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Raw Wasteload Characteristics of the Hardboard Industry

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RAW WASTELOAD CHARACTERISTICS OF THE HARDBOARD INDUSTRY

by

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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 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.

Characterization of an industry's raw wasteloads (in this instance from the hardboard industry) and identification of process conditions that affect the raw waste load provides information useful in controlling those wastes by process modification. Regulatory agencies can also use the information to assess the progress of the hardboard industries in controlling their wastes. The Food and Wood Products Branch, IERL-Ci, can be contacted for further information on the subject.

David G. Stephan
Director
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ABSTRACT

Raw waste loads from the hardboard industry are characterized. Factors that affect the raw waste load are studied. The raw waste load is most strongly affected by the wood cooking conditions. More of the wood is dissolved at the higher pressures and temperatures found in production of smooth on one side (S1S) board, which results in higher raw waste loads for smooth on two sides (S2S) production. Additional wood is dissolved in the hot press in the production of S1S board. Refining of the wood results not only in production of solids, but also in production of wood fines that add to the raw waste load.

Recycling of whitewater and press pit waters reduces the quantity of discharge from a hardboard mill. Raw waste loads are also decreased. Dissolved solids, suspended solids, and the temperature in the whitewater increase with increased recycling. The change in the raw waste load and whitewater characteristics are most dramatic when nearly all the process waters are being recycled.

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SECTION 1

INTRODUCTION

Hardboard production by the wet process often results in large flows of strong waste streams. The waste streams contain dissolved and suspended solids resulting from processing of wood. In-plant control of the quantity and quality of the raw waste load is predicated upon knowledge of factors affecting the raw waste loading origin, factors affecting the raw waste load during subsequent processing of the pulp, and the effect of process condition changes on product quality. The effects of raw waste load control measures on product quality and production costs must be fully accounted for.

Many variables cause raw waste loadings from hardboard mills to differ between mills. The variables include the wood species used, whether or not the wood is debarked, the product being manufactured, the steaming time and pressure used, the amount of whitewater recycle, whether or not the pulp is washed, and the additives and retention aids used.

Each of the variables has a particular role in determining the raw waste load from a hardboard mill. The amount of pollutants released into the manufacturing process water is influenced by the severeness of the cooking.The cooking time and pressure are determined by the wood species used and the product desired. Each type of wood reacts differently to the cooking step and releases different quantities of pollutants. Use of wood that has not been debarked adds 45% to 50% to the raw waste load (2,3) . Other variables modify the raw waste load. An increase in the amount of whitewater recycled can reduce the amount of pollutants reaching the effluent. Increased retention of finely divided wood on the mat by use of polymers and retention aids reduces the raw waste load. Some additives have a BOD of their own and their use increases the raw waste load.

Many hardboard mills are reducing their raw waste load by recycling their process water to ultimately eliminate discharges of all process waters. The resultant high concentration of dissolved wood constituents in the process waters may cause problems in maintaining board quality standards. The causes and solutions to these board quality problems are being sought.

SECTION 2

SUMMARY AND CONCLUSIONS

A literature survey indicated that several hardboard mills have attempted to recycle their process waters to eliminate all contaminated discharges and have met with varying degrees of success. Several mills have achieved complete closeup of their process water systems. Other mills have experienced product quality and operating problems once the dissolved solids concentration in the white water reached a specific level. The most common product quality and operating problems encountered are board sticking on the hot press, loss of board strength, slow drainage of water from the mat, and high water adsorption of the finish board.

Raw waste loads differ from mill to mill and show considerable variation within a single mill. Laboratory work was undertaken to determine the dependence of raw waste loads on the cooking conditions and the species of wood used. Raw waste loads increased dramatically as the steaming pressure and/or steaming time was increased. Different wood species produced different raw waste loadings. Wood species generating the highest raw waste loadings are often the least severely cooked in industry thus reducing differences in raw waste loading due to different wood species. Production of S2S board generally uses more severe cooking conditions than S1S production and thereby generates a larger raw waste loading.

Studies were also undertaken to investigate the benefits derived from partial closure of a hardboard process water system. Reductions in waste-water flow from a hardboard mill resulted in some BOD removal, largely due to increased suspended solids capture on the mat. There was little reduction of soluble BOD until flows were reduced to less than 6.6 l/kg (1437 G/Ton) pulp. Reduction in flow improves the efficiency of in-place effluent treatment systems. Reduction in quantities of BOD and suspended solids discharged occurred when flows to the biological treatment were reduced, thereby increasing residence time the discharge of BOD and suspended solids was decreased.

Complete recycle of mill process waters may be possible in situations where the dissolved solids loading to the whitewater system is low, as is the case in most S1S mills. When high dissolved solids loadings are delivered to the white water system, as in S2S mills, evaporation of the excess white water should be considered as a means of eliminating the effluent. Evaporation of wastewater from a hardboard mill can be made profitable at very high dissolved solids loadings to the white water system through sales of the evaporator concentrate as a molasses substitute in animal feeds.

SECTION 3

RECOMMENDATIONS

Complete closure of process water systems at hardboard mills is being accomplished. Not all hardboard mills will be able to achieve complete closure of their process water systems because of high dissolved solids production during cooking and refining and, consequently, high dissolved solids contents in their white water systems. A better understanding of the causes of board quality problems would be beneficial to mills encountering product quality problems while attempting to close their process water systems. Methods of reducing board sticking in the hot press that don't affect the board surface qualities need to be developed. An understanding of the mechanisms of board strength loss at higher white water recycle needs to be developed. Problems of slow water drainage from the mat, high water adsorption by the board, and poor dimensional stability of the board resulting from high white water dissolved and suspended solids content need to be solved.

The effects of reducing cooking times and temperatures on product quality and energy consumption should be investigated. The necessity of a shive-free surface on S2S board is doubtful. If there is no effect on board strength, swelling, or water adsorption properties, there is no reason to maintain the severe cooking conditions.

For mills planning on evaporation of wastewater, more efficient pulp washing systems are required. A transfer of technology from the chemical pulping industry may be possible. The possibility of using reverse osmosis or ultrafiltration technology to increase evaporator feed concentrations at low cost should be investigated. A system to use digester blow steam for evaporation of wastewater should be developed.

SECTION 4

LITERATURE SURVEY

THE HARDBOARD INDUSTRY

There are 16 manufacturers of wet process hardboard in the United States. Six hardboard mills are operated in conjunction with insulation board mills. Hardboard produced in conjunction with insulation board mills is smooth on both sides (S2S board). One mill produces S2S board without the production of insulation board. Production of S2S board is accomplished by what is referred to as the wet/dry process. The remaining nine hardboard mills produce hardboard that is smooth on one side and has a screen pattern on the back side (S1S board). Figures 1 and 2 diagram an S1S and an S2S hardboard mill respectively.

Wood Supply

The hardboard industry derives its wood from a number of sources. Most hardboard mills in the north central section of the United States use roundwood. Mills in the east and south parts of the country use a combination of roundwood and wood residue. Hardboard mills in the west use primarily wood residue from either sawmills or plywood mills.

There is a trend toward use of more wood residue in the hardboard industry. The demand for roundwood by lumber and plywood mills is increasing the cost of roundwood. The demand for chips by paper mills is making chips scarce. Some mills are experimenting with whole tree chips and forest residues. The use of lower quality wood usually results in a lower quality product. It is likely that hardboard mills built in the future will be built in conjunction with other wood products processing to ensure a steady supply of raw material.

The wood may be processed with the bark still attached or debarked. When barking is convenient, as with roundwood, the bark is normally removed and disposed of by incineration. Bark processed with the wood disintegrates into fine material in the cooking and refining process. Some of the bark fines go into the product and some end up in the effluent. Sometimes roundwood or chips are washed to remove dirt.

Fiber Preparation

There are three methods of preparing fiber for the manufacture of hardboard: (1) thermomechanical, (2) explosion process, and (3) stone ground wood. All of these methods use some degree of preheating the chips or wood.

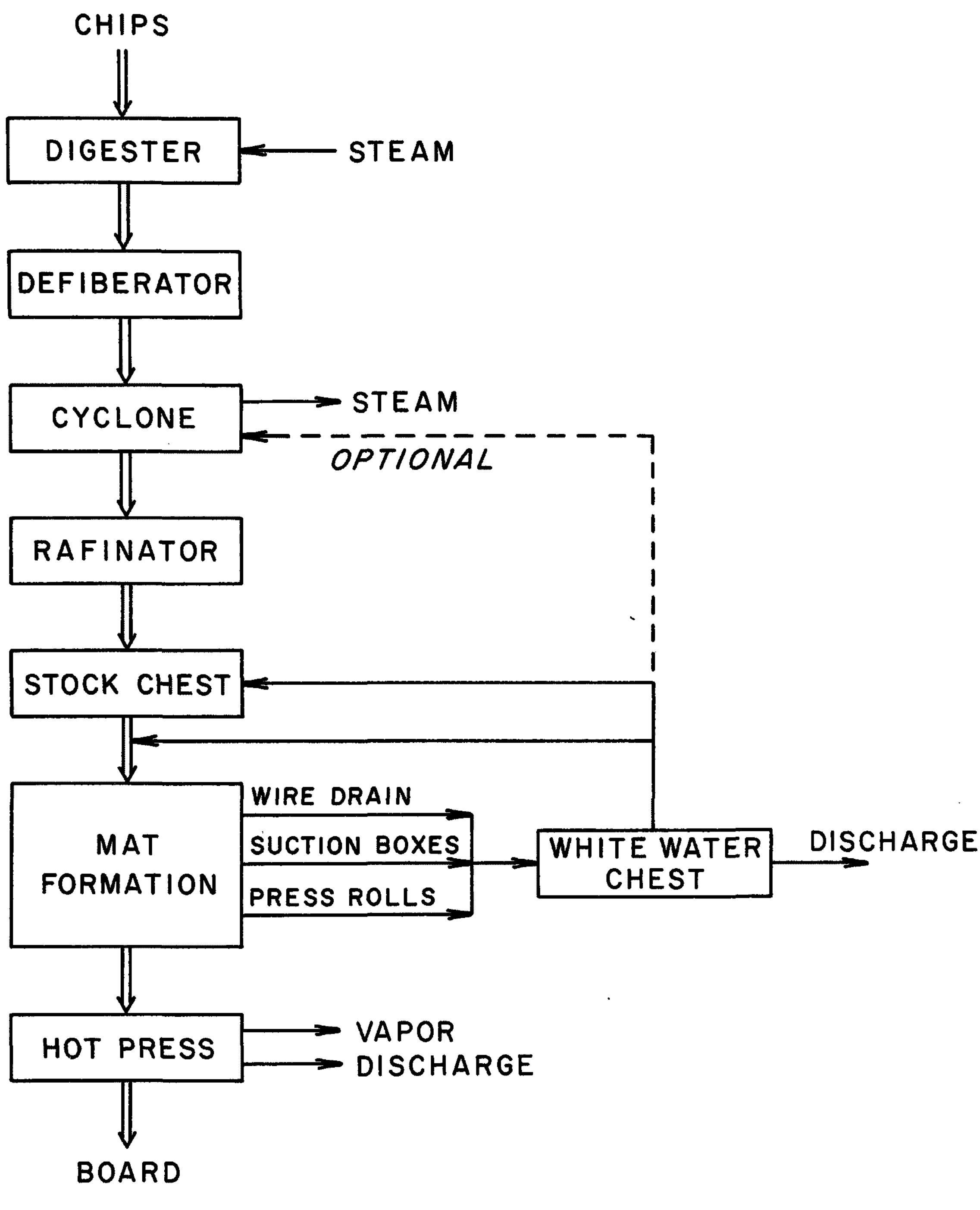

Figure 1. Diagram of an S1S hardboard mill.

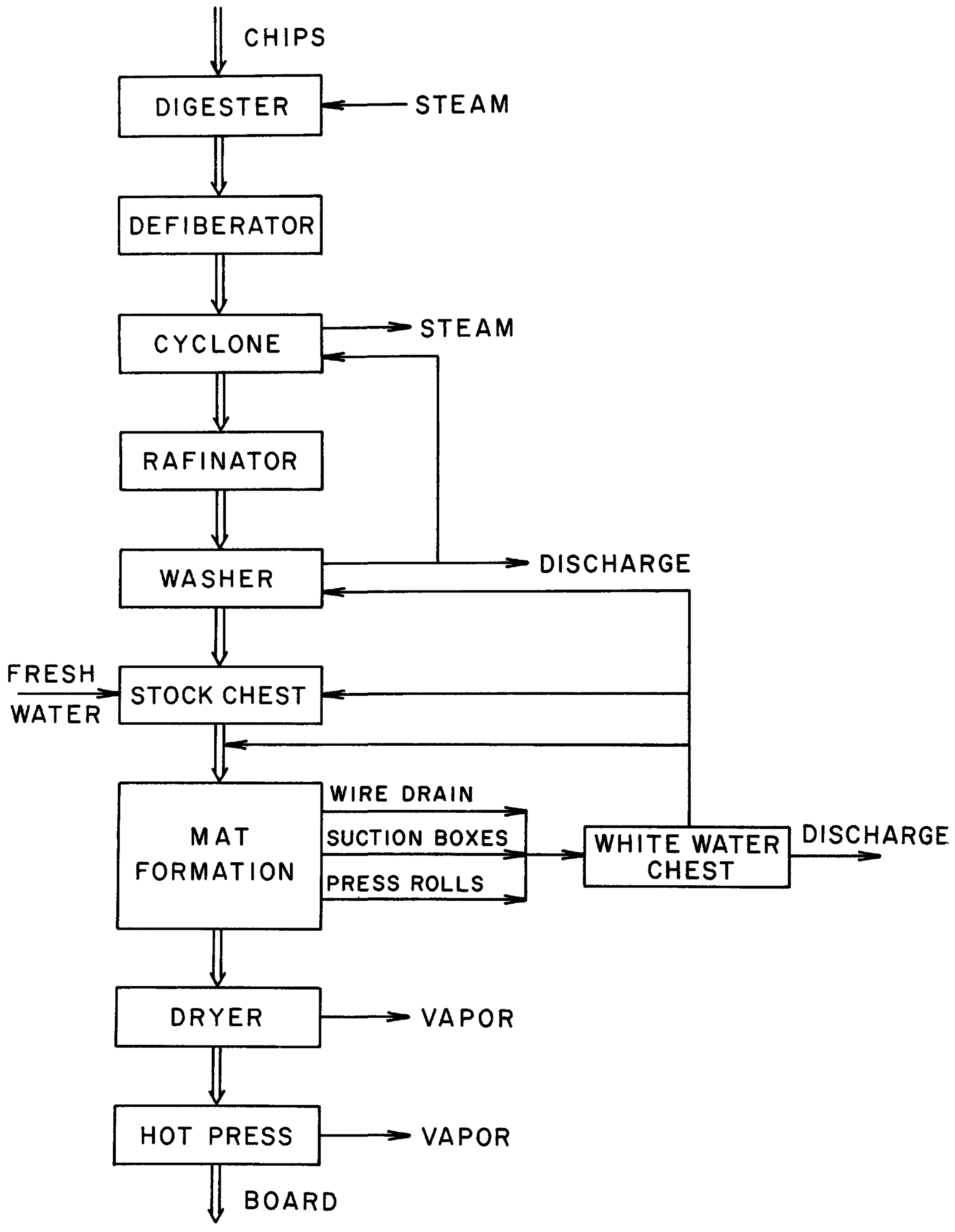

Figure 2. Diagram of an S2S hardboard mill.

Heated wood is softer and will break down into pulp with less fiber breakage than cold wood. The longer fibers contribute to an increased strength of the board formed.

In the thermomechanical process chips are heated with steam in either a continuous or batch reactor. In a continuous reactor the chips are fed to the pressurized chamber with a screw. If the moisture content of the wood is high, water is squeezed out of the wood and drained away from the digester area. If dried wood residue is being used, water may be added to the digester along with the chips to keep the moisture content of the wood high enough to prevent scorching in the refining process. The chips are heated for 2 minutes to 15 minutes with 6.8 atm (100 psig) to 13.6 atm (200 psig) steam, depending upon the type of wood being used and the product being produced. The chips are then passed through rotating disc refiners. The chips may or may not be refined at the cooking pressure. The chips are then blown into a cyclone to separate the steam from the fiber. The steam is partially condensed in the cyclone by a water spray which serves to wash the pulp out of the cyclone. If the pulp is not washed from the cyclone, bridging occurs and the cyclone becomes plugged.

Some mills bypass the cyclone and blow directly to the stock chest, or have specially designed cyclones wherein the pulp is removed mechanically from the cyclone to prevent pulp bridging.

In the explosion process chips are heated with 40 atm (600 psig) steam for one minute. The pressure is then increased to 68.1 atm (1000 psig) for 5 seconds whereupon the contents of the digester are suddenly released to atmospheric pressure. The sudden reduction of pressure causes the chips to explode into individual fibers or fiber bundles. The pulp is then refined to insure all shives and fiber bundles are reduced to pulp.

Pulp is produced by the stone ground wood process at one hardboard mill which also produces insulation board. Preparation of fiber by the stone ground wood process is common in the insulation board industry. No preheating of the wood is used. Conventional pulp wood grinders are used with coarse burred artificial stones of 16 to 25 grit with various patterns. Roundwood is hydraulically forced against the rotating stone and reduced to fiber. Water is sprayed on the stone to wash the fiber away and to keep the stone cool.

Washing of the pulp sometimes follows refining. Pulp washing is used to improve consistency control later in the operation and to remove excess dissolved solids which may result in surface flaws in the board. Washing is commonly accomplished on deckers which are rotating, wire covered cylinders that dip into a pulp slurry. A vacuum pulls water through the screen. Pulp is pulled out of the vat on the screen and then removed from the screen by a doctor blade.

Board Formation

After dilution to 1.5% consistency, the pulp enters the head box of the fourdrinier machine. A urea formaldehyde, phenolic formaldehyde, or other thermo setting resin is added to the pulp either prior to pulp storage or just prior to entering the head box. Waxes and starches are sometimes added for sizing. Alum is added to help retain the resin on the board. Sulfuric acid is added for pH control to precipitate the resin.

The fourdrinier machine is similar to those used in the paper industry. It consists of a moving screen onto which pulp is delivered at a steady rate and thickness by the head box. On the first portion of the screen water is allowed to drain from the pulp. Further water is removed by a vacuum under the screen. Press rolls then squeeze water out of the pulp mat until a consistency of about 27% is achieved. Then the mat is trimmed and cut into section of either 2.44 m (8 ft) or 4.88 m (16 ft) long, depending upon the size of the press.

