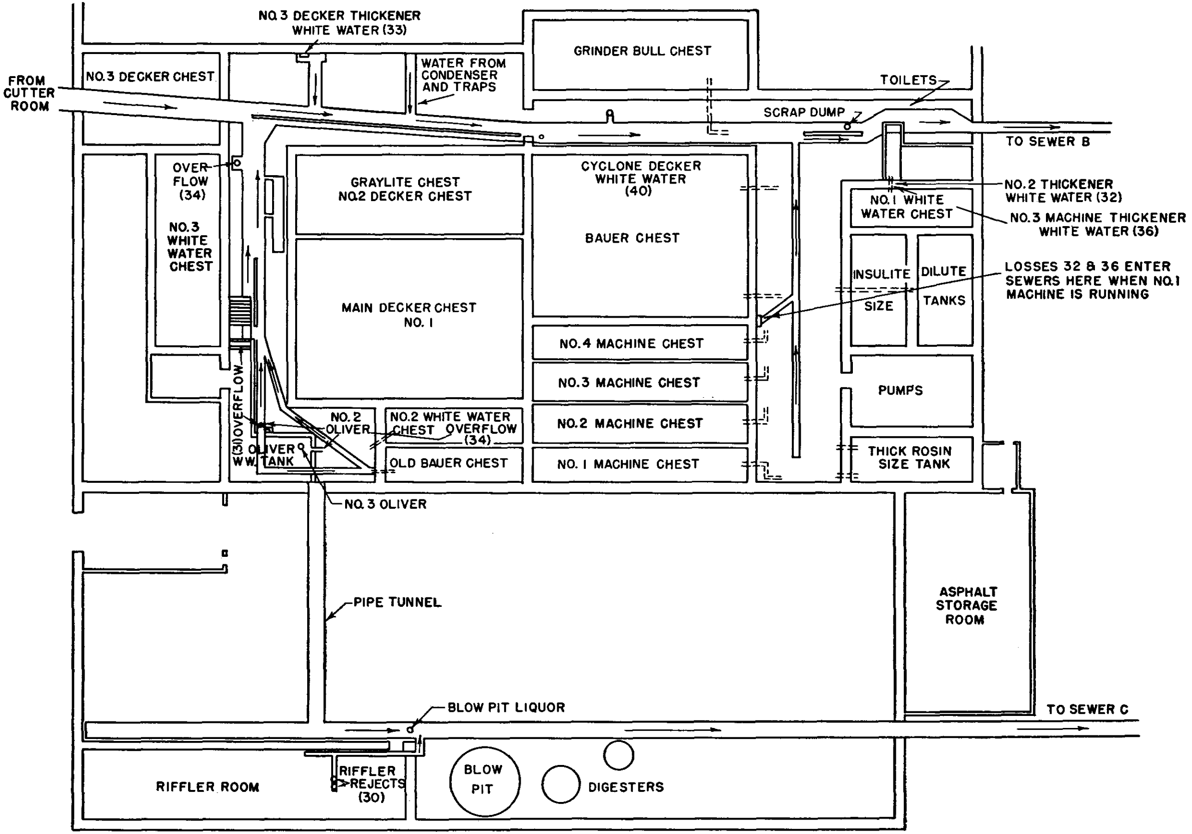


FIG. 10. INSULITE MILL SEWER DIAGRAM

SOURCES OF PLANT WASTE

A common numbering system has been used to designate all losses on the flow charts, sewer diagrams, and in various other portions of this bulletin. The code designations together with a brief description of each of the losses are as follows:

1. *Bark refuse from skids, trucks, railroad cars, etc.*—The logs entering the wood room are hauled into the plant either by trucks or railroad cars and are stored before processing either in the pond, on railroad cars, or on skids which are adjacent to the conveyors entering the wood room. Before entering the wood room a small amount of bark is removed in the handling of these logs and is periodically collected, conveyed to the boiler house, and burned. This bark is shoveled either directly onto the conveyor chains leading to the slashers where the logs are cut into short lengths or onto a special conveyor chain connecting the boiler house and the wood room. The refuse collected from the yard can be dumped directly onto this latter conveyor from the yard.

2. *Sawdust from slashers.*—Practically all the logs entering the wood room are between 96 and 100 inches in length and are cut to shorter lengths at the slasher saws before being sent to the drum barkers where the bark is removed. The sawdust from the slashers is conveyed to the boiler house and burned.

3. *Wood dust from chip screens.*—The logs used in the manufacture of kraft and sulphite pulp are passed through chippers where revolving blades reduce the logs to small chips of correct size for cooking in the manufacture of sulphite and kraft pulp. These chips are sent to screens where the large chips and the wood dust are removed and the chips of correct size separated and conveyed to the kraft and sulphite mills. The wood dust is conveyed to the boiler house where it is burned.

4. *Water from bark screens.*—After the logs entering the mill have passed through the slashers, they are sent to barking drums. The logs are automatically fed into one end of these rotating drums where they are tumbled about and are automatically discharged from the other end. During this tumbling process the bark is rubbed from the logs and is washed out through slots in the drums to the sewers. The logs that are discharged are sent to the sorting chains where the various species are separated and sent to either the kraft chippers, the sulphite chippers, or the groundwood mill, and the incompletely barked logs are returned and again sent through the barking drums. The bark and water discharged from the barking drums are conveyed to a rotary screen where the bark is removed from the water and sent to the bark presses, and the water is discharged to the sewers. During normal operation there is usually some water and bark by-passing this screen, thereby discharging some bark to the sewers.

5. *Bark from bark presses.*—The bark removed by the rotary bark screen (see Loss 4) is sent to reciprocating bark presses where the bark is compressed and much of the moisture is removed. The bark discharged from these presses is conveyed to the boiler house and burned.

6. *Water from pond.*—A pond is used to convey logs from the slashers and the sorting chain to the drum barkers and, as fresh water jets are used to aid circulation of water and logs in this pond, there is some overflow. This overflow, containing some bark and sawdust, is discharged to the sewers.

7. *Gases from acid towers.*—A two-tower acid system is used in the preparation of cooking acid for the manufacture of sulphite pulp. Melted sulphur is fed to sulphur burners where the principal product of combustion is sulphur dioxide. This gas is passed through coolers and then through the acid towers. The sulphur dioxide first enters at the bottom of the strong-acid tower which is charged with limestone and through which sulphurous acid formed in the weak-acid tower is pumped. The sulphur dioxide, sulphurous acid, and limestone react to form the calcium bisulphite used in the sulphite cooking process. The weak sulphur dioxide gases discharged from the top of the strong-acid tower are conducted to the bottom of the weak-acid tower which is also charged with limestone and through which water is sprayed from the top. These react to form the sulphurous acid used in charging the strong-acid tower. Approximately 75 to 95 per cent of the sulphur dioxide entering the strong-acid tower from the sulphur burners is absorbed

at that point, and practically all of the remaining sulphur dioxide is taken up in the weak-acid tower. There are, however, small sulphur dioxide losses occurring in the discharge to the atmosphere from the weak-acid tower.

8. *Blow pit gases.*—There are five digesters used for cooking wood by the sulphite process in order to separate the cellulose fibers from the lignin, rosin, and other materials contained in the wood. The wood chips, together with the cooking acid, are placed under temperature and pressure for a period of approximately eight to nine hours. After completion of the cooking process, the stock and liquor are blown from the digesters to blow pits and the gases are released through blow stacks to the atmosphere. The principal consitutents of this gaseous discharge are sulphur dioxide, steam, and air.

9. *Sulphite blow pit waste liquor.*—When the stock and liquor are blown from the sulphite digesters to the blow pits (see Loss 8), the waste liquor is drained from these pits to the sewers.

10. *Sulphite knotter screen rejects.*—After the sulphite pulp has been cooked in the digesters and discharged to the blow pits (see Losses 8 and 9), the stock is sent to the knotter screens where any undigested chips or knots are removed and rejected to the sewers.

11. *Rejects storage tank overflow.*—The furnish supplied to each of the Fourdrinier paper machines is first passed through fine screens and the rejected stock from here sent to tailings screens. The stock accepted by the tailings screens is returned to the wire pits, and the rejected stock sent to a rejects storage tank. This rejects storage tank also receives stock from the broke beaters, savealls, and couch pits when it is necessary to wash them out because of changes in the color of the stock. Stock collected in the rejects storage tank is deckered and then sent to a wet machine (see Losses 14 and 15), where it is made into rejects lap. An overflow is connected between the rejects storage tank and the sewers, although this is rarely in operation.

12. *Rejects decker white water.*—Stock from the rejects storage tank and from a rejects screen, which receives rejects from the kraft plant and from the "tail-end" flat screens, is sent to the rejects decker. This decker, as in the case of all other deckers or thickeners found at various points in the plant, by removing much of the water, serves the purpose of concentrating the stock before further processing. This water is originally added to the stock to aid in its economical transportation throughout the plant. In the International Falls plant the thickened stock from the rejects decker is sent to a wet machine (see Losses 14 and 15), where it is manufactured into rejects lap, and the white water from this decker is discharged to the sewers.

13. *Sulphite decker white-water chest overflow.*—The sulphite decker white-water chest receives white water from all of the sulphite deckers and from the Kamyr machine (see Loss 14) and supplies white water to the blow pits and to the flat screen showers. The overflow from this chest is discharged to the sewers.

14. *Kamyr wet machine white water.*—It is sometimes necessary to convert chemical or cooked pulp into such form that it can be shipped considerable distances or can be stored before it is eventually used in the manufacture of paper. In order to accomplish this it is necessary to extract the water from the screened stock and to collect the fibers into layers or sheets so that they may be bundled. The stock thus prepared is called lap, and the machines upon which this is accomplished are called wet machines. The International Falls plant contains one Kamyr wet machine and four Rogers wet machines. In the Kamyr machine a portion of the white water discharged is returned to the sulphite white-water storage chest, and the remainder is rejected to the sewers.

15. *Rogers wet machine white water.*—In the Rogers wet machines the spray water and the white water drained from the felts are rejected to the sewers. The white water from the forming roll is drained to a pit and then pumped to the groundwood white-water chest (see Loss 18). During periods when any of these machines is used in the manufacture of rejects lap, all of the white water is drained to the sewers.

16. *Fort Frances stock riffler rejects.*—Mechanical or groundwood pulp is manufactured at the Fort Frances plant, and some of this is piped across the river for use in the International Falls plant. This stock is passed through long settling troughs or rifflers containing pockets into which sand and other impurities can settle. These rifflers are washed out to the sewers periodically.

17. *Groundwood filter white water.*—A single groundwood filter is operated in parallel with a series of groundwood deckers for the purpose of thickening the groundwood stock received from the Fort Frances plant. The white water from the deckers is sent to a white-water chest and recirculated, whereas the white water from the groundwood filter all passes to the sewers.

18. *Groundwood white-water storage chest overflow.*—The white water discharged from the deckers used to thicken the groundwood stock received from the Fort Frances plant (see Loss 17) is sent to a groundwood white-water storage chest. The majority of the white water from this chest is returned and re-used at the rifflers, and the rest of it overflows to the sewers.

19. *Beater and chest washouts.*—When the paper machines are shut down or when the stock being run through the machines is changed from a dark to a light color, it is necessary to wash out the machine beater, the beater dump chest, the machine chest, the broke beater, the machine head box, the filter, and the couch pit. On three of the four paper machines the stock washed from the couch pits, the savealls, and the broke beaters is sent to the rejects storage tank (see Loss 11) and eventually converted into rejects lap. All other stock is washed to the sewers.

20. *Floor drains at wet end of paper machines.*—Floor drains are located on either side of the wet end of each Fourdrinier paper machine to collect any stock spilled and to drain any cleaning water. These drains discharge to the sewers.

21. *Flat box white-water overflow.*—Each Fourdrinier paper machine has a series of flat boxes or suction boxes used to remove white water from the furnish during the manufacture of the paper. On three of the four paper machines, the majority of this white water is returned to the wire pit and the excess or overflow discharged to the sewers. From the wire pits the white water is sent to the savealls where most of the stock is recovered. On the fourth paper machine all of the white water is returned to the wire pit, and there is no sewer overflow.

22. *Vacuum pump white water.*—On all of the paper machines vacuum pumps are used to maintain seals on the suction boxes, and some white water is discharged from these pumps. Part of this water is returned to the wire pits and part discharged to the sewers.

23. *Saveall white water.*—The white water from the wire and couch pits of each of the four paper machines is passed through savealls where it is screened in order to reclaim as much stock as possible. The International Falls plant has four such savealls, and the white water discharged from one of these is partially recirculated with the excess discharged to the sewers. With all three of the remaining savealls the white water is sent to the sewers.

24. *Kraft sludge.*—In the manufacture of kraft pulp the wood chips are treated with a liquor consisting principally of sodium hydroxide and sodium sulphide. After the chips have been properly cooked, the charge is emptied into washing tanks or diffusers where the fiber is separated from the black liquor formed during the cooking process. This black liquor is sent through evaporators where the moisture is driven off by the application of heat. The resulting black ash is sent to the smelting furnaces. Sodium salts are here added, and the organic matter and combustion gases are driven off. The smelted inorganic matter is sent to the dissolving tanks and there mixed with a weak wash from the causticizing system to form the green liquor. This green liquor consists principally of sodium carbonate and sodium sulphide. In the causticizing system the green liquor is treated with lime and water to form the white liquor used in the digesters for digesting the wood chips and to form the sludge which is sent to the sewers. By the addition of lime and water the sodium carbonate contained in the green liquor is converted into calcium carbonate and sodium hydroxide. The calcium carbonate is the principal constituent of the sludge, and sodium hydroxide along with sodium sulphide are the principal constituents of the white liquor used in the digesting processes. In the causticizing system, the lime is added to the green liquor in liming tanks, and the resulting mixture pumped to settling tanks, where the insoluble calcium carbonate or sludge is allowed to settle from the mixture. The white liquor is then drawn off and the sludge discharged to the sewers.

25. *Gases from smelting furnaces.*—In the manufacture of kraft pulp the black liquor coming from the diffusers (see Loss 24) is sent to disc evaporators where much of the water is driven off. Further evaporation is carried out by pumping the viscous black liquor from the evaporators to rotary furnaces which discharge nearly dry black ash containing the major portion of the organic substances from the wood and the inorganic salt. At this point sodium sulphate is added to the

black ash and the mixture discharged to the smelting furnaces where the combustibles are burned. The resulting smelt is sent to dissolving tanks where the green liquor, containing principally sodium carbonate, sodium sulphide, sodium hydroxide, and sodium sulphate is formed.

The products of combustion from the smelters are discharged through the rotary furnaces to the disc evaporators where they aid in evaporating the water from the black liquor. From here the gases are discharged to the atmosphere. In the process of dusting the black ash with salt cake a considerable portion of the sodium sulphate is entrained in the products of combustion which are discharged from the mill. In addition, there is a certain amount of finely divided black ash which also becomes suspended in the air stream and is discharged from the mill.

26. *Kraft cyclone discharge.*—In the cooking of kraft pulp the digester is first charged with chips after which white liquor, heated by means of an indirect steam heater, is circulated to the digester for a period ranging from 90 to 120 minutes. During this time direct steam is blown into the digester until the pressure reaches approximately 80 pounds per square inch. At this point the liquor circulating pump is turned off, and the liquor remaining in the digester at that time is used for the remainder of the cooking process. After cooking has been completed, the digester is blown to the diffuser, from whence the pulp is sent to a storage chest and the black liquor drained off and returned to the evaporators. When the digesters are blown, the steam and gases are discharged through the kraft cyclone which removes any pulp contained in the gases and returns it to the diffusers. Gases and steam from the cyclone are discharged to the atmosphere.

