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Research and Development

Water Reuse in a Wet Process Hardboard Manufacturing Plant

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WATER REUSE IN A WET PROCESS HARDBOARD MANUFACTURING PLANT

by

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Grant No. S-804306-01

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

Hardboard mills generally discharge large quantities of biological oxygen demand (BOD) causing materials to the receiving waters near where they are located. Biological treatment of these BOD causing materials is only partially effective and is expensive. This report describes how one mill dramatically reduced their BOD and suspended solids discharge by reusing all of their process waters. Other hardboard mills should find the material contained in this report useful to greatly reduce the quantity of BOD causing materials being discharged from their mills.

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PREFACE

With increasing pressure from public concerns, and with local, state, and federal agencies promulgating new and tougher water pollution regulations, a successful manufacturing operation must find methods of economically reducing pollution loads to the environment. The wastes discharged by Superior Fiber Products, Inc., a wet process hardboard manufacturing plant, were colored and carried a high pollution load. This discharge into Superior Bay of Lake Superior was to be stopped or greatly reduced. Superior Fiber's aim was to maintain the quality of Lake Superior.

In searching for ways to reduce the pollution load to Lake Superior, numerous known treatment methods were evaluated both in Superior Fiber's laboratory and in other laboratories. Both biological and physical chemical methods were looked at and plants with interesting processes were visited. All methods evaluated were either economically unfavorable or involved too many unsolved problems. The severe winter climate in Wisconsin posed problems with biological treatment processes which are successful in warmer climates. Because the waste treatment systems investigated were not applicable to Superior Fiber's situation, efforts were focused in the direction of white water (process water) reuse and mill close-up.

All close-up attempts in the past resulted in a severe drop in product quality along with other operational problems. In October of 1974 a totally closed white water system in operation at the Isorel hardboard mill in Casteljaloux, France, was located. Representatives of Superior Fiber Products visited the mill and found the system to be compatible with the requirements of the Superior Fiber mill. On September 5, 1975, an agreement was signed with Isel S.A., a division of Isorel which deals only with the closed white water system, further referred to as the "Isel process", for detailed information on how to go about the close-up and avoid the product quality problems that were experienced in the past.

ABSTRACT

Superior Fiber Products, Inc., a manufacturer of smooth on one side wet process hardboard, undertook a project to eliminate any discharge of process water through a program of increasing the reuse of process water until there was none left to discharge. Before implementation of the process water reuse Superior Fiber was discharging around 757,000 l/day of white water with a BOD_5 loading of 2,710 Kg/day. Today they are discharging about 18,925 l/day with a loading of about 340 Kg/day BOD_5. This residual flow consists of wash water and a small amount of white water leakage from pump seals. Further work will be done to eliminate or reduce this remaining discharge.

White water total solids concentration went from 1% to about 7% when white water was reused. Physical properties of the hardboard were watched closely during the close-up process. Board strength was equal to or better than the strength before closing the system. Water absorption and linear expansion of the board increased after close-up. Close-up of the processes reduced chemical usage, both in the board manufacturing and in wastewater treatment. Production was reduced in the early phases of the close-up due to then unsolved production problems. The stock drained slower. Alteration of the formation line brought production to its normal level. Some of the drawbacks of the closed system are a darker board color and overall reduced cleanliness of the mill. The highly concentrated white water leaves much more residue when spilled or spattered. This report was submitted in fulfillment of grant S-804306-01 by Superior Fiber Products. This report covers a period from 1-23-76 to 7-22-77 and was completed as of 5-12-78.

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ACKNOWLEDGMENTS

The firm of Isel S.A., B.P. 25, 47700 Casteljaloux, France, was instrumental in adoption of the closed system, in project engineering, and in guiding the staff through to completion of the project. Mr. Bernard Marechal, Director, and Mr. Stig Selander, Marketing, are particularly acknowledged with sincere thanks.

The cooperation and assistance of the firm of Eder, Connors and Associates of Long Island, New York, are gratefully acknowledged with particular debt to Mr. Leonard J. Eder.

The success of close-up and ensuing improvement in Lake Superior water quality were achieved in spite of severe technical difficulties. The difficulties proved surmountable with intense effort by engineering and management staff of Superior Fiber Products, Inc. The support of the project by the U.S. Environmental Protection Agency and the help of Mr. Victor Dallons is gratefully acknowledged.

SECTION 1

INTRODUCTION

Superior Fiber Products, Inc., undertook a project to eliminate any discharge of process water through a program of increasing reuse of process water until there was none left to discharge. Reuse of water was predicated by a close watch of the mill water balance and the elimination of all fresh water inputs to the system. Furthermore, to achieve a closed water system in this mill, evaporation of process water was encouraged. Evaporation of process water served two objectives, to remove excess water from the process, and to remove excess heat from the process. Evaporation was encouraged in the cyclone following primary refining by not using a water spray in the cyclone and at the hot press.

SECTION 2

CONCLUSIONS

Based upon eight months of full scale investigations on white water close-up, the following conclusions were drawn.

One hundred percent white water reuse is technically and economically feasible in a wet process S1S mill. Balancing incoming water with water evaporated in the process is a necessity for close-up. Board strength can be maintained or improved when close-up is instigated, although some problems have to be overcome. Less resin is required after close-up so chemical costs are lower. There is no odor problem.

Prior to close-up, white water had a pH ranging between 3.5-4.0. Since close-up it is necessary to maintain a range of 5.0-5.5. Operation at a higher white water concentration resulted in shorter stainless steel plate life due to solids depositing on the plates and the resultant hardboard surface irregularities. When the pH was raised to 5.0-5.5 the deposits formed much more slowly. Stainless steel press plate life is now equivalent to that normal before close-up.

The white water temperature will continue to rise to an intolerable level as process water is reused unless some control is put on it. The main control is at the cyclones. Allowing steam to escape to the atmosphere at the cyclone rather than condensing it into the process water reduces the heat input into the white water system. Heat exchangers are also used to remove heat from the white water.

White water storage capacity must be at least equal to stock storage capacity and must also be kept in reasonable balance. White water dissolved solids concentration will increase as more process water is reused. The final concentration will depend on solubility of raw material, amount of steaming at grinding section, evaporation at press, and fresh water additions to the system. The white water concentration can be controlled quite precisely through metered additions of fresh water when partial close-up is being practiced.

The ratio of total dissolved solids and BOD concentrations to total solids concentrations remains constant. No appreciable increased biological growth or plugging of piping systems occurred from increased white water concentration.

Stock drainage becomes slower as the white water total solids concentration increases. A coarser forming line screen increases drainage upon close-up. This coarser screen also helps in reducing the moisture content of the mat going to the press.

Hardboard production did not decrease significantly because of the closed system.

There are no hidden secrets or totally new techniques in the Isel process and no extra personnel are necessary. Capital and operating costs for the close-up system are lower than for conventional wastewater treatment facilities. Closure of the hardboard mill's water system resulted in additional power requirements for pumps, agitation, filters, etc., but power costs would have increased with conventional biological treatment.

The board color has a tendency to become darker and blotchy looking, but can be controlled by more careful operation of the press and forming line. Much more residue is left from spills, leaks, etc., therefore the plant equipment has to be cleaned more often.

SECTION 3

RECOMMENDATIONS

Eliminating the discharge from a hardboard mill by process water reuse may have several discouraging pitfalls. A hardboard mill desiring to take the closed water system approach to reducing or eliminating their water pollution problems should heed the following recommendations to avoid some of the pitfalls that may be encountered.

Maintain a 100% positive attitude that the closed system will work and the problems experienced can be solved. Strong upper management commitments are a necessity.

Make all employees aware of what you are going to do, how you are going to do it, and why you chose this method. Keep them periodically up-to-date on what is happening, and if any changes are made, make sure the people involved know about it and what to do differently. Mill employees have control of large quantities of water and their cooperation is a necessity in a successful close-up.

Make sure you have a handle on all incoming and outgoing water, installing flow meters where necessary. Keep a daily flow balance sheet.

Make changes slowly and observe results; proceed in a step by step procedure that has been well thought over. Do not close all the valves at once or major problems may occur.

Take maximum advantage of any means of evaporating process water. This does not mean buying evaporators but using your present equipment. It is always much better to have a negative water balance than to have excess water.

Try to maintain forming machine temperature at a maximum of 51°C (125°F). At higher white water temperatures resins set prematurely resulting in board strength losses.

Low white water pH values tends to result in buildup of deposits on the press stainless plates and in boards sticking to the plates in the press. Addition of acid should be decreased as the close-up progresses so as to maintain a pH above 5.0.

A detailed plan of action must be followed and as much pre-testing in the laboratory as possible should be done.

SECTION 4

PROCESS DESCRIPTION AND MODIFICATIONS

Superior Fiber Products, Inc. produces approximately 140 tons/day of hardboard for use in the automotive, television, furniture and construction industries. Located in Superior, Wisconsin, the mill is on the shore of Superior Bay and discharges its wastewater via five settling ponds into this bay.

The hardboard is produced from wood fiber pulped from locally cut aspen logs. The mill production process is classified as a "wet smooth one side (S1S) process" designed to utilize water in the manufacturing system.

PROCESS DESCRIPTION

The production of hardboard basically involves reducing trees to fibers, and reforming these fibers into boards with new properties not available to the raw unprocessed wood. Chemical additives are mixed with the pulp prior to board formation to increase strength, water resistance, and to add other desirable qualities.

The process flow diagram is illustrated in Figure 1. The logs, which are all aspen, are debarked with a rotary ring debarker. The bark, along with hardboard scrap, is burned in a waste fired boiler to produce process steam.

The debarked logs are then sent to the chipper where they are reduced to flat chips about 3/4-inch square. The chips are then fed into chip bins. From the chip bins the chips are fed via a screw feeder to a vertical preheater or cooker where they are steamed by 7.03 Kgf/cm^2 (100 psi) steam for 2-3 minutes. The preheater condenses steam onto the chips. The screw feeder squeezes water out of the chips. This water enters the white water system.

After the preheater, wax is added to the chips which then enter two 600 HP defibrators or primary grinders for reduction to fiber. The fiber is then blown to two cyclones for steam release and cooling. No water is added to these cylones. Almost all other mills add water to the top of the cyclone to prevent bridging and plugging; the added water condenses the steam which causes higher white water temperatures and an additional source of water to the system. Superior Fiber's process permits the maximum amount of steam to escape.

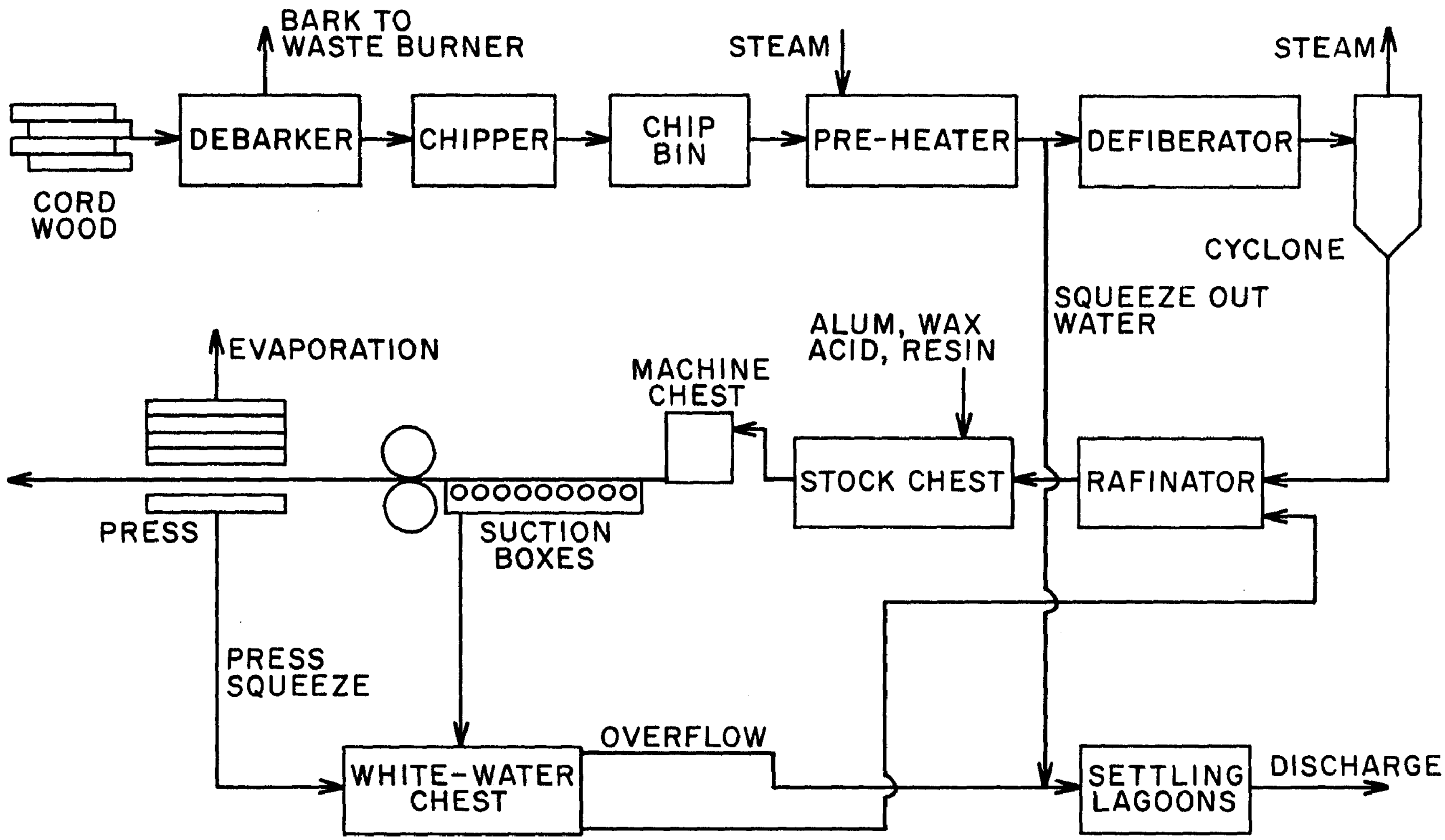

Figure 1. Process flow diagram of existing production facilities.

After the cyclones, white water is added to the fiber to bring the consistency to 10-20% and then is screw fed to two raffinators or secondary grinders for final fiber preparation. At this point white water is added to bring the pulp concentration down to 4% solids. This pulp is then stored in stock chests. Sulfuric acid is added at times to these chests. No alum is used at Superior Fiber Corporation. When the pulp is removed from the stock chest more white water is added to bring the consistency to between 2.0-2.5%.

The stock, with phenolic resin added, is sent to the forming machine where the fiber is laid down in mat form. Water is sequentially removed from the mat by gravity, suction, and pressure, and is returned to the white water system. The mat (wet-lap) is then trimmed and sent to the press.