Most S1S board is overlayed with a finely refined pulp just prior to the vacuum dewatering section. The overlay is to provide a smooth, shive-free surface. Some S2S mills put a layer of fine material on the bottom of the mat as well as an overlay so that both sides of the board will have high quality surfaces.

Further processing of the board differs from mill to mill depending on the type of board being produced. For S1S board the mat is placed on screen backed cauls and is fed directly to the hot press. Water is pressed out under 34 atm (500 psig) pressure at a temperature of 200°C to 300°C (392°F to 572°F) to a board consistency of about 40 to 55% solids. The remaining water is evaporated from the board. About 20 to 50% of the water in the mat going to the hot press is evaporated; the remainder is discharged. Hot pressing of the board causes the lignin in the wood to plasticize and melt together and the thermosetting resins added earlier in the process to set.

In the manufacture of S2S hardboard, the mat is dried prior to hot pressing, placed on smooth platens and fed to the hot press. There is no effluent from the hot press in S2S board manufacturing.

The boards are sent to a rehumidifying chamber and heat cured for several hours. After heat treatment the boards are trimmed to size and sent to the finishing department. Finishing is essentially a dry process causing no effluent.

PRODUCTS

Hardboard mills produce either S1S or S2S board of various densities and thicknesses. These products are used for a wide range of applications: interior wall paneling, exterior siding, automotive door paneling, T. V. cabinets and furniture, base for tile panels, concrete forms, and non-conductor material for electrical equipment.

The American Hardboard Association published a set of voluntary product standards to establish nationally recognized dimensional and quality requirements for various hardboard products (4). Products are listed in three categories: basic hardboard, prefinished hardboard paneling, and hardboard siding, each with its own product quality standards. Tables 1, 2, and 3 list

TABLE 1. BASIC HARDBOARD; CLASSIFICATION OF HARDBOARD BY SURFACE FINISH, THICKNESS, AND PHYSICAL PROPERTIES*

Class	Surface	Nominal thickness	Water resistance (max av per panel)				Modulus of rupture (min av per panel)	Tensile strength (min av per panel)	
			Water absorption based on weight		Thickness swelling			Parallel to surface	Perpendicular to surface
			S1S	S2S	S1S	S2S			
		inch	percent	percent	percent	percent	psi	psi	psi
1 Tempered	S1S	1/12	30	–	25	–	7000	3500	150
	S1S and S2S	1/10	20	25	16	20			
		1/8	15	20	11	16			
		3/16	12	18	10	15			
		1/4	10	12	8	11			
		5/16	8	11	8	10			
		3/8	8	10	8	9			
2 Standard	S1S and S2S	1/12	40	40	30	30	5000	2500	100
		1/10	25	30	22	25			
		1/8	20	25	16	18			
		3/16	18	25	14	18			
		1/4	16	20	12	14			
		5/16	14	15	10	12			
		3/8	12	12	10	10			
3 Service-tempered	S1S and S2S	1/8	20	25	15	22	4500	2000	100
		3/16	18	20	13	18			
		1/4	15	20	13	14			
		3/8	14	18	11	14			
4 Service	S1S and S2S	1/8	30	30	25	25	3000	1500	75
		3/16	25	27	15	22			
		1/4	25	27	15	22			
		3/8	25	27	15	22			
		7/16	25	27	15	22			
		1/2	25	18	15	14			
	S2S	5/8	–	15	–	12			
		11/16	–	15	–	12			
		3/4	–	12	–	9			
		13/16	–	12	–	9			
		7/8	–	12	–	9			
		1	–	12	–	9			
		1-1/8	–	12	–	9			
5 Industrialite	S1S and S2S	3/8	25	25	20	20	2000	1000	35
		7/16	25	25	20	20			
		1/2	25	25	20	20			
	S2S	5/8	–	22	–	18			
		11/16	–	22	–	18			
		3/4	–	20	–	16			
		13/16	–	20	–	16			
		7/8	–	20	–	16			
		1	–	20	–	16			
		1-1/8	–	20	–	16			

*Table is from reference 4.

TABLE 2. PREFINISHED HARDBOARD PANELING, PHYSICAL PROPERTIES OF THE HARDBOARD SUBSTRATE*

Class	Nominal thickness	Water resistance (max av per panel)		Modulus of rupture (min av per panel)	Tensile strength (min av per panel)	
		Water absorption based on weight	Thickness swelling		Parallel to surface	Perpendicular to surface
	inch	percent	percent	psi	psi	psi
1 Tempered	1/8	20	16	7000	3500	150
	3/16	18	15			
	1/4	12	11			
2 Standard	1/8	25	18	5000	2500	100
	3/16	25	18			
	1/4	20	14			
3 Service-tempered	1/8	25	22	4500	2000	100
	3/16	20	18			
	1/4	20	14			
4 Service	1/8	30	25	3000	1500	75
	3/16	27	22			
	1/4	27	22			

*Table is taken from reference 4.

TABLE 3. HARDBOARD SIDING PHYSICAL PROPERTIES AND MAXIMUM LINEAR EXPANSION*

Physical properties

Property	Requirement
Percent water absorption based on weight (max av per panel)	Primed 15 Unprimed 20
Percent thickness swelling (max av per panel)	Primed 10 Unprimed 15
Weatherability of substrate (max swell after 5 cycles), in	0.010 & no objectionable fiber raising
Sealing quality of primer coat	No visible flattening
Weatherability of primer coat	No checking, erosion, or flaking
Nail-head pull-through, lb (min av per panel)	150
Lateral nail resistance, lb (min av per panel)	150
Modulus of rupture (min av per panel) psi	1800 for 3/8 & 7/16-inch-thick siding 3000 for 1/4-inch-thick siding
Hardness (min av per panel), lb	450
Impact (min av per panel), in	9.0
Moisture content,[c] percent	2.0 – 9.0 incl., and not more than 3 percent variance between any two boards in any one shipment or order.

Maximum linear expansion

Type of siding	Thickness range	Maximum linear expansion
	inches	percent
Lap	0.325-0.375	0.38
	over 0.376	0.40
Panel	0.220-0.265	0.36
	0.325-0.375	0.38
	over 0.376	0.40

*Table is taken from reference 4.

some of the more basic product quality specifications for each of the categories, respectively. Further standards specify surface finishes, dimensions and tolerances, squareness, edge of straightness, moisture content, flame resistance, scrape adhesion, humidity resistance, and stain resistance.

WATER RECYCLE

Water Use

Hardboard mills use large quantities of water to transport pulp and form the product. Smaller water uses are numerous, and add up to a large flow. Water uses and inputs to a hardboard mill are delineated as follows.

Raw Material--

Chips and sawdust contain between 0 to 50% moisture (total weight basis). Chips and sawdust derived from plywood mill residues contain between 0 and 30% moisture, depending upon their origin and subsequent exposure to weather. Sawdust from kiln dry lumber contains about 30% moisture. Fresh chips contain about 50% moisture.

Steam and Impregnation Water--

Live steam is added directly to the digester cooking the chips. Some of the steam condenses during heating of the chips and some condenses in the cyclone when contacted with cyclone wash water. If the chips are dry, some water is added to the digester to prevent scorching of the chips.

Cyclone--

Water is sprayed into the cyclones to wash the pulp into the stock chests. Without the water spray the pulp is likely to bridge over the outlet and plug the cyclone. Water used for cyclone wash is either freshwater or recycled white water. If the mill blows directly to the stock chest or is equipped with mechanical pulp removal from the cyclone, there is no water use at this point.

Stock Dilution Water--

Pulp leaves the cyclone at about 5% consistency and must be further diluted before formation of the board. Recycled white water is most commonly used for dilution water, although freshwater is sometimes substituted to control the white water temperature when board formation problems occur or when there is insufficient white water available.

Consistency Regulator Water--

Consistency regulators control dilution of pulp to the consistency required for board formation of about 2.5%. Freshwater is often used by consistency regulators because of its assured continual supply. Recycled white water is more often used for consistency regulators.

Overlay Dilution Water--

Some of the pulp from the stock chest is further refined for use as an overlay on the already formed mat. Water used to dilute the overlay stock to about 1% consistency can be recycled white water.

Broke Dilution Water--

Broke is continuously produced by trimming the mat prior to its going to the hot press. System upsets and grade changes produce intermittent broke which is diluted and pumped back to the stock chest. Normally white water is used for broke dilution; however, when the entire mat is going to broke as in grade changes, insufficient white water may be available and freshwater is added.

Shower Water--

Water is sprayed on the fourdrinier screens and press screens to wash away debris and prevent buildup of solids. Freshwater is often used for screen washing, although filtered white water can be used. Large fibers and particles in unfiltered white water will plug spray nozzles. The presence of fines in re-used white water does not hinder screen washing and the higher temperature is sometimes helpful. Screen wash waters are often added to the white water.

Vacuum Seal Water--

A small amount of freshwater is used to insure a seal in the vacuum pumps. This water must be of high quality to prevent corrosion of the vacuum pump, and must be of low temperature.

Pump Gland Water--

Water low in suspended solids content is used on pump glands.

Chemical Make-up Water--

Freshwater is used to make-up chemical additives to the pulp system; alum, sulfuric acid, and resins account for most of this chemical make-up water.

Water Quality

Quantities and qualities of water used through a hardboard mill are listed in Table 4. Water usage will vary from mill to mill, depending upon moisture content of the chips and the amount of white water recycle practiced.

TABLE 4. WATER USE AND QUALITY IN A HARDBOARD MILL

Water use	Flow l/kg	Flow (Gal/Ton)	Quality*
Boiler water	0.32-0.55	(70-120)	very good
Chemical make-up	0.07-0.09	(15-20)	good
Cyclone spray	0-17.4	(0-3800)	low
Impregnation water	0-0.81	(0-200)	low
Consistency regulator and dilution water	0.07-2.29	(15,000)	low
Overlay dilution water	0-3.68	(0-800)	low

TABLE 4. (continued)

Water use	l/kg	Flow (Gal/Ton)	Quality*
Shower wash	0.91-1.84	(200-400)	medium
Vacuum seal	4.50	(1000)	good
Pump gland	32.17	(7000)	good
Broke repulping	2.29-4.60	(500-1000)	low
Hoses and miscellaneous	0.18-0.36	(40-80)	medium

*Definition of water quality: very good, deionized or softened water; good, freshwater; medium, filtered white water; low, unfiltered white water.

Water Discharges

Water is discharged from hardboard production at various process locations. In some mills the various discharges are collected into the white water system, in others they are discharged separately to the sewers. Discharge locations are listed as follows.

Screw Water--

When chips have high moisture contents, in the range of 50% or greater, moisture is squeezed from the chips in the screw feed to the digester. Screw water has a low dissolved solids content, but usually contains chips, slivers, and other solid material.

Cyclone Steam--

Noncondensed steam from cooking and refining escapes from the cyclone. Normally a water spray in the cyclone condenses much of the steam. Some mills do not use a cyclone, or do not have a spray in their cyclone, and much of the steam will escape.

Excess White Water--

Overflow from the white water chest is discharged directly to the sewers. The amount and quality of the overflow depends upon the amount of recycle practiced.

Shower Water--

Shower water is often added to the white water, but is sometimes discharged separately. Normally it has a low dissolved solids content but contains fibers and fines washed from the screens. When filtered white water is used for shower water, it has characteristics similar to the white water.

Wash Water--

Some mills, usually those producing S2S board, wash the pulp to remove dissolved solids after it comes out of the refiner. This wash water containing dissolved solids, colloidal material, and fibers is discharged directly to the sewer.

Dryer Vapor--

In production of S2S board the mat is dried prior to the hot press. The water contained in the mat leaving the tipple is vaporized and vented to the atmosphere.

Press Pit Effluent--

In production of S1S board, water is squeezed from the mat when the hot press is rapidly closed. About 70% of the water in the mat is pressed from the board. A screened platen allows for the water to freely drain from the mat giving S1S board its characteristic screen back appearance. This water is often the lowest quality water in the mill as it contains oil drippings from the press, fiber, and trash from problem boards.

Press Steam--

The remaining water in the mat in either S1S or S2S production is vaporized in the hot press and is vented to the atmosphere.

Pump Gland Water--

Pump gland water is often added to the white water, but is sometimes discharged separately.

Vacuum Seal Water--

Vacuum seal water is often added to the white water, but is sometimes discharged separately.

White Water Recycle

Most mills presently recycle over half of their white water. Various degrees of white water recycle are evidenced by the range of discharge from 45.9 liter/kilogram (10,000 gal/ton) to 2.6 liter/kilogram (930 gal/ton). The total flow of white water to the white water tank at various mills including shower water, pump gland, and vacuum seal water, is between 50 to 80 liter/kilogram (12,000 to 19,000 gal/ton).

Opportunities for reuse of white water and press pit water are numerous. The most obvious, and easiest to install, is to use white water for all cyclone sprays, pulp dilution water, consistency regulators, and for broke dilution. To achieve full white water utilization for these processes some additional white water storage tanks may be required to supply white water when demanded. Numerous saveall devices can be used to upgrade the white water quality so that it may be used for shower water without causing operational problems.

Solids Buildup--

During cooking and refining of the chips, soluble, colloidal, and finely divided material are released into the aqueous pulp medium. Other water soluble materials are added through resin and chemical additions. When recycle is practiced, the soluble material in the water drained from the mat is returned to the incoming pulp causing an increase in the concentration. Some of the soluble material is carried out with the water in the mat. A material balance will show that with increasing recycle, the concentration of solids in the white water will increase.

Figures 3 and 4 show the white water dissolved solids concentration vs. discharge flow, and discharge of dissolved solids vs. discharge flow, respectively as derived from a mass balance. The systems represented are an S1S mill where the press pit water is returned to the white water, and an S2S mill. No washing of the pulp is assumed in both situations. A dissolved solids loading to the white water system was assumed to be .09 kg/kg pulp, corresponding to a 90% yield pulp. Figures 3 and 4 show that when recycle is increased and the discharges decrease, the white water concentration increased and the solids sewered decreased. Significantly little increase in white water concentration or little decrease in solids discharged occurs until about 90% of the white water is recycled. Recycle of the remaining 10% of the white water causes significant increases in white water concentrations and significant decreases in solids discharged.

Most American mills operate with discharges of more than 22 l/kg pulp (4800 gal/ton). There appears to be plenty of opportunity to decrease the quantity of discharge; however, as the white water dissolved solids concentration increases, problems with board quality and other mechanical difficulties begin to occur. The concentration at which these problems begin to occur varies from mill to mill, and the problem causing the limitation is different for each mill.

The limiting concentration of dissolved solids in the white water will depend upon whether S1S or S2S board is being made. Assuming that the board quality deterioration is dependent upon the quantity of dissolved solids in the board, probably S2S boards cannot tolerate as high a dissolved solids concentration in the white water as can S1S boards. In S2S production all of the dissolved solids contained in the water in the mat leaving the tipple area becomes permanently part of the board when dried. In S1S production about 50 to 80% of the dissolved solids contained in the water in the mat leaving the tipple area are removed with the water upon squeezing in the hot press. At identical white water dissolved solids concentration S2S board will contain more soluble materials than will S1S board. The higher solids concentrations in the S2S board is more likely to cause product quality problems than would be encountered in S1S production. To maintain the same dissolved solids content in the board the S2S mill has to discharge twice as much water as the S1S mill. The quantity of dissolved solids in the effluent would be the same for both types of mills.

The concentration of suspended solids in the white water does not increase in the same manner as do dissolved solids when recycling is increased. Suspended solids are selectively removed from the white water by filtration during draining of the mat, which removes most of the larger

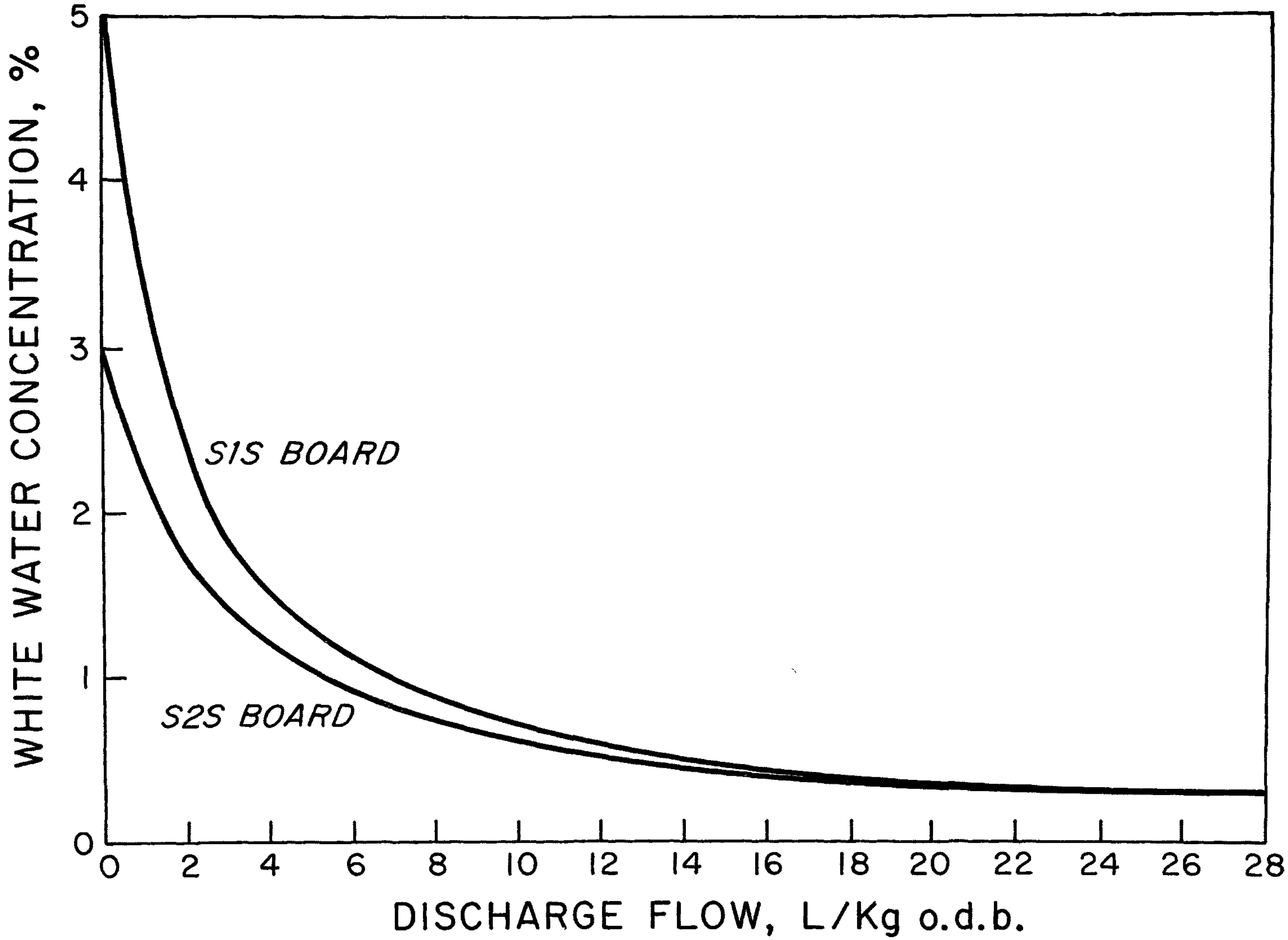

Figure 3. White water concentration vs. discharge flow.