27. *Kraft knotter screen rejects.*—The cooked pulp from the kraft diffusers is passed through knotter screens (see also Loss 10) to remove all knots and slivers not properly digested in the cooking process. The stock accepted by these screens is discharged for further screening, and the rejected knots, slivers, and water are discharged to the sewers.

28. *Kraft white-water chest overflow.*—White water from the kraft thickener (see Loss 29) is discharged to a white-water storage chest from which white water is supplied to the flat screens and to the knotter screens, and the overflow is discharged to the sewers.

29. *Kraft thickener white water.*—Before entering the beaters, the kraft stock to be used in the manufacture of paper is first passed through a thickener. The white water from this thickener is discharged to the sewers.

30. *Insulite riffler rejects.*—The stock entering the Insulite plant from the grinder room first passes through rifflers (see also Loss 16) before entering the storage chest. The usual procedure is to wash out each of these rifflers every day the plant is operated. During this process there is a certain amount of stock which, along with the mud and sand removed during the day's operation, is lost to the sewers.

31. *Insulite Oliver filter white-water tank overflow.*—In the Insulite plant, stock from the screens is sent to Oliver filters and the accepted stock from these sent to the grinder chest, the bull chest, and the Bauer chest. All white water from the Oliver filters is sent to the Oliver white-water storage tank from which a portion is recirculated to the screens. The overflow from the Oliver white-water tank is discharged to the sewers.

32. *Insulite No. 2 thickener white water.*—Stock from one of the Oliver filters is sent to a thickener from which the stock is discharged either to the Bauer chest or the grinder chest. There are three Insulite machines, here designated as Numbers 1, 2, and 3. If the No. 1 machine is not in operation, the white water from this thickener is discharged to the sewers. If the No. 1 machine is in operation, the white water from this thickener is discharged to the No. 1 machine white-water storage chest.

33. *Insulite No. 3 thickener white water.*—The No. 3 thickener receives stock from the Bauers, the flat screens, and the rotary decker chest and discharges it to the No. 3 decker chest. The white water from this thickener is all discharged to the sewers.

34. *Insulite white-water chest overflows.*—There are three Insulite machines, each of which has a corresponding white-water storage chest. The white water drained from the furnish supplied to the Insulite machines discharges to the corresponding white-water chest from which a portion of it is recirculated to the fan pump and the remainder overflows to the sewers. In addition to the white

water from the No. 1 machine, white water from the No. 2 thickener also drains to the No. 1 white-water chest. Thus this sewer overflow also contains a portion of the white water from this source.

35. *Insulite machine floor drains.*—Floor drains are located on either side at the wet end of each Insulite machine to collect any spilled stock or cleaning water. These drains are connected to the sewers.

36. *Insulite machine thickener white water.*—The trim from the wet end of the No. 3 Insulite machine is sometimes sent to a thickener from which the stock is returned to the machine chest and the white water discharged to the sewers.

37. *Volatiles from Insulite drying kiln.*—The insulation board coming from the Insulite machines is sent through drying kilns in which the temperature is maintained at approximately 300° F. Much moisture is driven off from the board upon exposure to the high temperatures and is discharged by exhuast fans to the atmosphere. In addition to the moisture driven off, there is also some loss of volatiles as the furnish to the Insulite machines contains not only pulp but also some size, rosin, wax, and chemicals. Some of the lighter fractions of the furnish volatilize and are discharged to the atmosphere along with the moisture.

38. *Stock reclaimed from Insulite cyclones when cyclone decker is not in operation.*—The dust collected at trimmer saws located at the dry end of all three Insulite drying kilns is recovered by means of two single-stage cyclones located on the roof of the Insulite plant. The dust recovered by these cyclones is piped into two double-stage cyclones also located on the Insulite roof and used primarily to recover the dust collected from the cutting room located on the fifth floor of the plant. The accepted stock from these cyclones is piped to a cyclone decker and the deckered stock thus recovered used in the manufacture of insulation. When the cyclone decker is not in operation, all stock accepted by the cyclones is discharged to the sewers.

39. *Insulite cyclone discharges.*—There are two single-stage cyclone dust eliminators which are fed by the exhaust system connected to the trimmer saws on the dry end of the Insulite drying kilns. There are also two double-stage cyclones connected to the dust collector system of the Insulite cutting room. The dust recovered by the single-stage cyclones is piped into the double-stage cyclones, and the recovery from these is piped to a decker (see Loss 38). Any stock or dust not recovered by these four cyclones is discharged to the atmosphere.

40. *Insulite cyclone decker white water.*—The accepted stock from the Insulite cyclones (see Losses 38 and 39) is piped to a decker, and the deckered stock from here sent to the wet-end beater and thus recovered and used in the manufacture of insulation. The white water from this decker is discharged to the sewers.

41. *Insulite blow pit gases.*—A single digester is installed in the Insulite plant for the purpose of manufacturing cooked pulp to supplement the groundwood used in the production of insulation board. When the stock in this digester is blown to the pit (see Losses 8 and 9), gases and flashed steam are released to the atmosphere.

42. *Liquor from Insulite blow pit.*—When the Insulite digester is blown to the pit (see Loss 41), the liquor used in cooking the pulp is drained to the sewers.

PROCEDURE AND APPARATUS USED IN ANALYZING LOSSES

Many difficulties are encountered in the measurement of large-scale sources of waste. Not only must the magnitude and quality of the losses be determined, but these must be correlated with the rate and type of production of the machines from which these losses originate. The time allotted for measurement of individual losses is limited, yet reasonable accuracy must be maintained. After all individual losses have been measured, these must be integrated to complete the picture of plant waste. During the processes of analyzing the losses, any contemplated changes in the manufacturing processes which might affect the tests must be kept in mind.

In making quantitative and qualitative determinations of the various losses at the Minnesota and Ontario Paper Company's International Falls plant, standard procedures and apparatus were utilized wherever it was deemed that these were of sufficient speed and accuracy. In many cases, however, it was necessary to develop original methods of analysis in order to accomplish these ends. All apparatus and methods of analysis used are here classified and discussed according to the nature of the measurements involved.

WOOD-ROOM BALANCE

(Losses 1, 2, 3, 4, 5, and 6)

Tests were conducted on the wood room with continuous measurements of the input and output made over a period of four and one-half days. These measurements were of the wood input on both a weight and cordage basis, the sawdust discharged from the slashers, the wood dust discharged from the chipper screens, the bark sent to the boiler house as fuel, and the bark and sawdust discharged to the sewers. The methods used in the measurement of the wood input and of each of the losses will be discussed individually.

Wood-room input.—The input to the wood room was recorded for each day of test in cords of peeled or rough wood of the various species fed to the Insulite, sulphite, and kraft slashers. Previous to the present series of tests the Minnesota and Ontario Paper Company had run a very extensive series of experiments in order to determine the average weights per cord of peeled and rough woods, the average moisture content, and the average percentages by weight of bark of the various species of wood supplied to the mill. The logs were weighed before and after peeling, and the weight of bark determined by difference. The cubical content of the logs was determined by water displacement in a large tank. The results of this series of tests were used to convert the wood-room input in the present series of tests from cords of wood to tons of wood, and a further break was made to give tons of green bark and tons of bone-dry bark. In this manner the weight of bark entering the wood room was determined and later checked by measurements of the weights of bark supplied to the boilers as fuel and the bark discharged to the wood-room sewer channel.

Slasher sawdust.—The weights of sawdust formed by the slasher saws were determined from measurements of the average width of the saw cuts and the number of cuts per log for each of the three slashers. The average width of a saw cut was determined both by actual measurement of the width for each of the saws and by measurements of partially cut logs taken from the different slashers. These measurements showed the average width of saw cuts to be three-eighths inch with only slight deviations from this figure. Practically all logs entering the wood room were between 96 and 100 inches in length. Each log entering the kraft slasher was given two cuts; each entering the sulphite slasher, one cut; and each entering the Insulite slasher, three cuts. This aided in distinguishing between the species on the sorting chains.

In order to determine the average percentage of wood converted to sawdust at the slashers, it was necessary to assume some typical distribution both as to specie of wood and weight of wood entering each slasher. The wood-room input for the entire previous year was used for this purpose, and calculations were made to determine the total number of tons of both green and bone-dry sawdust formed at each of the slashers, and also the percentage of the total weight of wood converted to sawdust entering the wood room during that period of time. This analysis indicated that 0.73 per cent of all wood entering the plant was converted into sawdust at the slashers.

Chip screen sawdust.—In order to determine the weight of sawdust discharged from the chip screens, a 24-hour test was made in which all of this sawdust was diverted, shoveled into tanks, and weighed. A record was kept during this time of the number of cords of wood of each specie entering the slashers. The moisture content of the sawdust coming from the chip screens was determined for 24 samples selected at random. Each sample was dried in a thermostatically controlled electric oven at a temperature of 105° C. for a period of 24 hours. As a result of these tests it was concluded that 2.1 per cent of the bone-dry wood entering the chip screens was discharged as sawdust.

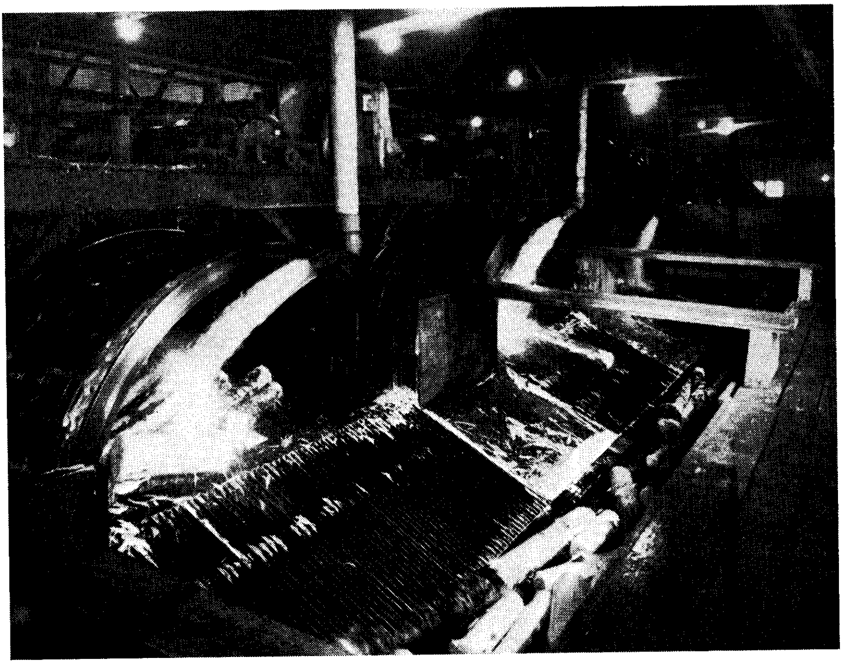


FIG. 11. BARKING DRUMS IN OPERATION

Bark discharged to wood-room sewer.—The bark, removed from the logs in the barking drums (see Fig. 11), is first passed through a rotating screen which separates the majority of the bark from the water. The water is discharged to the sewers, and the bark is sent to bark presses where the moisture content is reduced before it is conveyed to the boiler house for fuel. Some small bark passes through the bark screen, and a portion is by-passed around the screen to the sewers.

In order to calculate the amount of bark discharged to the wood-room sewer, it was first necessary to determine the velocity of water flow in the sewer channel. This was accomplished by two methods: first, by injecting small amounts of potassium permanganate powder as a coloring agent onto the surface of the water and measuring the time necessary for this colored portion of the stream to traverse a known distance between two stations; and second, by dividing the cross-sectional area in the channel into sections and traversing it by means of a pitometer. The velocity of flow determined by the first method is a surface velocity, and for channels of the shape involved in this case the mean velocity is approximately 0.9 times this value. The velocity determined by the pitometer traverse method is a true mean velocity.

In determining the velocity of flow by the dye method, a 44-foot straight length of channel was chosen, and the surface velocity was determined at channel water-level heights of 11 inches, 10 inches, and 9 inches. The pitometer traverse was made at a water height of 11 inches. As the velocity of flow varies as the two-thirds power of the hydraulic radius, it was possible to calculate the channel velocity at other water-level heights than that used during the traverse. A comparison between the average velocities as determined by the dye method at the three channel heights and the velocities determined by the pitometer, assuming this relationship, gave a maximum discrepancy of 3 per cent. The pitometer values, however, were probably the more accurate, and were therefore used to determine a calibration curve with channel water heights plotted against volumetric flow.

The special sampler was designed for making determinations of the amount of bark flowing to the wood-room channel. This sampler was approximately 2 x 2 x 14 inches and had a volume of 1.96 quarts. Doors on either end of the sampler were spring actuated and remotely controlled for rapid closing. In obtaining a sample of the bark-water mixture, both doors were opened and the sampler lowered to the desired position in the stream. The openings were moved in line with the direction of the flow so as to cause minimum disturbance of both the flow on the outside and on the inside of the sampler. The spring-actuated doors were then closed simultaneously, thus sampling a representative portion of the stream.

In order to determine the variations in the relative amounts of bark flowing in the bottom, middle, and top sections of the channel, preliminary tests were made in which several two-quart samples were removed from the bottom, the middle, and the top sections of the channel and screened progressively through 5-, 10-, and 20-mesh screens. This process was repeated until ten samples from each level had been screened. These screens and their bark deposits were then heated for 24 hours at 105° C. in order to obtain the bone-dry weights of bark. Five tests of this nature were made on different days and the results expressed in percentages of bark at the different levels. These tests indicated that approximately 40 per cent of the bark flowed at the bottom section of the channel, 30 per cent at the middle, and 30 per cent at the top. These percentages were approximately true, regardless of the size of the bark.

In making determinations of the amounts of bark discharged to the wood-room sewer, the analysis was somewhat complicated by the fact that the amounts of bark, the velocities of flow, and the areas all varied from top to bottom of the channel. In order to simplify the procedure, a relationship was derived by means of which it was possible to determine the actual amount of bark discharged when only the average velocity, the average weight of bark per unit volume of sample, and the cross-sectional areas were known. Table I shows a tabulation of the relationships between the areas, the velocities of flow, and the percentages by weight of bark associated with the top, middle, and bottom sections of the channel, and the total area, average velocity, and average percentage of bark. In order to determine the weight of bark passing through the sewer let

D = actual weight of bark passing through sewer, pounds per minute
V = velocity of flow, feet per minute
A = cross sectional area, square feet
W = weight of bark in sample, pounds per cubic foot

then

$$D = A_{top}V_{top}W_{top} + A_{middle}V_{middle}W_{middle} + A_{bottom}V_{bottom}W_{bottom}$$

Substituting the relationships of Table I,

$$D = (.453A)(1.102V_{avg.})(0.90W_{avg.}) + (.334A)(1.025V_{avg.})(0.90W_{avg.}) + (.213A)(.849V_{avg.})(1.20W_{avg.})$$

$$D = 0.975V_{avg.}W_{avg.}$$

This equation was used in determining the actual weight of bark discharged to the sewers during the wood-room tests and simplified the operating procedure by necessitating only the reading of the channel water heights and the collection of mixed samples taken from the top, middle, and bottom of the channel. During the actual tests, readings were taken of the height of the water in the channel and two-quart samples were removed from the top, middle, and bottom of the channel every 30 minutes. The water-bark samples were screened through 5-, 10-, and 20-mesh screens, and the effluent was drained into a calibrated container as a check on the total volume of the samples. Every 8 hours the screens were removed and heated at 105° C. for 24 hours to obtain the bone-dry weight. Samples of the effluent from the screens were also filtered through No. 1 Whatman filter paper every 8 hours and also heated to obtain the bone-dry weight of the fines in the sewer water.