The moisture content is still about 65-70% (total weight basis) prior to pressing. The press, operating under high temperature and pressure , squeezes out water until the wet-lap is about 45% moisture. This remaining moisture is then evaporated during pressing. When the board is dry, it is removed from the press and sent on for humidification and finishing which are both water free operations.

PROCESS DATES

Superior Fiber has gone through a long process in reducing the pollution load to Lake Superior. Listed below is the sequence of events that led to the implementation of a no discharge process.

February 21, 1968, D.N.R. issued order #1-68-27 requiring that Superior Fiber Products process water be treated to meet state water quality standards by October 1, 1970.

August 14, 1969, advised the Mayor of the City of Superior that joint municipal treatment was not in the best interests of the company.

January 1970, separation of all cooling waters from process waters.

June 1970, visited plants in Finland and Sweden to investigate water treatment methods.

July 1970, forming line spray water system completely recycled.

July 15, 1972, the Company entered into a stipulation agreement with the State D.N.R. requiring 85% BOD removal by December 1, 1974, with interim dates.

August 18, 1972, State D.N.R. approved plans of waste treatment facility. Completion date moved to August 1, 1973, with 60% BOD removal, 90% suspended solids.

May 1973, met August 1st requirements by debarking, polymer addition, and some close-up.

September 28, 1973, EPA issued NPDES permit number WI 0002798 to Superior Fiber.

July 1975, plans and specifications sent to State D.N.R. outlining how we would meet the EPA permit by close-up. The plans were accepted.

September 1975, Superior Fiber entered into agreement with Isel to close-up the process water system.

November 1975, applied for $100,000 grant from EPA. Grant approved early in 1976.

Each step resulted in some reduction of waste loads discharged to Lake Superior. Table 1 lists the chronological waste load reduction.

TABLE 1. CHRONOLOGICAL WASTE LOAD REDUCTION(1)

Date	Method	Kg/day	(BOD_5 #/day)	Kg/day	(SS #/day)
4-1-72	Existing	20,350	(44,865)	9650	(21,278)
6-20-72	Reduce chip cook close-up lagoon upgrading	13,150	(29,000)	3630	(8,000)
8-30-72	Debarking	8,160	(18,000)	1360	(3,000)
11-30-72	Polymer	4,080	(9,000)	450	(1,000)
5-30-73	More close-up	2,890	(6,380)	285	(630)
7-1-77	Isel		(550)	61	(135)

MILL MODIFICATIONS

To attain a no discharge mill, modifications of the process equipment were required. Some of these modifications were to allow greater control of the mill water balance, while others were made to maintain the product quality. These modifications are discussed below.

Pulping Section

Digester Feed Screw--

The digester is a steaming vessel used before the pulping section which softens the chips for grinding. This steaming vessel is capable of operating between 5.62-10.55 Kgf/cm^2 (80-150 psi) steam pressure, but is maintained at 7.03 Kgf/cm^2 (100 psi). In order to maintain the pressure in the vessel the chips enter as a continuous plug formed by a screw feeder. As the chips are compressed, wood water is squeezed out. This water discharge varies with the wood moisture content, anywhere from 0 to 34 l/min (0 to 9 gal/min). This water has a BOD_5 average of 13,000 ppm and passes over a side mill filter to remove shives and chips before entering the white water system. Previously the screw water went to the discharge without any screening.

Cyclone--

Before adding the cyclones, Superior Fiber used both pressurized primary and secondary refining with no steam escape. Water was added to the pulp between the primary and secondary refiners to control the consistency in the secondary refiners. This water addition would condense the steam into the pulp resulting in an addition of both heat and water to the process. The condensing steam added approximately 75,700 liters (20,000 gal) per day of water to the system).

Installation of the cyclones has reduced the white water temperature by 11-17°C (20-30°F) and has resulted in not only the release of the 75,700 liters (20,000 gal) per day of steam added to the preheaters, but also in an additional 13,250 liters (3,500 gal) per day of water entering the system as wood moisture.

These cylones are a very important part of the closed system. The principle of operation is that the fibers enter the top of the cyclone and immediately create a vortex. The fiber follows the cyclone wall downward to the bottom. The steam meanwhile is separating from the fiber and escapes out the top of the cyclone. Immediately after the fiber falls out the bottom of the cyclone, water is introduced and the resulting pulp is then transported by screw conveyor to the secondary grinders as shown in Figure 2.

It is very important that the cyclone and cyclone exhaust pipes be kept clean of fiber build-up. They are cleaned at least every two weeks.

Main Shaft Sealing Waters--

Fresh water used on the packing seals on primary grinders was replaced with steam. Savings accrued is of about 7570 liters (2,000 gal) per day per machine. Fresh water was completely shut off on the secondary grinders reducing water usage by an additional 7570 liters (2,000 gal) per day.

Miscellaneous--

Steam flow indicators were added to the preheaters to measure amount of steam being added so that steam use could be minimized. Stock temperature indicators were also added after secondary grinding consistency. The overall grinding procedure was modified to optimize the cyclone efficiency and temperature control. All the power possible was applied before the cyclones to further heat the stock, thereby enabling more evaporation in the cyclones.

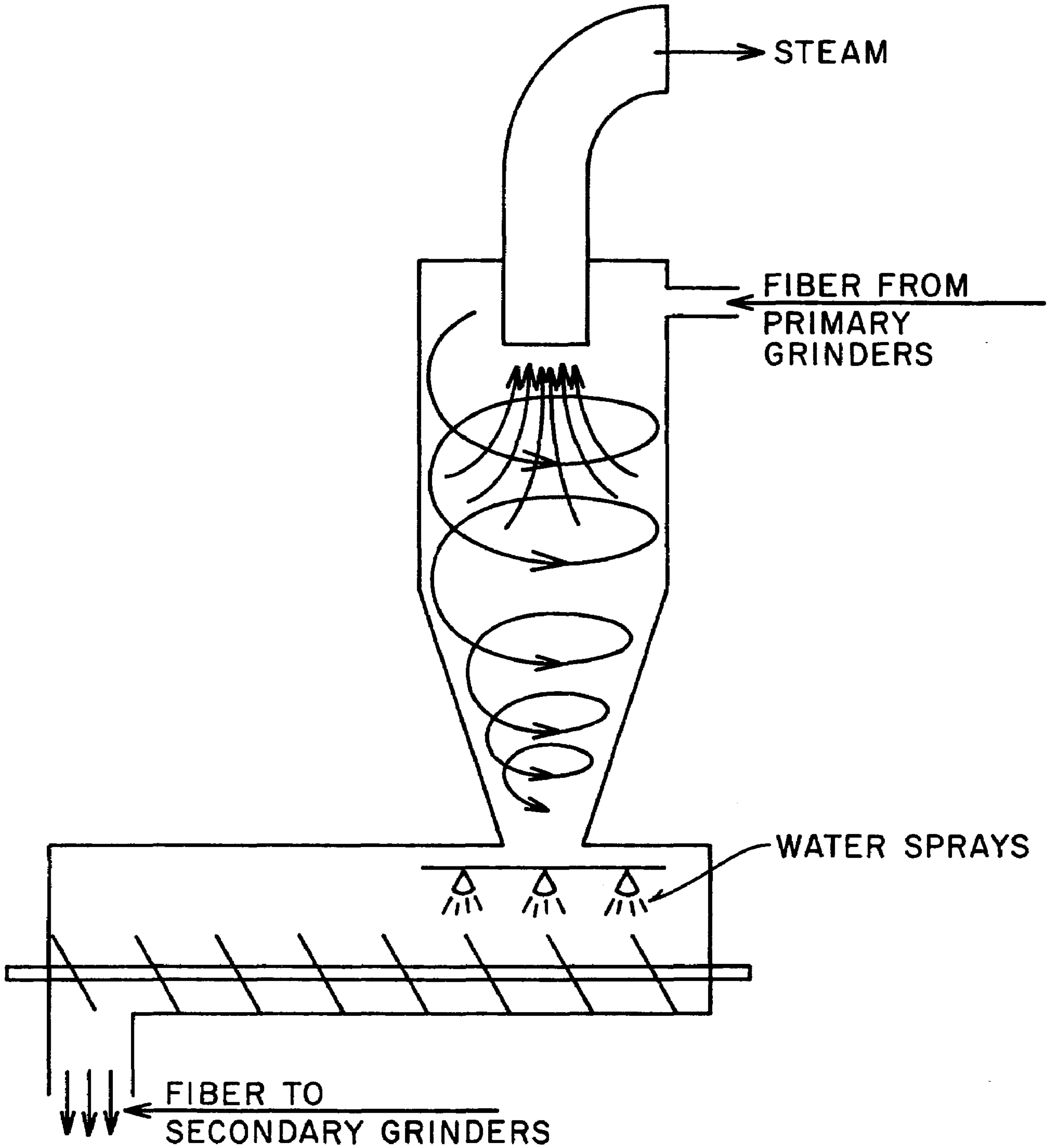

Figure 2. Diagram of cyclone to remove steam from fiber.

Forming Section

Forming Machine Screen Cleaning--

Screen sprays were mostly eliminated by use of a vacuum screen cleaning arrangement. The vacuum system was chosen over white water sprays because it is more efficient.

Forming Machine Screen--

The screen open area had to be increased from 25% open to about 50% open to facilitate the slower draining stock.

Machine Cleaning--

The forming machine was previously cleaned with low pressure high volume fresh water but has been changed to high pressure low volume fresh water.

Vacuum Boxes--

The forming line vacuum dewatering previously consisted of moving "rotobelts" over vacuum boxes. Fresh water was used to lubricate the rotobelts. These rotobelts have since been removed and replaced with stationary perforated plastic tops which need no water for lubrication and last longer.

White Water and Stock Systems

Three additional vats of 75,700 liters (20,000 gal) apiece were added to the white water system. This gives the mill a total of five white water vats and four stock vats. The storage capacity is necessary to avoid white water overflows due to unbalanced conditions between the grinding section and forming line. Agitators were installed in all white water vats to prevent settling out of solids. Level indicators were installed in all vats including stock vats to assist operators in preventing overflows.

Stock and White Water Pumps--

Fresh sealing water has been shut off on many pumps. These pumps now run with no sealing water, permitting water savings amounting to approximately 18,900 liters (5,000 gallons) per day.

Hot Press Section

Hot Press Squeeze Out Water--

This water was discharged directly to the lagoons but is now pumped back to the white water system after passing through an oil skimmer and down hill screen to remove large pieces.

Transport Screens--

Transport screens are now cleaned and changed every eight hours where before they were cleaned and changed every twenty-four hours.

Press Cleaning--

A high pressure pump has been purchased to keep the press clean. With the closed water system the residue from evaporation builds up much more rapidly than with an open system. The previous method of cleaning, which was scraping the press about every thirty days, was not sufficient. A high pressure water spray is now used and cleaning is done once a day.

Press Operations--

Experience has shown it to be necessary to reduce press temperature from about 204°C (400 °F) to 196°C (385°F). The temperature reduction was required to avoid discoloration and sticking in the press. As a result press cycles are a little longer. The press pressures have not been affected.

Miscellaneous

Water Sampling and Recording--

Before the close-up, wastewater samples were composited proportional to flow only at the lagoon discharge to Superior Bay. In addition to the lagoon effluent sample, composite samples are now taken of total mill discharge to the lagoons and of the white water system. Prior to close-up, flow was recorded only at the lagoon discharge to the bay, but no additional white water overflows nor total mill discharge to the lagoons were recorded. All flows were measured over 90 degree V notch weirs.

Lagoons--

Prior to close-up, five lagoons were used with a total volume of around five million gallons. Use of three lagoons has been discontinued leaving a total volume of around one and one-half million gallons. Eventually the remaining lagoons may be eliminated altogether. The three lagoons were filled to prevent possible odor problems in the future caused by the excessively long detention time, as well as for aesthetic reasons.

Debarking--

Tighter controls were put on bark removal to prevent the white water total solids concentration from becoming too high.

Phenolic Resin--

The resin addition point was changed from the defibrator section to the forming line area. Mill trials showed that addition of resin closer to the formation line improved the board strength. The resin was also diluted 3:1 with water before close-up, but it is now used as is (42% solids).

Sulfuric Acid--

Addition of sulfuric acid to the process was discontinued after close-up.

Polymer--

Polymer addition to the effluent prior to the settling lagoons to settle waste waters, suspended, and colloidal matter has been discontinued.

WATER BALANCE

In order to achieve no discharge, the water balance was carefully controlled. All unnecessary water additions were eliminated and process water was used in place of fresh water wherever possible. When this high degree of water control had been achieved, the major sources of water input to the process were to the water contained in the wood and the water put into the system as steam. Other fresh water uses were minimal. Table 2 shows the water input to the system.

Removal of water from the system by evaporation is very important. There is more water entering the system in the wood than there is in the product. Wood moisture is around 50% total weight basis while the hardboard leaves the process bone dry. All the water entering the system in the wood plus all the miscellaneous water additions must be evaporated from the system to achieve a zero discharge.

Evaporation takes place at two major points, at the cyclone and at the hot press. Table 2 shows how much water leaves the process at what location. When the press closes, about 57% of the water is squeezed from the mat. The water remaining in the mat is evaporated. The amount of water evaporated in the hot press is less than the amount of water coming into the process in the wood. There the amount of water being evaporated at the cyclone must be greater than the amount of steam added to the process. This extra evaporation of water at the cyclone is effected by utilizing the energy put into the primary refiner to evaporate wood water at the cyclone. Figure 3 shows the water and energy balance for the mill.

When the amount of water being evaporated in the process is the same as the water input to the process, there is no discharge.