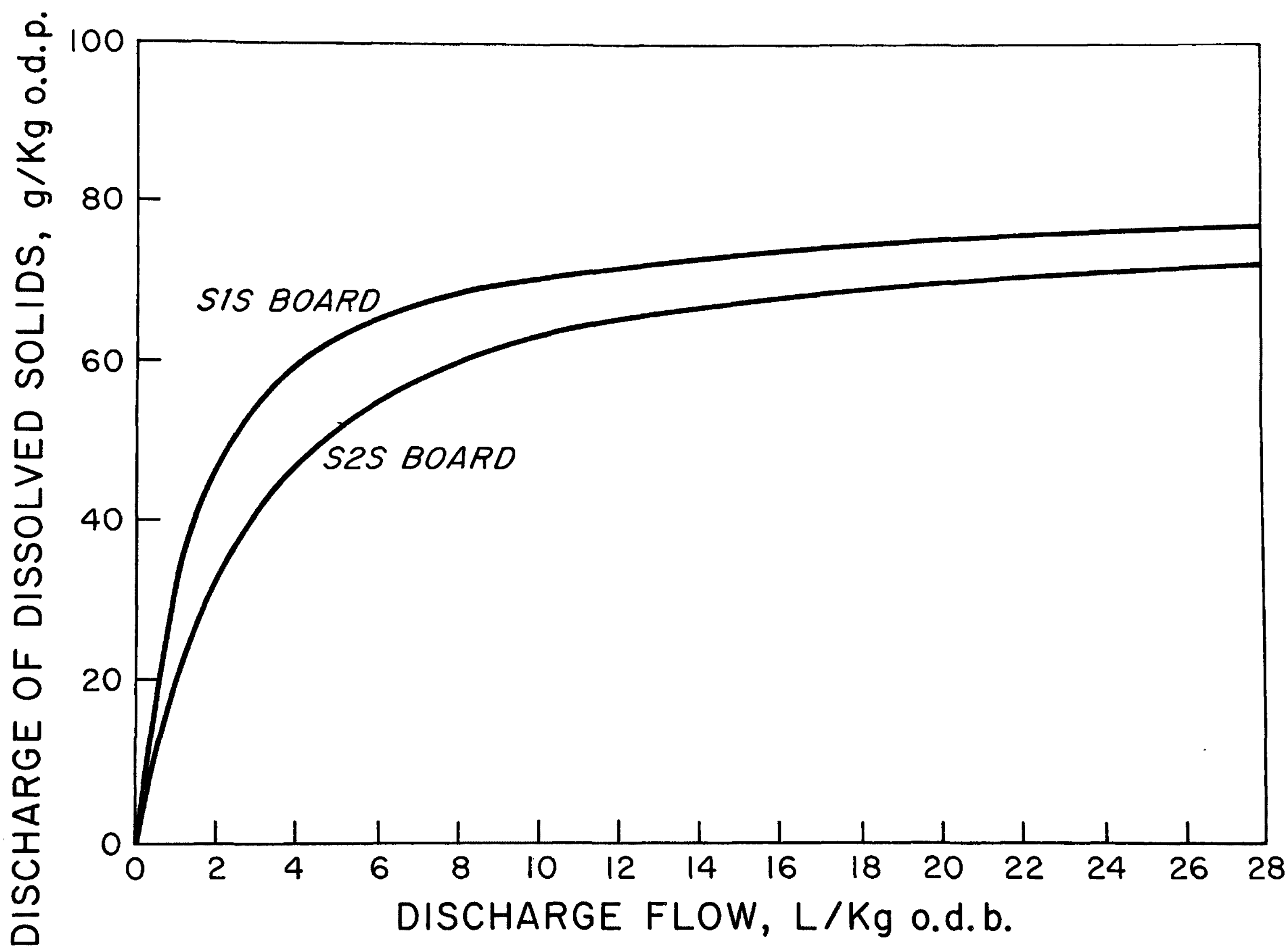

Figure 4. Discharge of dissolved solids vs. discharge flow.

particles and fillers. Colloidal particles are not so easily removed and will increase in concentration in the white water as recycling is increased unless a flocculating agent is added to the white water system. A flocculating agent such as alum will increase the particle size, rendering them filterable or possibly attach the colloidal material to the fibers. Most mills already use alum to precipitate resins. A buildup of sulfates from alum additions to a closed system may result in decreased retention of resins. The double negative charge of the sulfate ion could impair the affirmity of the alum for the resin and fibers.

Effects of White Water Recyle on Board Quality

Numerous reports of board quality problems have been reported in the literature when hardboard mills attempt to recycle greater quantities of white water. Problems that occur most often are sticking in the hot press, and loss of board strength. Other problems reported are alteration of specific board properties, such as dimensional stability, discoloration, and leaching of solubles from boards in use.

Press Sticking--

Sticking of the board to platens in the hot press is often the first problem encountered when recycle is attempted. When the white water dissolved solids concentration exceeds about 3.5%, sticking is prone to occur. Gross clinging of the board to the hot press platen is seldom experienced. Pinpoint sticking is more often encountered, which disrupts the smooth continuity of the board surface.

Release agents are often used to reduce sticking of the board to platens in the hot press. The most common release agent is a wax emulsion that is lightly sprayed on the surface of the mat just prior to the tippe area. Other proprientory release agents are also used, especially if the hardboard is to be painted for its intended use. These release agents are capable of preventing sticking in the hot press until the white water dissolved solids concentration exceed 7% (1). The highest reported white water concentration where sticking is not a problem is 10% dissolved and suspended solids (2).

Another method of reducing sticking in the press is to lower the press temperature (3). Lowering the press temperature may be the only method available to S2S mills to reduce press sticking because the back side of S2S board cannot be sprayed with a release agent. Lowering the press temperature has the disadvantage of requiring a longer press cycle time.

Temperature--

The heat added to the hardboard process in the cooking stage normally leaves the process in the effluent. With increasing recycle, heat is retained in the system in the form of higher white water temperature. The white water temperature increases until some equilibrium temperature is reached. Temperatures as high as 70°C have been reached.

High white water temperatures can cause high temperatures and humidities around the forming line, especially in the summer, making working conditions uncomfortable. Condensation of moisture on cold surfaces, such as cold water lines, causes dripping of water around the forming line.

These problems can be prevented if adequate measures are taken. The area around the forming line can be well ventilated to keep temperatures and humidities down. The white water can be cooled with heat exchangers to tolerable levels.

Board Strength--

Some attempts at increasing white water recycle have been thwarted by decreases in board strength properties, modulus of rupture (MOR) in particular. The cause of the strength loss has not been determined, one theory is discussed below.

When recycle is practiced white water chemistry changes; acidity increases. The increased acidity and lower pH may cause the resins to prematurely set or not react at all causing a weak board to be formed. High white water temperatures may cause the thermosetting resins to prematurely set. If the resins set before the board reaches the hot press it will not assist in binding fibers together.

Water Absorption--

The greater amount of fines and dissolved solids content of the board due to high recycle levels may lead to an increase in board water absorption. Water absorption sites are much more readily accessible in the small amorphous colloidal particles and dissolved solids than in the crystalline structure of the fibers. Wood celluloses and hemicelluloses are highly hygroscopic, and readily exchange moisture with the air upon humidity changes.

Dimensional Stability--

When wood adsorbs water it expands. The increase in water adsorption of hardboard produced with a high degree of white water recycle thereby decreases the dimensional stability of the board. Dimensional stability is especially important for hardboard siding products.

Bleedout--

Dissolvable materials in boards may leach out of the board if the board should get wet. Uneven wetness of the board may cause discoloration of the board. Bleedout may be a problem when hardboard is used around sinks or showers.

Color--

Sugars in the board are subject to scorching and burning in the hot press. When a high degree of recycle is practiced a darker board color is noticed, which is partially due to scorching in the hot press and partially due to the higher wood extractives content of the boards.

Corrosion--
The higher dissolved solids and acidity and the lower pH found in mills that practice high degrees of recycle are conducive to high corrosion rates. Most hardboard mills use stainless steel piping throughout the mills and should not be bothered by harsher white water chemistry. Replacement of other metal parts exposed to white water with stainless steel should minimize corrosion.

Decay--
Free sugars in the hardboard are an inviting food source for various fungus and biota. Dry rot will attack hardboard if the moisture content is about 15%. Boards with a high dissolved solids content will rot twice as fast as those with low sugar contents (5). Termites are attracted by the high sugar content.

CHEMICAL REACTIONS DURING HARDBOARD PRODUCTION

Composition of Wood

Wood is composed of lignins, celluloses, hemicelluloses, wood extractives, and small quantities of other materials. Most wood compounds are insoluble in water. Table 5 lists the compositions of various wood species and their hot water solubilities. Hardwood and softwoods vary significantly in composition, mainly in respect to their hemicellulose content. Softwood contains between 5 to 13% pentosans, whereas hardwoods contain between 17 to 32% pentosans. Table 6 shows differences in hardwood and softwood carbohydrate polymers.

The area near the cell wall contains most of the hemicellulose. The fibers (cell walls) are held together with lignin. Between the lignin and cell walls, lignin and hemicellulose are closely intermingled. Relative solubilities of these wood components are different.

Chemical Reactions

When wood is heated hydrolysis of acetyl groups connected to the hemicellulose occurs, as evidenced by a drop in pH in an aqueous medium. With the decrease in pH, hydrolysis of hemicellulose increases. The product of hydrolysis is acetic acid. The drop in pH at a constant cooking time is more pronounced as the cook temperature increases. The pH drops rapidly at temperatures above 160°C (320°F) (6).

The lowering of the pH within the wood causes hydrolysis of the hemicelluloses and celluloses to sugars or oligosaccharides. Hydrolysis of the hemicellulose and cellulose material proceeds at different rates. The rate of hydrolysis is also temperature dependent. Above 140°C (284°F) dissolution of hemicelluloses becomes rapid, and above 150°C (302°F) the rate of dissolution of cellulose increases (7). Below 150°C (302°F)

TABLE 5. COMPOSITION OF NORTH AMERICAN WOODS
(% EXTRACTIVE-FREE WOOD)

Species	Glucan	Mannan	Galactan	Xylan	Arabinan	Uronic anhydride	Acetyl	Lignin	Ash	Solubility in hot water % of wood
Hardwoods:										
Trembling aspen (Populus tremuloides)	57.3	2.3	0.8	16.0	0.4	3.3	3.4	16.3	0.2	3.0
Beech (Fagus grandifolia)	47.5	2.1	1.2	17.5	0.5	4.8	3.9	22.1	0.4	--
White birch (Betula papyrifera)	44.7	1.5	0.6	24.6	0.5	4.6	4.4	18.9	0.2	--
Yellow birch (Betula lutea)	46.7	3.6	0.9	20.1	0.6	4.2	3.3	21.3	0.3	4.0
Red maple (Acer rubrum)	46.6	3.5	0.6	17.3	0.5	3.5	3.8	24.0	0.2	--
Sugar maple (Acer saccharum)	51.7	2.3	0.1	14.8	0.8	4.4	2.9	22.7	0.3	4.4
Sweetgum (Liquidambar styraciflua)	39.4	3.1	0.8	17.5	0.3	--	--	23.7	0.2	2.0
White elm (Ulmus americana)	53.2	2.4	0.9	11.5	0.6	3.6	3.9	23.6	0.3	3.6
Southern red oak (Quercus falcata)	40.6	2.0	1.2	19.2	0.4	4.5	3.3	23.9	0.8	--
Yellow poplar	--	--	--	20.0	--	--	--	20.0	--	0.2
Sycamore	49.0	1.6	1.1	16.0	10.0	--	--	25.0	0.6	--

TABLE 5. COMPOSITION OF NORTH AMERICAN WOODS (Continued)
(% EXTRACTIVE-FREE WOOD)

Species	Glucan	Mannan	Galactan	Xylan	Arabinan	Uronic anhydride	Acetyl	Lignin	Ash	Solubility in hot water % of wood
SOFTWOODS:										
Balsam fir (Abies balsamea)	46.8	12.4	1.0	4.8	0.5	3.4	1.5	29.4	0.2	--
Eastern white-cedar (Thuja occidentalis)	45.2	8.3	1.5	7.5	1.3	4.2	1.1	30.7	0.2	--
Eastern hemlock (Tsuga canadensis)	45.3	11.2	1.2	4.0	0.6	3.3	1.7	32.5	0.2	3.7
Jack pine (Pinus banksiana)	45.6	10.6	1.4	7.1	1.4	3.9	1.2	28.6	0.2	3.7
White pine (Pinus strobus)	44.5	10.6	2.5	6.3	1.2	4.0	1.3	29.3	0.2	4.5
Loblolly pine (Pinus taeda)	45.0	11.2	2.3	6.8	1.7	3.8	1.1	27.7	0.3	1.8
Douglas-fir (Pseudotsuga taxifolia)43.5 taxifolia)	43.5	10.8	4.7	2.8	2.7	2.8	0.8	31.5	0.4	5.6
Black spruce (Picea mariana)	47.9	10.5	--	8.0	--	4.1	1.1	28.0	0.4	--
White spruce (Picea glauca)	46.5	11.6	1.2	6.8	1.6	3.6	1.3	27.1	0.3	2.9
Tamarack (Larix laricina)	46.1	13.1	2.3	4.3	1.0	2.9	1.5	28.6	0.2	--

TABLE 6. MAJOR CARBOHYDRATE POLYMER COMPONENTS OF HEMICELLULOSES

Polymer	Relative amount present	
	Softwoods	Hardwoods
4-0-Methyglucuronoxylan acetate	Small or none	Very large
4-0-Methylglocuronoarabinozylan	Medium	Trace
Glucomannan	Nil	Small
Glucomannan acetate	Large	Small
Galactoglucomannan acetate	Small	Nil
Arabinogalactan	Trace to medium	Nil

very little hydrolysis and dissolution of cellulose occurs. Solubilization of hemicelluloses begins at about 140°C (284°F).

The amount of cellulose solubilized depends upon the amount of hemicelluloses present. For hardwood, where the hemicellulose content is high, the cellulose removal during cooking is quite low. On the other hand, where the original hemicellulose level is low, as in softwoods, the degradation of celluloses upon cooking is much greater (7).

Richter's work (7) showed different yields for different wood species at identical cooking conditions. White birch had the lowest yield whereas Douglas fir, western hemlock, spruce, and gumwood had similar yields at identical cooking conditions. Gran showed the differences in yield for birch and beech at identical cooking conditions (3).

Bornardin reported that the yield of wood is a logarithmic function of time (8). He also reported that the material removed from black gumwood by water hydrolysis at 160°C (320°F) consisted of about 55% hemicelluloses. The remainder of the materials removed were extractives, lignin, and decomposition products.

The solubility of wood in hot water is not a good indication of how much of the wood will be solubilized at fiberboard cooking conditions, but is mainly a measure of the water soluble extractives content. In the solubility test, insufficient time or temperature is available for significant degradation of the hemicelluloses and celluloses. In the hardboard mill most of the water soluble materials result from the degradation of hemicellulosic materials.

Softening of Lignin with Heat

When wood chips are heated the lignin and hemicelluloses between the cell walls becomes soft, beginning at specific temperatures referred to as the glass point. During cooking the lignin is heated to the glass point so the fibers can be easily separated upon refining. At temperatures below the glass point the wood fractures through the outer layer of the secondary cell wall when refined. At temperatures above the glass point the wood fractures through the lignin layers between the cells when refined. When wood has been fiberated above the glass point the fibers will be coated with a layer of lignin (12). When these lignin coated fibers are pressed together under heat and pressure such as during hot pressing of hardboard, the lignin remelts and the fibers are glued back together in a new pattern.

Steamed wood passes through two softening regions. Table 7 shows these softening regions for several species of wood (13). The lower temperature softening region is thought to be due to degradation of bonding between the lignin and cellulose; that is, solubilization of the hemicelluloses during the steaming process. The higher temperature softening region is thought to be due to the softening of the lignin. In practice, the transition between refined spruce fractured in the cell wall or fracturing in the cell wall or fracturing between the cell walls during refining occurs between 120-135°C (248-275°F) (12).

TABLE 7. SOFTENING TEMPERATURES OF SOME WOOD SPECIES

Wood species	Lower transition temperature, °C	% of change	Higher transition temperature, C°	% of change
Aspen	60 - 140	50	180 - 230	50
Birch	60 - 150	60	180 - 240	40
Spruce	80 - 170	20	170 - 240	80

Several minutes are required to heat the entire chip to a uniform temperature. For most chips 2 minutes of heating is all that is necessary. If the chips are not uniformly heated shives are likely to occur because the center of the chip won't break into fibers because it is too hard.

The number of shives is also a function of the cook temperature; more shives appear at lower cooking temperatures. The number of shives in the final pulp can be reduced by increasing the refining energy, i.e., by bringing the plates closer together.

White Water Composition

As indicated by the previous section, the composition of the white water in a hardboard mill should contain a large portion of dissolved cellulosic materials in the form of simple sugars or as water soluble oligosaccharides. The ratio of the types of sugar compounds present is dependent upon the types of wood being processed and the cooking conditions used. Where hardwoods are being cooked a high content of pentosans should be found. When soft woods are being cooked the pentosan fraction should be lower and the hexosan content higher.

Analyses of the dissolved substances in the Masonite process (cooked) at 275°C (527°F) from a coniferous wood showed a composition of 70% carbohydrates, 10% lignin, and 20% organic resins. The carbohydrates were 35% pentosans, mostly xylans, and 65% hexosans (3). Analysis of the dissolved substances in a mill using an Asplund defiberator (cooked at 180°C (356°F)) on beech showed a composition of 75% carbohydrates, a few percent lignin type materials, and about 10% acetic acid. Eighty percent of the carbohydrates were pentosans, mainly xylans, and 20% hexosans (3). Analysis on Aspuland process white water resulting from Douglas fir cooked at 180°C (356°F) showed 44% of the dissolved materials were carbohydrates. Twenty two percent of the carbohydrates were pentosans, mostly arabinose, and the remainder hexosans, mainly mannose, and galactose. Glucose, a decomposition product of cellulose, was only 15% of the carbohydrates (9). The low glucose content indicates minimal dissolution of the cellulosic content of the wood.