TABLE I

AREA, VELOCITY, AND WEIGHT OF SAMPLE RELATIONSHIPS FOR WOOD-ROOM SEWER CHANNEL*

Channel Section	Area, A, in Sq. In.	$\frac{A}{\Sigma A}$	Vel., V. Ft. per Sec.	$\frac{V}{V_{avg.}}$	Relative Wt. Bark in Lbs. per Cu. Ft., W	$\frac{W}{W_{avg.}}$	Area in Terms of Total Area	Vel. in Terms of Average Vel.	Wt. Bark in Terms of Average Weight
Top	100.65	.453	7.20	1.102	0.30	0.90	$A_{top} = .453A$	$V_{top} = 1.102V_{avg.}$	$W_{top} = 0.90W_{avg.}$
Middle	74.10	.334	6.70	1.025	0.30	0.90	$A_{middle} = .334A$	$V_{middle} = 1.025V_{avg.}$	$W_{middle} = 0.90W_{avg.}$
Bottom	47.30	.213	5.54	0.849	0.40	1.20	$A_{bottom} = .213A$	$V_{bottom} = 0.849V_{avg.}$	$W_{bottom} = 1.20W_{avg.}$

* Height of water in channel = 11 inches.

Bark to boiler house from bark presses.—The amount of bark screened out of the wood-room sewer channel, passed through reciprocating bark presses, and conveyed to the boiler house as fuel was determined by placing revolution counters on 12-inch diameter wheels traveling on the surface of the bark leaving the presses. The rim surfaces of these wheels were spot welded to reduce to a minimum slippage between the wheel and the bark.

Forty preliminary calibration tests were made on each bark press to determine the average weight of bark discharged per counter revolution. Moisture determinations were made on a series of 31 samples from bark obtained at random from different points throughout the cross section of bark leaving the presses. Each sample was dried in a thermostatically controlled electric oven at a temperature of 105° C. for a period of 24 hours in order to determine the moisture content on the bone-dry weight. These tests indicated that the average moisture based on moist weight was approximately 60 per cent for the bark from both presses.

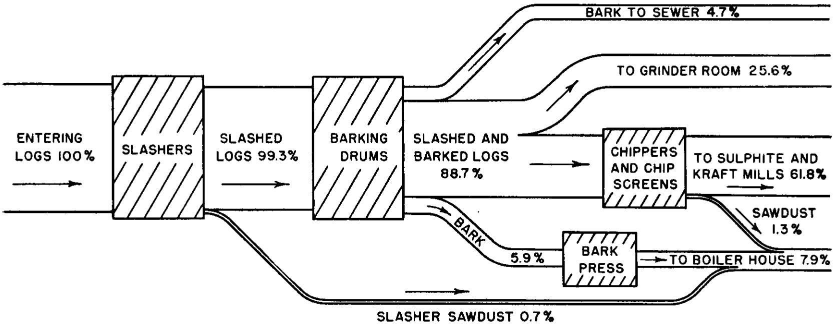


FIG. 12. WEIGHT DISTRIBUTION OF WOOD ENTERING AND LEAVING WOOD ROOM

The actual tests, conducted to determine the amount of bark being sent from the presses to the boiler house, were made concomitantly with the wood-room sewer loss and input measurements over two continuous test periods of 24 and 48 hours. The readings of the bark presses were made hourly and the weights of bark sent to the boiler house determined from the bark press counter calibrations and the moisture determinations. The average weight of bone-dry bark sent to the boiler house per cord of rough wood input was 166 pounds, and the weight of green bark (60 per cent moisture) was 416 pounds.

The results of these tests to determine the weight of bark sent to the boiler house and the weight of bark discharged to the sewers are shown in Table II. These tests indicated that 44 per cent of the total bark from the wood room was discharged to the sewers and 56 per cent conveyed to the boiler house as hog fuel. Of the 44 per cent discharged to the sewers, 51.9 per cent was removed by 5-mesh screens and 31 per cent consisted of fines removed by filter paper. Figure 12 shows the distribution in percentage by weight of all wood entering and leaving the wood room.

TABLE II

PERCENTAGE DISTRIBUTION OF BARK FROM WOOD ROOM

	Bark to Sewer, Bone-Dry Basis					Bark to Boiler House, Bone-Dry Basis
	Removed by 5-mesh screen	Removed by 10-mesh screen	Removed by 20-mesh screen	Removed by No. 1 Whatman filter paper	Total	
Distribution of sewer bark, per cent	51.9	6.2	10.9	31.0	100	.....
Distribution of all bark, per cent	22.9	2.7	4.8	13.6	44	56

WHITE WATER

(Losses 12, 13, 14, 15, 17, 18, 20, 21, 22, 23, 28, 29, 31, 32, 33, 34, 35, 36, and 40)

At many points in the kraft, sulphite, groundwood, and Insulite mills (for examples, see Figs. 13 and 14), white water, or water used to convey the pulp to the screening system, is extracted. Much of this white water is re-used for thinning fresh stock in various parts of the system, but some of it is wasted to the sewers. Two methods, described in the following paragraphs, were used for the analyses of these white-water losses.

Approximate white-water loss analyses.—If the magnitude of a white-water loss was obviously small or if it was desired to make a preliminary determination of a loss, a rapid approximate method of analysis was used. This evaluation consisted of obtaining four 2,000-cubic-centimeter samples of the white water at different times and analyzing by the TAPPI Standard Method of Measuring, Sampling, and Analyzing White Waters (see Appendix). This gave a measure of the suspended and dissolved solids per unit volume of white water. In order to determine the yearly loss of white water from these sources it was further necessary to approximate the average rate of flow and the number of days' operation per year. The days of operation were obtained for the various machines

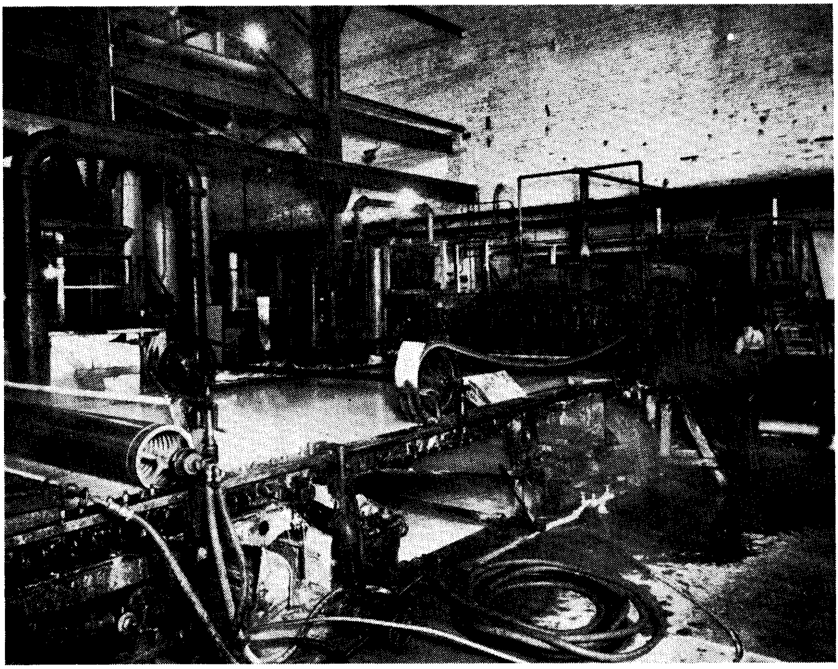


FIG. 13. WET END OF FOURDRINIER PAPER MACHINE

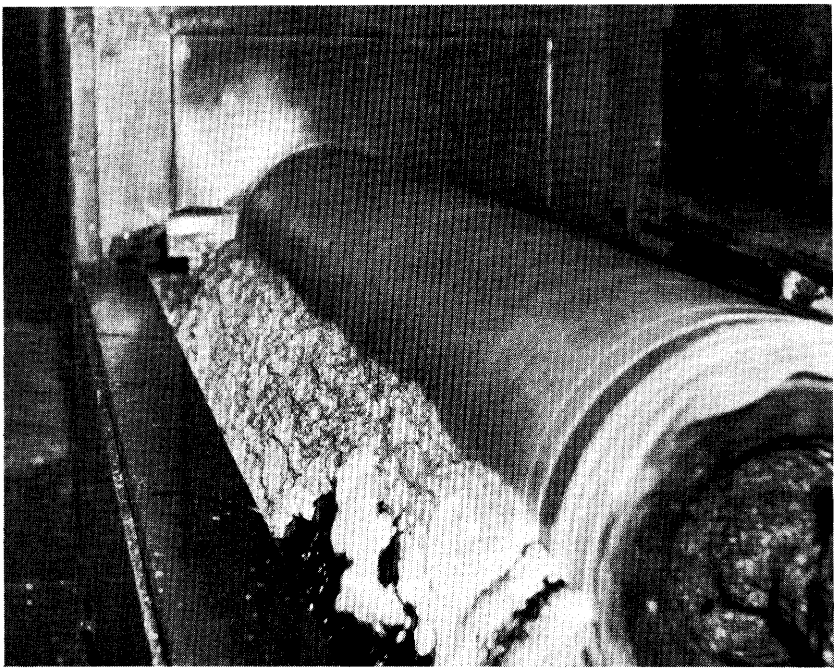


FIG. 14. DECKER IN OPERATION

from the actual plant records, and the rates of flow were obtained from the machine capacities, together with determinations of the inlet and discharge consistencies. In all cases where such preliminary tests indicated a loss to be of appreciable magnitude, further tests were conducted using a weir channel with automatic level recorder for the rate of flow determinations and an automatic sampler for collection of the white-water samples.

Weir channel white-water analyses.—No measurements were made of the composite white-water losses in the main sewers, but instead the individual sources from the various machines were studied and the total loss determined by integration. Although this involved considerably more work, it enabled not only the determination of the total waste discharged to the sewers but also analyses of the efficiencies of the various machines. In all cases where the white-water losses were of appreciable magnitude, the weir channel, shown in Figures 15 and 16, was used to determine the volume. This portable weir channel was 7 feet 2 inches x 45 inches x 39 inches in over-all dimensions and constructed of 14-gage galvanized iron. The weir itself was of the V-notch type in order to permit accurate measurements of both high and low discharge and was designed to measure rates of flow as high as 2,000 gallons per minute. The lip of the weir was constructed of brass to prevent changes in calibration caused by corrosion.

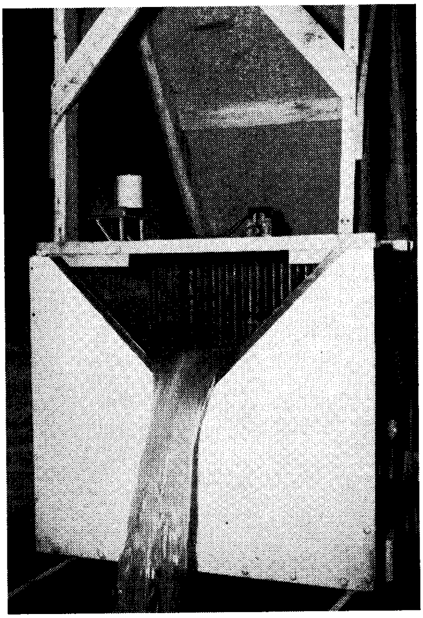


FIG. 15. WEIR CHANNEL IN OPERATION

In order to keep the space taken up by the weir channel to a minimum, it was desirable in its design to reduce all the dimensions below those required for streamlined flow and the prevention of end contractions at the weir plate. It was necessary, therefore, to make an actual calibration of the weir in order to determine the relationship between the volumetric flow and the head back of the weir. These calibration tests were made by diverting the discharge from the weir box into a tank of several thousand gallons capacity and measuring the head and rate at which the tank filled. The equation of the calibration curve obtained from these measurements was

$$Q = 3.477H^{2.52}$$

where

Q = volume in gallons per minute
H = head in inches

Two white-water samplers were used for collecting the samples for analysis during the weir channel tests. One consisted of a small trough, pivoted at the center and with one end extending into the white-water intake pipe located on the weir box (see Fig. 16). During operation this trough was automatically tilted once every nine minutes so that a small portion of the entering white water was diverted from the weir channel into a container. Tilting of the trough was accomplished by means of a cam rotated by a low-speed motor and gear train. An alternate sampling device was used where the percentage of suspended solids in the white water was low, and the space available for installation of the channel was limited. This consisted of a ½-inch pipe opening at the center of the chanel between the baffles and the weir plate and mounted on a level with the bottom of the weir notch. The top of the pipe was beveled 60 degrees and formed the seat for a babbit plug valve operated by the low-speed motor previously described. Theoretically, the volume of the periodic white-water samples taken should be in proportion to the volume of flow to the channel, and these sampling devices resulted in an approximation to this condition. Two thousand cubic centimeters of the composite sample taken by this device were analyzed every eight hours to determine the weight of total suspended solids, fixed suspended solids, volatile suspended solids, total dissolved solids, fixed dissolved solids, and volatile dissolved solids. These analyses were carried out in accordance with the TAPPI Standard Method of Analyzing White Waters (see Appendix).

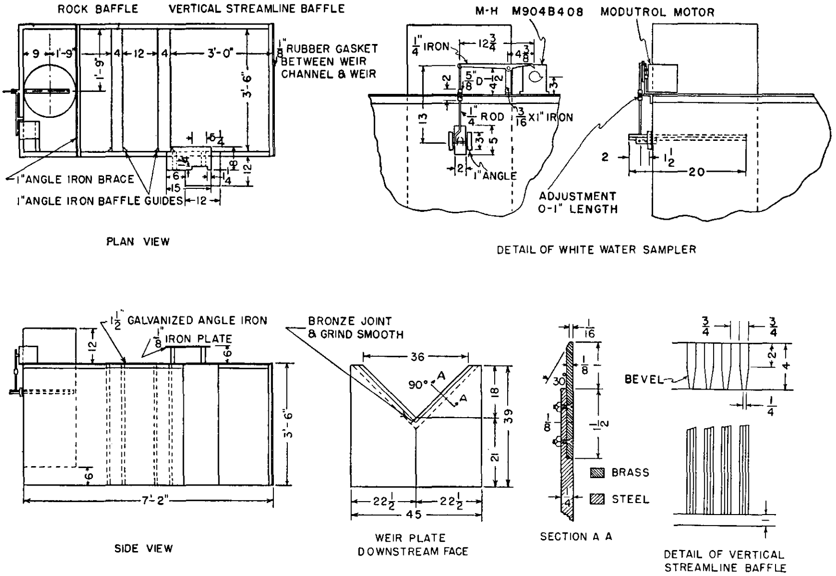


FIG. 16. DETAILED DRAWING OF WEIR CHANNEL AND WHITE-WATER SAMPLER

Continuous measurements, ranging from two to five days in length, were made of the various white-water losses by means of this weir channel. During these tests, continuous records were kept of the head on the weir and consequently the volumetric flow by means of a water-level recorder. Figure 17 shows reproductions of typical charts as recorded during tests of the white-water losses from the kraft thickener, the kraft white-water chest overflow, and the kraft knotter screens. The volume of white water discharged to the sewers during these tests was determined by the charts and the weir channel calibration curves.