TABLE 2. MILL WATER BALANCE

Source	Water Input Kl/KKg Board	Water Input Gal/Ton	Exit	Water Out. Kl/KKg Board	Water Out. Gal/Ton
Wood water	0.80	193	Cyclone evap.	0.60	143
Steam condensate	0.45	107	Press evap.	0.79	189
Pump sealing	0.06	14.3	Pump leaks	0.03	7.1
Wet-lap saws	0.12	28.6	Misc. evap.	0.03	7.1
Resin	0.01	2.1			
Misc.	0.01	1.4			
Total	1.45	346.4		1.45	346.2

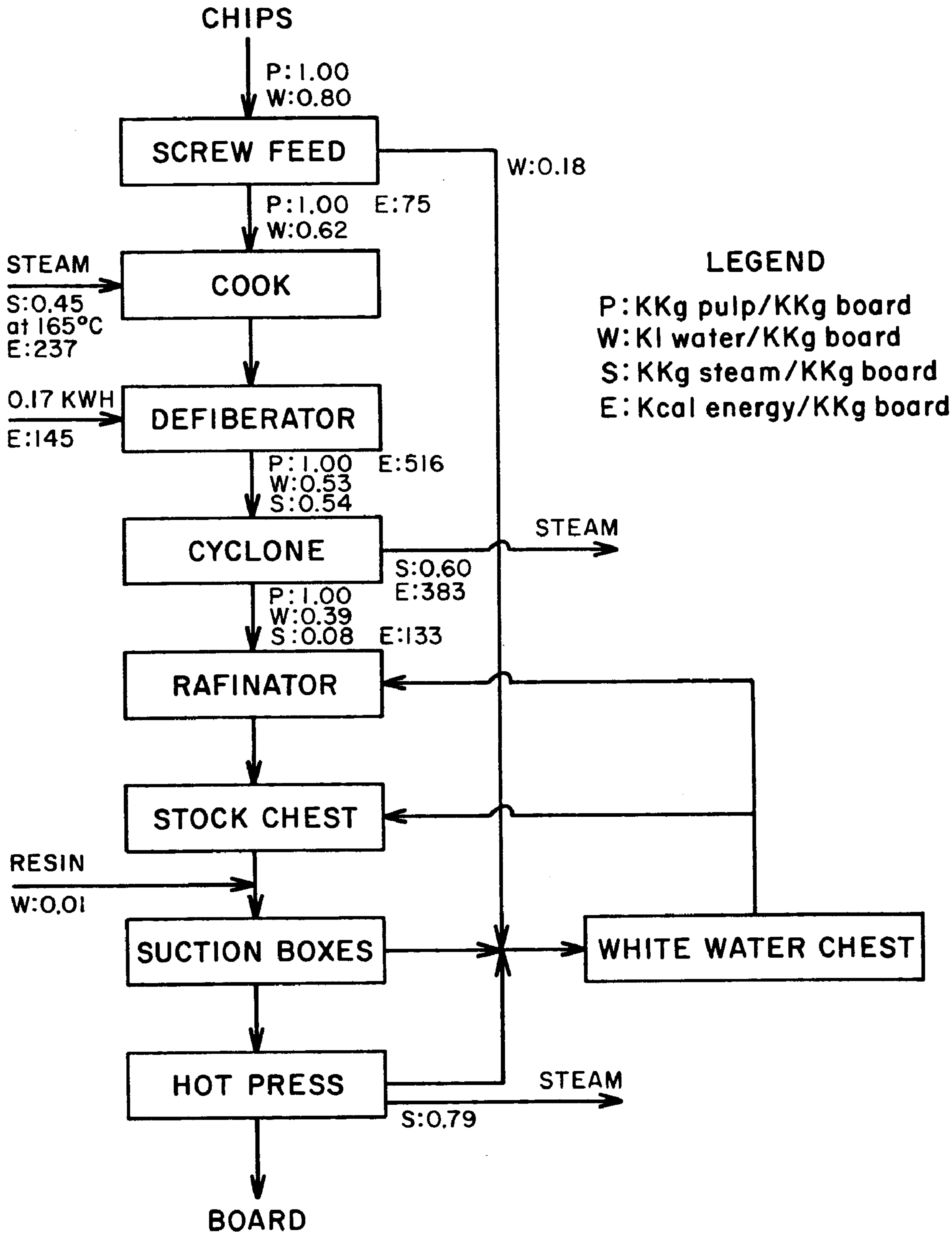

Figure 3. Process flow diagram and water balance for a totally closed system.

COST COMPARISONS

Capital costs for a conventional biological treatment system were estimated to be about $608,600 in July 1975, by Leonard J. Eder Engineers (1). The system consisted of a primary settling lagoon, followed by an aerated lagoon, followed by a final settling lagoon. The system was designed to handle 938,800 l/day (248,000 gal/day) or about 7.45 l/KKg (1772 gal/Ton) production.

The cost of the totally closed water system as of May 1977 was $620,644. This cost includes a $111,500 contract to Isel Corp. of France for information on how to set up and operate a closed cycle hardboard mill. The itemized costs are listed in Table 3.

TABLE 3. ITEMIZED COST FOR THE CLOSED WATER SYSTEM

Item	Cost
Equipment	$285,136
Installation labor (including fringes)	125,273
Isel	115,000
Installation (outside contractors)	82,114
Supplies	13,121
Total	$620,644
Grant	-$100,000
Net	$520,644

The estimated costs for each piece of equipment installed are listed in Table 4.

Annual operating costs for conventional treatment would have been about $60,300. We estimate annual operating costs for the Isel system to be: Power, $2,000; Maintenance, $3,000; Supplies, $1,000; and Chemicals for cleaning, $3,000; or a total of $9,000.

TABLE 4. INTERNAL PROCESS EQUIPMENT FOR ZERO DISCHARGE

Item	Description	Estimate Cost
1	Cyclones (2)	$ 40,000
2	White water chests	25,000
3	Agitators	20,000
4	White water pumps	35,000
5	Piping	40,000
6	Drum screens	40,000
7	Instruments and control equipment	30,000
8	Spray cutting arrangements	20,000
9	Contingencies	25,000
		$275,000

SECTION 5

EFFECTS OF CLOSURE ON THE PROCESS AND PRODUCT QUALITY

As water reuse is increased in a hardboard mill, water properties are changed. These changes in white water properties result in changes in product quality and production methods. A close record of the changes in white water characteristics and the hardboard quality were kept. Problems in production and board quality, and their solutions, were related to white water properties.

WHITE WATER CHARACTERISTICS

Sampling

Samples from the white water system are taken from a common in-line water valve. They are taken twice every eight hours and are composited daily. These samples are then stored at 35-40°F in a refrigerator until testing. Some tests require grab samples and immediate testing.

All testing is done in accordance with the applicable procedure set forth in "Standard Methods" 13th Edition (3).

Discharge Flow--

All discharges out of the white water system are metered over a 90 degree V-notch weir with a Leopold-Stevens level recorder. The system is designed so that any overflow from the white water system will always overflow from the same vat. On occasions, certain systems have malfunctioned causing discharges other than the normal vat overflow. These accidental discharges are then recorded by another 90 degree V-notch weir and level recorder. This weir measures total mill discharge just before it is pumped to the lagoons. Samples are also taken proportional to flow there.

Total Solids--

Total solids is tested every four hours. This test provides data used as an indicator on close-up performance. The reason total solids was chosen instead of the more commonly used dissolved solids is that it is faster and easier. There is a good correlation between total solids and dissolved solids (Figure 4).

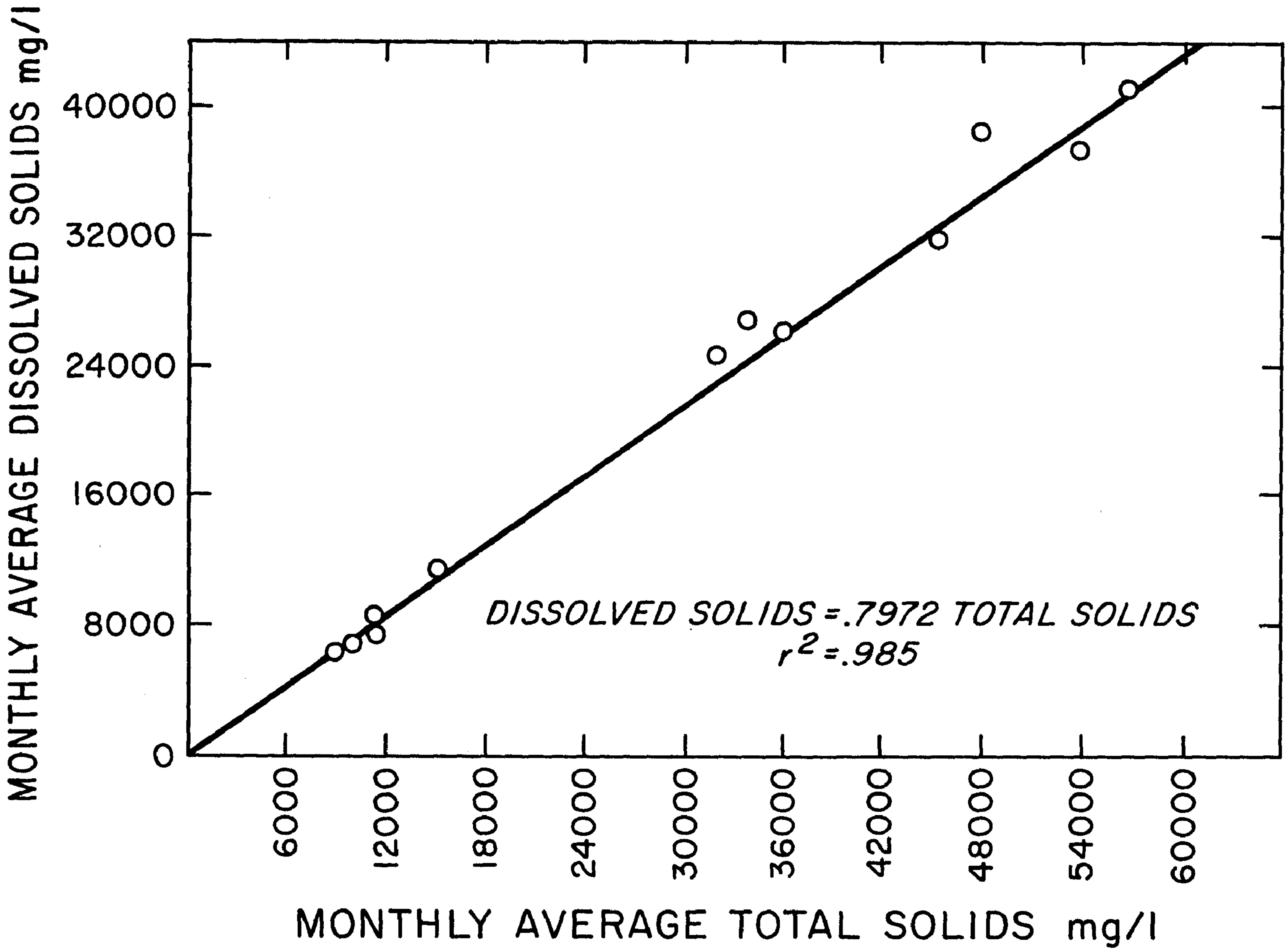

Figure 4. Correlation between monthly average total solids and monthly average dissolved solids.

Dissolved Solids--

The dissolved solids of the white water is tested every 24 hours. Many of the operating and board quality problems can be related to the white water dissolved solids.

Suspended Solids--

The suspended solids of the white water is tested every 24 hours. The white water suspended solids concentration is closely related to the total solids concentration as shown in Figure 5.

Other Parameters--

The biochemical oxygen demand of the white water is monitored every 24 hours and the pH is monitored continuously. Total acidity is tested every 4 hours. The white water temperature is monitored continuously.

Parameters Affecting White Water Properties

Extraneous Factors--

Numerous factors, other than increased process water reuse, can affect the properties of white water. Some of these factors are discussed below.

White water temperature--A high white water temperature will tend to dissolve more soluble material from the pulp, resulting in a slightly higher white water concentration. A lab test has shown that a 8.3°C (15 °F) rise in stock temperature will give a 0.5% increase in white water concentration in one hour. This test was performed on stock with a high white water total solids concentration (8%) to start with; therefore, white water temperature might have a more dramatic effect at lower concentration levels.

Cooking Time--Cooking time is the length of time chips are subject to steam pressure in the vertical preheater. Longer cooking times result in more solids being dissolved out of the wood. The cooking time is maintained by adjusting chip level in the preheater to correspond with different speeds of the grinders. Cook time is held constant at about 2.5 minutes and, therefore, does not tend to vary white water concentration.

Cooking Pressure--Changes in the preheater steam pressure will vary white water dissolved solids concentration. Higher pressures result in more solids being dissolved from the wood. Continuous pressure of 7.03 Kgf/cm^2 (100 psig) is maintained; therefore, this factor is not a variable in the system.

Bark Content--The amount of bark that enters the system could also have an effect on white water concentration. Bark is more soluble than wood. Higher bark content in the raw material would result in a higher white water total solids concentration. All logs are debarked and a maximum of 1.5% bark is allowed in the chips. This variable is controlled efficiently.

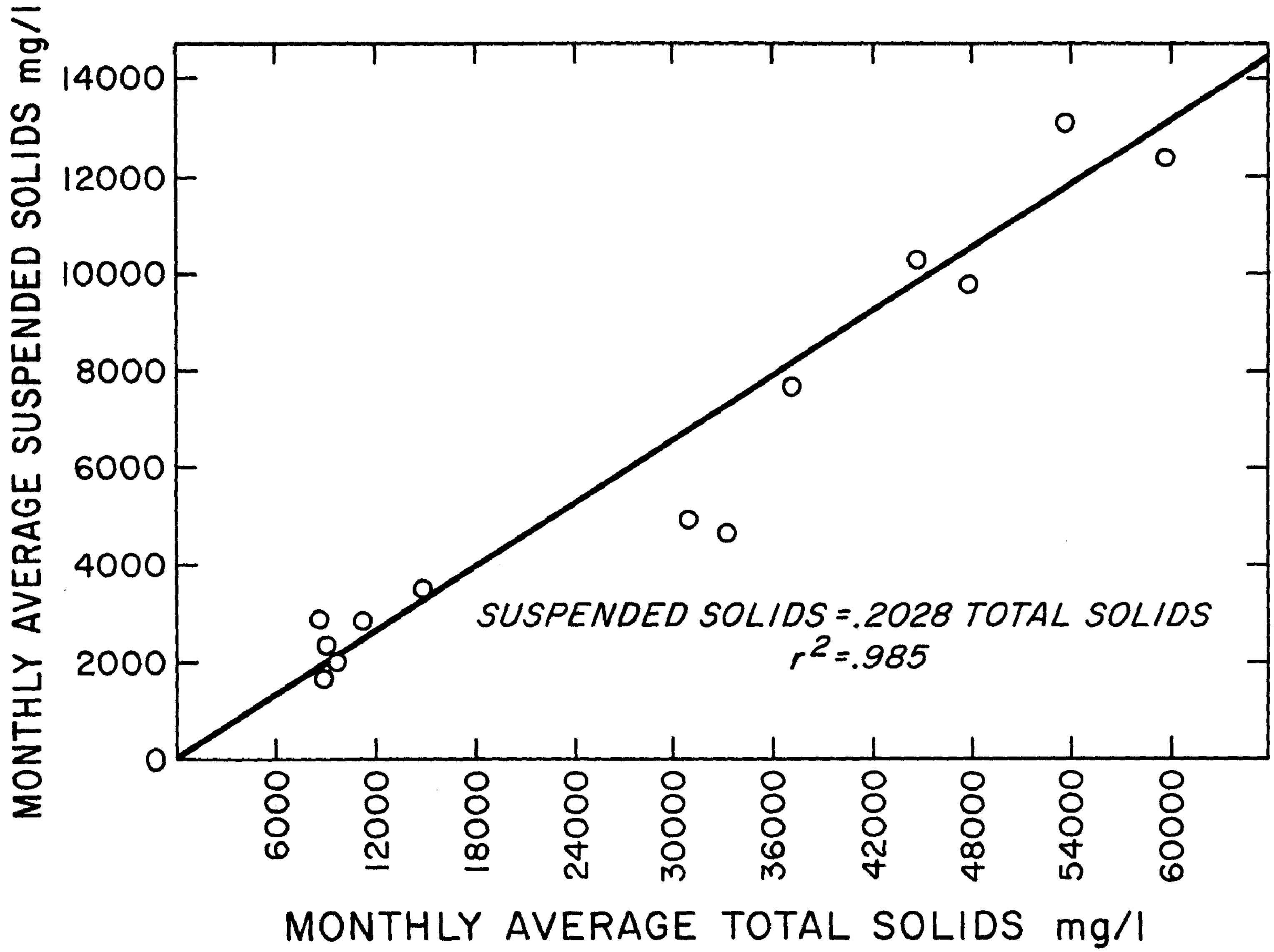

Figure 5. Correlation between monthly average total solids and monthly average suspended solids.