Another mill cooking Douglas fir at 166°C (330°F) reports that of the free carbohydrates in the combined discharge from the mill, 58% is arabinose, 15% xylose and the remainder hexosan sugars, largely mannose. Galactose is present mostly as a polymerized carbohydrate. There was practically no glucose present (15).

Effects on Hardboard of Hemicellulose Removal From Raw Material

Rot Potential--

Dry rot, or fungal attack, begins on wood when the mositure content of the wood is above 15%. Hardboard, being essentially wood, also begins to rot at this moisture content and is seldom used in applications where they will receive much moisture. Exceptions are uses in shower stalls, outside sheathing, or in applications where inadequate vapor barrier precautions have been taken.

The hemicellulose content of wood is responsible for a portion of its water adsorption characteristics from air. Hemicellulose has an amorphous structure and can easily adsorb water. The cellulose portion of wood is crystalline in nature and water molecules have difficulty in penetrating the crystalline structure. Consequently, the equilibrium water concentration in hardboard that has had a high degree of hemicellulose removal during production is about 70% that of wood. Removal of hemicelluloses reduces the amount of water moisture the board can hold and thereby reduces the dry rot potential.

A study of decay of hardboards showed that some fungi and molds attacked the hemicellulose portion of the wood first, then when the hemicellulose content had been reduced to about 12%, began to attack the cellulosic material of the wood. Other molds and fungi attacked the celluloses and hemicelluloses indiscriminately (10). Removal of hemicelluloses reduces the susceptibility of hardboard to rot (5).

Dimensional Stability--

When wood absorbs water it swells. As described in the previous section, the amount of water a board can adsorb is in part controlled by its hemicellulose content. Hardboard with a high hemicellulose content will expand and contract more than a board with a low hemicellulose content.

Because higher cooking temperatures prior to refining reduce the hemicellulose content of the board, water adsorption and dimensional stability of the board can be directly related to the chip cooking pressure. Reduction of the cooking pressure from 8 atm (118 psig) to 3 atm (44 psig) increases the 24 hr submersion water adsorption by 16% (11). Correspondingly, thickness swelling increases by 33%. There is little change in water adsorption or swelling thickness above 8 atm cooking pressure. Changes in relative humidity from 90% to 30% resulted in an 8% higher dimensional change in thickness swelling and a 4% higher dimensional change in sheet direction swelling for boards produced with pulp cooked at 3 atm (44 psig) as compared to that cooked at 8.5 atm (124 psig) (11).

Board Strength--

Back and Larson reported some loss in internal bonding strength (Z strength) when chips used in making hardboard were cooked at low pressures (11). Z strength is related to the amount of refining and to the shive content of the pulp. The tensile strength was reported to be unaffected by the cooking pressure.

RAW WASTE LOAD VARIABILITY

Two subjects are covered by the term raw waste load variability: difference in raw waste loads between mills, and variation of the raw waste load from any one mill. The former results from differences in operation between mills, and the latter results from changes occuring within a mill. The causes of raw waste load variations, either between mills or within a mill, are difficult to determine. Some possible causes of raw waste load variation are discussed in the following text.

Differences Between Mills

Many variables cause raw waste loadings from hardboard mills to differ. These include the wood species used, whether or not the wood is debarked, the product being manufactured, the steaming time and pressure used, the amount of white water recycle, whether or not the pulp is washed, and the additives and retention aids used. Each of the variables has a particular role in determining the raw waste load from a hardboard mill. The amount of pollutants released into the manufacturing process water is influenced by the severeness of the cooking. The cooking time and pressure are determined by the wood species used and the product desired. Each type of wood reacts differently to the cooking step and releases different quantities of pollutants. Use of wood that has not been debarked adds 45% to 50% to the raw waste load (3, 2) and other variables modify the raw waste load. An increase in the amount of white water recycled can reduce the amount of pollutants reaching the effluent. Increased retention of finely divided wood on the mat by use of polymers and retention aids reduces the raw waste load.

Some additives have a BOD of their own and their use increases the raw waste load.

Figure 5 is a monthly average raw waste BOD variability plot for 7 U.S. hardboard mills. Mills A, B, C, and E produce S1S hardboard, whereas mills D and F produce S2S hardboard, and mill G produces both S1S and S2S hardboard. Mills F and G wash their stock. Mills A, D, and E process chips that have bark included. Cooking conditions for the mills are listed in Table 8.

TABLE 8. COOKING CONDITIONS AT VARIOUS MILLS

Mill	Wood Species	Digester Pressure Atm (psig)	Time min.	Board Type
A	Hardwood and softwood chips	10 (140-150)	2.5	S1S
B	Douglas fir plywood trim	8.5 (120-130)	2-3	S1S
C	Douglas fir plywood trim	6.5 (96)	3	S1S
D	Pine, hardwood, FRC	10.2 (150) 6.8 (100)	8-14 6-12	S2S S2S
E	Aspen	10.2 (150)	1.5-2.5	S1S
F	Hardwood	10.2 (150)	1.5-4	S2S
G	Hardwood	12.2 (180)	2	S2S

Isacson and Back reported on pulp yields using various materials and cooking conditions and the corresponding BOD's produced, as shown in Table 9.

Determining which of the many factors or combination of factors listed affects the raw waste load is a difficult task. More information about each of the factors listed needs to be gathered before a clear understanding is attained about why raw wastes differ from mill to mill.

Raw Waste Load Variability Within a Mill

Figure 5 also shows that there is considerable monthly variation in the raw waste loading from any particular mill; day to day variation can be greater. Mill variations can be either long term variations, as expected in monthly averages, or short term variations expressed by daily averages. Causes for each type of variation are likely different, but accumulation of short term variations can lead to long term variations.

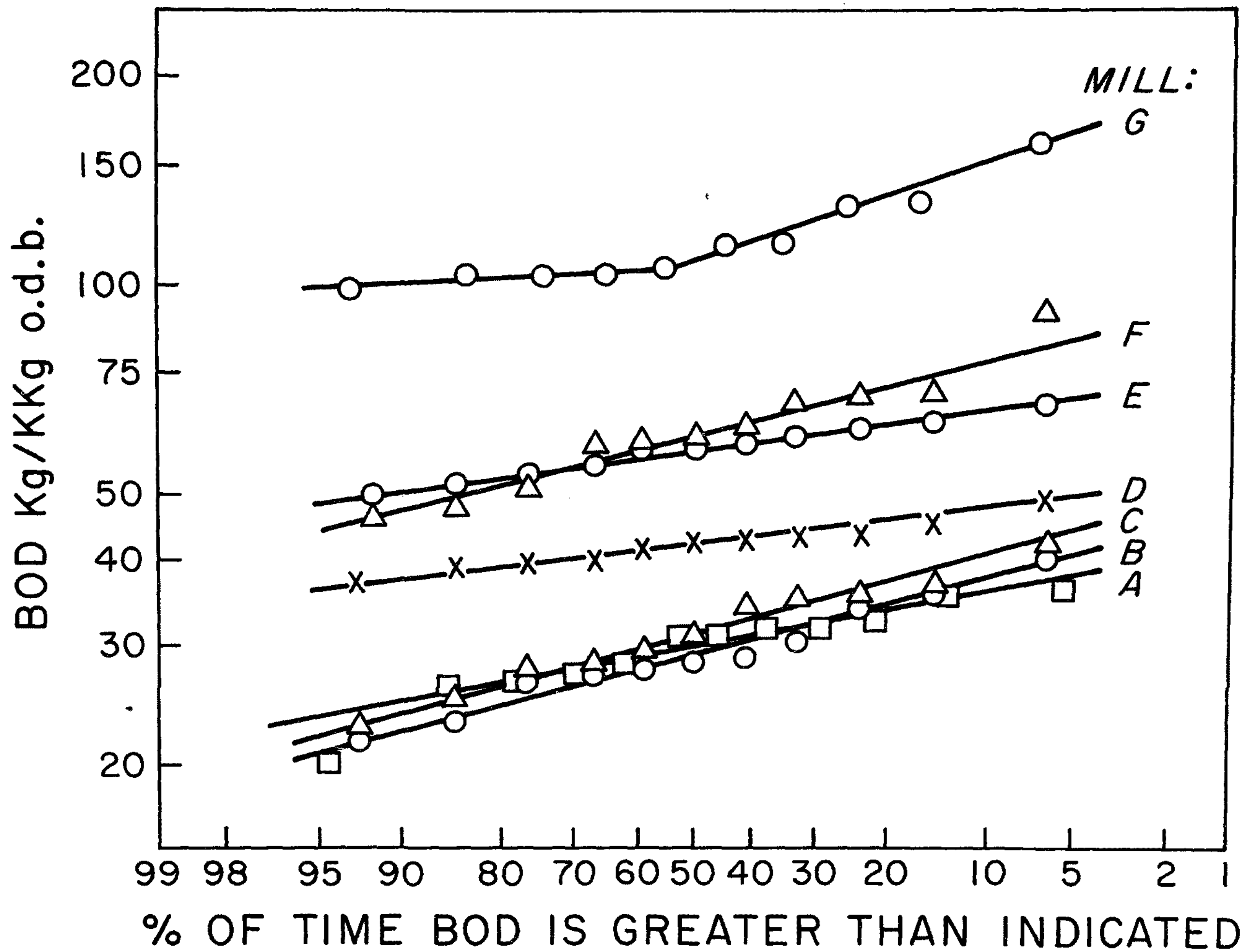

Figure 5. Raw waste load variation for several hardboard mills.

TABLE 9. BODs RESULTING FROM DIFFERENT WOOD SPECIES COOKED AT VARIOUS PRESSURES

Raw Material	Steam Pressure Atm (psig)	Time min	BOD kg/t (lb/Ton)
40% Spruce 40% Pine 20% Birch	10 (147)	--	29.4 (58.8)
70% Pine 30% Birch	12 (176)	3	21.4 (42.80)
100% Barked Birch	13 (191)	4	43.2 (86.4)
70% Pine 30% Birch	13 (191)	--	44.6 (89.2)
Sawmill slabs, pine	11 (161)	--	44.8 (89.6)
Sawmill slabs, pine	12 (176)	--	38.4 (76.8)
Pine logs	13 (191)	--	43.2 (86.4)
Pine saw mill slabs	13 (191)	--	33.1 (66.2)
Softwood, 20% bark	11 (161)	--	30.0 (60.0)

Short term variations may result from a number of process changes and upsets. Daily changes in the nature of the wood supply can cause changes in the way the wood is processed. Changes in the thickness of the board being produced result in different retentions of suspended solids in the mat. Other process fluctuations can also result in short term variation.

Long term changes may result from factors such as length of storage of chips, season the wood was harvested, wood bark content, or changes in product orders. When wood is stored for long periods of time the chances for fungal degradation of the cellulose is increased. Degraded cellulose is likely to be water soluble and thereby contribute to the raw waste loading. Further study of causes of long and short term raw waste load variation is required.

SECTION 5

COMPARISON OF POLLUTION LOADS RESULTING FROM USE OF DIFFERENT WOOD SPECIES

An experiment was designed to determine differences in raw waste loading due to processing different wood species and due to the product manufactured. Pollution loadings resulting from processing each of several wood species at different cooking conditions corresponding to those in use in the hardboard industry were determined. The relative importance of wood species processed and the product produced in determining the raw waste load are compared.

BACKGROUND

When chips are preheated in the hardboard process two reactions take place, a softening of the lignin material that holds the individual fibers together, and hydrolysis of the hemicellulose. Thermal softening of the lignin reduces the amount of energy required to refine chips to pulp. Softening of the lignin is a reversible process. The lignin will harden when the chips are cooled. The temperature at which softening occurs when the chips are heated differs among wood species.

Although not as pronounced an effect as the softening of the lignin, hydrolysis of the hemicellulose produces a permanent softening of the chips. The hemicelluloses are hydrolyzed into low molecular weight, water soluble molecules. About half of the soluble material found in a hardboard mill effluent is hemicellulosic material (3, 4, 5). The remaining material consists of extractives, lignin, and organic acids resulting from the decomposition of wood components. Hydrolysis of cellulose does not occur below 170°C (338°F) (6).

Because of these differences in the softening temperature of the wood and rates of decomposition, mills using different species of wood will preheat chips to different temperatures and for different durations. Oak breaks down more rapidly than do other species of wood, and when cooked too long produces a slow draining pulp. Other types of wood are more resistant to thermal softening and degradation and require more severe cooking conditions.

Cooking conditions are largely determined by the degree of cooking required to produce a pulp suitable for the manufacture of the type or grade of hardboard being produced. A major difference exists in the cooking conditions used in the manufacture of S1S and S2S hardboard. Other product quality factors also influence the cooking conditions used.

S1S boards are normally produced by forming a thick mat of coarsely refined fiber and overlaying the mat with a thin layer of finely refined fiber. The overlay produces a high quality, shive free, smooth surface. Since the majority of the board can contain shives, the fiber in the bulk of the board does not need to be finely refined. Coarse refining requires less energy than fine refining, so cooking conditions need not be as thorough.

Most S2S production processes do not use an overlay to produce a smooth surface on both sides of the board. The whole of the board is made from the same stock. The fibers throughout the board are highly refined so that the surface is shive free. To keep refiner energy consumption at a minimum, the chips need to be thoroughly softened. Thoroughly softened chips call for higher preheating pressures.

Other factors affect steaming times and pressures used at a particular mill. Formation and drainability are affected by refining conditions. More severe cooking conditions may permit less usage of drying oils and resins. Press cycles are shorter for boards made from more severely cooked chips. Longer steaming times are required for frozen chips during winter months.

EXPERIMENTAL PROCEDURE

A questionnaire was sent to all U.S. hardboard manufactures to determine typical wood species mixes, cooking conditions and products made that are relevant in the hardboard industry. Aspen, southern yellow pine, Oregon white oak, Douglas fir, and Douglas fir plywood trimmings were chosen as representative of the wood used by hardboard mills throughout the United States.

Samples of chips used at several mills were shipped to Corvallis. Oak chips were prepared by chipping freshly cut oak logs. Size distributions determined in a Williams Classifier, and moisture contents determined on a total weight basis of the chips are presented in Table 10. The moisture content of the plywood trimmings is higher than oven dry because the chips were stored in an outside pile and subjected to rainfall.

For the tests, bark-free chips were screened on a Williams Classifier to sizes inclusive of 5-29 mm. Each species was steamed in a batch digester at pressures ranging from 6.8 to 13.6 atm (100 to 200 psig) for 2 to 10 minutes. After steaming, all chip samples were refined in a bauer refiner at gap setting of .25 mm (0.010 inch) and a speed of 1755 rpm. All condensate from the digester, refining and wash water, and pulp were diverted to pit where water samples and consistencies were taken. Water was separated from the pulp by drainage through a 32 mesh screen. The water samples were analyzed for total solids, dissolved solids, soluble chemical oxygen demand, total chemical oxygen demand, soluble biological oxygen demand, total biological oxygen demand, and pH. The consistencies, out volume, and initial chip weights were used to determine yields.

TABLE 10. MOISTURE CONTENT AND SIZE DISTRIBUTION OF CHIPS

Species		Aspen	Oak	Southern Yellow Pine	Douglas Fir	Plywood Trimmings
Moisture content		48.1%	36.5%	48.6%	42.4%	27.9%
Size distribution through - retained on						
in.	in.					
1-1/8	7/8	9.4%	52.4%	23.0%	6.4%	4.3%
7/8	5/8	27.9%	34.6%	36.4%	22.7%	9.0%
5/8	3/8	47.4%	12.2%	33.7%	45.6%	32.3%
3/8	3/16	15.4%	1.4%	6.9%	25.4%	54.4%

EXPERIMENTAL RESULTS

When the test results were plotted against pressure considerable scatter of data was evident. Checking the recorded temperature of the cooks showed some deviation of the cook temperature from the theoretical temperature of the steam at the set pressure. Actual temperatures were always lower than theoretical temperatures as shown in Figure 6. The lower temperatures were due to the partial pressure exerted by the volatile wood components and air remaining in the chips. The digestor was flushed with steam prior to the cooks to reduce the effects of the partial pressure of air. When data were plotted against the recorded temperature, trends became better defined.

A test showed that no statistically significant relationship exists between suspended solids and either time or pressure at the 90% confidence level. There were differences in the amount of suspended solids between individual wood species. Suspended solids averages and standard deviations for each species are listed in Table 11. Also listed are values for the average chemical oxygen demand of the suspended solids along with standard deviations.

The quantity of suspended solids that reaches the effluent is dependent upon retention of the suspended solids on the forming wire. Retention of suspended solids on the wire is governed by the thickness of the board being produced, white water chemistry, use of retention aids, and the amount of white water recycle practiced. At 50% recycle suspended solids make up approximately 45% of the raw waste load, and at 80 to 90% recycle suspended solids make up approximately 15% of the raw wasteload chemical oxygen demand (COD). The raw waste loading due to the dissolved solids content of the

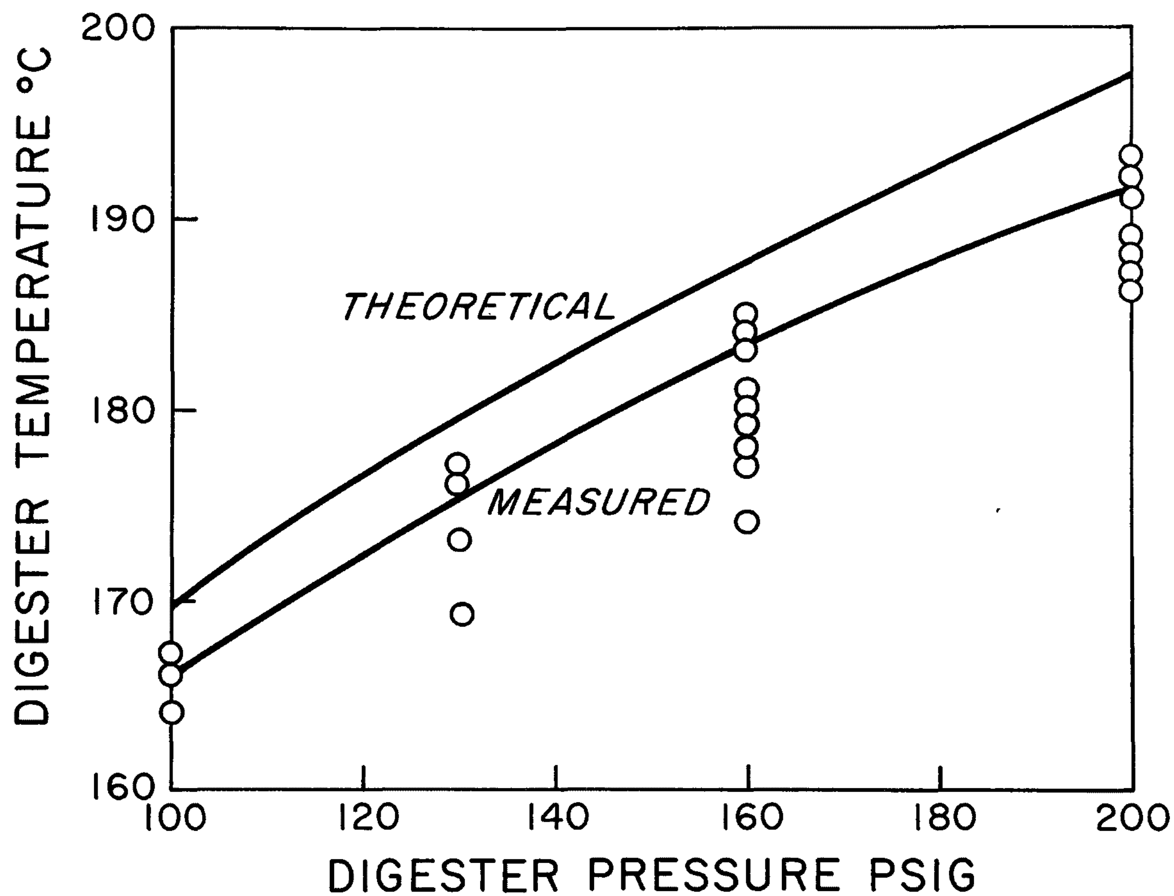

Figure 6. Digester temperature vs. digester pressure.