Correlation of white-water loss and machine production.—Wherever possible, the actual white-water loss over a period of time was correlated with machine production as determined by plant records over the same period of time. Thus, as shown in Figure 18, it was possible to correlate the tailings screen losses with the paper machine production

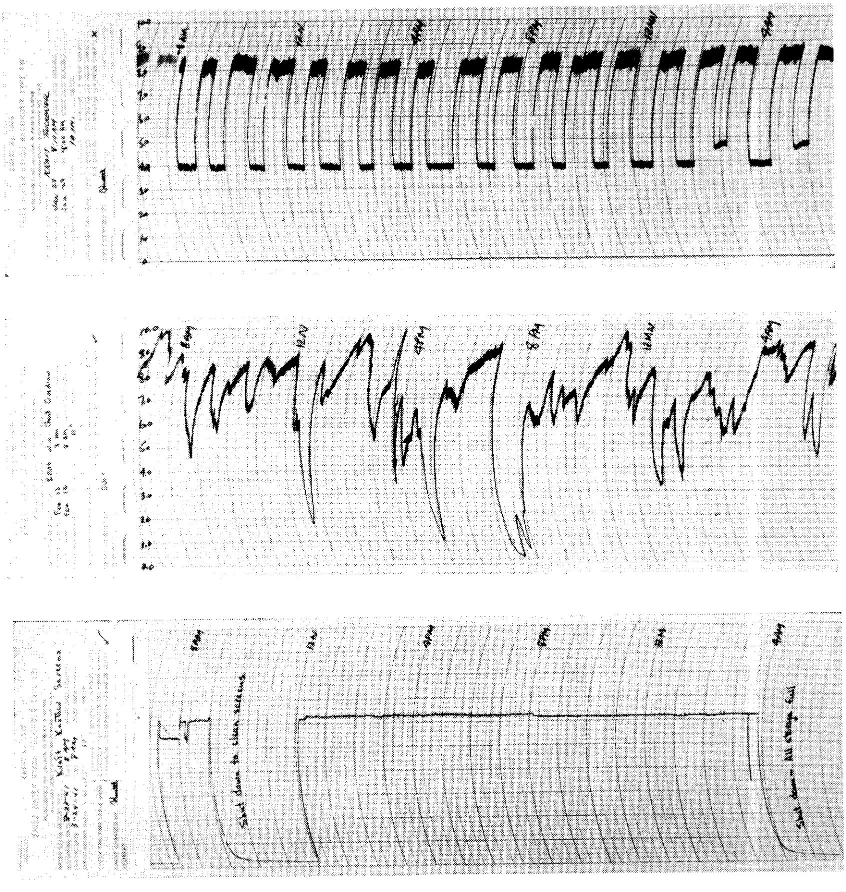


FIG. 17. TYPICAL WEIR CHANNEL WHITE-WATER LEVEL RECORDS DURING TESTS OF KRAFT THICKENER, KRAFT WHITE-WATER CHEST OVERFLOW, AND KRAFT KNOTTER SCREENS

associated with that particular tailings screen. This graph shows the relationship between rate of white-water discharge, the weight of suspended and dissolved solids, white-water losses, and the paper machine production.

In some cases there was no correlation between ultimate loss and paper or insulation board production, as the particular machines from which the loss originated supplied stock to several different paper or insulation board machines or storage chests. In such cases it was necessary to determine the production from actual measurements of the white water discharged over the weir and from the entering and leaving consistencies. For example, in the case of the groundwood filter, measurements were made of the amount of fresh water entering the filter, the volume of white water discharged over the weir, and the consistencies of the entering and leaving stock and of the white water. Then, referring to Figure 19, if

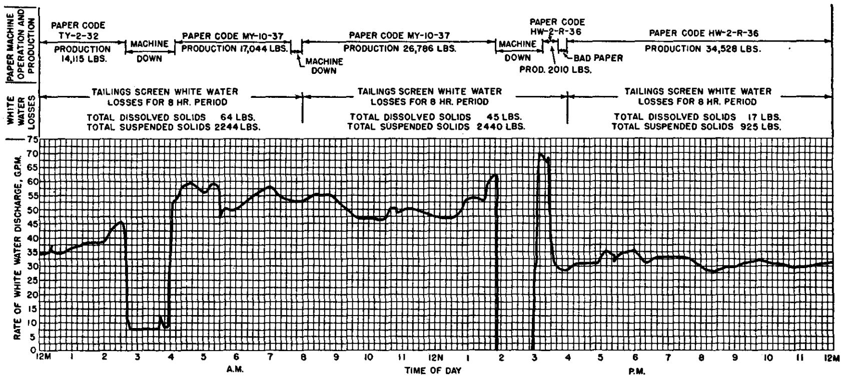


FIG. 18. CORRELATION BETWEEN PAPER MACHINE PRODUCTION AND TAILINGS SCREEN WHITE-WATER LOSSES DURING TYPICAL TEST

c_1 = consistency of stock entering groundwood filter
c_2 = consistency of stock leaving groundwood filter
c_3 = consistency of white water rejected to sewer
W_1 = weight of stock entering groundwood filter, pounds per minute
W_2 = weight of stock leaving groundwood filter, pounds per minute
W_3 = weight of white water discharged to sewers, pounds per minute
q_1 = weight of fresh water through cleaner spray = approximately 1800 pounds per minute
q_2 = weight of fresh water through peeler spray = approximately 750 pounds per minute
V = volume of white water discharged to sewer, gallons per minute

and

Weight mixture entering = weight mixture leaving
Weight bone-dry stock entering = weight bone-dry stock leaving

then

$$W_1 + q_1 + q_2 = W_2 + W_3$$
$$W_1c_1 = W_2c_2 + W_3c_3$$

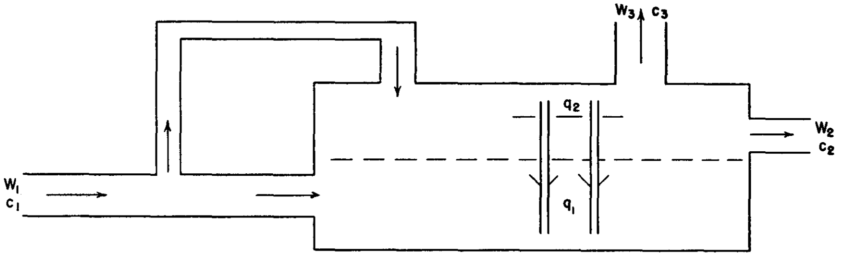


FIG. 19. DIAGRAMMATIC SKETCH OF GROUNDWOOD FILTER FOR DERIVATION OF PRODUCTION EQUATION

From these relationships, it may be shown that

$$\text{Weight of bone-dry stock filtered} = W_1c_1 = 60c_1\left[\frac{8.33V(c_3 - c_2) + c_2(q_1 + q_2)}{c_1 - c_2}\right] \text{pounds per hour}$$

Fiber photomicrographs.—In many cases it was found that although the losses were of appreciable magnitude, the actual fiber sizes as found in the white water were quite small, and therefore such losses would be difficult to recover. For this reason white-water samples were taken from several of the machines, concentrated by boiling, and slides prepared to enable microscopic examination of these fibers. Photomicrographs of these slides were taken at 50 diameters magnification. Figures 20, 21, and 22 show representative photomicrographs of the normal kraft, sulphite, and groundwood pulp before entering the beaters. Figures 23, 24, and 25 show photomicrographs of the fibers contained in samples of the white water discharged from one of the wet machines, one of the savealls, and one of the deckers, respectively. The scales printed adjacent to these photographs are two millimeters in over-all length.

KNOTTER SCREEN REJECTS

(Losses 10 and 27)

The cooked stock discharged from the diffusers in the kraft plant and from the blow pits in the sulphite mill is first screened through knotter screens where any undigested chips or knots are removed and rejected to the sewers. The white water from these screens was measured by means of the portable weir channel previously described and the knots were separated from the white water by means of an inclined saveall (see Fig. 26) mounted on top of the channel. The knots were separated from the white water by means of an 8-mesh screen and the white water was carried by means of a trough to the inlet side of the weir channel. All of the rejected knots were shoveled into containers and weighed.

FIG. 20. KRAFT PULP (50 ×)

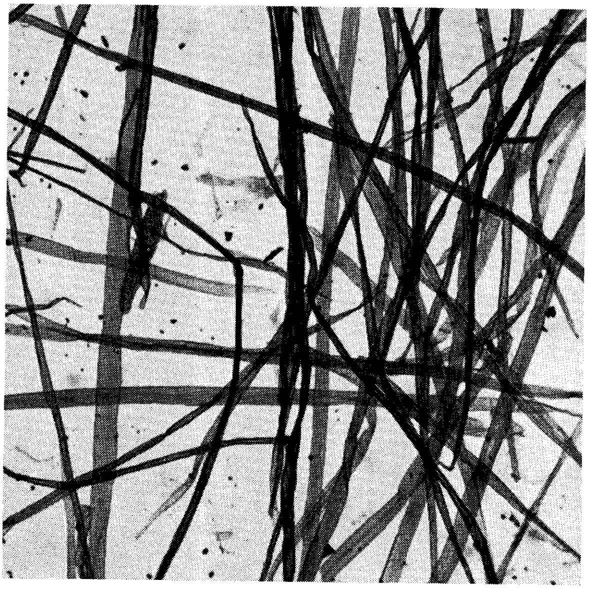
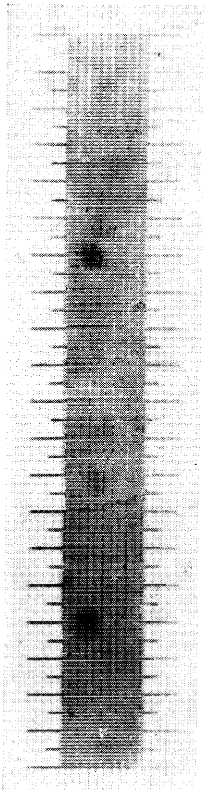


FIG. 21. SULPHITE PULP (50 ×)



TWO-MILLIMETER
SCALE

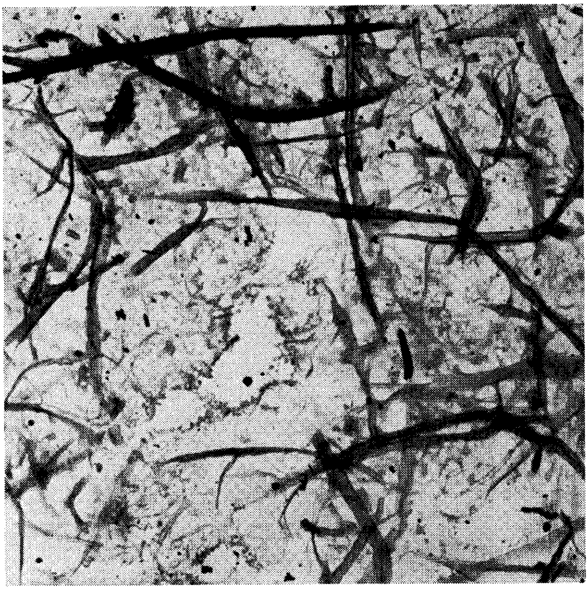
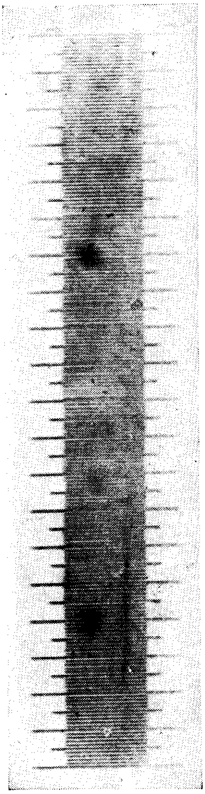


FIG. 22. GROUNDWOOD PULP (50 ×)



TWO-MILLIMETER SCALE

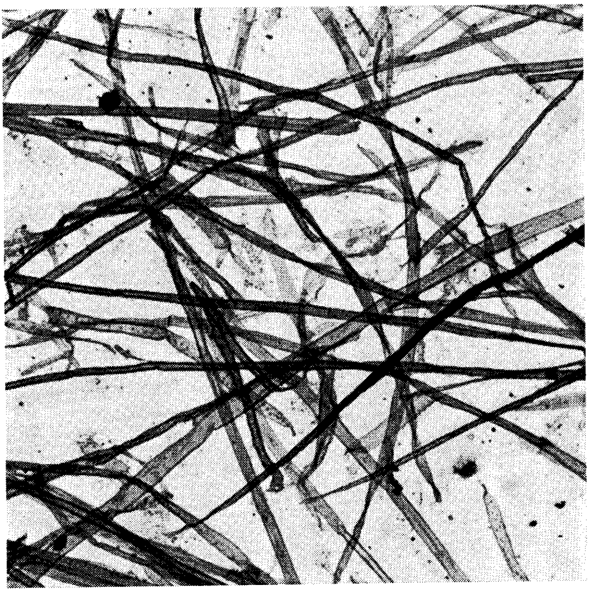


FIG. 23. PULP CONTAINED IN WET MACHINE WHITE WATER (50 ×)

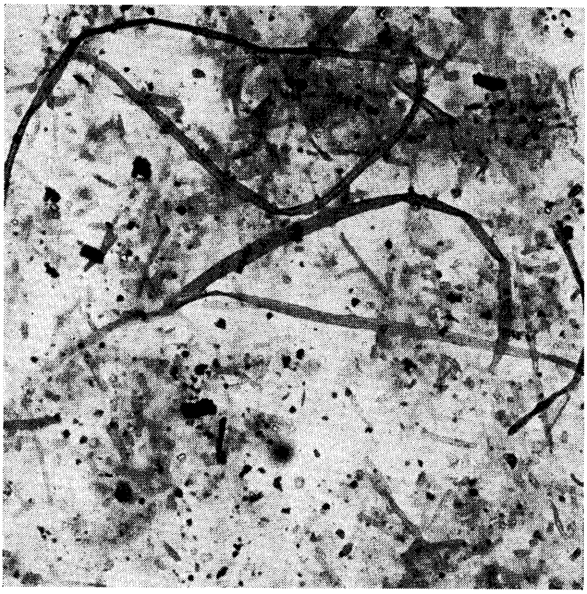
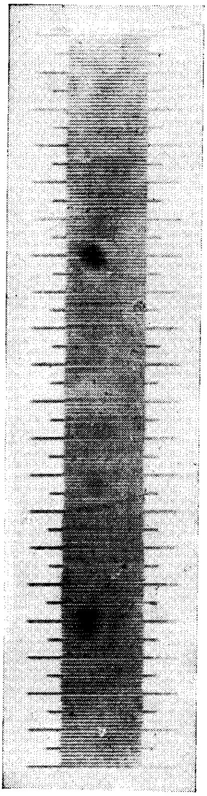


FIG. 24. PULP CONTAINED IN SAVEALL WHITE WATER (50 ×)



TWO-MILLIMETER SCALE

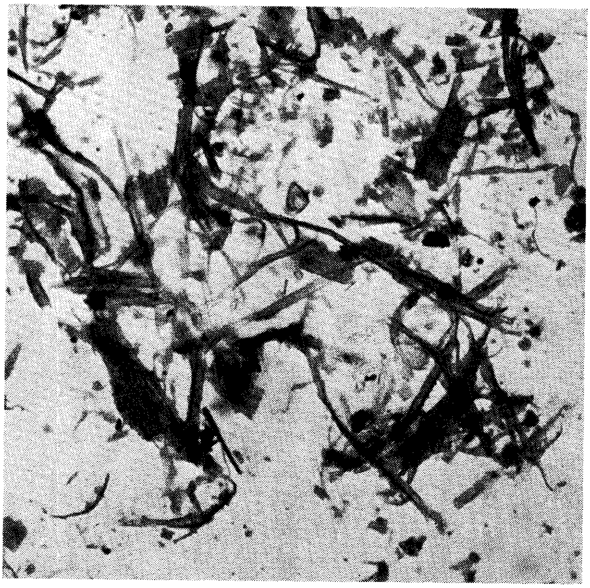


FIG. 25. PULP CONTAINED IN CYCLONE DECKER WHITE WATER (50 ×)

Three moisture determinations were made of the discharged knots for each eight hours of tests. Determinations were made of the white-water volumetric flow by means of the weir channel, and white-water samples were collected and analyzed to determine the weight of total suspended solids, fixed suspended solids, volatile suspended solids, total dissolved solids, fixed dissolved solids, and volatile solids, in accordance with the TAPPI Standard Method of Analyzing White Waters (see Appendix). The results of these tests indicated an average loss of 26.9 pounds of air-dry knots per ton of air-dry pulp for the kraft knotter screens and 26.4 pounds of air-dry knots per ton of air-dry pulp for the sulphite knotter screens.