Cyclone Steam Removal Efficiency--The ability of the cyclone to remove steam from the pulp affects the temperature of the white water. Greater steam removal at the cyclone results in less steam condensing into the white water and, hence, less heat addition to the process and lower process temperatures.

EFFECTS OF PROCESS WATER REUSE ON WHITE WATER PROPERTIES

Increasing the reuse of white water and press pit water changes the properties of the white water. To follow the changes in white water properties and any possible product quality or operational problems, the amount of water reuse was increased slowly, in steps. To maintain a steady reference, the white water total solids was controlled by the addition of fresh water. For example, total solids of 2.0%-2.5% were run for two to four weeks and then raised to 2.5%-3.0%, etc. This procedure has performed efficiently. Reduction of fresh water additions reduced the quantity of water discharged. The parameters discussed below are in terms of the amount of water discharged from the mill.

Dissolved Solids

Figure 6 shows that when the quantity of water discharged is smaller, the concentration of dissolved solids is larger. The concentration of dissolved solids in the whitewwater and effluent increases rapidly when the last bit of discharge is eliminated.

Suspended Solids

As less water was discharged, the concentration of suspended solids in the white water remained constant at about 0.3% until less than 1.0 Kl/KKg water was discharged. At less than 1.0 Kl/KKg discharge, the dissolved solids concentration rose rapidly to 1.3% dissolved solids at zero discharge as shown in Figure 7.

Biochemical Oxygen Demand (BOD)

The BOD_5 of the white water has continued to climb along with white water solids. Figure 8 illustrates this steady climb in terms of the quantity of discharge. BOD concentrations have increased about tenfold as the amount of discharge was decreased.

White Water pH

Two conditions exist which contribute to the acidic nature of the white water. The first is the hydrolysis of acetyl groups present in the wood furnish which causes the formation of acetic acid during the preheating of the chips. This source of acid or hydrogen ions is relatively constant because of debarked aspen chips and uniform cooking time. The other source is the addition of sulfuric acid to the process to precipitate the phenolic resin. Sulfuric acid usage was reduced as the amount of recycle was increased and was discontinued in the last two months of the study. Before close-up, the pH was between 3.5 and 4.0. Today a pH between 5.0 and 5.5 is maintained, although at times it has gone as high as 6.2. In the past, management felt that good strong hardboard could never be made at such a high pH. Figure 9 illustrates white water pH for the last year.

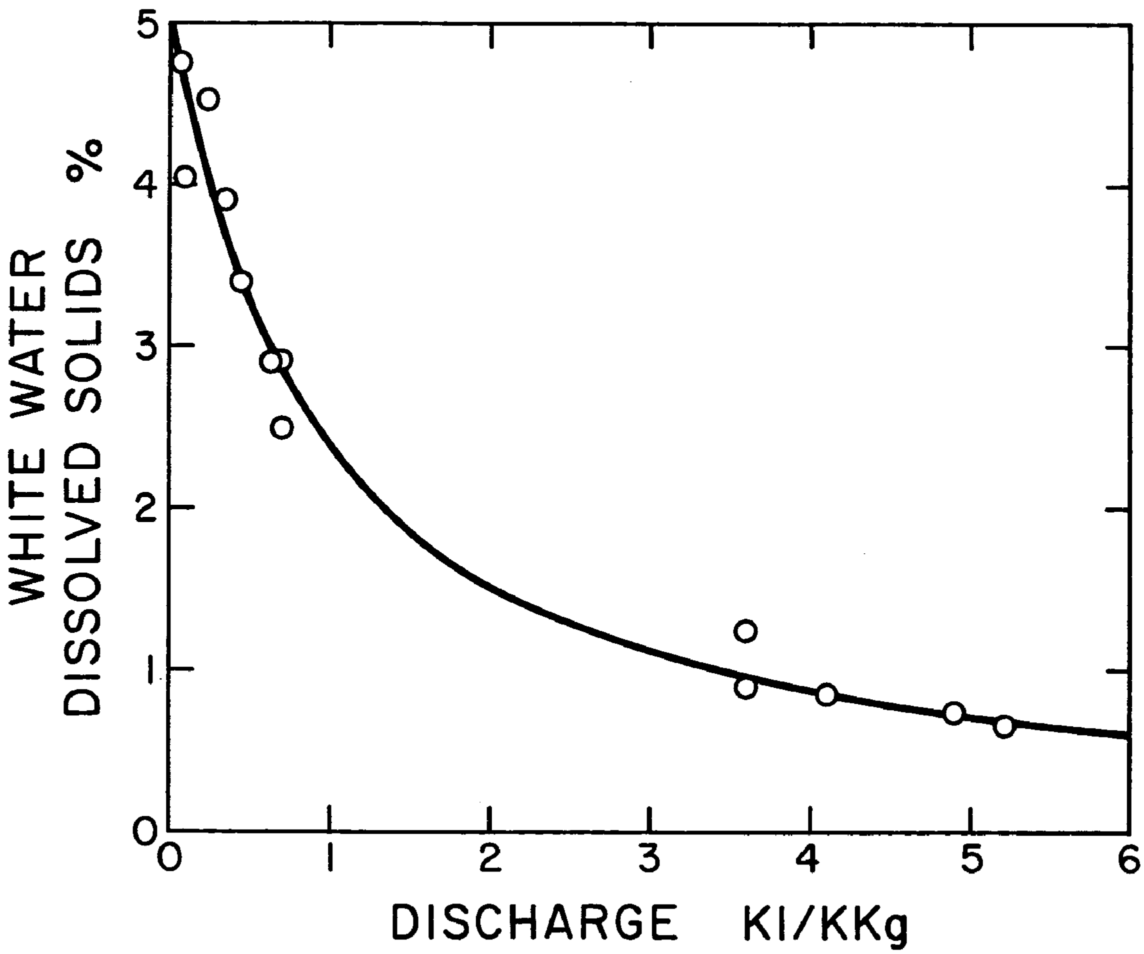

Figure 6. Percent dissolved solids in the white water as a function of the discharge flow.

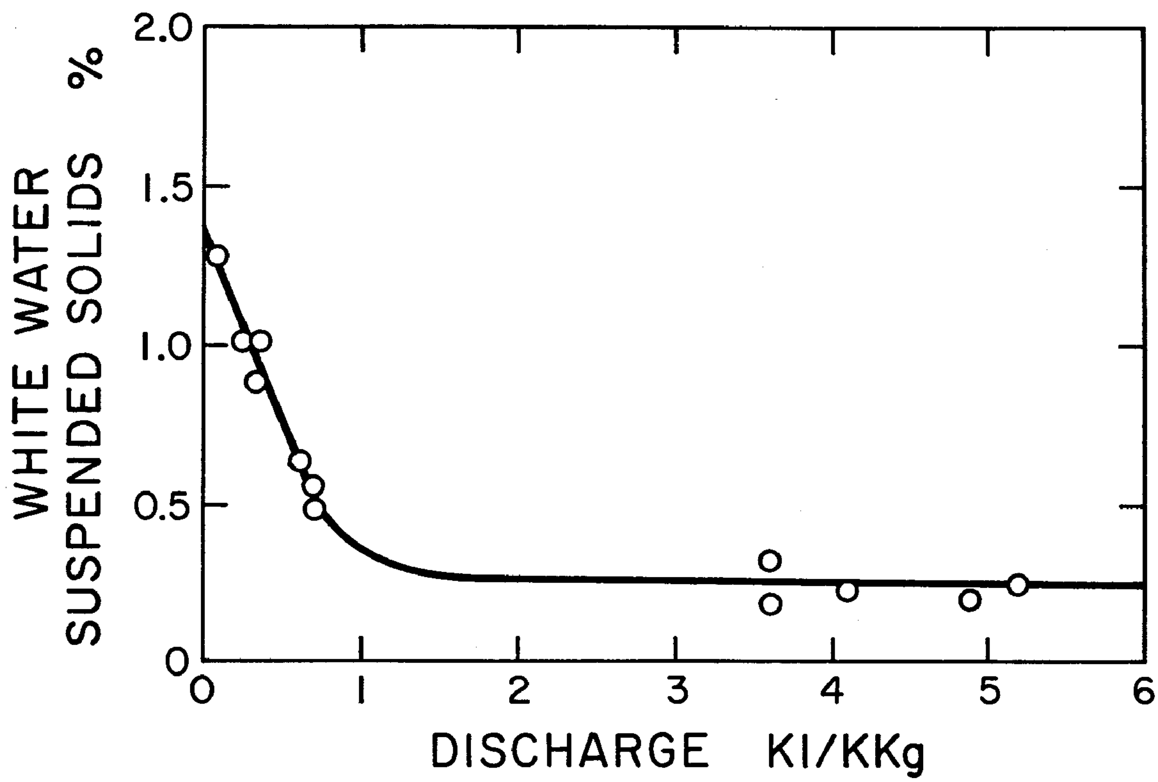

Figure 7. Percent suspended solids in the white water as a function of the discharge flow.

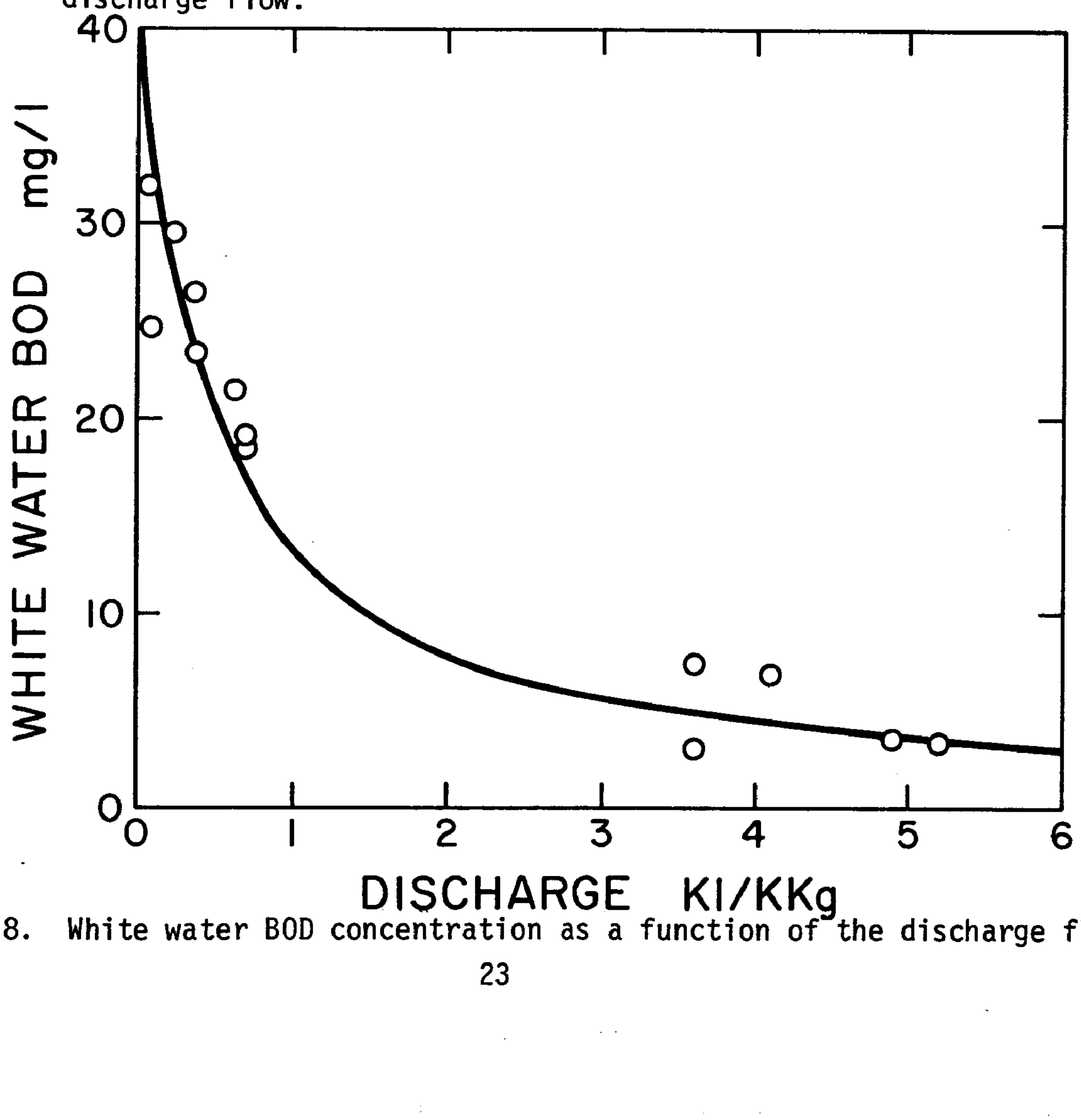

Figure 8. White water BOD concentration as a function of the discharge flow.