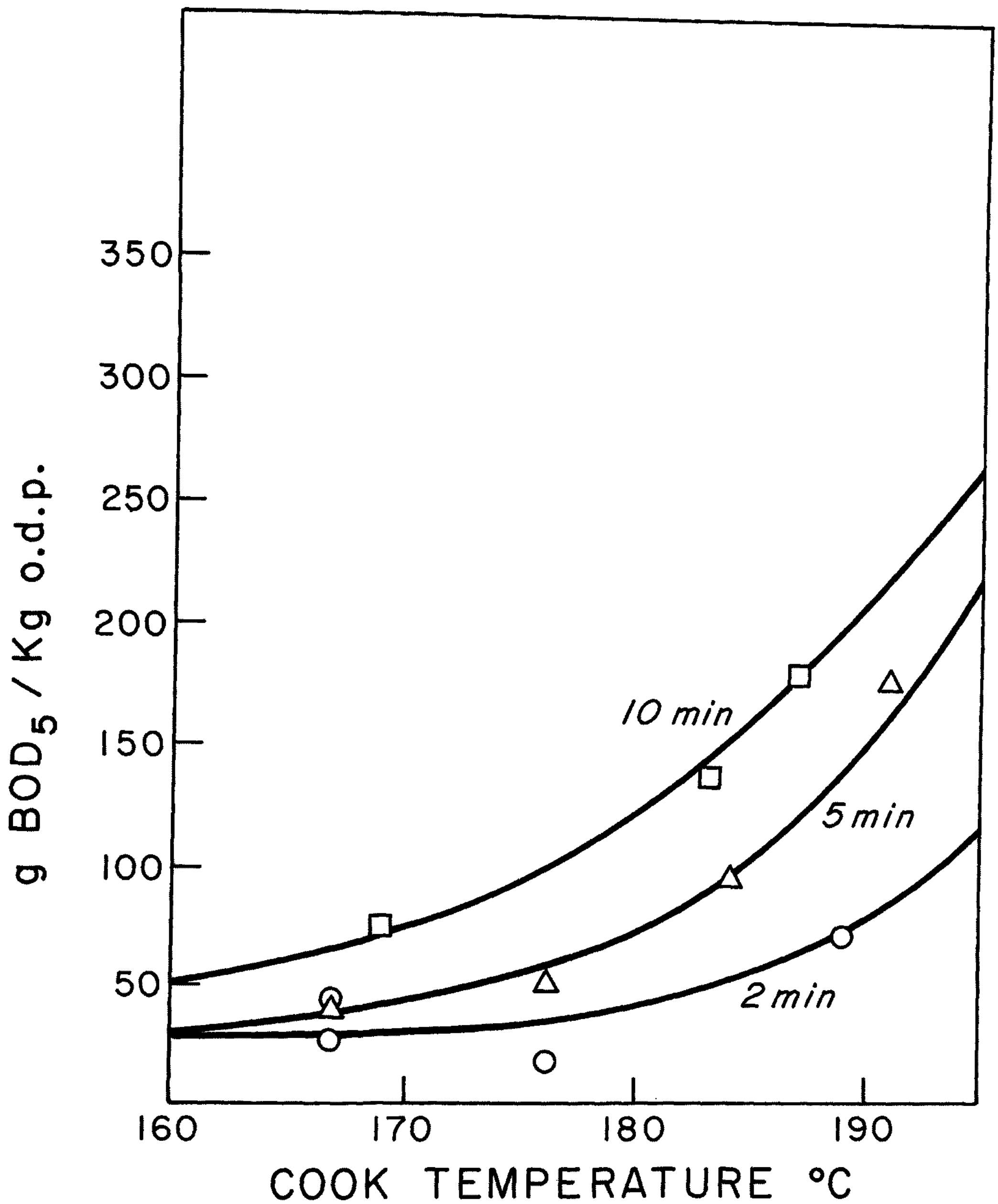

Figure 7. Grams soluble BOD vs. cook temperature, aspen.

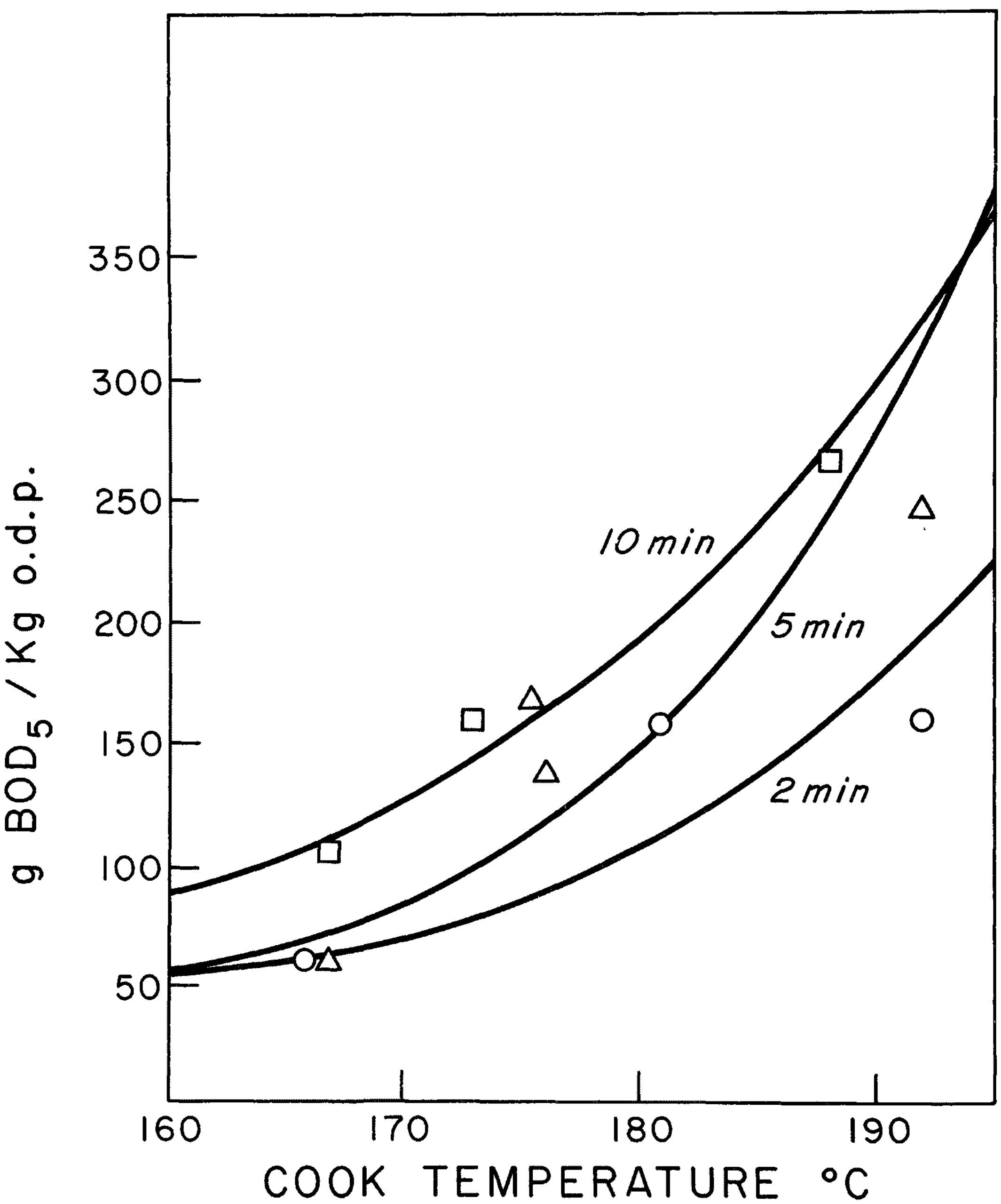

Figure 8. Grams soluble BOD vs. cook temperature, oak.

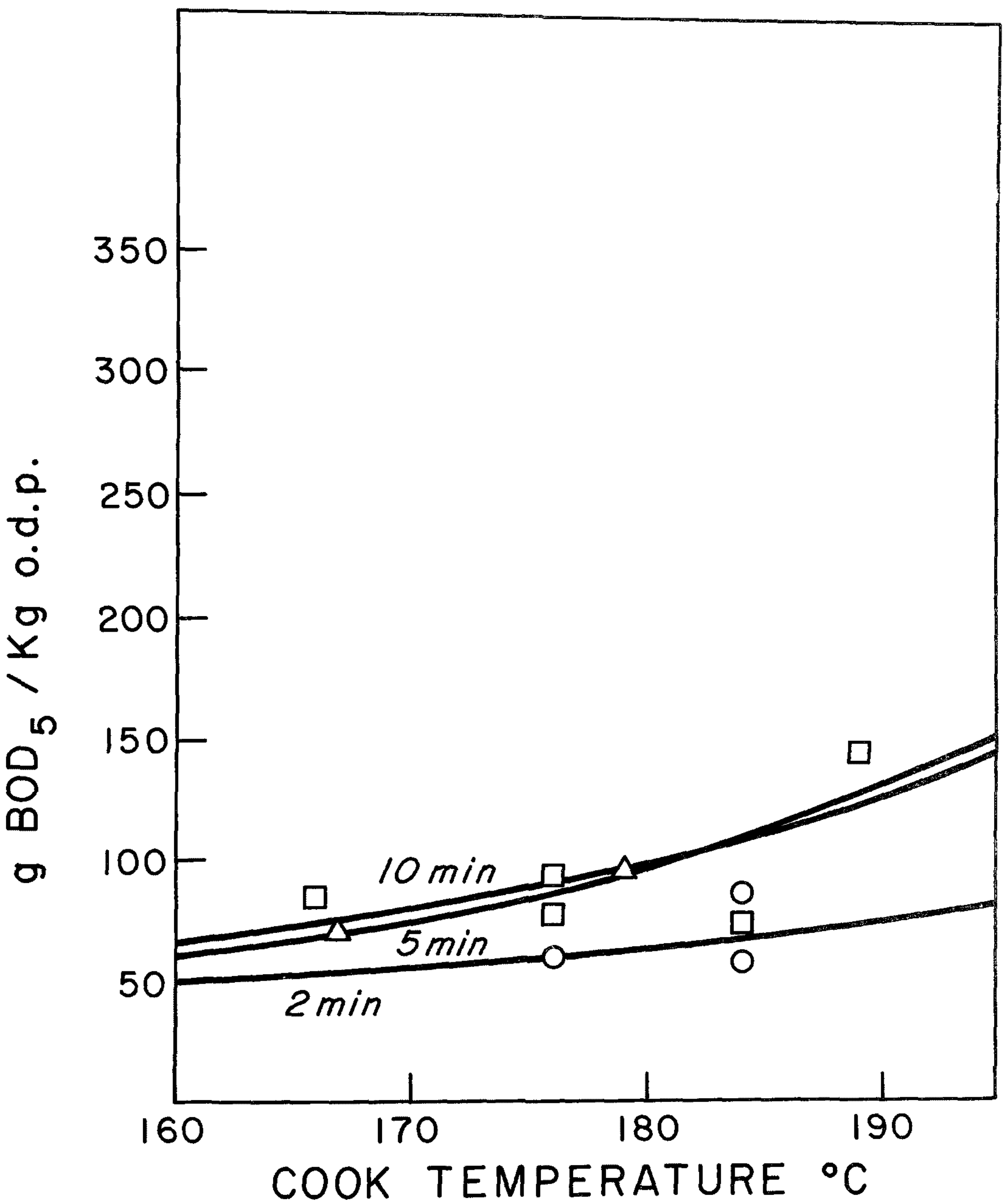

Figure 9. Grams soluble BOD vs. cook temperature, Douglas fir.

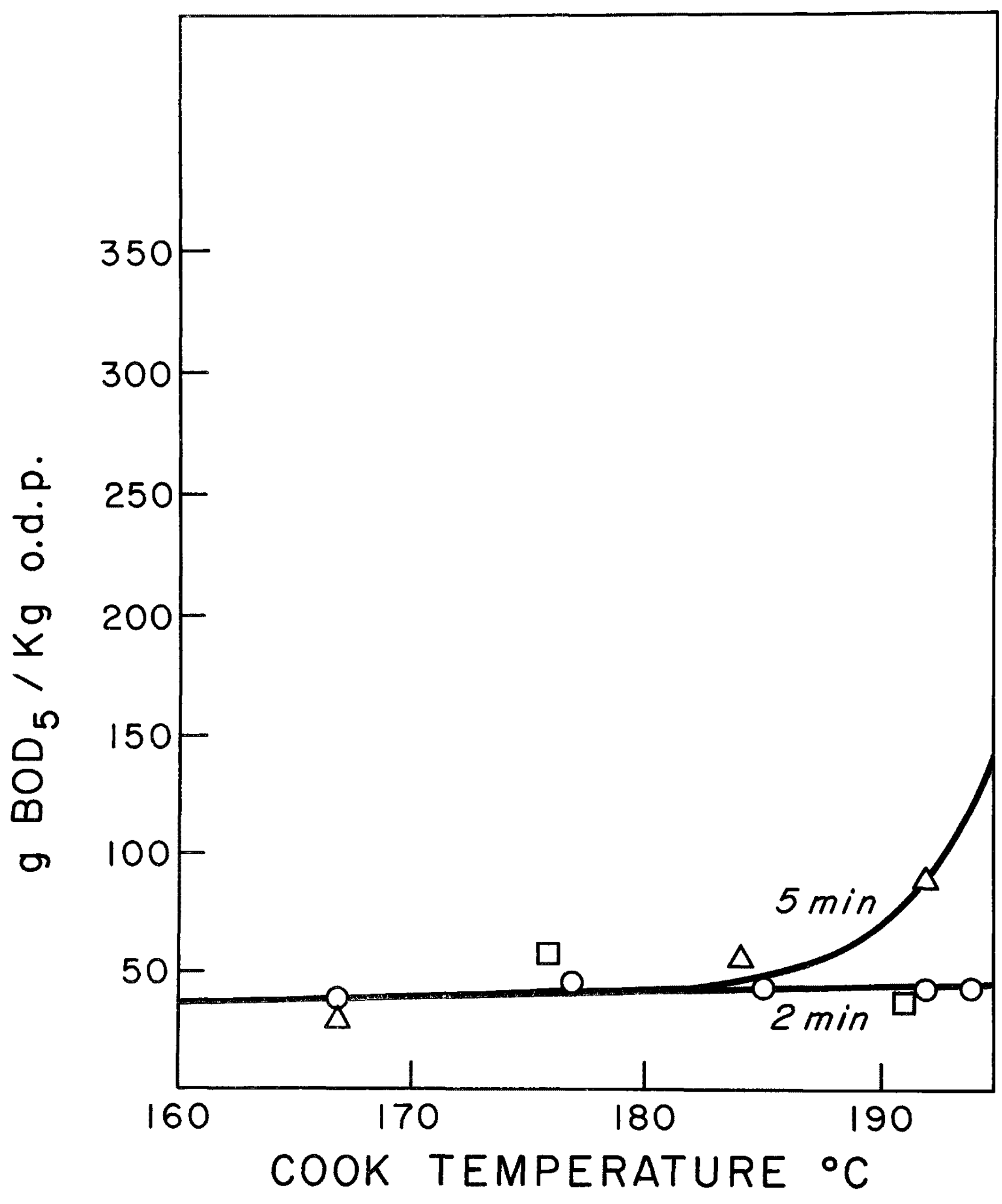

Figure 10. Grams soluble BOD vs. cook temperature, plywood trim.