RIFFLER AND BEATER WASHOUTS

(Losses 16, 19, and 30)

The groundwood stock entering the paper and Insulite plants from the grinder rooms first passes through rifflers before going to the storage chest or screens. Each of these rifflers is washed out periodically, and during this process there is a certain amount of stock which is lost to the sewers along with the sand and other materials removed during their operation. Several measurements were made on each of these rifflers just prior to the time of washout with the depth of the stock remaining in the rifflers and the consistencies recorded. These measurements were used to calculate the amount of air-dry stock rejected to the sewers per washout. The yearly losses were calculated from records of the time periods between washouts.

When the paper machines are shut down or when the color of the stock being run through the machines is changed from a dark to a light color, it is necessary to wash out the machine beater (see Fig. 27), the beater dump chest, the machine chest, the broke beater, the machine head box, the filter, and the couch pit. In some cases this stock was sent to a rejects storage tank and was eventually converted into rejects lap. In other cases this washout stock was discharged to the sewers. In order to determine how much of a loss this constituted over a period of time, a survey was made in which the average amount of stock contained in each

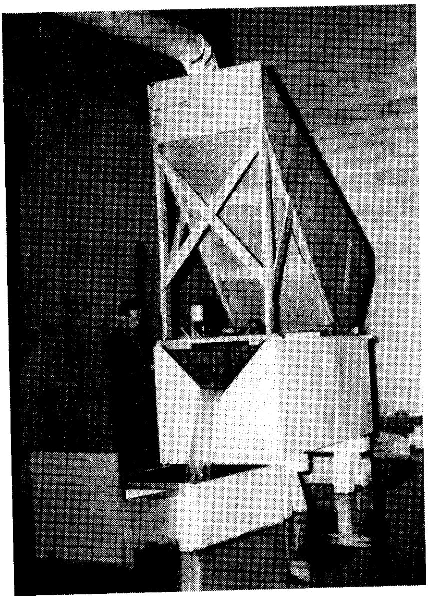


FIG. 26. WEIR CHANNEL AND INCLINED SAVEALL FOR REMOVING KNOTS DURING KNOTTER SCREEN TEST

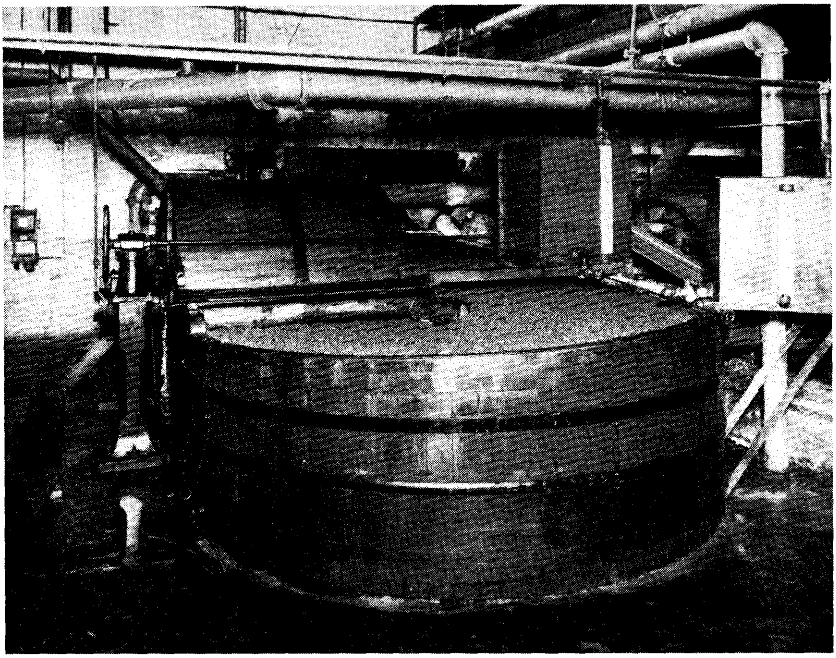


FIG. 27. MACHINE BEATER IN OPERATION

of these machines or chests at the time of dumping to the sewers was determined and a record of the number of times these machines were washed to the sewers over a six-month period was recorded. The yearly losses were calculated from this information.

KRAFT SLUDGE

(Loss 24)

In the manufacture of kraft pulp the wood chips are treated with a liquor consisting principally of sodium hydroxide and sodium sulphide. After the chips have been properly cooked, the charge is emptied into washing tanks or diffusers where the fiber is separated from the black liquor formed during the cooking process. The black liquor is sent through evaporators where the moisture is driven off by the application of heat, and the resulting black ash is sent to the smelting furnaces. Sodium salts are here added, and the organic matter and combustion gases are driven off. The smelted inorganic matter is sent to the dissolving tanks and there mixed with a weak wash from the causticizing system to form the green liquor. This green liquor consists principally of sodium carbonate and sodium sulphide. By the addition of lime and water the sodium carbonate contained in the green liquor is converted into calcium carbonate and sodium hydroxide. The calcium carbonate is the principal constituent of the sludge, and sodium hydroxide along with sodium sulphide are the principal constituents of the white liquor used in the digesting processes. The lime is added to the green liquor in liming tanks and the resulting mixture pumped to settling tanks where the insoluble calcium carbonate or sludge is allowed to settle from the solution. The white liquor is then drawn off and the sludge sent to the sewers.

Sludge sampling procedure.—Volumetric measurements of the sludge discharged to the sewers were made, and samples of this sludge were obtained for chemical analysis over three 48-hour periods. The total volume of sludge contained in the settling tanks was determined by measuring the depth of the sludge in the tanks after the white liquor had been drained off just prior to the time of dumping the sludge into the sewers. After the sludge had been allowed to drain, measurements were made of any deposits remaining at the bottom of the tanks, and the volumes of these deposits subtracted from the total sludge volume in order to determine the amount discharged to the sewers.

A vertical section of the sludge in the settling tanks was sampled for chemical analysis just prior to the time of dumping by means of the apparatus shown in Figure 28. This sampler consisted of a rotary valve fastened to the bottom of a section of two-inch pipe, 14 feet long. In sampling, the rotary valve was open, the pipe and valve lowered into the settling tanks until the valve rested on the bottom. The valve was then closed and the entrapped sample withdrawn. As the sample consisted of a vertical section of the liquid in the tank, this method compensated for any stratification of the insoluble suspensions.

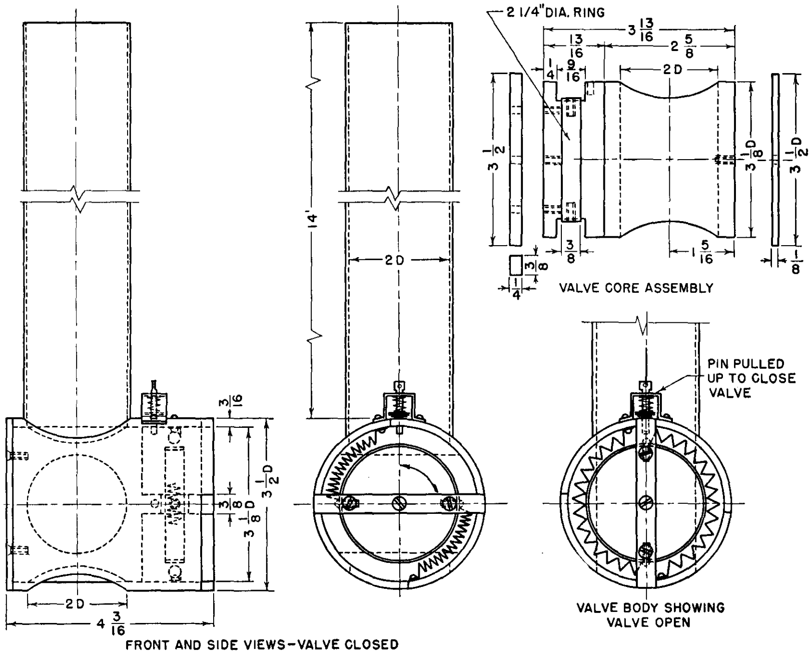


FIG. 28. DETAILED DRAWING OF KRAFT SLUDGE SAMPLER

Chemical analysis.—In analyzing the sludge samples chemically, analyses were made to determine the total weight of dry sludge per unit volume of the liquid sample, the per cent of total soda (Na_2SO_4) in the dry sludge and the per cent of free lime (CaO) in the sludge. An evaporating dish was first cleaned, dried, and weighed to 0.01 gram. The sludge sample was then mixed thoroughly and a 50-cubic-centimeter portion taken for analysis. This was poured into the evaporating dish and dried to constant weight at 105° C. The weight of this dry sludge sample was then determined and taken as representative of the weight of dry sludge per 50 cubic centimeters of the liquid sludge. This weight was also taken as a basis for the calculation for the percentage of total soda and the percentage of free lime. Another 50-cubic-centimeter portion of the original sample was rinsed into a 250-cubic-centimeter beaker and covered with approximately 100 cubic centimeters of water. This was then stirred, covered with a watch glass, and brought to boiling. The mixture was then filtered using a Buchner funnel and vacuum. To the filtrate was then added two cubes of $(NH_4)_2CO_3$ and the mixture heated until no more NH_3 was given off. This was then filtered, washed well with hot water, and two to three drops of methyl orange added to the filtrate. This was then titrated with N/HCl, and the filtrate and precipitate rejected. The following equation was used to determine the percentage of total soda:

$$\frac{100 \times (\text{HCl titration in cc.}) \times 0.0772}{\text{Grams dry sludge per 50-cc. sample}} = \text{per cent total soda as } Na_2SO_4$$

An iodine titration was used to determine the percentage of free lime. Fifty cubic centimeters of the sludge sample were diluted with about 100 cubic centimeters of the hot distilled water and the mixture brought to a boil. The mixture was then filtered without washing the filter cake, the entire residue added to about 400 cubic centimeters of boiling distilled water and stirred for about ten minutes. An excess of iodine was added, the solution stirred for another ten minutes, and starch added as an indicator. The excess iodine was titrated with 1/10 N solution of sodium thiosulphate. The following equation was used to determine the percentage of free lime:

$$\frac{100 \times (\text{iodine titration in cc.}) \times 0.0028}{\text{Grams dry sludge per 50-cc. sample}} = \text{per cent free lime (CaO)}$$

The results of these tests indicated a loss of 724 pounds bone-dry sludge per ton of air-dry pulp produced. This included approximately 57 pounds of sodium sulphate and 6 pounds of lime.

KRAFT SMELTER STACK DISCHARGE

(Loss 25)

In the manufacture of kraft pulp the black liquor discharged from the diffusers contains practically all of the chemicals charged to the digesters during the cooking processes and also much organic material removed from the wood. Approximately 80 per cent by weight of the black liquor consists of water and the other 20 per cent of solid materials. Of these solids approximately 50 per cent is combustible. The sodium compounds contained in the black liquor are removed for use by driving off the moisture and by burning the combustible. The black liquor coming from the diffusers is first sent to the evaporators where much of the water is driven off. Further evaporation is carried out by pumping the viscous black liquor from the evaporators to rotary furnaces which discharge nearly dry black ash containing the major portions of the organic substances from the wood and the inorganic salts. At this point salt cake (Na_2SO_4) is added to the black ash and the mixture discharged to the smelting furnaces where the combustibles are burned. The resulting smelt is sent to dissolving tanks where the green liquor containing principally sodium carbonate, sodium sulphide, sodium hydroxide, and sodium sulphate is formed. The products of combustion from the smelters are discharged through the rotary furnaces to the disc evaporators where they aid in evaporating the water from the black liquor. From here the gases are discharged to the atmosphere.

In the process of dusting the black ash with salt cake a considerable portion of the sodium sulphate is entrained in the products of combustion which are discharged from the mill. In addition there is a certain amount of finely divided black ash which also becomes suspended in the air stream and is discharged from the mill. The magnitude of these losses will depend to a certain extent upon the settings of the induced draft fan used to aid discharge of the combustion products. Figure 29 shows a diagrammatic sketch of a disc evaporator, rotary furnace, and smelter as arranged at the International Falls plant.

Test apparatus and procedure.—In order to determine the losses from the smelter stacks, samples of the gases discharged from these stacks

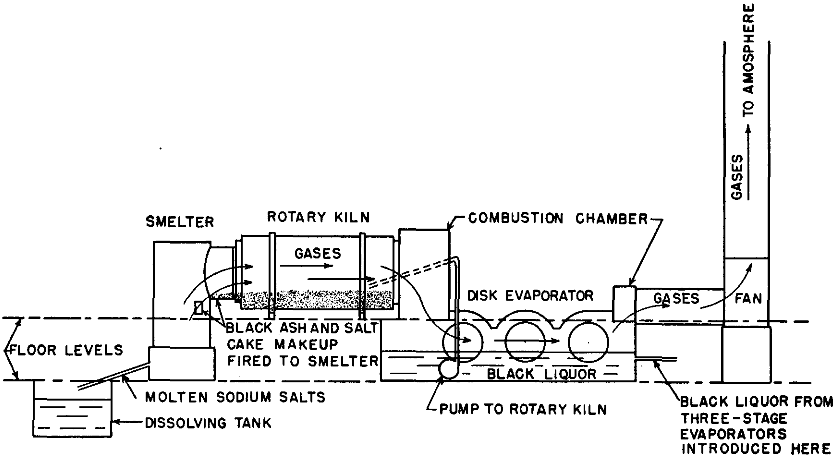


FIG. 29. DIAGRAMMATIC SKETCH OF DISC EVAPORATOR, ROTARY FURNACE, AND SMELTER

were analyzed chemically and measurements of the total volume of smoke and gas discharged made hourly over several nine-hour periods. Velocity and temperature traverses were made of each of the stacks hourly in order to determine the average velocity and the average temperature of the gases discharged. The cross-sectional areas of each of the stacks were divided into five annular rings of equal area and the traverse points taken in each of these rings. Two complete traverses across the entire diameter of the stack were made at right angles to each other for each set of readings. Velocity pressure traverses were made by means of a Pitot tube and an inclined draft gage, and temperature traverses, by means of an iron-constantan thermocouple and direct reading potentiometer.