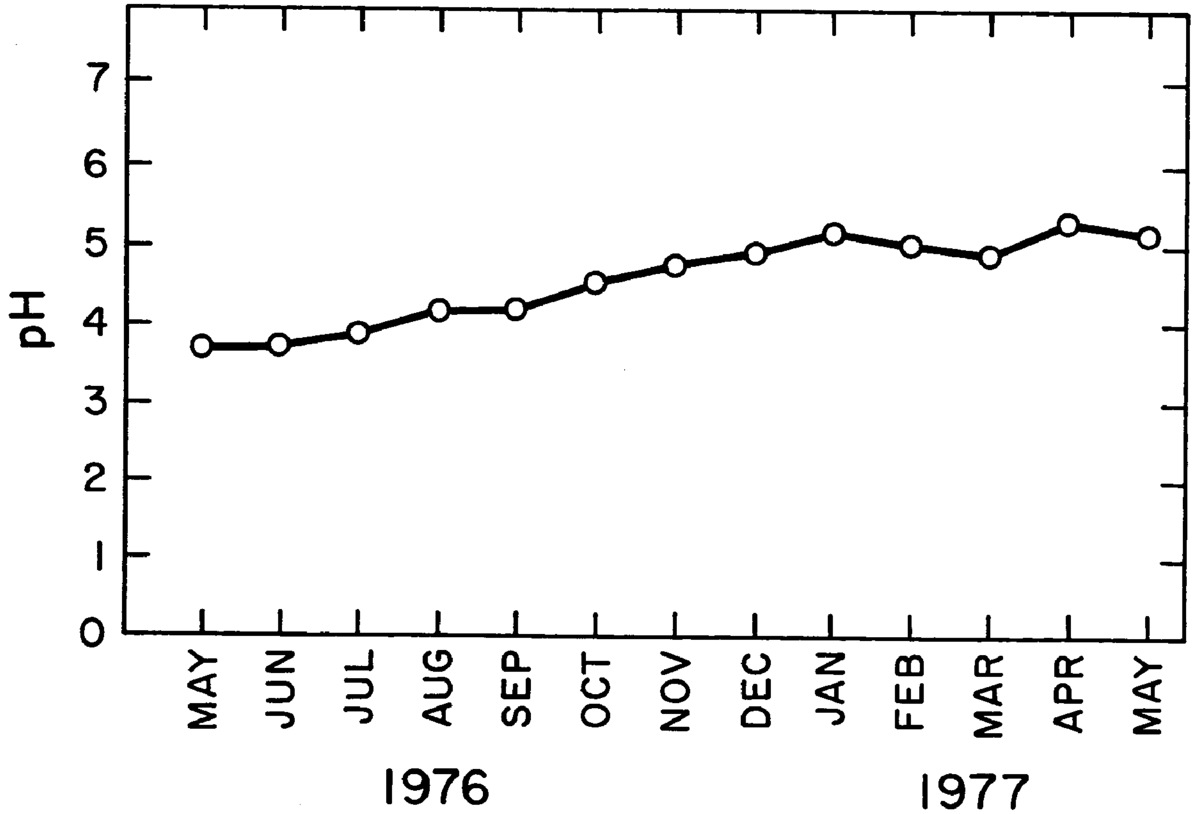

Figure 9. Average white water pH.

Total Acidity

There seems to be no definite trend in total acidity as the effluent is decreased, as illustrated by Figure 10. What can be seen is that it varied considerably when sulfuric acid was used, but has since leveled off and slowly climbed along with other parameters.

White Water Temperature

As the quantity of water discharged decreases, the quantity of heat that accompanies it decreases. Heat continues to be added to the stock due to the cooking and refining of the chips. This results in an increase in the temperature of the stock unless the temperature is controlled.

In this system stock temperature is controlled basically three ways. One way is to add fresh water to the system to cool it; however, with a closed system this method is not available. Another way is with the heat exchanger in which white water is cooled with bay water. This exchanger has been running at capacity so there is no added help there. The last and most important control for use in a closed system is regulation of the amount of heat entering the white water system from the grinding section. Much of the heat released from the grinding section is contained in the steam escaping from the cyclone. When this steam is condensed by water addition to the cyclone or refiners, as was done prior to the system close-up, the heat is added directly to the white water. The amount of steam passing from the grinding section to the white water is carefully controlled. More steam passage results in higher white water temperature. This steam entering the white water system is controlled by the blow-valve (the valve which passes the fiber from the pressurized primary grinder to the cyclone) and the cyclone efficiency. This means optimum conditions must be kept at the grinding section along with clean cyclones. If not, too much steam will condense into the white water and the temperature will climb. Figure 11 shows the stock temperature throughout the recycle effort.

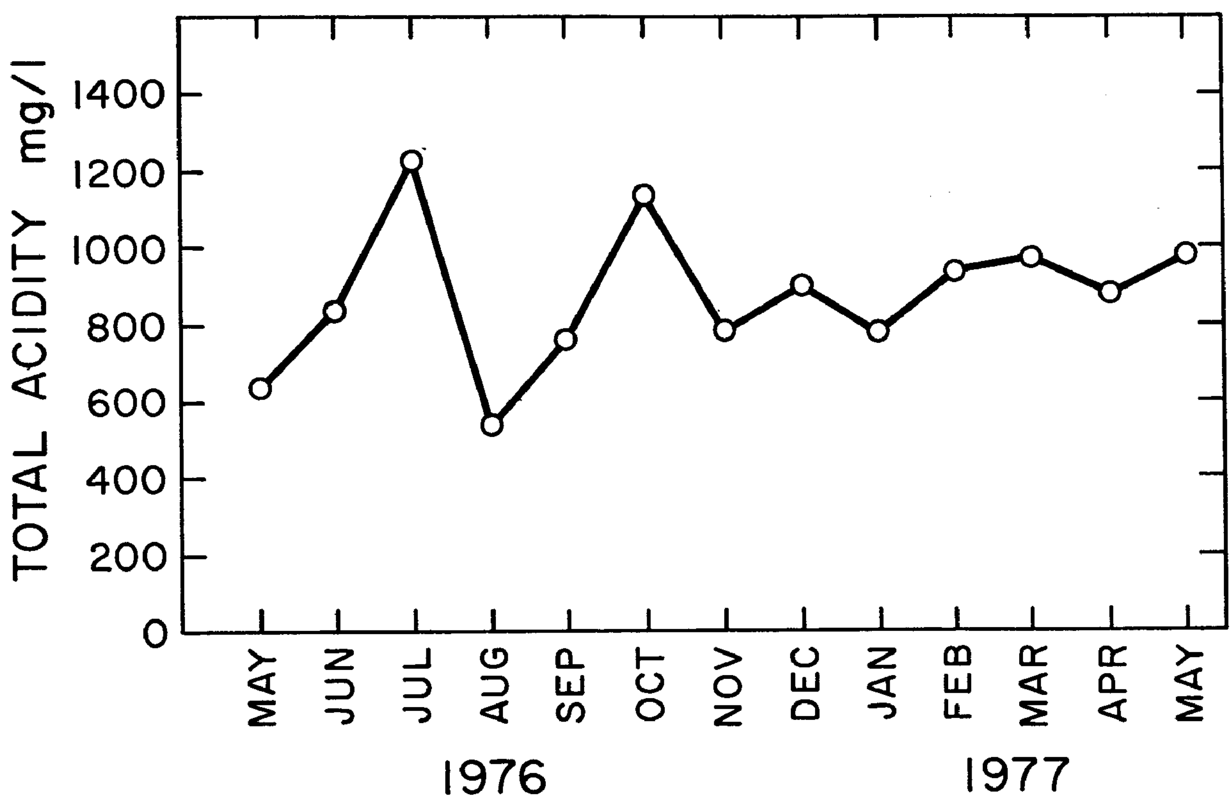

Figure 10. Average white water total acidity.

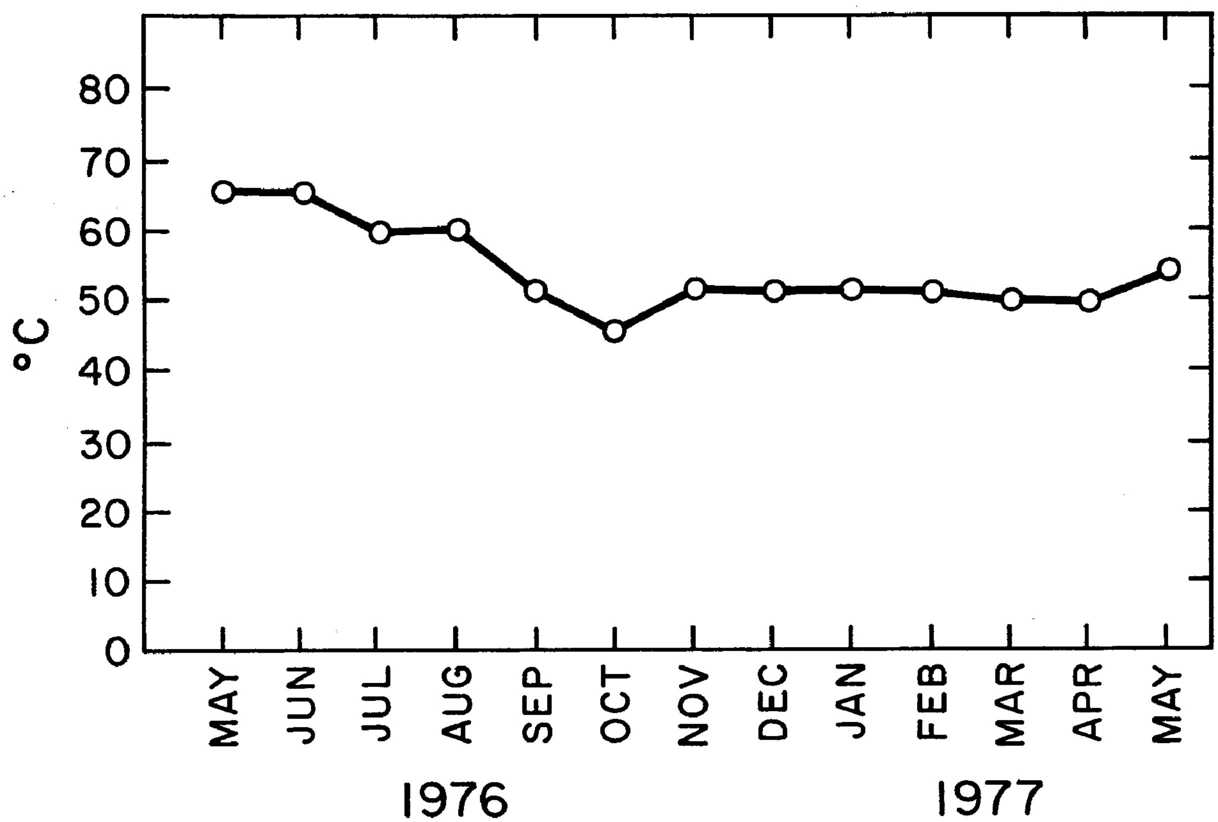

Figure 11. Average temperature of slurry.

SECTION 6

RESULTS AND DISCUSSION

PRODUCT QUALITY

Strength Properties

One of the major questions dealt with before deciding to use the Isel system concerned board strength. In all previous close-up attempts, serious strength problems appeared. Other industry and research leaders also doubted if high strength standards could be met with high white water dissolved solids concentration as characteristic of the closed system. The Isorel Mill in France has somewhat lower strength standards than are customary here. They also heat treat all their hardboard to give strength, a process which is not practiced by Superior Fiber. They even had to add phenolic resin to some of their more critical boards to get the required strength. After many discussions with Isel, they convinced Superior Fiber that if strength problems occurred, available technology could provide ready solutions. After eight months of close-up experience and with a white water total solids concentration of up to 8.5%, strengths are running slightly better than before close-up.

Modules of Rupture--

Modules of Rupture of (MOR) is the strength property most used. It is tested every two hours in accordance with the applicable test in Part B of American Society for Testing and Materials (ASTM) D 1037-72a, (a) Standard Methods of Evaluating the Properties of Wood - Base Fiber and Particle Panel Materials. It is also referred to as bending strength. As stated earlier in this report, the MOR has been equal to or slightly better than before the close-up (Figure 12).

Phenolic Resin--

Phenol-formaldehyde resin, more often called phenolic resin, is used in the manufacturing of hardboard to impart added strength to the finished board. Superior Fiber uses anywhere from 0.5% to 1.5% resin (dry on dry) depending on the type of product. When strength problems occur, resin usage normally is increased; therefore, resin usage is a good indicator of strength properties. Figure 13 illustrates resin usage equal to or slightly less than before, after the close-up.

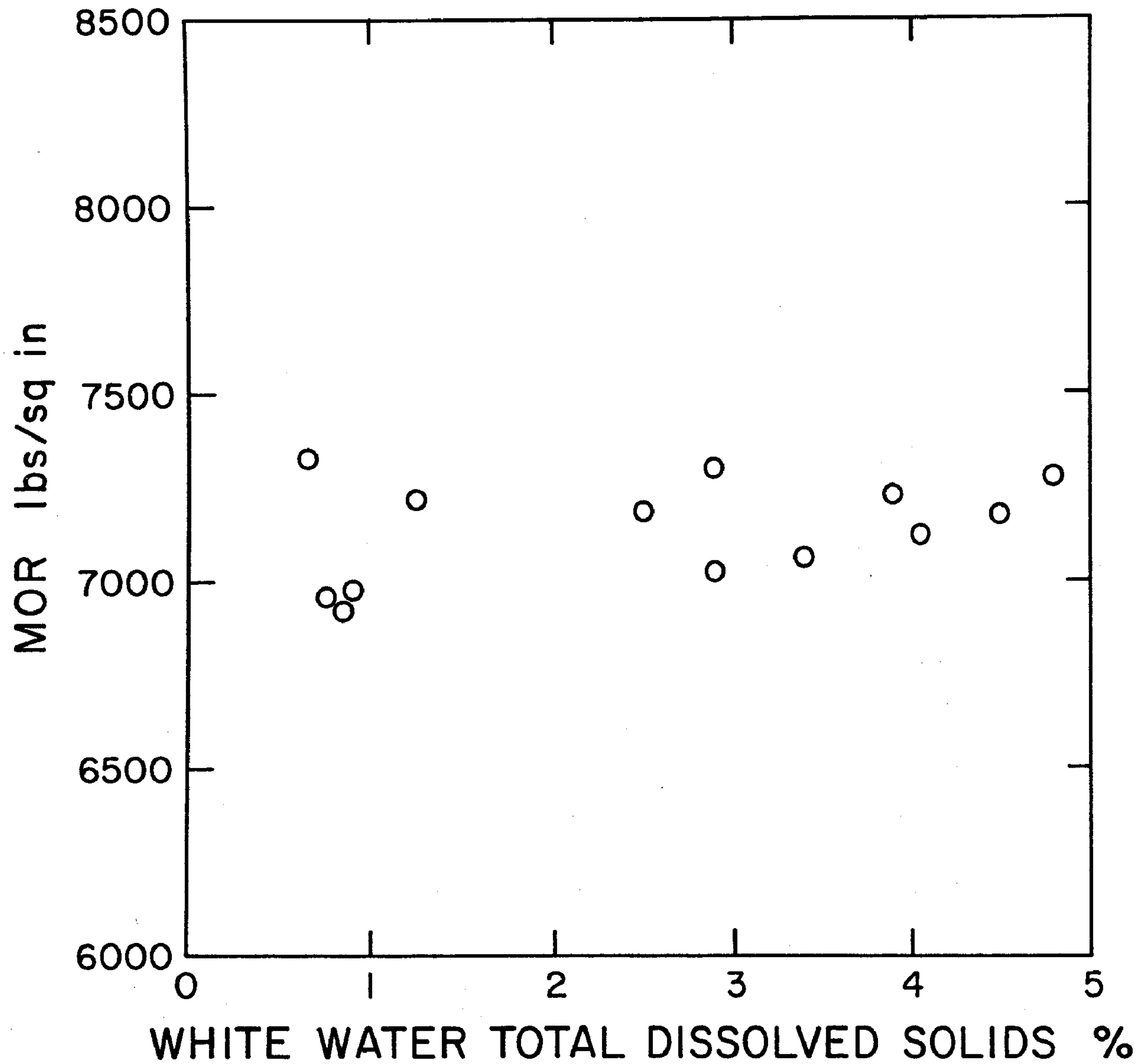

Figure 12. Hardboard MOR as a function of the white water total dissolved solids.