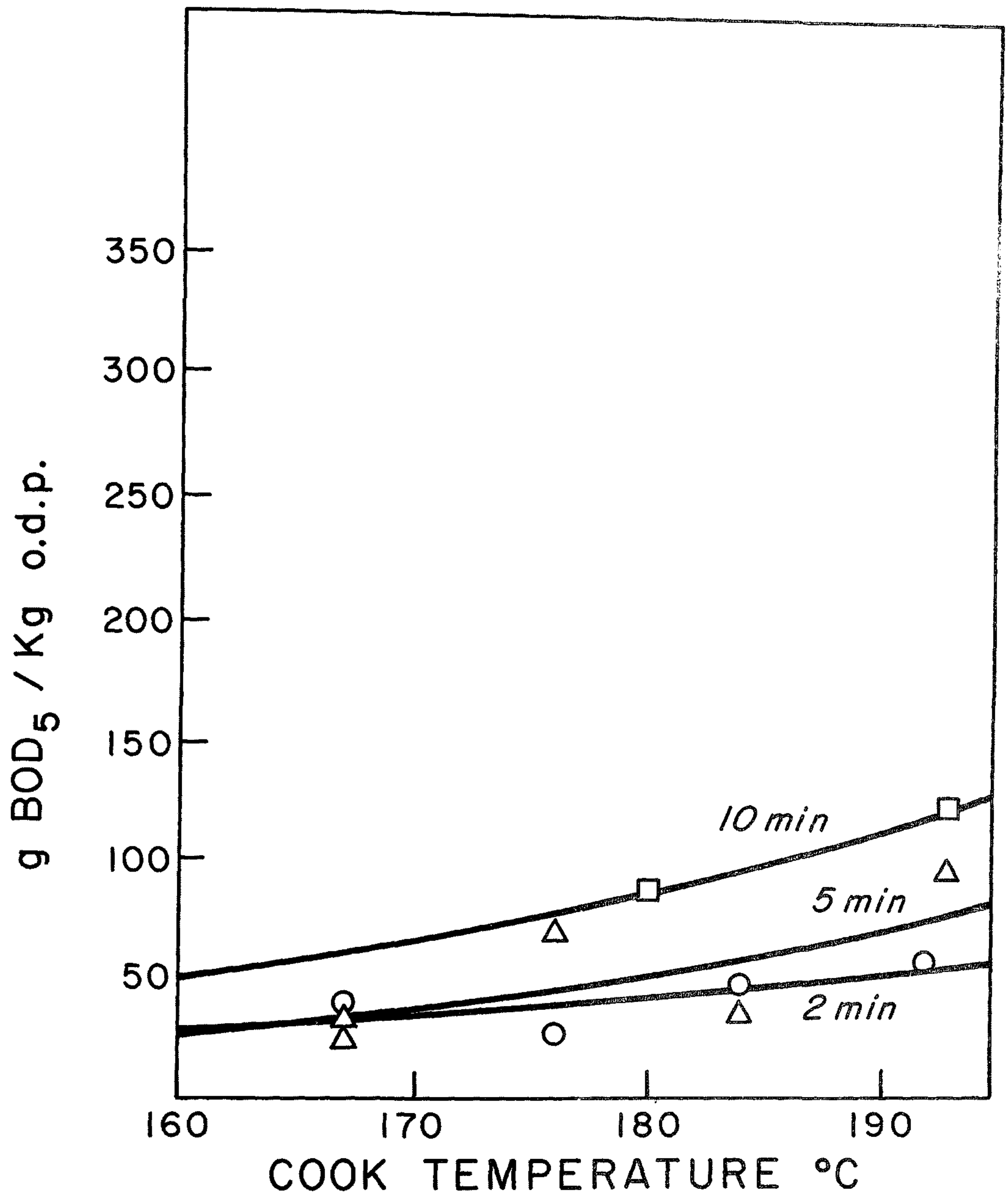

Figure 11. Grams soluble BOD vs. cook temperature, southern yellow pine.

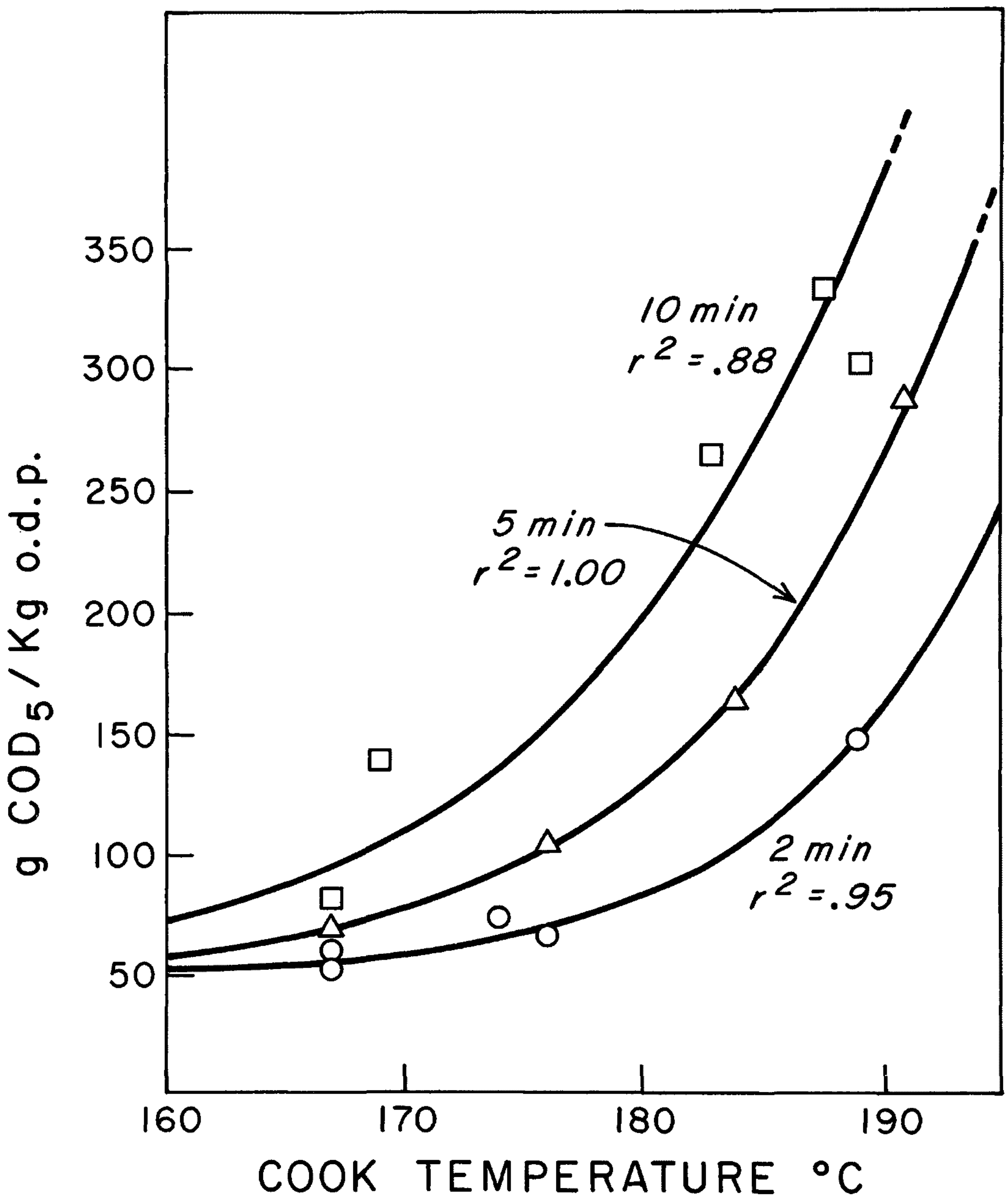

Figure 12. Grams soluble COD vs. cook temperature, aspen.

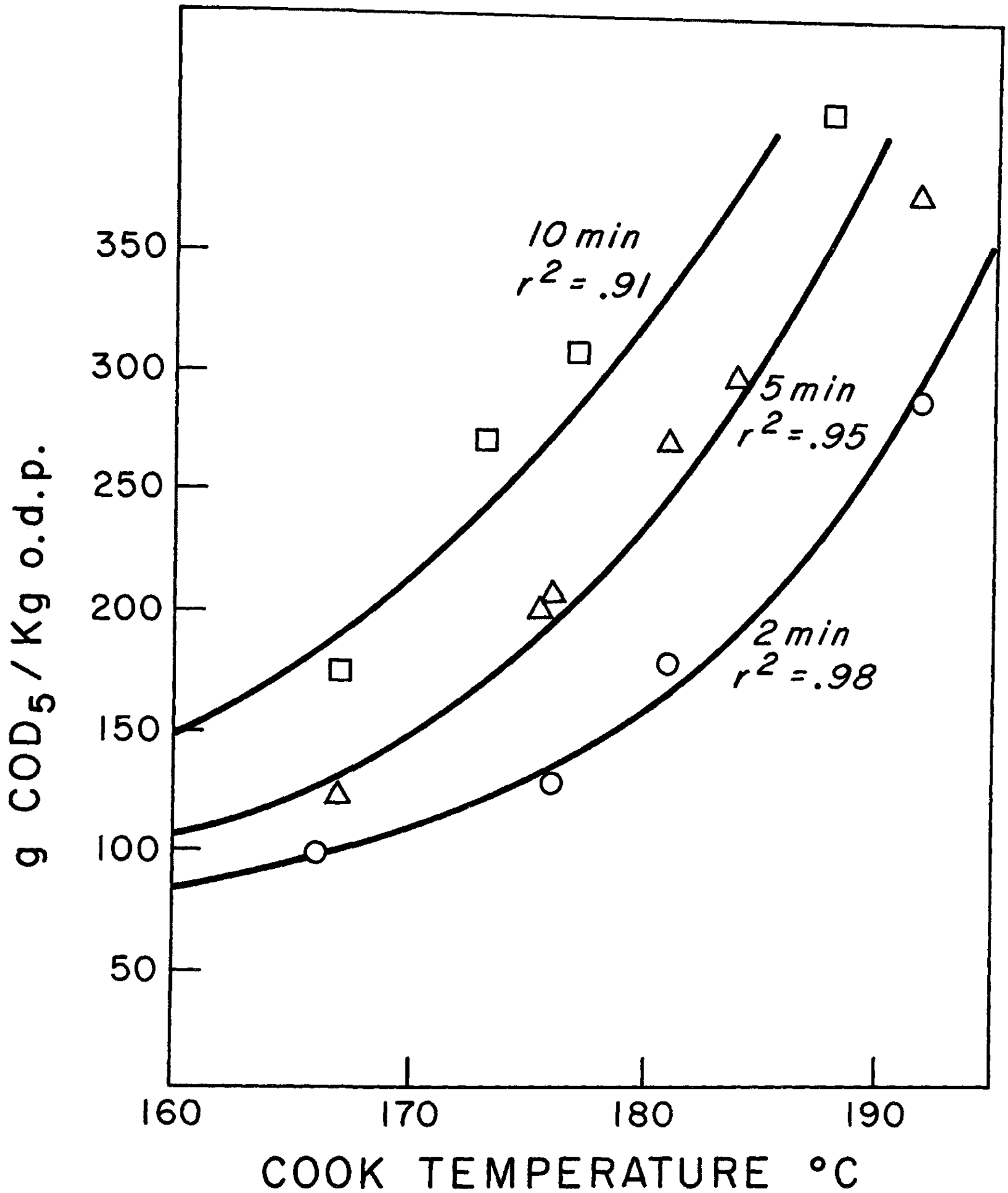

Figure 13. Grams soluble COD vs. cook temperature, oak.

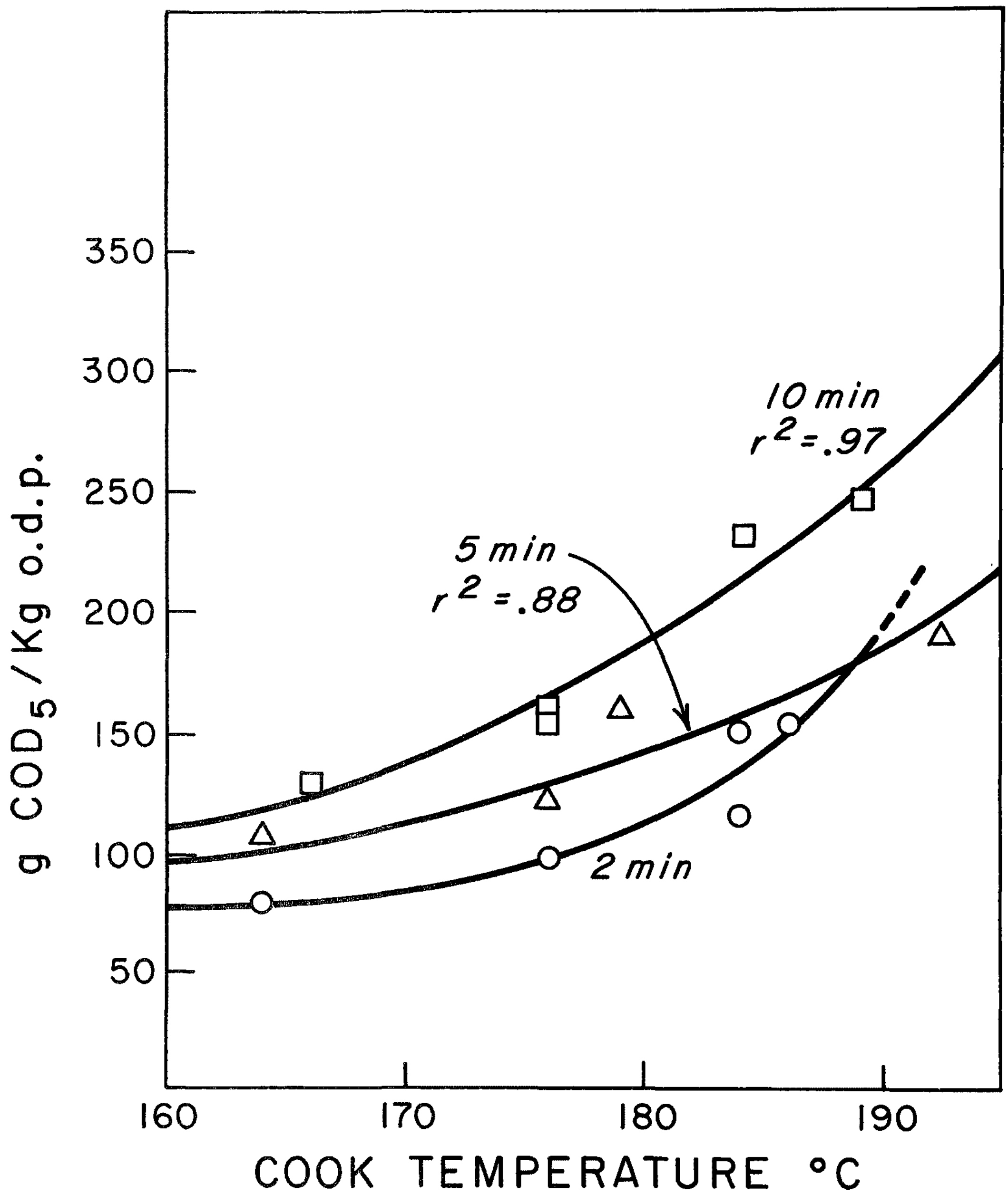

Figure 14. Grams soluble COD vs. cook temperature, Douglas fir.

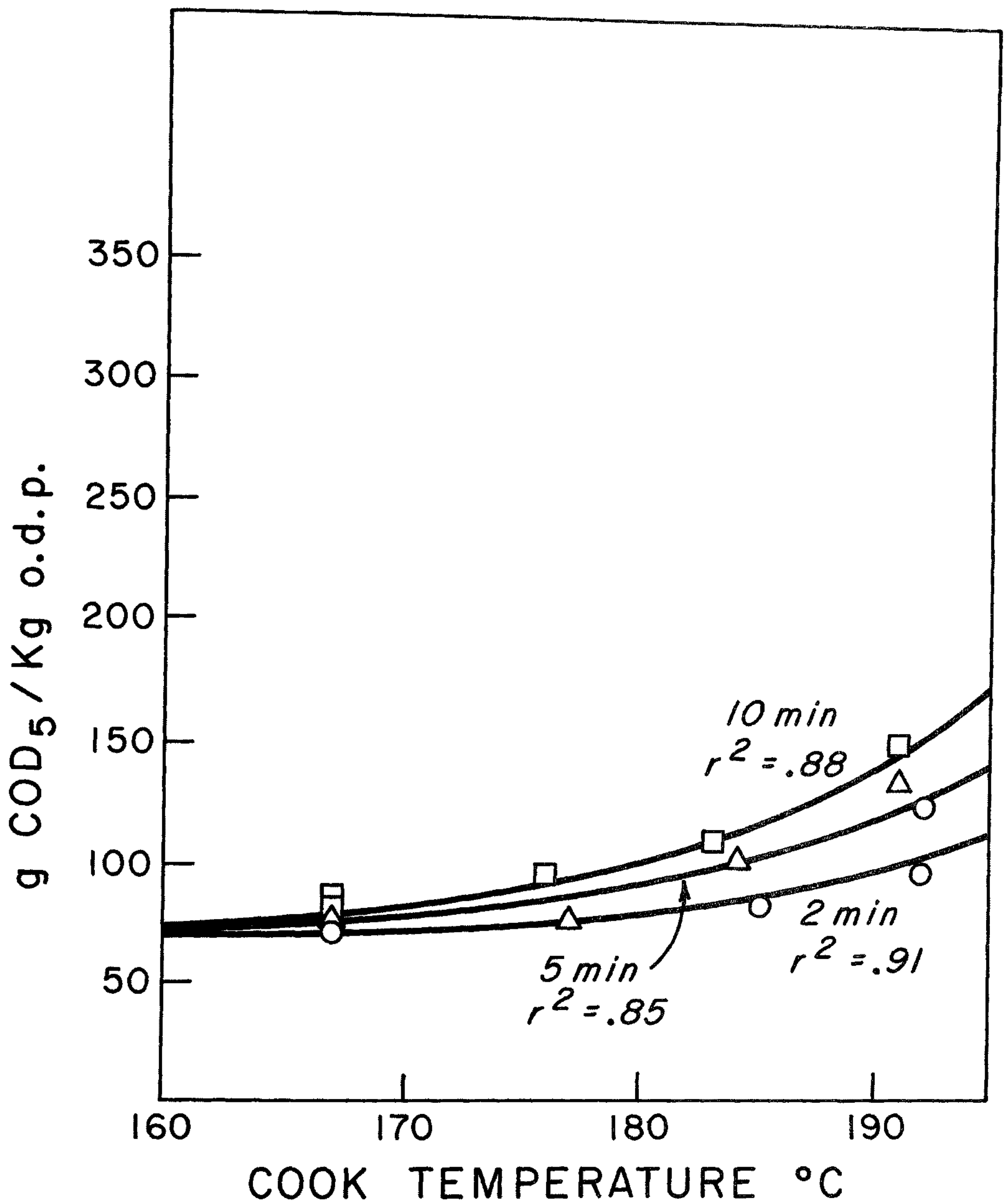

Figure 15. Grams soluble COD vs. cook temperature, plywood.