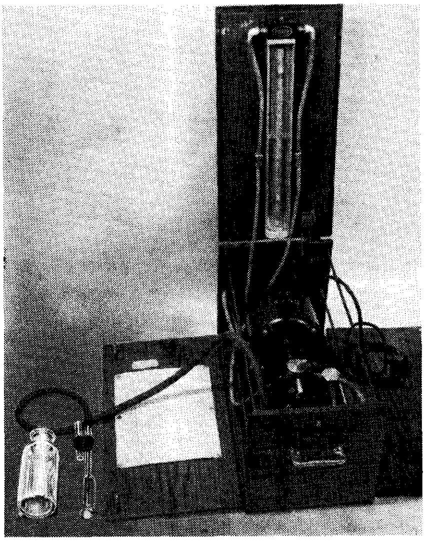


FIG. 30. SMITH-GREENBURG IMPINGER AND CALIBRATED PUMP FOR REMOVING SALT CAKE AND BLACK ASH FROM SMELTER STACK GASES

A 10-cubic-foot sample of the gases from each stack was removed hourly and analyzed. This was done by drawing samples from the stack through ½-inch sampling tubes and passing them through a series of three Smith-Greenburg impingers similar to those used for making atmospheric dust determinations (see Figs. 30 and 31). The samples were removed at a constant rate of one cubic foot per minute, by means of a calibrated positive displacement pump. The Smith-Greenburg impingers were placed in series and used to remove the salt cake and black ash entrained in the stack gases. Each of the impinger flasks consisted of a plain glass wide-mouthed bottle of 500-cubic-centimeters capacity. The impinger tubes through which the gas samples were drawn and impinged against glass plates under water were made of ½-inch pyrex glass tubing. The ends were drawn down to nozzles of 2.3 millimeters diameter and the impingement plates located 5 millimeters from the ends of the nozzles and perpendicular to the direction of air flow. It was found that periodically there were comparatively large pieces of black ash passing through the sampling apparatus which tended to plug the small nozzles of the impingers and, for this reason, an ordinary open piece of ½-inch pyrex glass tubing without nozzle or impinger plate was used for the impinger in the first bottle. The bottom of this tube was located approximately ½-inch from the bottom of the sampling bottle so that some impingement was effected regardless of the lower velocity of the gases ejected

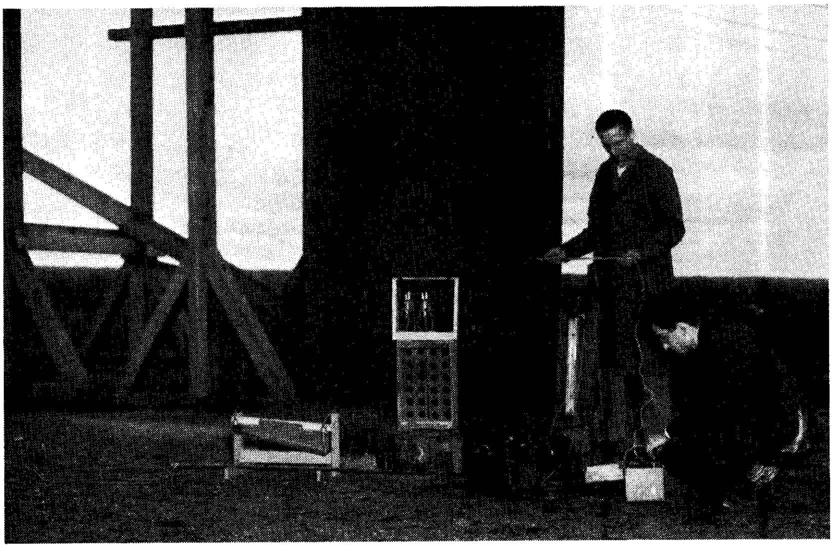


FIG. 31. TEST OF KRAFT SMELTER STACK GASES FOR ENTRAINED SALT CAKE AND BLACK ASH

from the tube. The first sampling flask removed all of the larger pieces of black ash and the second and third impingers removed the finely divided ash and salt cakes. In the operation of the apparatus the impinger tubes and bottles were first thoroughly cleaned with distilled water. Approximately 100 cubic centimeters of distilled water was then poured into each of the flasks and the impingers placed so that the impinger tips were approximately one inch beneath the surface of the liquid. The suction pump was then connected to the suction tube and the inlet of the first impinger bottle connected to the stack sampling tube. After the samples had been collected at constant rates, the impinger and suction tubes were removed from the sampling flasks and thoroughly rinsed with more distilled water to remove any adherent solids. These rinsings were then added to the water in the sampling flasks and the entire volume measured by means of a graduate.

Before using the Smith-Greenburg impingers for the determination of the salt cake and black ash losses, several preliminary tests were made to determine the efficiency of the apparatus. These determinations were made by drawing several 10-cubic-foot samples from the stacks through the impinger bottles and making analyses of the amounts of salt cake and black ash eliminated by each of the impingers. The results indicated that approximately 21 per cent of the material was eliminated by the first bottle which contained no impinger nozzle or plate, approximately 72½ per cent by the second impinger, and approximately 6½ per cent by the third impinger. These tests indicated that the addition of any further impingers in the series would have resulted in negligible increases in the total amount of salt cake and black ash eliminated from the gases and that the efficiency was somewhat over 99 per cent.

In order to determine the moisture content of the gases discharged from the smelter stacks, several samples were analyzed by drawing them first through a tube filled with glass wool to remove any entrained black ash and then through a series of three calcium chloride tubes. Preliminary tests indicated that practically all the moisture was removed from the gases in passing through the first two of the calcium chloride tubes. During sampling all tubes were placed in an ice bath and thermocouples stationed in the stack and in the discharge from the last tube to determine the temperature of the gases. Several 2-cubic-foot samples were drawn through the apparatus and the amount of moisture picked up by the calcium chloride determined by weighing before and after the test. These moisture determinations along with the temperature readings were used to determine the specific volume of the gases discharged from the stacks, assuming the composition of the gases to be the same as that of air.

Chemical analyses of samples—The total solids contained in the distilled water samples removed from the Smith-Greenburg sampling bottles after test were determined by evaporating to dryness. The amounts of sodium sulphate or salt cake contained in the water samples were determined by the benzidine method which consists in adding approximately 10 cubic centimeters of benzidine solution to 50 cubic centimeters of the sample containing the dissolved salt cake. The resulting precipitate is filtered and the residue washed three times in distilled water. The filter paper and residue are placed in approximately 75 cubic centimeters of distilled water in a small Erlenmeyer flask and shaken well. This solution is then titrated with N/10 sodium hydroxide using phenophthalein as an indicator. Each cubic centimeter of N/10 sodium hydroxide used in the titration indicates the equivalent of 142 grams of sodium sulphate in the original solution.

The results of these tests indicated a stack loss to the atmosphere of 103 pounds of salt cake per ton of air-dry pulp produced and 22.2 pounds of black ash per ton of air-dry pulp produced.

GASES FROM ACID TOWERS

(Loss 7)

A two-tower system is used at the International Falls plant for the manufacture of the cooking acid used in cooking the sulphite pulp. Melted sulphur is fed to sulphur burners where the principal product of combustion is sulphur dioxide. This gas is passed through coolers and is then sent to the acid towers. The sulphur dioxide first enters at the bottom of the strong-acid tower which is charged with limestone and through which sulphurous acid formed in the weak-acid tower is pumped. The sulphur dioxide, sulphurous acid, and limestone react to form the calcium bisulphite used in the sulphite cooking process. The weak sulphur dioxide gases discharged from the top of the strong-acid tower are conducted to the bottom of the weak-acid tower which is also charged with limestone and through which water is sprayed from the top. These react to form the sulphurous acid used in the strong-acid tower. Approximately 75 to 95 per cent of the sulphur dioxide entering the strong-acid tower from the sulphur burners is absorbed in this tower and practically all of the remainder in the weak-acid tower. However, there are small sulphur dioxide losses occurring in the discharge to the atmosphere from the weak-acid tower.

A series of chemical analyses was made on different days to determine the concentration of the sulphur dioxide in the gases discharged to the atmosphere from the weak-acid tower. In making these analyses, a known amount of N/10 iodine was diluted to approximately 300 cubic centimeters with distilled water, and starch was added to the solution as an indicator. A sample of the gases from the weak-acid tower was drawn through a sampling tube located in the stack discharging to the atmosphere and was bubbled through the iodine solution. An aspirator bottle filled with water and connected to the bottle containing the iodine solution was used to draw the gas sample through the solution. The volume of water allowed to pass from the aspirator bottle was equivalent to the volume of gas sampled and was measured by means of a 2,000-cubic-centimeter graduate. Sampling was continued by bubbling the gases through the iodine solution until the end point was reached—that is until the solution became colorless. As it required 11.17 cubic centimeters of sulphur dioxide to equalize 10 cubic centimeters of N/10 iodine, the percentage sulphur dioxide in the exhaust gases when 10 cubic centimeters of the iodine solution was used was calculated from the following equations:

$$\text{Per cent } SO_2 = \frac{11.17}{V + 11.17}$$

where

$$V = V_o \frac{P_o - W}{760\ (1 + 0.00367t)}$$

and

V_o = measured volume of sample in cubic centimeters
P_o = barometric pressure in millimeters of mercury
W = vapor pressure in millimeters of mercury at temperature of sample
t = temperature of sample in degrees Centigrade

The results of these tests indicated concentrations of sulphur dioxide in the gases exhausted from the weak-acid tower ranging from 0.028 to 0.124 per cent with an average value of 0.064 per cent. No measurements were made to determine the actual volumes of gas discharged from the weak-acid tower per unit of time.

SULPHITE BLOW PIT WASTE LIQUOR

(Loss 9)

The wood chips used in the manufacture of sulphite pulp are charged to digesters (see Fig. 32) where the cellulose fibers are removed from the lignin, rosin, and other materials contained in the wood by cooking with acid under temperature and pressure. After completion of the cooking process, the stock and liquor are blown from the digesters to blow pits where the waste liquor is separated from the stock and drained to the sewers.

For the digesters under consideration a charge consisted of approximately 26 cords of chipped wood and 27,000 to 30,000 gallons of cooking liquor. In order to raise the temperature and pressure during the cooking process, approximately 4,300 pounds of steam were injected into the digester per ton of air-dry pulp produced. The entire cooking process required approximately 8 to 9 hours and the yield was about 14.5 tons of air-dry pulp per cook.

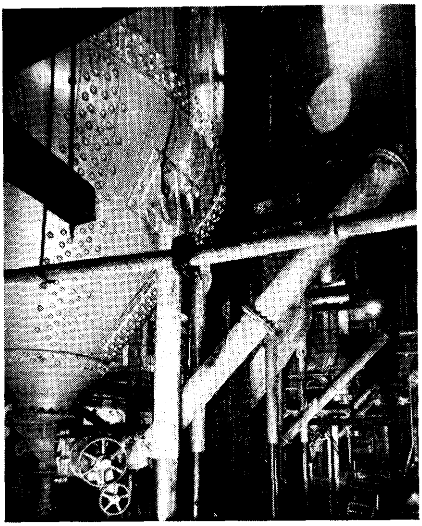


FIG. 32. SULPHITE DIGESTERS

Measurement of waste liquor volume.—In order to determine the total volume of waste liquor discharged to the sewers per blow, measurements were made of the height of the liquor and pulp in the digester just prior to blowing. The average volume of pulp and liquor contained in the digester was determined by these tests as 4,954 cubic feet. If an average yield of 13 tons of bone-dry pulp and a specific gravity of the pulp of 1.60 is assumed, then this pulp occupied 260 cubic feet of digester space. As the actual volume of the pulp is small in comparison with the total volume of liquor in the digester, it may be seen that comparatively large variations in the assumptions as to the charge and specific gravity have little effect upon the calculations of the volume of liquor discharged to the sewers. By difference the average volume of discharged liquor per digester blow was 4,694 cubic feet, or 35,111 gallons. This amounted to 325 cubic feet, or 2,432 gallons, of sulphite liquor per ton of air-dry pulp.

In order to determine what volume of waste liquor could be removed from the digester charge by normal draining in the blow pit without any washing of the stock, consistency measurements were made on a series of samples of stock removed from the digesters after draining the stock without washing it. The results of these tests showed consistencies ranging from 14.62 to 15.50 per cent with an average value of 14.98 per cent. If it is assumed that the average charge during these measurements consisted of 13 tons, or 26,000 pounds, of bone-dry stock, then the weight of liquor retained in the stock was

$$26{,}000 \times \frac{85.02}{14.98} = 147{,}565 \text{ pounds} = 17{,}708 \text{ gallons}$$

Therefore, although it may be assumed that during the normal draining and stock washing process employed, all of the 35,111 gallons of waste liquor are washed and discharged to the sewers, the amount of liquor which would drain to the sewers without washing would be 17,403 gallons per blow, or 49.5 per cent of the waste liquor.

Waste liquor analyses.—Since work has been done by several investigators to determine the complete qualitative analyses of sulphite waste liquor, it was decided that little would be gained by carrying out any such additional investigations in these tests. However, a series of tests was made to determine the percentage of dissolved solids and the percentage of suspended solids contained in the waste liquor. During these tests all samples were taken before any wash water was added to the blow pit, and the percentages recorded were therefore based upon undiluted waste liquor. Preliminary tests indicated that there was little variation between the percentages of dissolved solids for samples taken from the first liquor to drain from the pit and from samples taken from the last liquor to drain. However, as would be expected, due to a packing of the pulp in the pits, the percentage of suspended solids was higher for the first samples draining from the pit than for later samples.

In determining the weight of suspended solids contained in the sulphite waste liquor, the TAPPI Standard Method of Measuring, Sampling, and Analyzing White Waters (see Appendix) was followed. Because of the probability of appreciable quantities of chemicals and incrustations difficult to remove by washing and not properly to be regarded as pulp, the TAPPI recommendations are that in the measurements of waste liquors for suspended solids a disc of cheesecloth or 200-mesh wire cloth be used as the filtering medium in place of regular filter paper. In the present tests 200-mesh copper screen was used for this purpose. After the deposits of fibers had been removed from the liquor by this screen, they were washed into an evaporating dish and evaporated to dryness. The determinations made in this manner thus represented entirely pulp fibers. The total dissolved solids contained in the samples of waste liquor were determined from measurements of the temperature and the specific gravity of the sample and from relationships between these variables and the total dissolved solids for sulphite waste liquors as found by L. Morin and published as *C.P.P.A. Technical Data Sheet No. 55.*

A series of preliminary tests was made to determine the variations in the percentages of suspended solids contained in samples of the first sulphite waste liquor to drain from the pit and for other samples obtained as the draining progressed. These tests clearly indicated that the first liquor to drain from the pits contained small but definite amounts of suspended solids, but that after draining had proceeded for 15 to 20 minutes, this loss become negligible. Although these tests were made without washing the stock, and, therefore, were not made under conditions quite identical with the usual draining procedure, they should, nevertheless, indicate the general magnitude of the losses to be expected from this source.

A series of tests was conducted in which samples of the sulphite waste liquor were taken over a period of four months from all of the blow pits.

All samples were taken at the start of pit draining, and for this reason the analyses of the suspended solids represented the maximum fiber losses which were encountered in any portion of the waste liquor drained to the sewers. The average value for all samples of dissolved solids was 13.1 per cent by weight and for the suspended solids 0.0515 per cent by weight. Although low, this value for the average suspended solids or fiber losses was still greater than the average loss, as it is actually only representative of the initial period of draining when the greatest losses were encountered.