Early in the close-up attempt the MOR began to drop off and about 40% more resin had to be added to maintain the board strength. The forming line temperature had increased to 65-71°C (150-160°F). When the temperature of the forming line was reduced to 50-52°C (120-125°F) by venting more steam from the cyclone, the resin usage returned to normal.

Stock or furnish temperature plays a part in MOR results. Hotter stock temperature tends to pre-cure the phenolic resin before the hot press resulting in lower MOR values. This phenomenon seems to be more pronounced with a closed system than with an open system. Stock temperature is now running cooler than before (Figure 11).

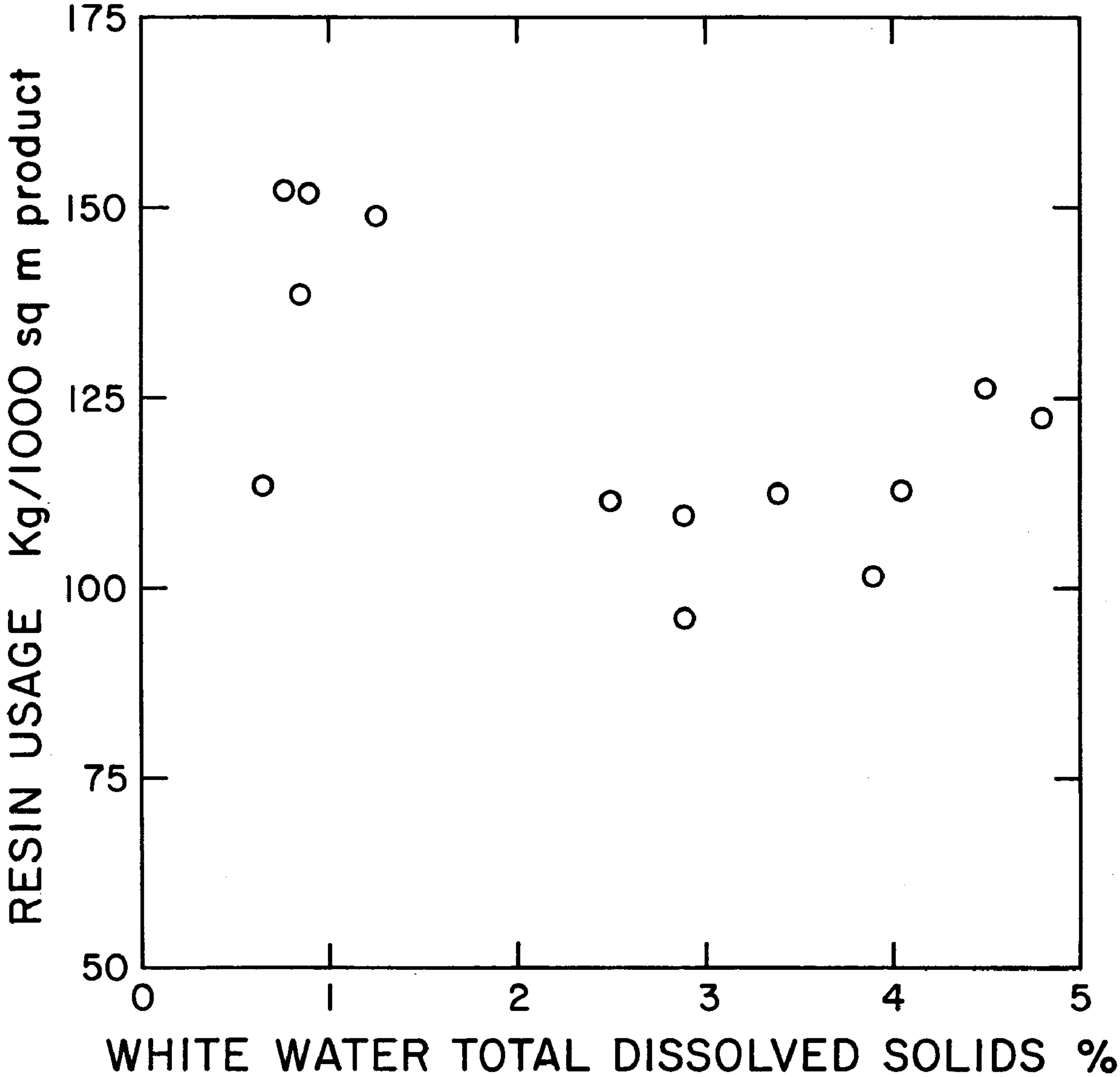

Figure 13. Resin usage as a function of the white water total dissolved solids.

Resin is purchased containing 42% solid material. Previous to September 1976, the resin was further diluted to a consistency of 14% solids and 86% water. It was added to slurry immediately after coming out of the refiner. The high solids content in the purchased resin required the addition of 8330 liters (2,200 gal) of water per day to the white water system. Higher temperatures of the slurry also caused the presetting of the resin.

After experimenting with several addition points we found that the addition of the resin just prior to the consistency regulators produced the best results. The addition here meant that the stock would normally be on the forming line within 15-20 minutes after resin addition. This reduced the possibility of any pre-setting of the resin. Finally, using resin undiluted at 42% solids was tried and found workable.

Hot Press Adjustments--

Hot press temperature, time, and pressures have a noticable effect on the MOR of the hardboard. Although many tests were made changing the press variables, the same press cycle exists as did before. In an effort to clear up the surface of the board and to prevent sticking in the press, press temperatures are between 196-199°C (385-390°F) instead of 204-210°C (400-410°F).

Water Properties

Various uses of hardboard require that the board exhibit certain degrees of water resistance. Tests performed on water properties are explained below and are also tested in accordance with the applicable test of ASTM Methods (2). In only a few of Superior Fiber's products is water resistance critical.

Water Absorption--

The water absorption test is performed every four hours. The board is submerged in a water bath for 24 hours. The weight of water pick-up is determined and the water absorption value is calculated. The water absorption of Superior Fiber's board has increased since the close-up as is evident in Figure 14. Research is continuing to find a method to bring it back down. Testing is being done with different types of wax.

Dimensional Stability

Dimensional stability or linear variation is a parameter showing the expansion or contraction of the board along with plane of the surface. It is tested in accordance with the applicable procedure in ASTM Methods (2) with the exception of conditioning. Superior Fiber's test conditions the board for 24 hours in a 21°C (70°F) water bath and then for 24 hours in an oven at approximately 100°C (212°F). This method then gives both linear expansion and contraction. The dimensional stability of the board has decreased with the closed-up system as is indicated by the increase in linear expansion as shown in Figure 15.

Wax Usage

A low grade paraffin wax, often called "slack wax", is used to impart water resistance to the hardboard. Wax usage varies from 1% to 2% depending on the type of board being made. Figure 16 illustrates wax usage during the close-up effort.

Density

Board density or specific gravity has increased slightly as is shown in Figure 17.

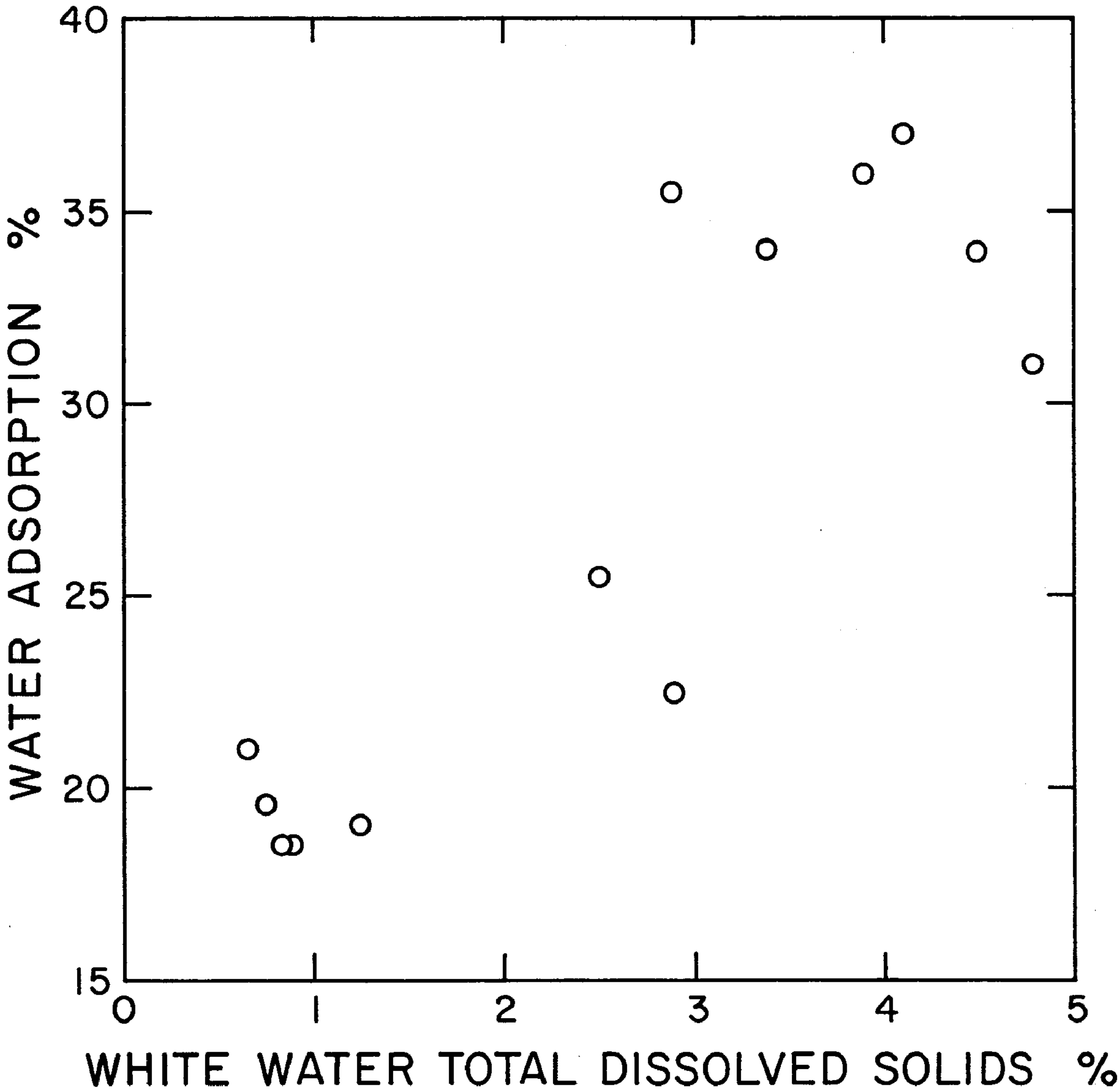

Figure 14. Board water adsorption as a function of the white water total dissolved solids.

Surface Quality

Running with a closed system has resulted in darker board surface. Due to the high white water concentration, surface defects appear much more rapidly and are normally much more pronounced than when running with an open system. Process variables must be closely controlled or unacceptable board can be produced.

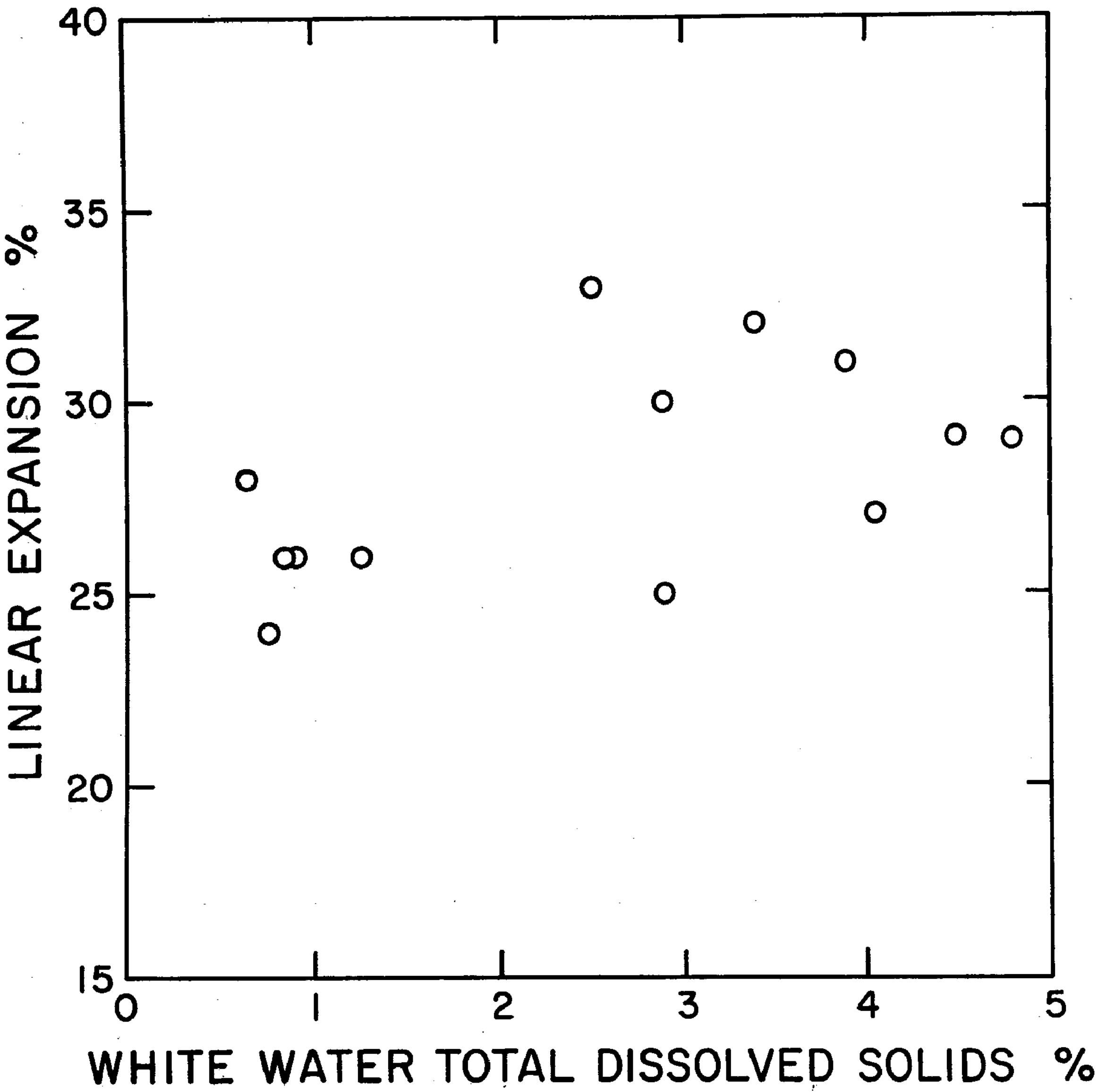

Figure 15. Linear expansion of the board as a function of the white water total dissolved solids.