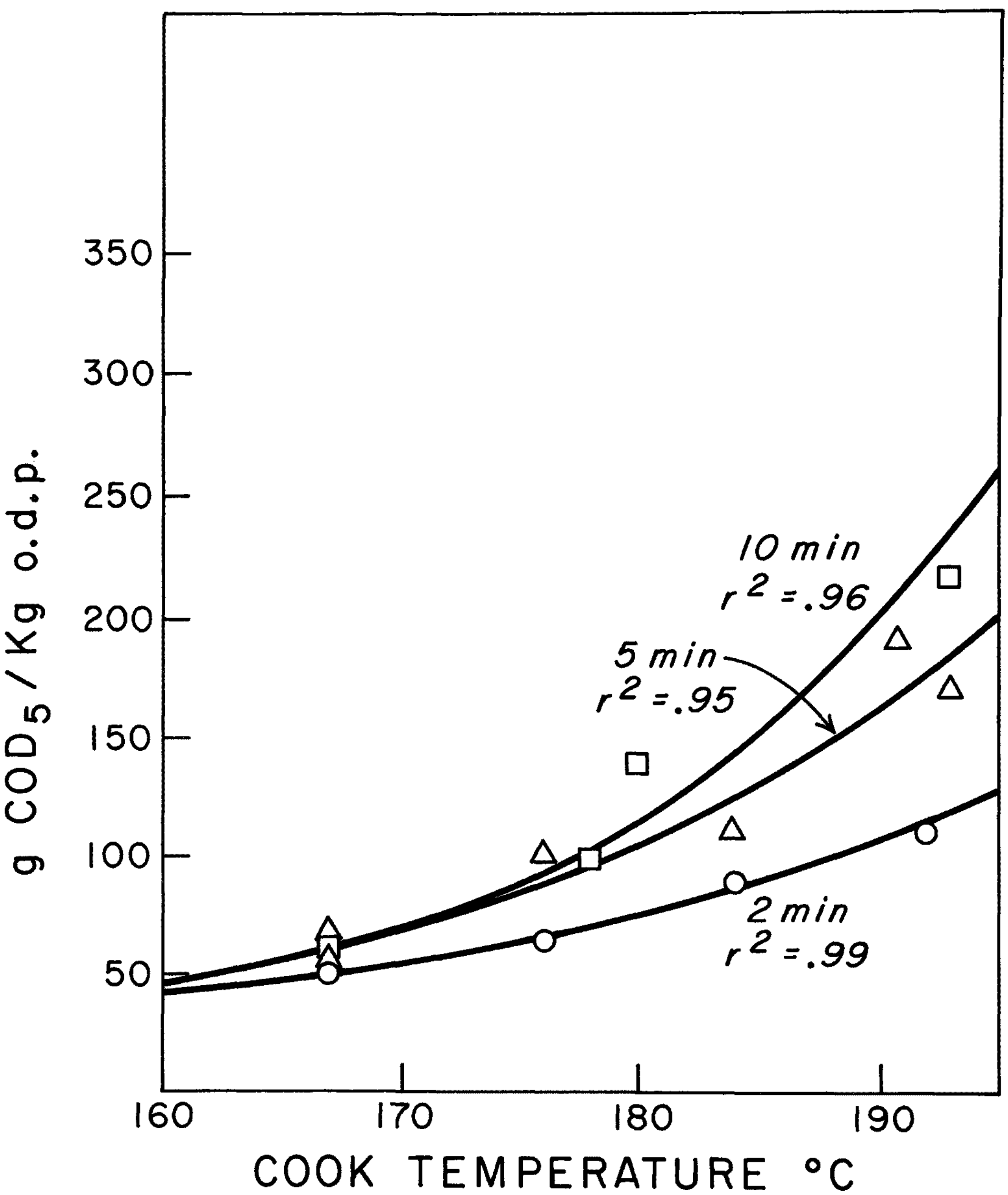

Figure 16. Grams soluble COD vs. cook temperature, southern yellow pine.

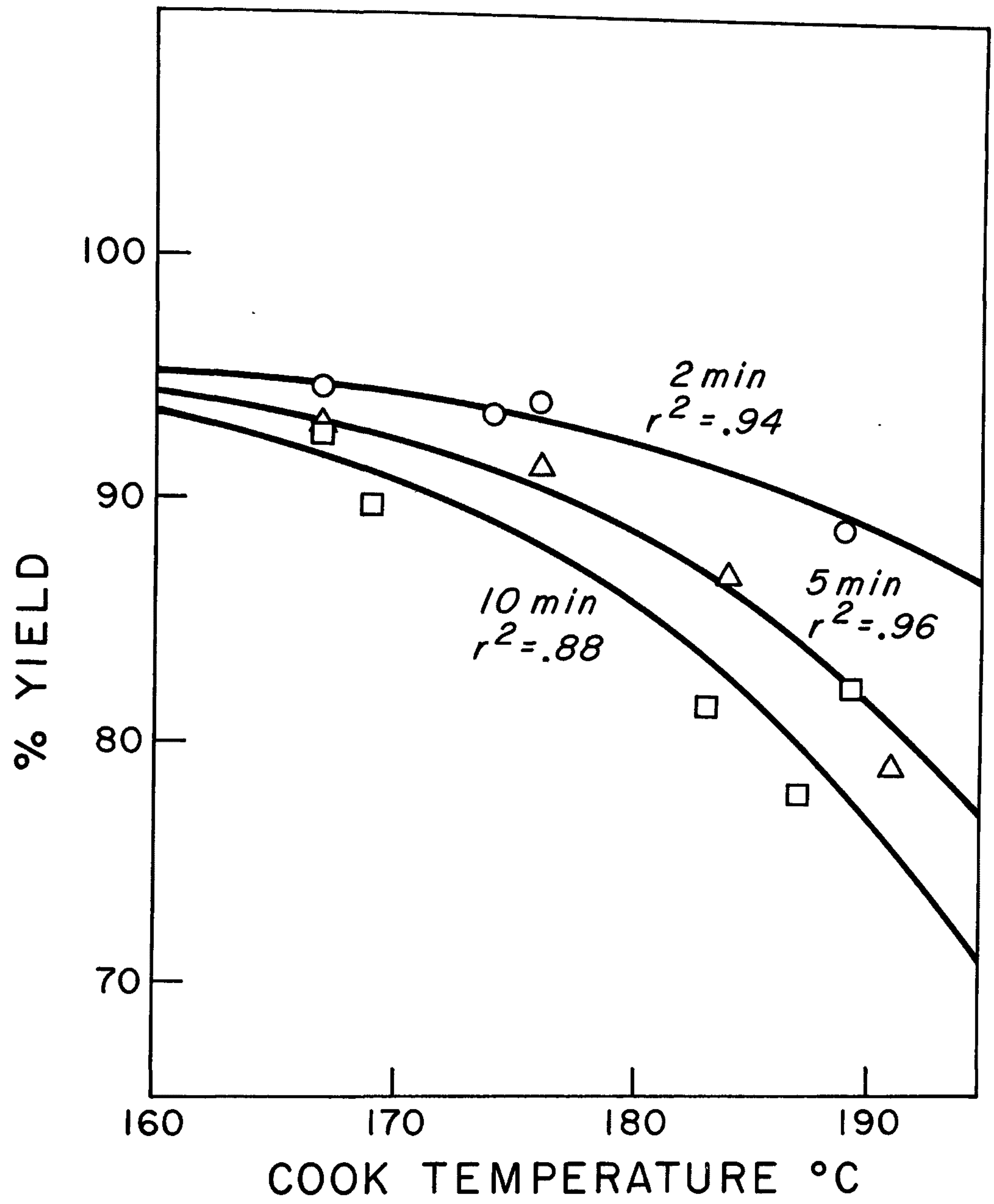

Figure 17. Yield vs. cook temperature, aspen.

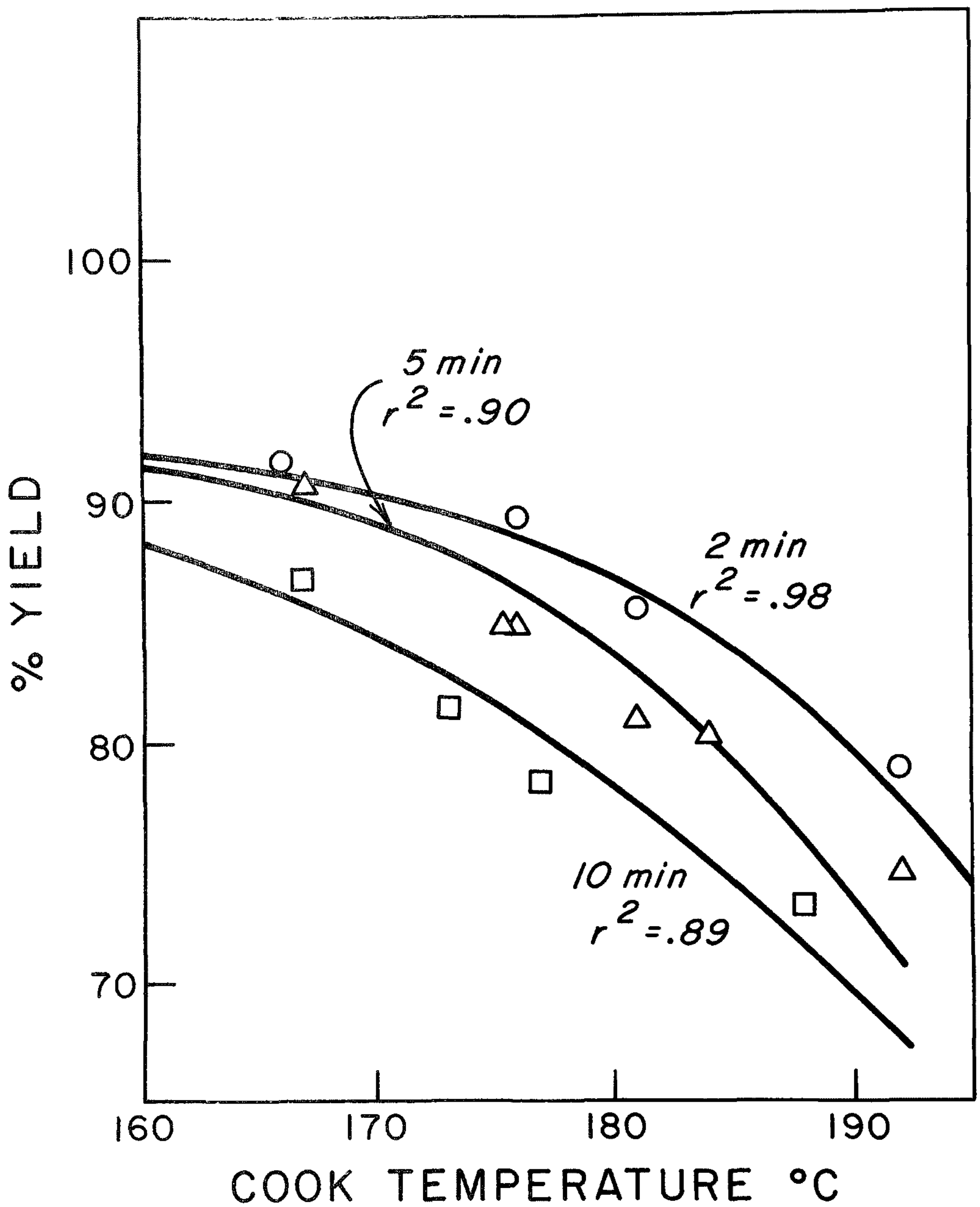

Figure 18. Yield vs. cook temperature, oak.

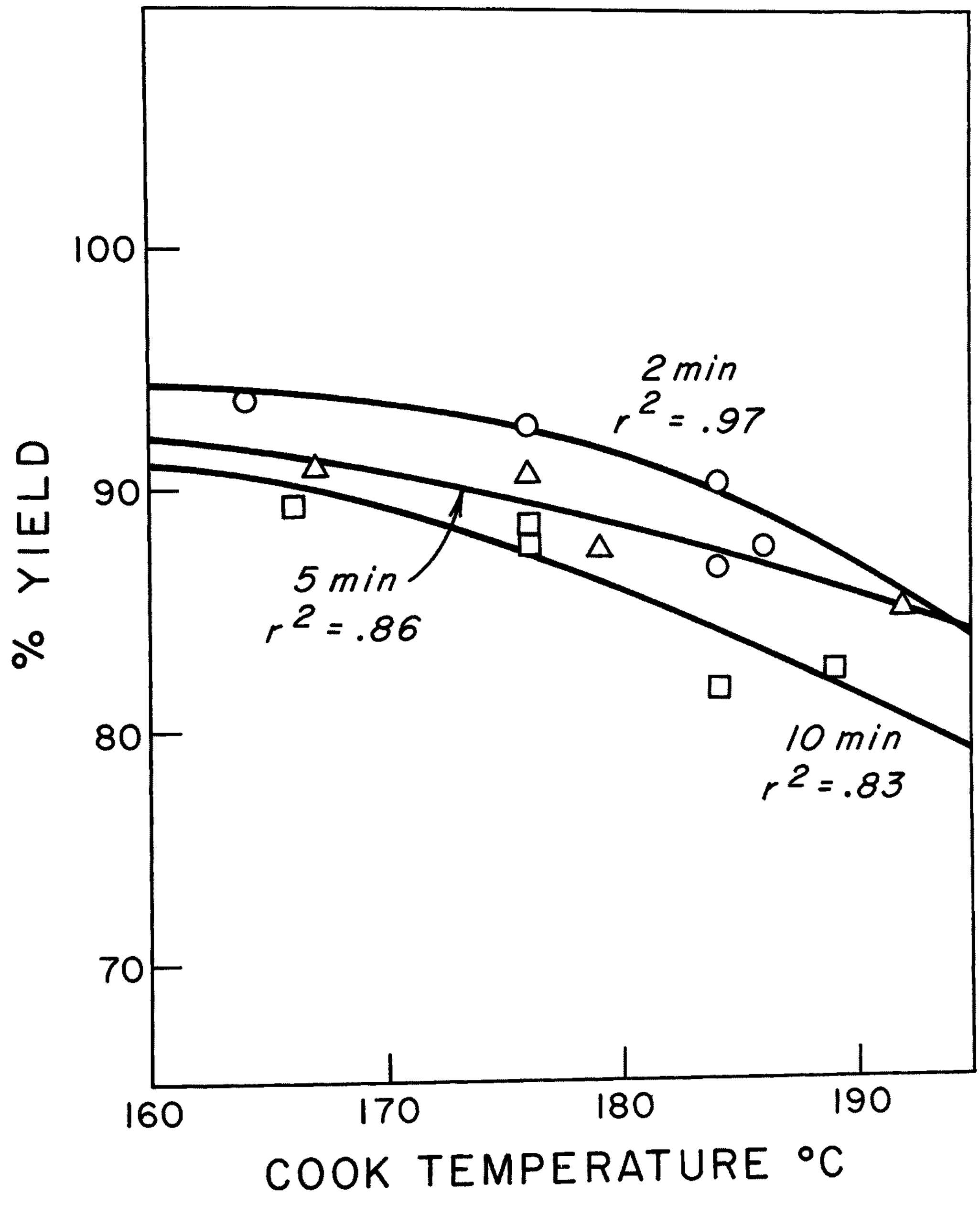

Figure 19. Yield vs. cook temperature, Douglas fir.

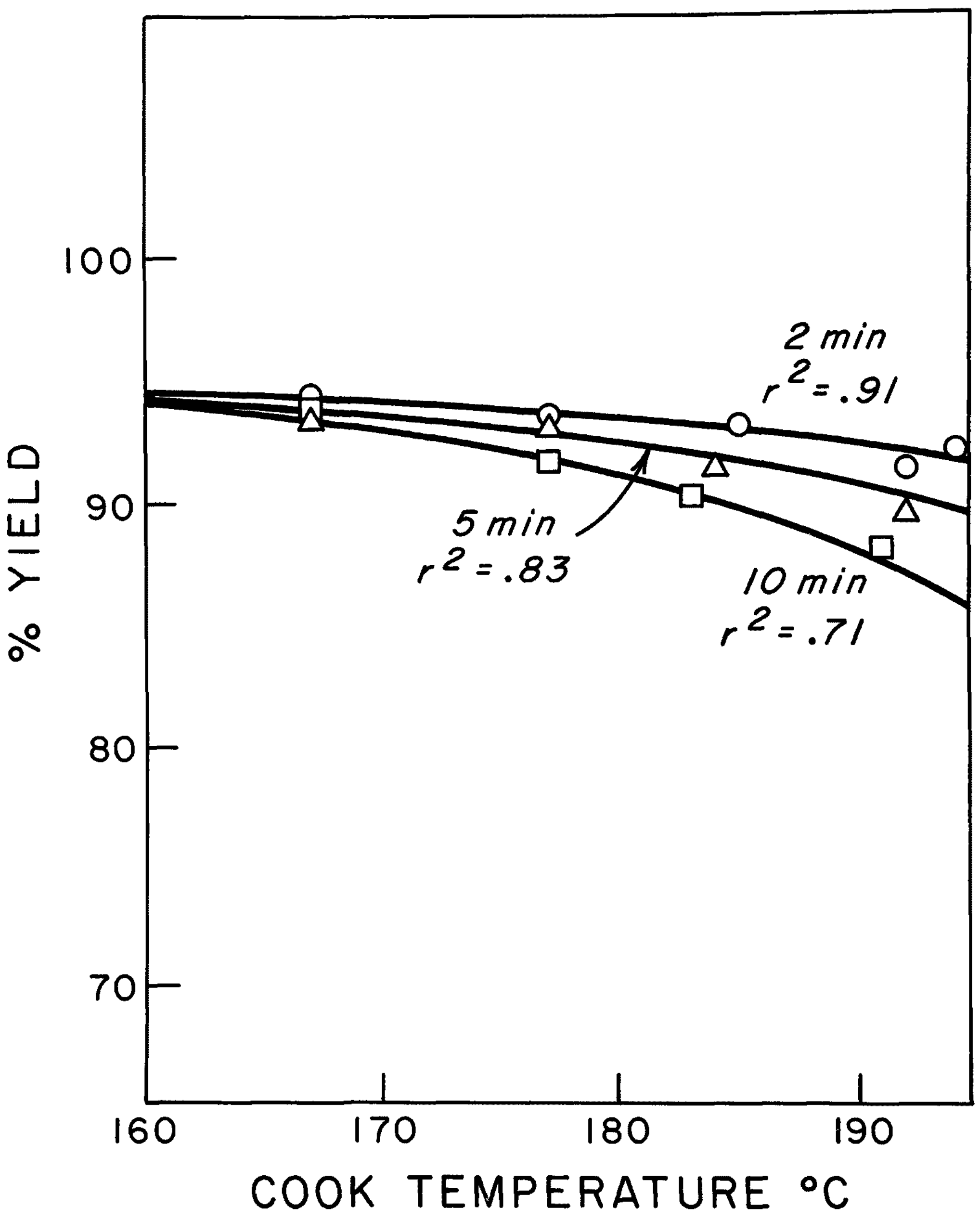

Figure 20. Yield vs. cook temperature, plywood trim.