INSULITE DIGESTER WASTE LIQUOR

(Loss 42)

Although the majority of the pulp used in the manufacture of insulation board in the Insulite plant consists of groundwood, there is also a small amount of cooked pulp used. The wood chips used for this purpose are given a short cook of approximately 45 minutes during which time the temperature is raised to 165° C. and the pressure to 80 pounds per square inch gage. After cooking is completed, the digester is blown, the cooked chips sent to the Bauers, and the waste liquor drained to the sewers.

Waste liquor volumetric measurements.—Two methods were used to determine the volume of the waste liquor. The more accurate method of the two was that in which the waste liquor was piped directly into the calibrated weir channel, previously described, before being sent to the sewers. The flow of liquor through the weir channel was automatically recorded by means of a water-level recorder throughout a 24-hour period. During this time there were twelve digester blows, and the volume of liquor discharged during each of these blows was calculated from the water level charts. The volume of liquor discharged from the digester at each blow was also determined by making a water balance on the digester. The moisture content of the entering and leaving chips was determined, and the volume of water and steam charged to the digester measured. It was assumed that the amount of steam flashed upon blowing the digester was approximately equivalent to the amount of steam added in cooking. The volume of liquor discharged to the sewers was then taken as the difference between the amount of water contained in the entering chips and added in charging the digester and the amount of water contained in the leaving chips.

Waste liquor analysis.—Several samples of the waste liquor were analyzed to determine the weight of suspended solids and the weight of dissolved solids contained in the liquor. In making these determinations, the TAPPI Standard Method of Measuring, Sampling, and Analyzing White Waters (see Appendix) was followed. Because of the probability of appreciable quantities of chemicals and incrustations difficult to remove by washing and not properly to be regarded as pulp, the measurements of waste liquor for suspended solids was made by filtering through a 200-mesh wire screen, as recommended by TAPPI. After the deposits of wood and pulp had been removed from the liquor by this screen, they were washed into an evaporating dish and evaporated to dryness.

The results of these tests indicated an average percentage of dissolved solids in the waste liquor to 3.20 per cent. The measurements made of the suspended solids, or fiber losses, indicated a considerable variation even during the draining of the same charge. In order to investigate this variation, several samples collected at 10-minute intervals during the draining period, were analyzed. As would be expected, the samples collected during the initial draining of the pits were higher in fiber content than any of the others. However, in practically all cases, the actual percentage of suspended solids in the waste liquor was very low, with an average value of 0.006 per cent.

SULPHITE BLOW PIT GASES

(Loss 8)

In addition to the loss through the discharge of waste liquor to the sewers upon blowing the sulphite digesters, there is also some gaseous discharge (see Fig. 33) to the atmosphere through the blow stacks. The constituents of this gaseous discharge are probably flashed steam, sulphur dioxide, and air. The principal constituent of this discharge, therefore, both from a nuisance and a waste standpoint, is the sulphur dioxide. During the cooking process, the pressure and temperature in the digester are controlled by the addition of direct steam and by bleeding off some of the gases. These gases are sent to the accumulator system where any sulphur dioxide contained is recovered. At the end of the cook the digester pressure is relieved to atmospheric, and all of the gases are discharged through the blow stack to the atmosphere.

FIG. 33. GASEOUS DISCHARGE FROM SULPHITE BLOW STACK

Sulphur dioxide measurements.—The difference between the total sulphur dioxide contained in the digester cooking liquor just before the digester is blown to the pit and the total sulphur dioxide concentration in the waste liquor drained from the blow pit to the sewers is a direct measure of the sulphur dioxide discharged through the blow stacks to the atmosphere during the blow. This is true only if the waste liquor analyzed for total sulphur dioxide has not been diluted with any wash water.

In these tests a series of measurements of the sulphur dioxide concentration of both the cooking liquor prior to blowing the digester and the waste liquor sent to the sewers was made on different digesters at different blows. From these data, the weight of sulphur dioxide discharged to the atmosphere per ton of product was determined.

In making measurements of the initial concentration, two samples of approximately 200-cubic-centimeter volume were taken from the digester just before its contents were blown into the pit. These samples were passed through water-cooled coils to reduce the temperature to approximately 25° C. to 30° C. and the sample bottles were immediately covered to reduce to a minimum any free sulphur dioxide losses to the atmosphere. The blow pit waste liquor samples were removed at a point where the blow pits connect to the sewers, and in order to prevent any dilution of the waste liquor before the samples were obtained, no water was added to the pits before blowing and no wash water was injected into the pits until the samples had been taken.

The total volume of liquor contained in the digester was obtained from measurements made of the height of liquor and pulp in the digester prior to blowing and of the weight and specific gravity of the yield as previously described under Sulphite Blow Pit Waste Liquor. In these measurements and calculations it was assumed that the liquor volume in the digester before blowing was the same as that of the liquor drained to the sewers. This is only approximately true since there is some steam flashed upon blowing and there is some spray water from the blow stacks added to the pits. These water sprays in the stacks absorb small amounts of the sulphur dioxide relieved from the blow pits and carry it back into the pits. During these tests the sprays were left on in order to take into account only the sulphur dioxide actually discharged to the atmosphere. These two sources of error, the flashed steam and spray water, tend to compensate for each other, and the actual error introduced in assuming the liquor volume to be the same before and after blowing should be small.

The sulphur dioxide contained in the cooking of waste liquors is in both the combined and the free forms with the major portion of the combined sulphur dioxide in combination with the calcium bisulphite. In analyzing the samples for total sulphur dioxide, 10 cubic centimeters of the sample was titrated with N/10 iodine, using starch as an indicator. As one cubic centimeter of N/10 iodine is the equivalent of 0.003204 gram of sulphur dioxide, this relationship was used in making the total sulphur dioxide calculation.

The results of these tests indicated fairly wide variation in the sulphur dioxide losses between different digester blows. The average value for all tests was 1,090 pounds per blow. The largest variation in sulphur dioxide concentration appeared in the cooking liquor samples taken just prior to blowing the digesters. The concentrations in the samples taken after blowing showed comparatively small absolute variation. There are several possible explanations for the variations in the total sulphur dioxide in the cooking liquor, most of which are based upon variations in the cooking procedure and in the human factor in judging whether or not the stock is cooked to the right degree. As indicated by the results of these tests, the sulphur dioxide discharged to the atmosphere was approximately 75.5 pounds per ton of air-dry pulp, of which approximately 37.7 pounds consisted of sulphur.

VOLATILES FROM DRYING KILNS

(Loss 37)

The insulation board coming from the wet end of the Insulite machines is sent through drying kilns in which the temperature is maintained at approximately 300° F. The speed at which the insulation board is sent through these kilns varies somewhat with the nature of the board, and the temperature varies in different sections of the kilns. Much moisture is driven off from the board upon exposure to the high temperature and is discharged through exhaust fans to the atmosphere. In addition to this moisture, however, there is also some loss of volatiles as the furnish to the Insulite machines contains not only groundwood and cooked pulp but also some size, rosin, and other chemicals. Some of the lighter fractions of the furnish apparently volatilize and are discharged to the atmosphere along with the moisture.

In order to determine the magnitude of these volatile losses, a series of tests was made in which samples of the insulation board were weighed upon entering the kilns and upon leaving the kilns, and similar samples taken from the boards entering the kilns were subjected to a low temperature drying process in order to remove the moisture without volatilizing any of the other constituents of the board. By means of these data it was possible to calculate the percentage by weight of volatiles driven off from the board. The calculations to determine the weights of these volatiles were made according to the following analysis:

W_1 = weight of wet sample for low-temperature drying
W_2 = bone-dry weight of sample obtained by low-temperature drying
W_3 = weight of wet sample run through kiln
W_4 = bone-dry weight of sample run through kiln
W_5 = bone-dry weight of sample run through kiln plus the volatiles lost
W_6 = weight of sample leaving kiln (1½ per cent moisture)
w_1 = weight of moisture in sample for low-temperature drying
w_2 = weight of volatiles driven off in passing through drying kiln
w_3 = weight of moisture in sample leaving kiln (1½ per cent moisture based on weight leaving kiln)
p_1 = percentage moisture in sample based on wet weight
p_2 = percentage volatiles driven off based on wet weight
p_3 = percentage volatiles driven off based on weight of sample leaving kiln (1½ per cent moisture)

The percentage of moisture contained in the sample based on the weight of the wet sample was determined as follows:

$$w_1 = W_1 - W_2$$

$$p_1 = \frac{w_1}{W_1} \times 100$$

The percentage of volatiles driven from the insulation board in passing through the drying kiln, based on the weight of wet sample, was determined from the following equations:

$$W_5 = W_3\ (1 - p_1)$$
$$w_2 = W_5 - W_4$$
$$p_2 = \frac{w_2}{W_3} \times 100$$

The percentage of volatiles driven from the insulation board in passing through the drying kiln, based on the weight of the samples leaving kiln (1½ per cent moisture), was determined from the following equations:

$$w_3 = (W_4 + w_3) \times 0.015$$
$$w_3 = \frac{0.015W_4}{0.985}$$
$$W_6 = W_4 + w_3$$
$$p_3 = \frac{w_2}{W_6} \times 100$$

The results of these tests indicated that the standard Insulite sustained an average percentage by weight loss in volatiles of 0.93 and that the Graylite containing some asphalt sustained an average loss of 1.30 per cent based on kiln-dry weight.

INSULITE CYCLONE DISCHARGE MEASUREMENTS

(Loss 39)

There are two single-stage cyclone dust collectors used in conjunction with the exhaust system of the trimmer saws at the discharge end of the drying kilns in the Insulite plant, and there are also two double-stage cyclones connected with the dust collector system from the main cutting room. The dust collected by the single-stage cyclones is discharged into the double-stage cyclones, from whence the recovered stock is wetted and returned to the plant for use. As the single-stage cyclones were identical in design—as were also the double-stage cyclones—only one single-stage and one double-stage cyclone were chosen for test to determine the fiber losses.

In order to determine the volume of air discharged from these cyclones, total pressure traverses were made at the discharge section (see Fig. 34). The cross-sectional areas of these discharges were divided into concentric rings of equal area in the case of the round discharges and into rectangles of equal area in the case of the rectangular discharges, and a complete traverse made hourly throughout the tests to determine the average velocities of discharge. The velocities corresponding to these velocity pressure readings were averaged to determine the average velocity.

The weight of dust discharged from the cyclones was determined by passing a continuous sample of the discharged air through an alundum crucible, capable of removing practically 100 per cent of the weight of the

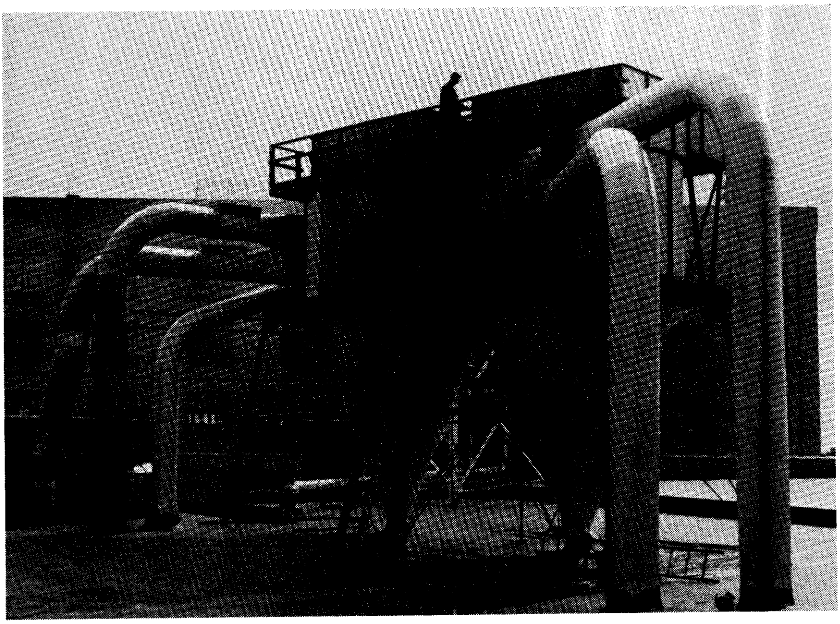


FIG. 34. TEST OF SINGLE-STAGE CYCLONE DUST COLLECTOR

dust. The sampling was done at approximately one cubic foot per minute by means of a calibrated pump and orifice. The alundum crucibles were weighed before and after each eight-hour test in order to determine the increase of weight due to the dust collected. Because of the varying rates of discharge from the different sections of the cyclone openings, it was necessary to traverse the discharges with the dust sampler in a manner similar to that used for determining the average velocity. The same traverse stations were used as in the velocity traverses. A complete sampling tube traverse was made for each of the eight hours of test, and the time of sampling at each station was proportioned directly to the discharge velocity at that station. Thus, a station which was discharging twice the volume of air in comparison with another station would also have twice the volume of sample collected at that point. In this way any variations of weight of dust per unit volume of air between the different stations were taken into consideration. The total amount of dust discharged from a cyclone during an eight-hour test was determined by multiplying the increase in weight of the crucible by the ratio of the total volume of air discharged from the cyclone to the total volume of air sampled by the crucible during the test. Wherever possible, the amount of dust sent to the cyclones was calculated from data recorded as to the width of saw cuts, length of cuts, number of cuts, number of sheets, and thickness of sheets for all board processed during the periods of test.

SUMMARY OF LOSSES

The methods of paper plant waste analysis presented in this bulletin were applied at the Minnesota and Ontario Paper Company International Falls plant to determine the integrated losses for each plant and for the entire mill. The summaries of these losses presented in this section have been prepared on a basis of the losses per ton of air-dry product or per 1,000 square feet of product.

Several of the losses included in these summary tables have been eliminated by the plant since the measurements were completed. For example, the rejects from the tailings screens are now all utilized in the manufacture of rejects lap. Many of the other losses are being studied with the viewpoint of their ultimate utilization or elimination. Several of the minor losses were not measured and were therefore not included in these summary tables. For example, there are unmeasured small white-water losses from some of the vacuum pumps used in conjunction with the paper machine suction boxes. Very infrequently the rejects storage tanks may overflow to the sewers; or again, any stock reclaimed from the cyclone decker in the Insulite plant may be discharged to the sewers if the rest of the plant is not in operation. Such minor losses are of little consequence from either an economic or a pollution standpoint.

Tables III, IV, and V present summaries of the white-water losses from the screen and machine rooms, the kraft mill, and the Insulite mill, respectively. Table VI presents a summary of the wood-room losses. Tables VII, VIII, IX, and X summarize the various miscellaneous losses encountered in the sulphite mill, the kraft mill, the screen and machine rooms, and the Insulite mill, respectively.