Color

The board color progressively became darker as the white water concentration increased. The fact that the board is darker is really not a problem for Superior Fiber because their customers can use a dark board as well as a light board.

Color variations across a board are sometimes quite extreme. This color variation is caused by white water evaporation in the hot press where in some places more white water evaporates than it does in other places. Upon evaporation this white water leaves a very dark residue. This problem originates at the forming line.

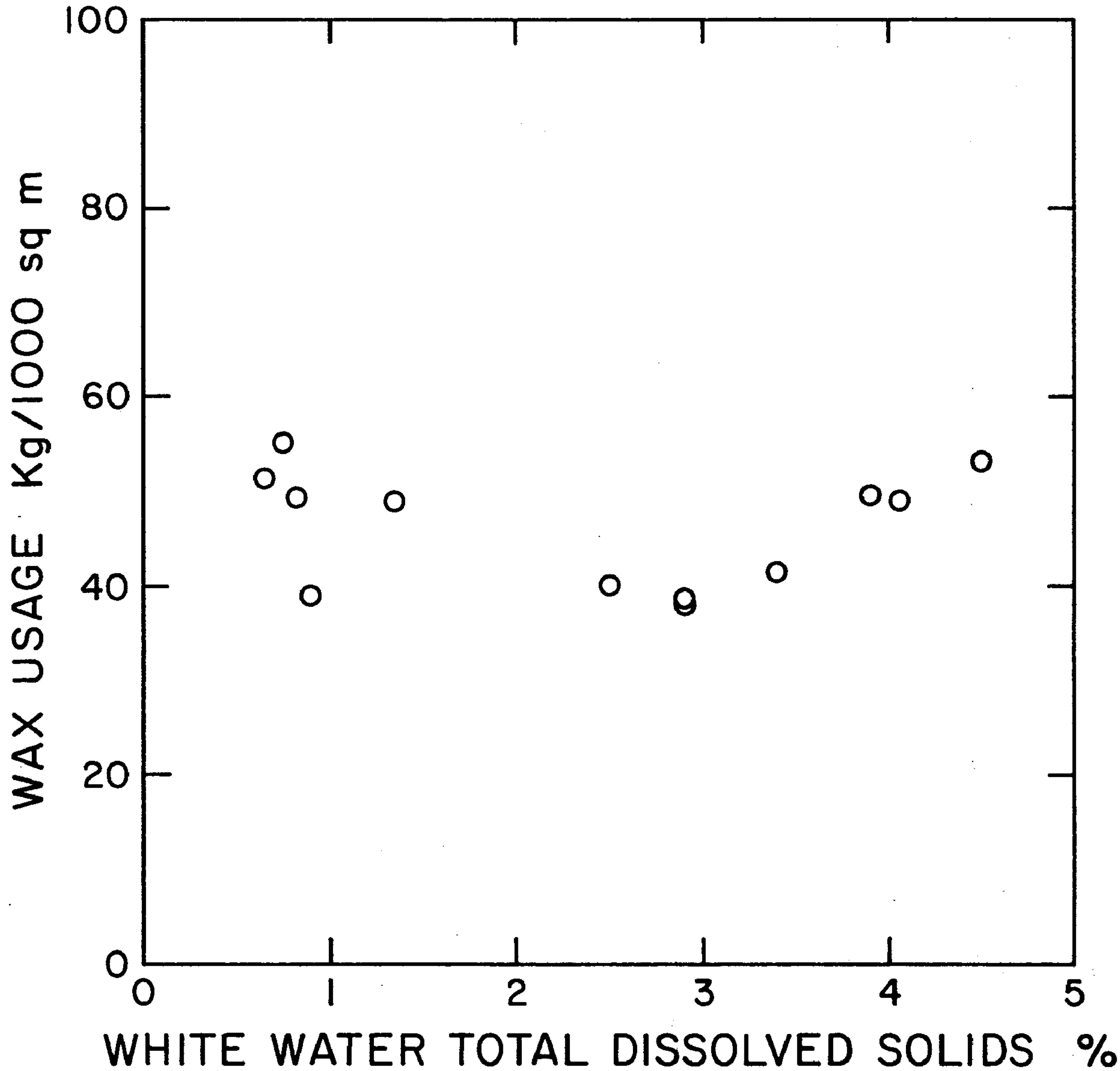

Figure 16. Wax usage as a function of the white water total dissolved solids.

Some areas of the stock contain more fiber than other areas due to fiber bundles and high stock consistency. When this stock is pressed in the hot press the white water from the denser areas will tend to flow to the less dense areas to equalize the density. This water then evaporates leaving much darker areas. Superior Fiber refers to these areas as dewatering patterns. To illustrate further, a fracture is an actual break or pulling apart of the wet-lap. With an open white water system this fracture appears lighter after pressing than the surrounding board simply because it is less dense. In a closed white water system it will be just the opposite, a very dark area, because the water from the surrounding area enters this break and evaporates.

To prevent this problem the forming line must be watched and monitored closely, and the wet-lap must be kept as dry as possible before pressing. Lowering press temperature also helps to some degree. The dewatering patterns or discolorations always occur predominantly along the edges of the board because the water from the board has to work its way out the edges.

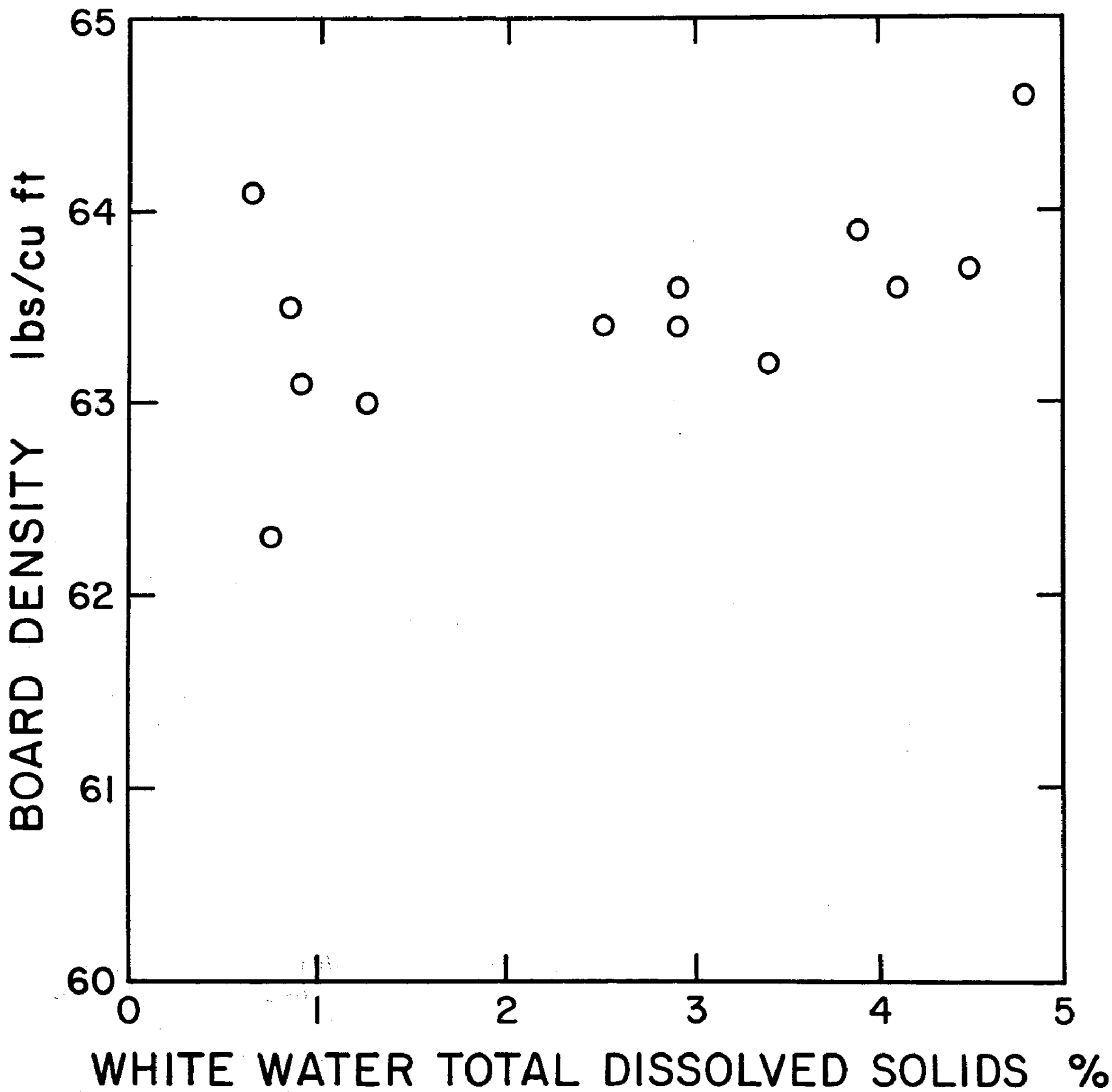

Figure 17. Board density as a function of the white water dissolved solids.

Roughness

Even before white water close-up, Superior Fiber never produced what could be called a smooth surface board. Although the board always had a glossy surface, it generally exhibited an "orange peel" or hill and valley effect. This was evident by feel and also by sight in the right light. This inherent property of the board is not any different now after the white water close-up than before, but to maintain this characteristic it must be watched and controlled more. Without close control, density blisters may occur.

This orange peel effect is related to slower draining stock. The drainage time of the stock increased as the white water concentration became higher. A fiber solution that used to take 20 defibrator seconds to drain will now take between 24 and 26 seconds to drain. Therefore, to compensate for the slower draining stock Superior Fiber now grinds a little coarser fiber and also runs at a higher fiber concentration (less water) on the forming line. The forming line wire was changed from a 30% open to an approximately 50% open mesh to improve drainage.

Paintability

Superior Fiber also runs a small paint line where they prime some garage door stock and stock of other limited applications using a simple roller coater. Paint hold down and drying have not changed between pre-close and post-close-up. Because of darker colored board and color variations, paint hiding is not as good as with the lighter colored board.

Surface wax tests indicate no lessening in paintability after close-up.

Production Problems

Stainless Steel Plates--

A major concern with the closed system was the length of time the stainless steel plates could be used before they required cleaning. Isel advised that they did not see any major change in the life of their stainless steel plates; their normal change was every 10 days, much less than Superior Fiber's usual 30-day interval.

Superior Fiber's initial close-up effort was not a slow procedure. All fresh water valves were closed and the white water concentration increased rapidly. After about two weeks the white water total solids concentration went over 5%. Severe plate shedding problems began to occur. Plate life as low as six days was experienced. Using a wax emulsion spray on the surface of the wet-lap helped very little.

The problem of short plate life was resolved by polishing the plates and maintaining a white water pH between 5.0 and 5.5. Figure 18 illustrates the effect of pH and total dissolved solids on the plate life. By controlling the pH to remain above 5.0, stainless steel plate lives of approximately 30 days can be maintained with white water concentrations up to 7.5%.

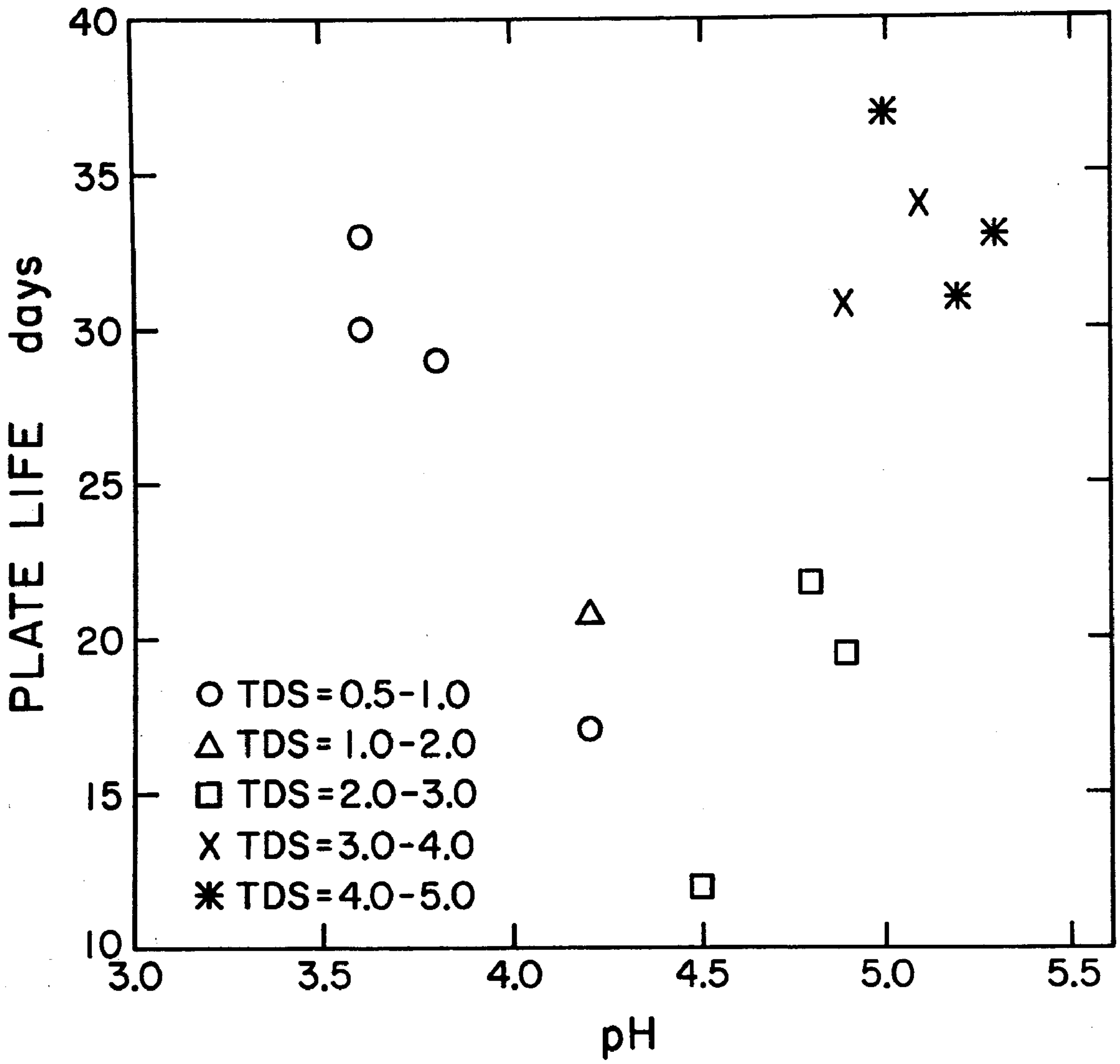

Figure 18. Hot press stainless steel plate life as a function of white water total dissolved solids and pH.