TABLE III

SUMMARY OF WHITE-WATER LOSSES—SCREEN AND MACHINE ROOMS

Source	Loss	Effluent, Gallons per Ton of Air-Dry Product	Total Suspended Solids, Pounds Bone-Dry per Ton of Air-Dry Product	Total Dissolved Solids, Pounds Bone-Dry per Ton of Air-Dry Product	Total Solids, Pounds Bone-Dry per Ton of Air-Dry Product	Fibrous Material, Pounds Air-Dry per Ton of Air-Dry Product	Nonfibrous Material, Pounds Bone-Dry per Ton of Air-Dry Product
Groundwood filter	17	67,745	93.7	113	207	102	115
No. 1 saveall	23	17,868	26.0	8.7	34.7	28.0	9.5
No. 2 saveall	23	20,386	85.8	13.7	99.5	35.6	67.5
No. 3 saveall	23	23,020	58.9	23.7	82.6	32.9	53.0
No. 4 saveall	23	20,230	7.89	15.6	23.5	8.29	16.0
Nos. 2 and 4 Rogers wet machine	15	8,223	3.40	4.51	7.91	3.41	4.84
Rejects decker	12	3,450	2.04	2.72	4.76	2.17	2.81
No. 1 suction box	21	11,280	14.4	7.90	22.3	15.2	8.63
No. 2 suction box	21	2,980	20.8	1.55	22.4	9.74	13.6
No. 4 suction box	21	12,670	14.8	8.90	23.7	15.0	10.2
Fourdrinier floor drains	20	287	0.51	0.05	0.56	0.30	0.29
Sulphite knotter screens	10	2,465	1.28	4.50	5.78	1.32	4.59
No. 1 tailings screen	......	389	7.16	0.35	7.51	7.85	0.45
No. 2 tailings screen	......	1,125	73.7	4.5	78.2	72.7	12.8
Nos. 3 and 4 tailings screens	......	270	10.6	0.45	11.1	10.7	1.45

TABLE IV

SUMMARY OF WHITE-WATER LOSSES—KRAFT MILL

Source	Loss	Effluent, Gallons per Ton of Air-Dry Product	Total Suspended Solids, Pounds Bone-Dry per Ton of Air-Dry Product	Total Dissolved Solids, Pounds Bone-Dry per Ton of Air-Dry Product	Total Solids, Pounds Bone-Dry per Ton of Air-Dry Product	Fibrous Material, Pounds Air-Dry per Ton of Air-Dry Product	Nonfibrous Material, Pounds Bone-Dry per Ton of Air-Dry Product
Knotter screens	27	4,620	4.3	3.0	7.3	4.0	3.7
Kraft white-water chest overflow	28	7,535	2.2	6.7	8.9	2.0	7.1
Kraft thickener	29	5,587	4.5	2.1	6.6	4.4	2.6

TABLE V

SUMMARY OF WHITE-WATER LOSSES—INSULITE MILL

Source	Loss	Effluent, Gallons per 1,000 Square Feet of Product	Total Suspended Solids, Pounds Bone-Dry per 1,000 Square Feet of Product	Total Dissolved Solids, Pounds Bone-Dry per 1,000 Square Feet of Product	Total Solids, Pounds Bone-Dry per 1,000 Square Feet of Product	Fibrous Material, Pounds Air-Dry per 1,000 Square Feet of Product	Nonfibrous Material, Pounds Bone-Dry per 1,000 Square Feet of Product
Oliver white-water tank overflow	31	3,492	2.30	5.74	8.04	2.51	5.78
No. 3 decker thickener	33	36,984*	63.8*	40.1*	104*	70.2*	40.7*
No. 2 white-water chest overflow	34	5,360	5.98	12.1	18.1	6.56	12.2
No. 3 white-water chest overflow	34	5,285	4.40	8.46	12.86	4.82	8.52
No. 1 white-water chest overflow	34	6,095	7.27	14.3	21.6	7.96	14.4
Cyclone decker	40	31,388*	53.8*	74.4*	128.2*	57.4*	76.5*

* Rate of flow or rate of loss based on tons bone-dry stock deckered.

TABLE VI

WOOD-ROOM LOSSES

Sewer Losses	
Total bark, pounds per cord of rough wood input	
Bone dry	130.0
Green (60 per cent moisture)	325.0
Bark, 5-mesh or larger, pounds per cord of rough wood input	
Bone dry	67.5
Green (60 per cent moisture)	168.8
Effluent, gallons per cord of wood input	11,867
Boiler Fuel	
Bark, pounds per cord of rough wood input to wood room	
Bone dry	166.0
As delivered (60 per cent moisture)	415.0
Slasher sawdust, pounds per cord of wood input to wood room	
Bone dry	16.2
As delivered (42 per cent moisture)	27.9
Chip screen sawdust, pounds per cord of wood input to chip screens	
Bone dry	49.3
As delivered (48.4 per cent moisture)	95.7

TABLE VII

SULPHITE MILL—MISCELLANEOUS LOSSES

Gases from Acid Towers (Loss 7)	
Average percentage of SO_2 in discharged gases	0.064
Blow Pit Gases (Loss 8)	
Pounds of SO_2 per ton of air-dry pulp produced	75.5
Pounds of sulphur per ton of air-dry pulp produced	37.7
Sulphite Waste Liquor (Loss 9)	
Total gallons of sulphite waste liquor per ton of air-dry pulp produced	2,432
Average percentage of solids in sulphite waste liquor	13.1
Tons of solids (excluding fibers) per ton of air-dry pulp produced	1.39

TABLE VIII

KRAFT MILL—MISCELLANEOUS LOSSES

Kraft Sludge (Loss 24)	
Total pounds of bone-dry sludge per ton of air-dry pulp produced	724
Pounds of soda per ton of air-dry pulp produced	57.3
Pounds of free lime per ton of air-dry pulp produced	6.02
Gallons of sludge to sewer per ton of air-dry pulp produced	509
Gases from Smelting Furnace (Loss 25)	
Pounds of salt cake per ton of air-dry pulp produced	103
Pounds of black ash per ton of air-dry pulp produced	22.2
Millions cubic feet of gases (at approximately 246°F.) to atmosphere per ton of air-dry pulp produced	1.05
Knots from Kraft Knotter Screens (Loss 27)	
Pounds of air-dry knots per ton of air-dry pulp produced	26.9

TABLE IX

SCREEN AND MACHINE ROOMS—MISCELLANEOUS LOSSES

Knots from Sulphite Knotter Screens (Loss 10)	
Pounds of air-dry knots per ton of air-dry pulp produced	26.4
Fort Frances (Groundwood) Stock Riffler Rejects (Loss 16)	
Pounds of air-dry stock per washout	2,638
Beater and Chest Washouts (Loss 19)	
Average pounds of air-dry fibers per ton of air-dry production	0.23

TABLE X

INSULITE MILL—MISCELLANEOUS LOSSES

Volatiles from Nos. 2 and 3 Drying Kilns (Loss 37)	
Pounds of volatiles per 1,000 square feet of low density and standard Insulite board produced	5.97
Pounds of volatiles per 1,000 square feet of Graylite and oil board produced	8.91
Cyclone Discharges (Loss 39)	
Average percentage of dust discharged to air from trimmer saw cyclones based on weight of dust handled	1.48
Pounds of air-dry dust per day from trimmer saw cyclones	237
Pounds of air-dry dust per day from cutter-room cyclones	24
Blow Pit Gases (Loss 41)	
Average pounds of steam per blow	4,950
Liquor from Blow Pit (Unlined Digester) (Loss 42)	
Average gallons of liquor drained per blow	1,293
Average percentage of dissolved solids	3.20
Average percentage of suspended fibers	0.006
Weight of fibers per blow, pounds	0.66
Insulite Groundwood Riffler Rejects (Loss 30)	
Pounds of air-dry stock per washout	1,136

APPENDIX

MEASURING, SAMPLING, AND ANALYZING WHITE WATERS[1]

(Revision of TAPPI Standard M 400 p-36)

This standard is intended to present dependable methods of white-water evaluation so that different mills may use substantially the same methods and thus establish a common basis of comparison. The complete method is intended to evaluate as accurately as possible paper-mill white waters, and to separate fibrous and nonfibrous constituents. Obviously a pulp mill will use only those portions of this standard that are applicable. In a similar manner for routine testing only those parts dealing with total solids, suspended and dissolved, correlated with rate of flow, for determination of inorganic and organic materials as mineral filters, fibers, etc., may be used. The complete procedure, however, should serve as an excellent periodic check of routine methods. When checks are made it is recommended that they cover a period of 1 to 2 weeks.

MEASUREMENT OF WHITE-WATER VOLUME

The effluent from each manufacturing unit, such as paper machine, the wet machine room, blow pits, etc., should be kept separate and be led to a suitable outlet from which it discharges through a suitable metering device of either the indicating or integrating type. The preferred method of installing weirs and other metering devices is given in TAPPI Standard E 2 p-40 (Flow Measurements of White Waters and Waste). The average rate of flow can be obtained either by a recorder or by taking readings at 15- or 30-minute intervals 24 hours per day.

The flow of white water can be calculated and reported in terms of tons of production.

Calculation:

$$\frac{\text{gal. per minute} \times 2{,}880{,}000}{\text{net pounds product per 24 hr.}} = \text{gal. of white water discharged per ton of product}$$

SAMPLING OF WHITE WATER

For representative conditions in a white-water outlet, samples should be taken where there is good agitation, such as from a small box receiving the discharge of the metering weir. A composite sample for each 24-hour period should be obtained either by a suitable automatic sampler or by combining portions collected at 15- or 30-minute intervals. Composite sample increments should be taken proportional to the flow and representative of typical conditions. If there are wide fluctuations in rate of flow, particular attention must be given to the measuring device to avoid accumulation of solids during periods of low flow.

The composite sample should be large enough, preferably 5,000 cc. (or about 1.5 gallons) to furnish precision in analysis. Should the sample be likely to decompose before analysis, the addition of a small amount (1 or 2 cc. per liter) of chloroform or other suitable preservatives will protect it. However, with chipboard and similar grades decomposition is very rapid and the sample should be

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[1] Reprinted with permission from *Paper Trade Journal,* 3:34, December 26, 1940. This standard was revised by the Water Committee of the Technical Association of the Pulp and Paper Industry, under the chairmanship of Lewis B. Miller.

analyzed within 2 hours after collection instead of depending on a preservative. In hot weather it may be advantageous to pack such samples in ice immediately after collection and before analysis.

METHOD OF ANALYSIS

(1) Total Suspended Solids

(A) For Paper Machine and Groundwood Mill White Water: Using a rather thick but fast-filtering qualitative filter paper which has been dried to constant weight at 100-105 deg. C., filter a well-mixed composite sample of not less than 2,000 cc. through a 15-cm. Buchner funnel, using suction. (Where large quantities of filler are used, the amount of sample may be reduced.) If this filtrate is cloudy, filter a second time. Take care that none of the suspended solids (filler and fiber) pass over the edge of the filter paper. Wash the residue on the paper with several small portions of distilled water. Remove the paper, wiping off with it any deposit on the filter walls. Dry the filter paper and contents to constant weight at 100-105 deg. C. Do not prolong the drying unnecessarily. Save the filtrate.

For the suggested volume, a balance having a practical sensitivity of 1 mg. is sufficiently accurate. A balance adapted for mounting on a drying oven greatly facilitates this work.

The gain in weight of the filter paper is a measure of the moisture-free total suspended solids present. Calculate it in terms of pounds per 1,000 gallons.

Calculation:

$$\frac{\text{grams of dry suspended solids} \times 8345}{\text{cc. of sample taken}} = \begin{array}{l}\text{pounds of dry total suspended solids}\\ \text{per 1,000 gallons of white water}\end{array}$$

(B) For Sulphite Blow Pits, Sulphate Mill Diffusers, and Similar Wastes: Since the filter paper in the foregoing would retain, in addition to pulp fiber, chemicals and incrustants which cannot properly be regarded as pulp- or paper-making material, it is recommended that a disc of cheesecloth or 200-mesh wire cloth be used. In this case, provision must be made to effect suction filtering by means other than a Buchner funnel. It is not necessary in this instance to obtain suction greater than that produced by the usual handsheet machine. With this exception, the weighing and drying procedure can be followed as above outlined for the use of filter paper. However, only the fiber content is calculated; the filtrate is discarded.

(2) Fixed Suspended Solids

This determination is particularly important in the case of paper-mill white water when fillers are used in the furnish.

Place the filter paper and contents in a previously ignited and weighed porcelain crucible (or other suitable container), carefully burn off the organic matter, and ignite the residue to constant weight. Cool the crucible and contents in a dessicator and weigh on an analytical balance. The weight of the residue minus the weight of the ash in the filter paper is a measure of the fixed suspended solids (largely filler residue). Calculate to pounds per 1,000 gallons of white water.

Calculation:

$$\frac{\text{grams of fixed suspended solids} \times 8345}{\text{cc. of sample taken}} = \begin{array}{l}\text{pounds of fixed suspended solids}\\ \text{per 1,000 gallons of white water}\end{array}$$

NOTE: In mills where fillers are used which decompose on heating, such as carbonates, sulphides, and sulphates, correction must be made, when possible, for the volatilization loss caused by heating.

It must be recognized that fillers such as clay contain a certain amount of absorbed moisture which is driven off by drying at 100 deg. C. Usually they also contain other volatile constituents, such as water of constitution, which are driven off during ignition. By drying samples of the filler constituents present in the specific case at 100-105 deg. C. and subsequently igniting them, factors may be obtained for converting the fixed suspended solids to the moisture-free basis and to the basis as furnished into the beaters.

(3) Volatile Suspended Solids

The moisture-free volatile suspended solids (largely fiber) are obtained by subtracting the fixed suspended solids (item 2) from the total suspended solids (item 1). This may be converted, if desired, to the air-dry basis, as well as to loss per 24 hours and per ton of production.

(4) Total Dissolved Solids

Place an aliquot portion (equivalent to at least one tenth) of the filtrate and washings from item 1 in a beaker and evaporate to about 25 cc. Transfer quantitatively to a previously ignited and weighed platinum or glazed porcelain crucible (platinum is preferable). Evaporate to dryness on a steam bath and dry to constant weight at 100-105 deg. C. (avoid prolonged heating). The residue in the crucible is the moisture-free total dissolved solids. Calculate to pounds per 1,000 gallons.

Calculation:

$$\frac{\text{grams of dry total dissolved solids} \times 8345 \times \text{aliquot factor}}{\text{cc. of original sample}} = \text{pounds of dry total dissolved solids per 1,000 gallons of white water}$$

Note: A part of the total dissolved solids in the white water may originate from the soluble material present in the raw water. The solids introduced into the white water from this source cannot be considered as a loss; therefore a blank determination should be run on a sample of the raw water supply in a manner similar to that given above. Subtracting the blank determination from the total dissolved solids gives the total dissolved solids resulting from furnish.

(5) Fixed Dissolved Solids

Ignite the crucible containing the solids from item 4 to constant weight at about 1,000 deg. C., cool in a dessicator and weigh. The weight of the residue is the fixed dissolved solids. Calculate to pounds per 1,000 gallons.

Calculation:

$$\frac{\text{grams of fixed dissolved solids} \times 8345 \times \text{aliquot factor}}{\text{cc. of original sample}} = \text{pounds of fixed dissolved solids per 1,000 gallons of white water}$$

Part of this value consists of matter originating from the raw water supply which is determined by igniting the crucible containing the moisture-free residue from the blank determination on the raw water supply (see note under item 4).

(6) Volatile Dissolved Solids

Subtract the result of item 5 from item 4 to obtain the volatile dissolved solids.

(7) Biochemical Oxygen Demand (B. O. D.)

All effluents from pulp and paper mills are classified as industrial sewage. As such they usually have a deleterious effect upon the dissolved oxygen content of the receiving stream or body of water. The B. O. D. determination should be run periodically on a sample of water from the trunk sewer or samples from each sewer discharging to the stream. B. O. D. determinations on composite samples from several sewers, mean little and should be discouraged.