Other problems exist with the stainless steel plates which can be related to the closed system. One such problem is build-up of material on the surface of the plates. This is caused by a short wet-lap going into the press or one that is just about pulled apart. This condition causes the water being squeezed out of the wet-lap to evaporate on an unused area of the stainless steel plate, leaving a deposit. This deposit then has to be scraped off the plate or the board produced will have a dull recessed area on its surface.

Another lesser problem is the build-up of material along the edges of the stainless steel plate. If set-down is not monitored closely, the boards will stick to this build-up. Set-down refers to the exact placing of the wet-lap on the transport plate. Ideally, exact sized wet-lap should set in exactly the same spot in the press every time.

Drainage--

Because a forming line screen with sufficient open area to properly drain the wet-lap has yet to be found, the mat goes into the hot press with excess moisture. The result is poor quality board surface. Experimentation with screens containing 42-44% open area proved unsatisfactory because they failed to hold up. The larger open areas seemed to weaken screen strength. Equipment using a vacuum to remove the water is now being installed for a new forming line. It will not now be necessary to use a more open screen. The goal is to move wet-lap into the hot press with a moisture content of between 68 and 71%.

Hardboard Production

Hardboard production has dropped off slightly with the closed system. This is probably due to lack of experience with the closed system. As experience increases, it should be possible to regain a higher production level.

Production per month has dropped 1.6% since close-up. This figure compares nine months before close-up to nine months after. Production per hour, which is the production per running hour, downtime excluded, dropped only 0.25%. The difference between the two figures is a result of more down time after the closed system than before.

SECTION 7

EFFLUENT CHARACTERISTICS

Until May 1977, Superior Fiber utilized five lagoons with a total capacity of approximately 19 million liters (5 million gal) of water. The lagoons served basically as primary settling ponds. A cationic guar gum polymer was added to the influent to aid in the settling of suspended and colloidal material (Figure 19) prior to close-up. Today because of low flow discharges, addition of polymer is not necessary to meet requirements of the NPDES permit. Superior Fiber is filling in three of their five lagoons because the long detention time is not needed and for aesthetic reasons. A complication caused by the low flows during the winter months was freezing. Normal drainage channels from the lagoons to Superior Bay completely froze last winter and the discharge had to be pumped directly into the bay.

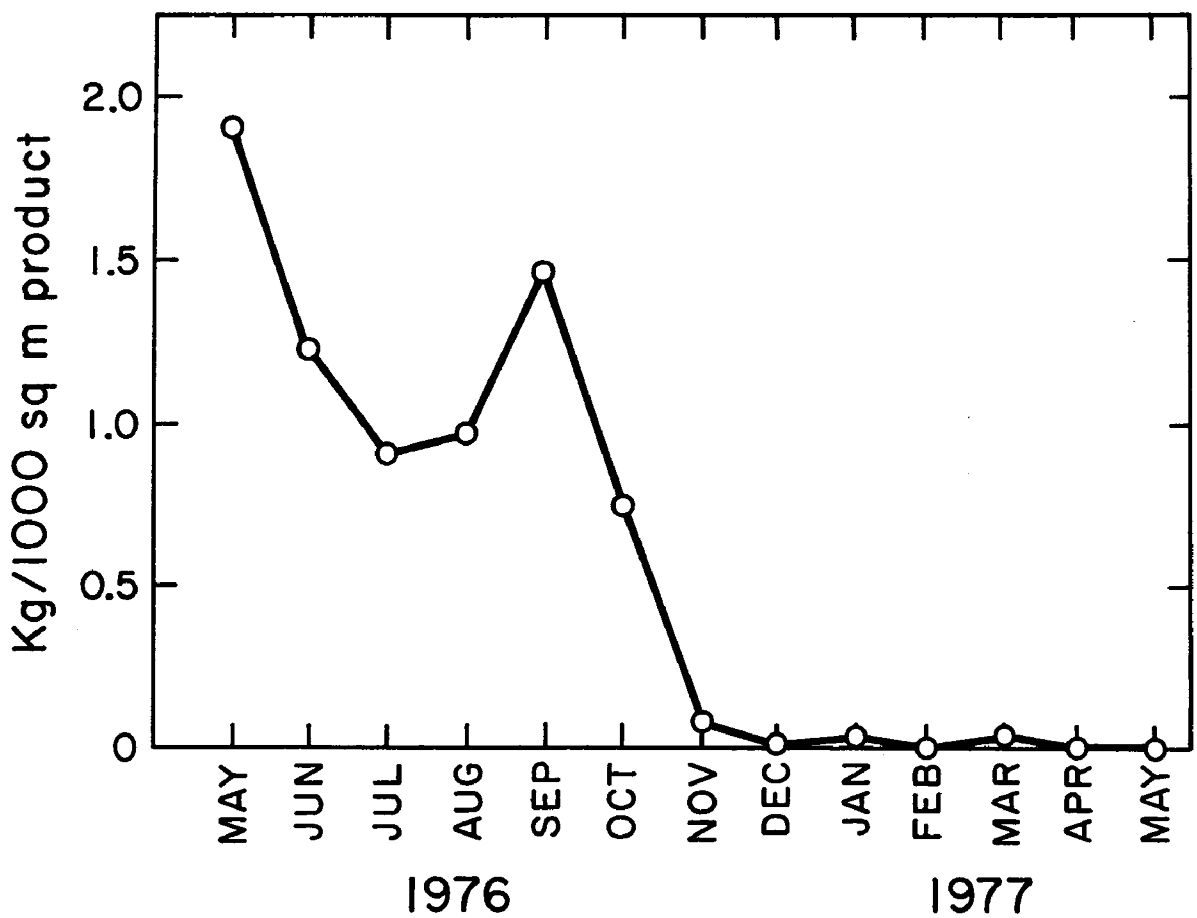

Figure 19. Polymer usage.

Sampling

Samples are taken by a flow proportional automatic sampler. Samples are then stored at 17°C (35°F) until testing.

Discharge Flow

Measurement--

The lagoon discharge flows over a 90 degree V-notch weir. Level over the weir is recorded with a Leopold-Stevens level recorder.

Volume--

Before the Isel system, close-up discharge was somewhere between 568,000 and 757,000 liters (150,000 and 200,000 gal) per day. Now discharge is less than 19,000 l (5,000 gal) per day.

During the months of April and May 1977 lagoons number 1, 2, and 3 were emptied and land filled. For this reason all data for these months show much higher flows than if the flow due to pumping ponds 1, 2, and 3 into 4 and 5 had been excluded from the data.

Test Results

As the quantity of water discharged from the mill decreased, the quantity of BOD_5 discharged also decreased as shown in Figure 20. Prior to the close-up, BODs were in the range of 22 Kg/KKg (44 lb/Ton) production. After the close-up the BODs were about 3 Kg/KKg production. The small flows and BODs after close-up were due to leaks, spills, and wash water. BODs decrease significantly with close-up because the BOD causing materials become part of the hardboard.

The quantity of suspended solids discharged also decreases with decreasing effluent flow as shown in Figure 21.

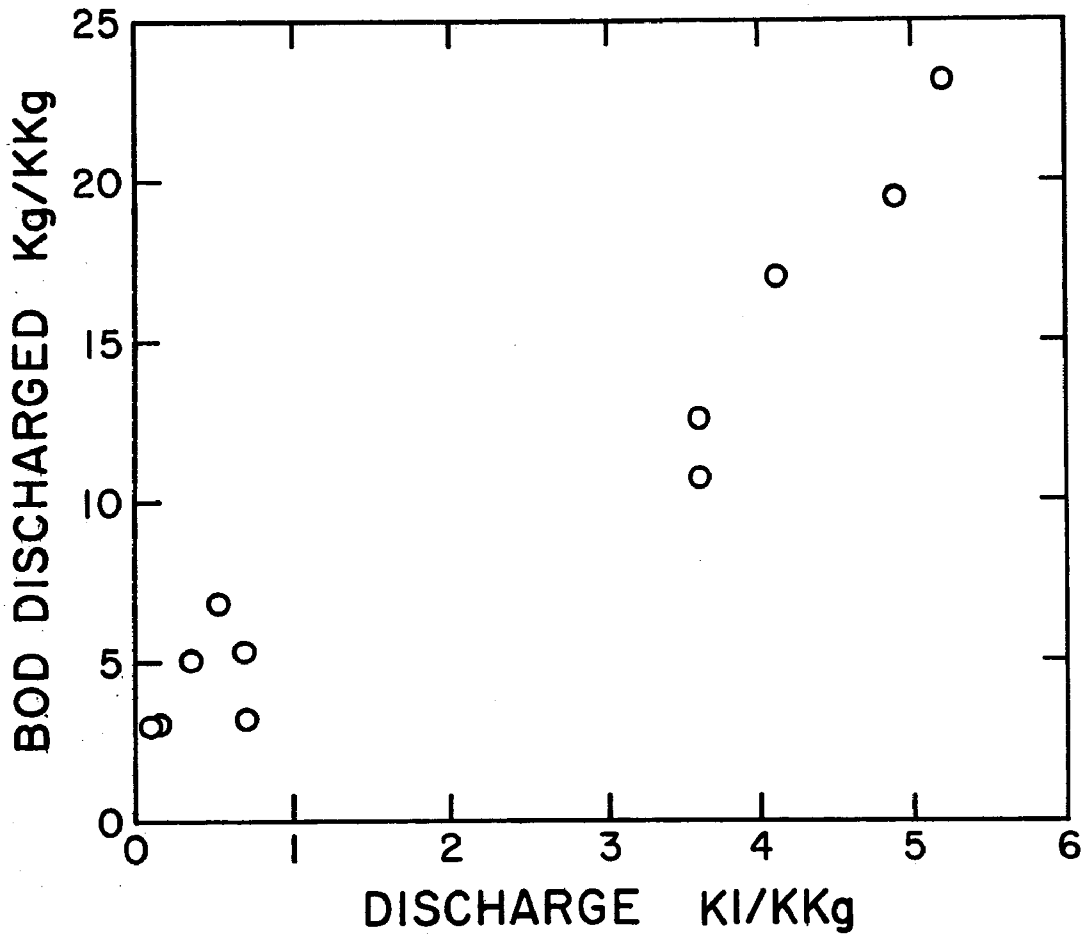

Figure 20. BOD discharged as a function of process water discharge.

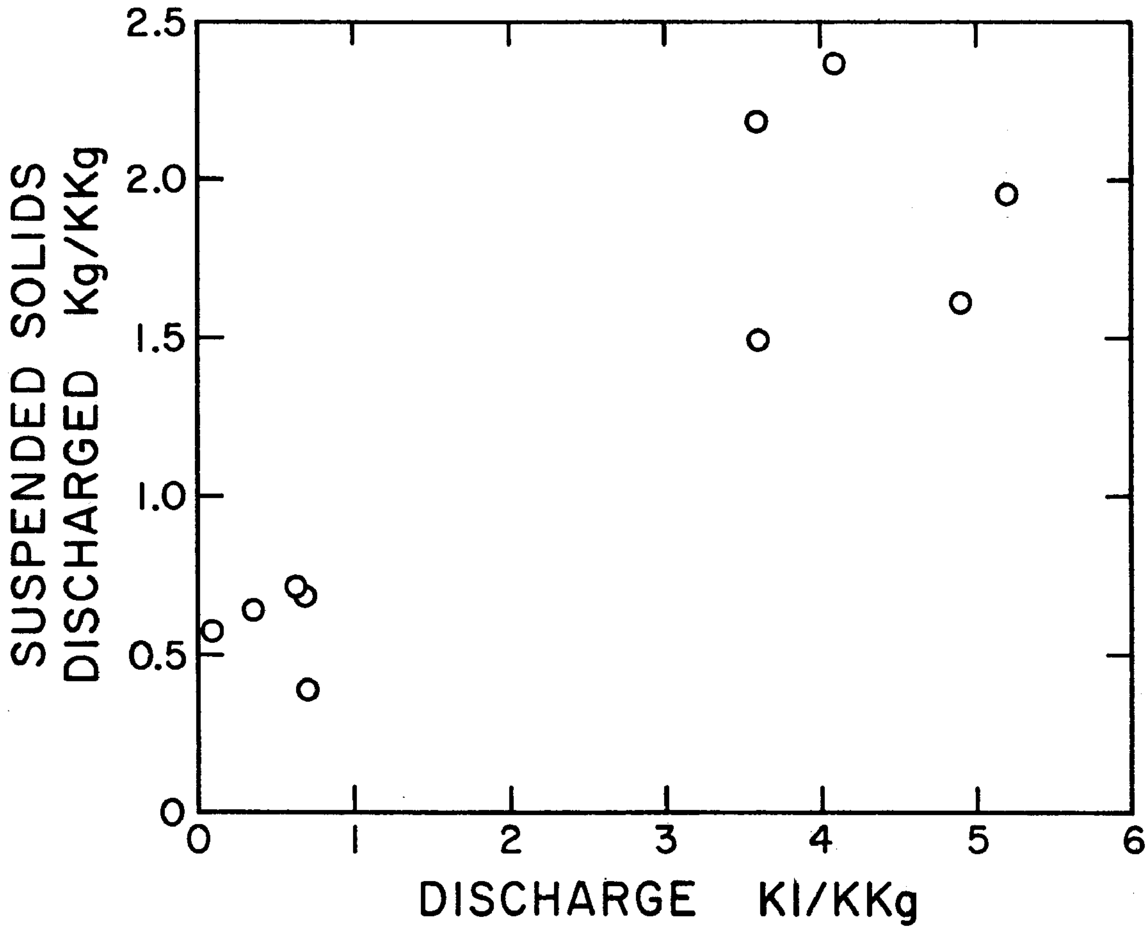

Figure 21. Suspended solids discharged as a function of process water discharge.

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1. Eder, L. J., and Connors, J. E. Engineers report describing proposed waste load reduction facilities in accordance with NPDES Permit requirements for Superior Fiber Products, Locust Valley, New York.

2. American Society for Testing and Materials 1970 Annual Book of ASTM Standards, Part 16. Page 12-14.

3. APHA AWWA WPCF; Standard Methods for the Examination of Water and Wastewater, Thirteenth Edition. Page 18.

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16. ABSTRACT

Superior Fiber Products, Inc., a manufacturer of smooth on one side wet process hardboard, undertook a project to eliminate any discharge of process water through a program of increasing process water reuse. All but wash up water and some pump seal leak water discharges were eliminated. White water total solids concentration went from 1% to about 7%. Physical properties of the hardboard were watched closely during the close up process. Water absorption and linear expansion of the board increased after close up. Close up of the process reduced chemical usage. Board strength problems were eliminated through control of the white water temperature. Slower drainage of the stock was countered by formation line alterations. Some remaining draw backs to the system are a darker board color and overall reduced cleanliness of the mill.

17. KEY WORDS AND DOCUMENT ANALYSIS

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