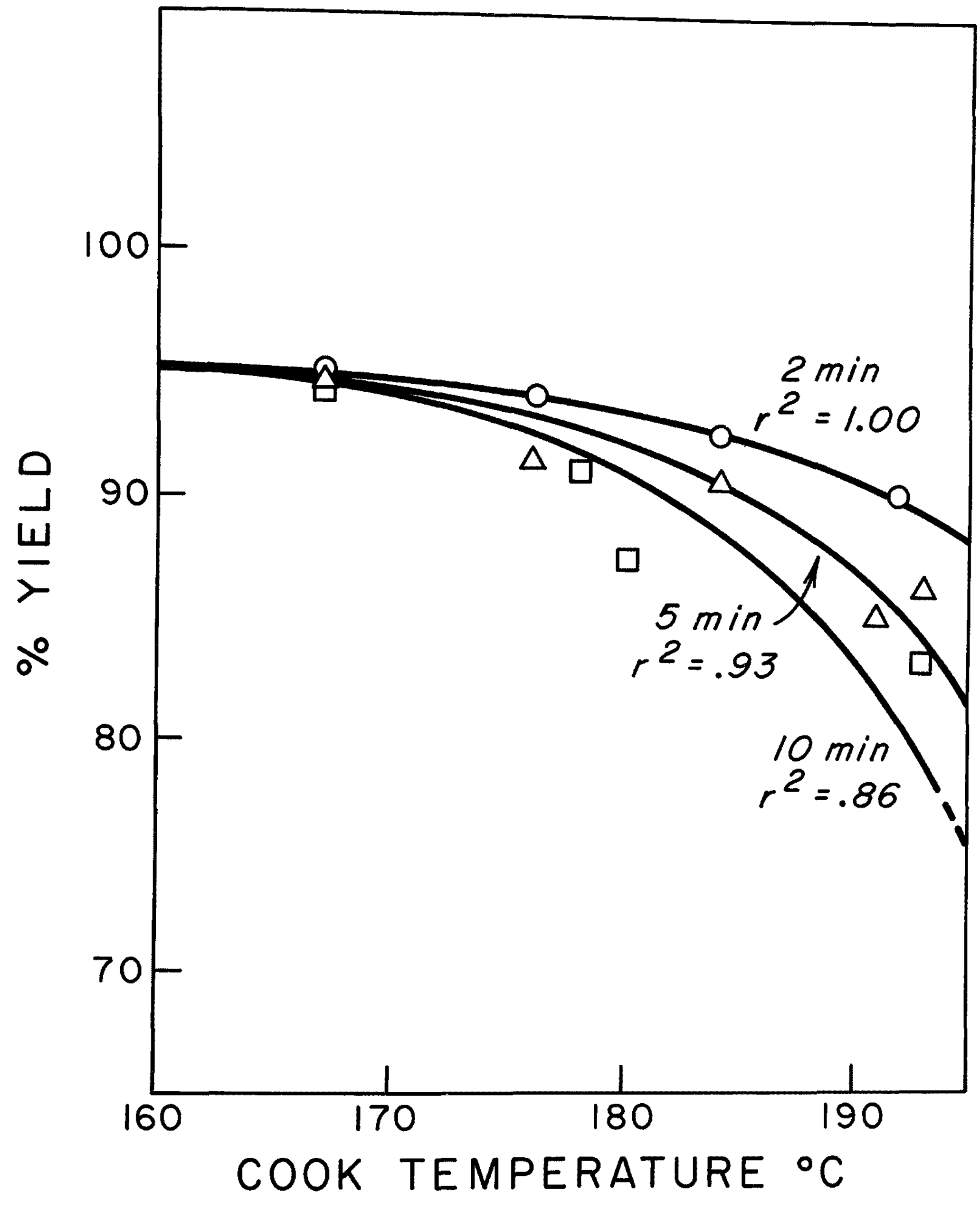

Figure 21. Yield vs. cook temperature, southern yellow pine.

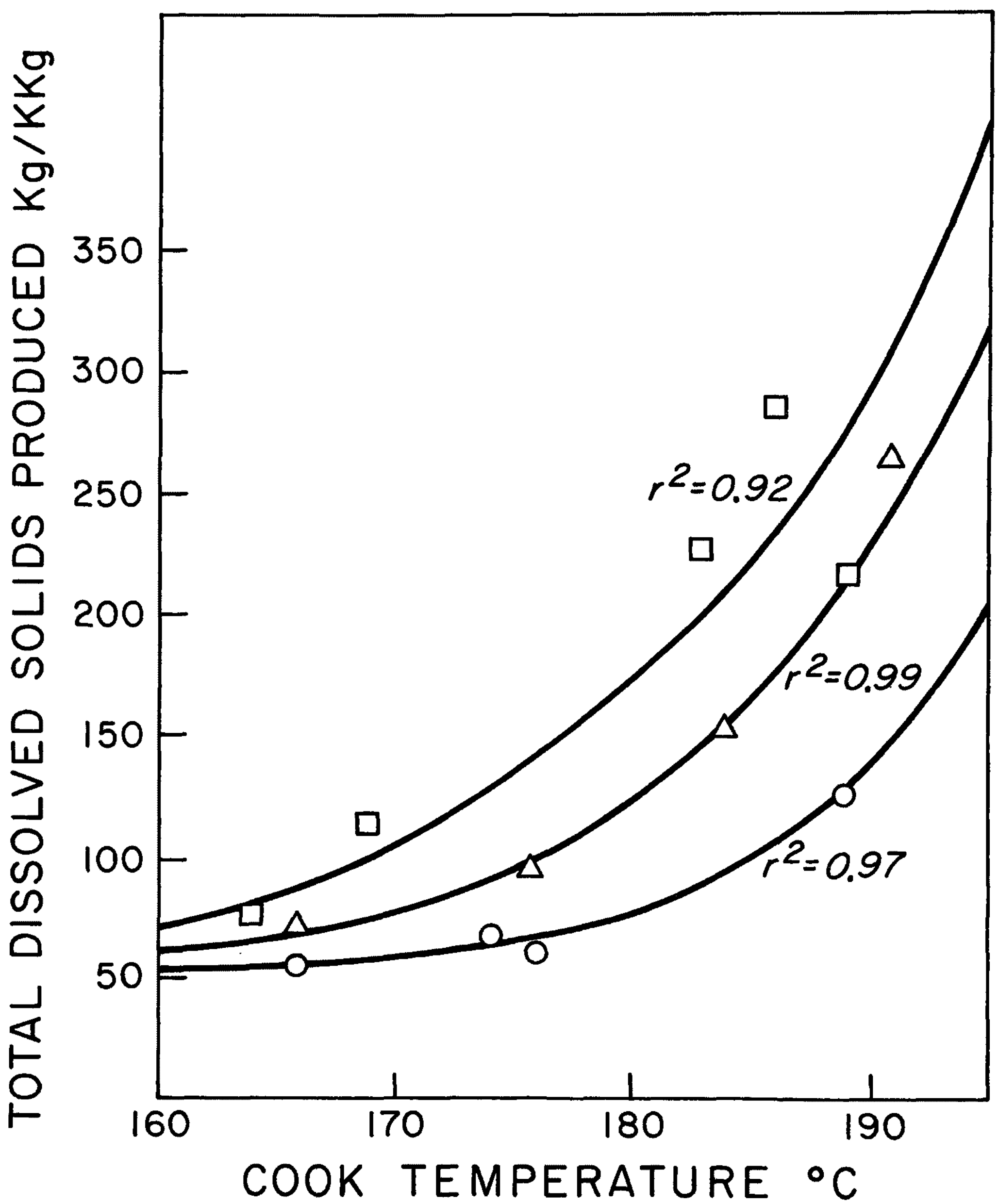

Figure 22. Total dissolved solids vs. cook temperature, aspen.

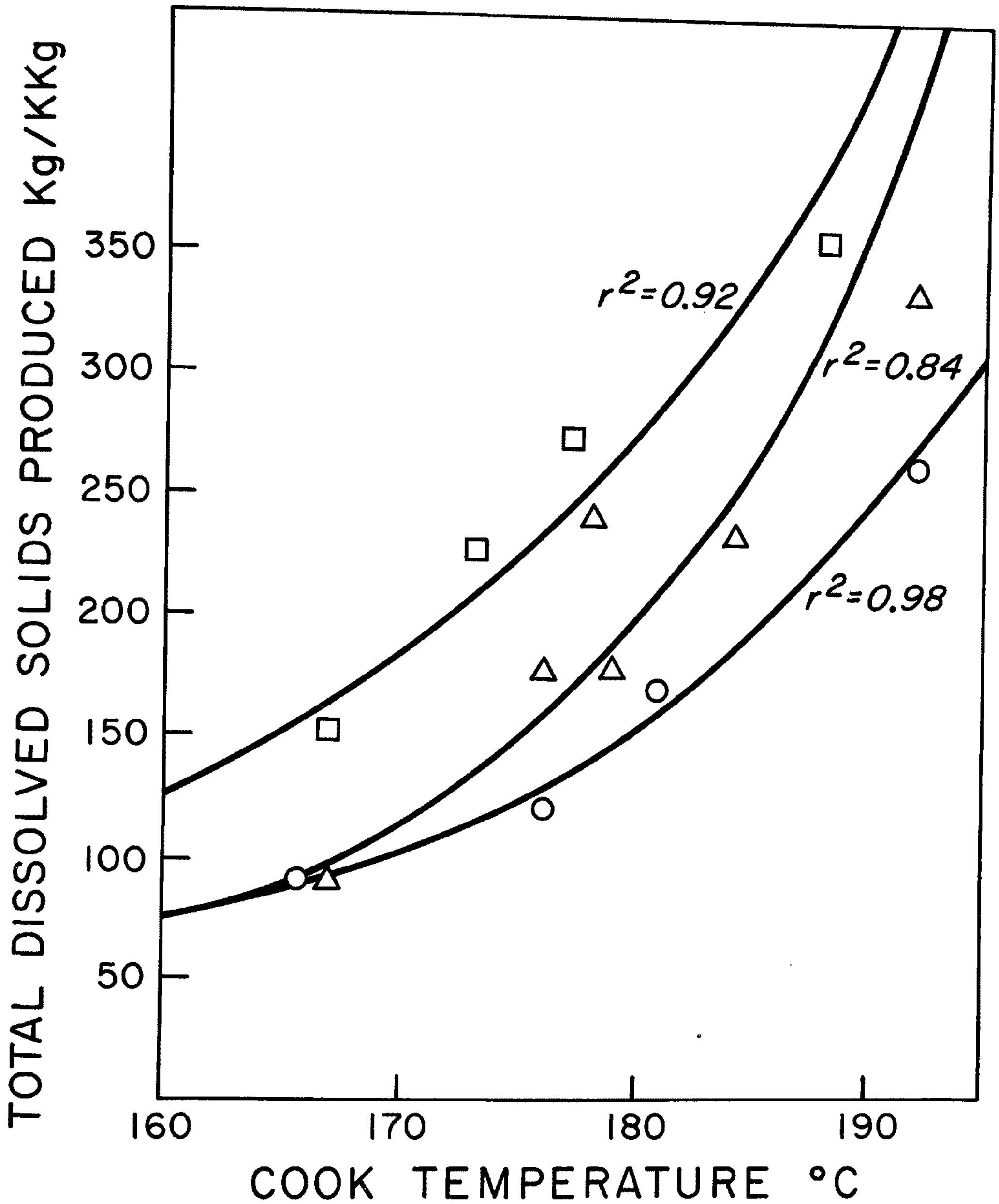

Figure 23. Total dissolved solids vs. cook temperature, oak.

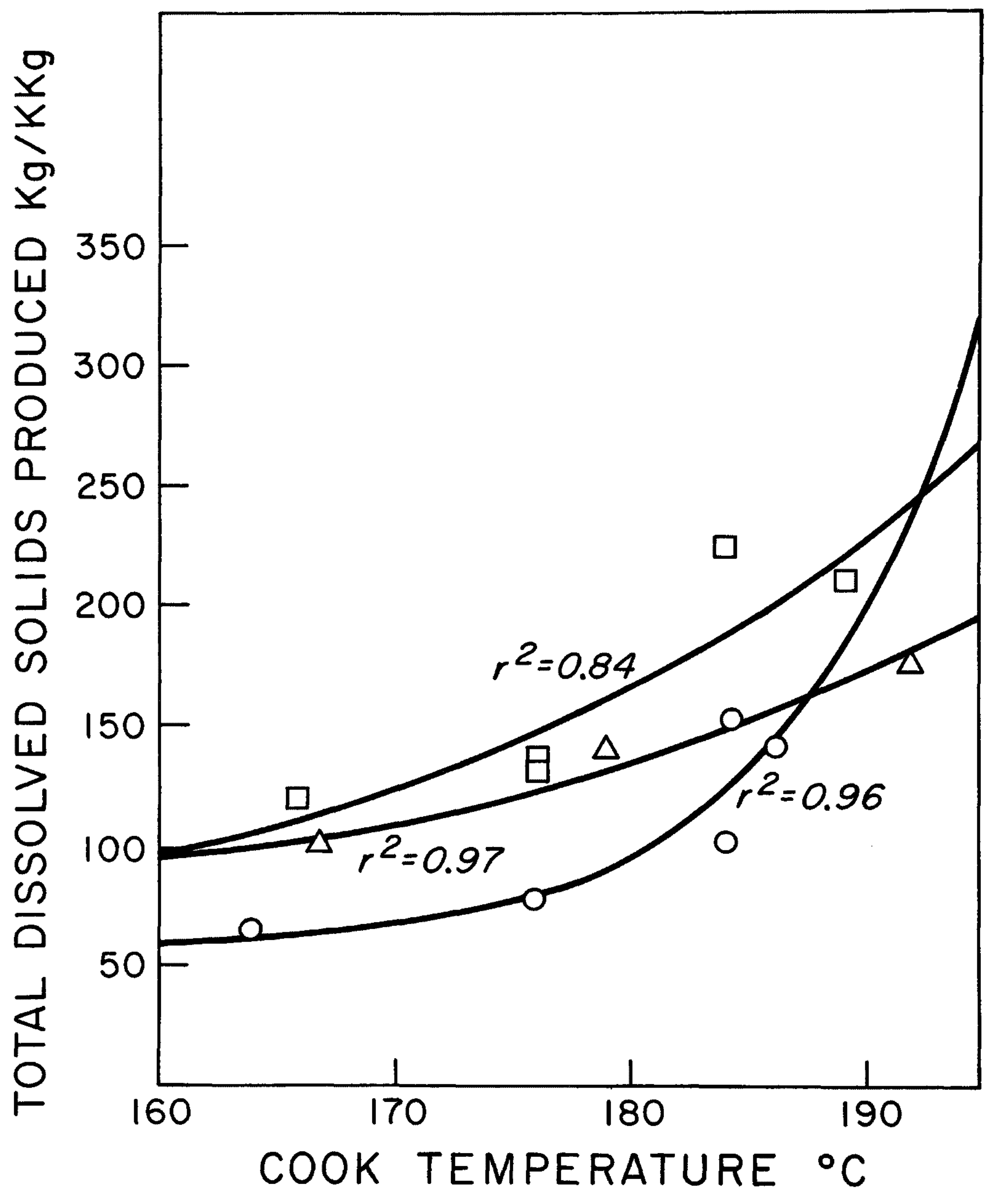

Figure 24. Total dissolved solids vs. cook temperature, Douglas fir.

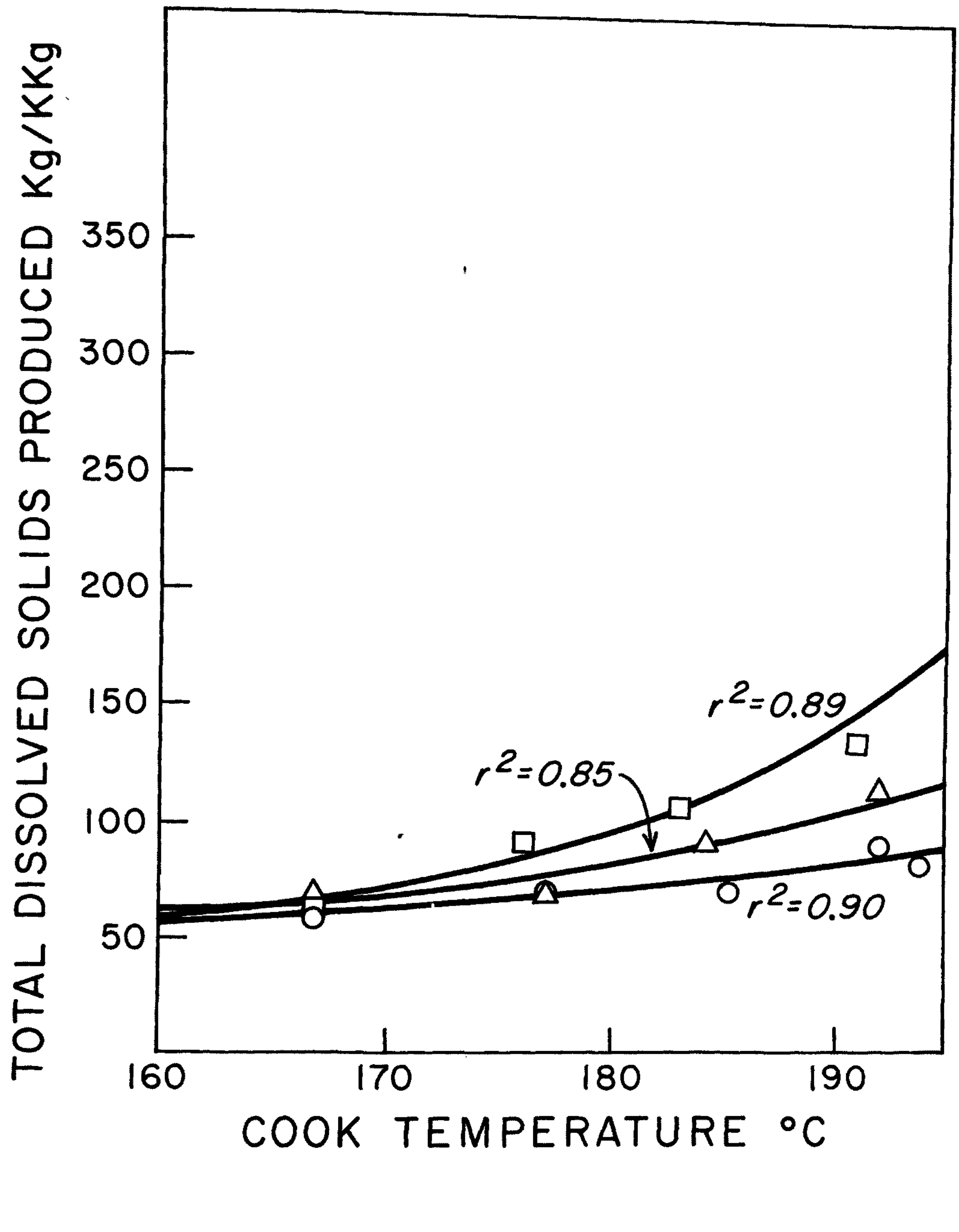

Figure 25. Total dissolved solids vs. cook temperature, plywood trim.

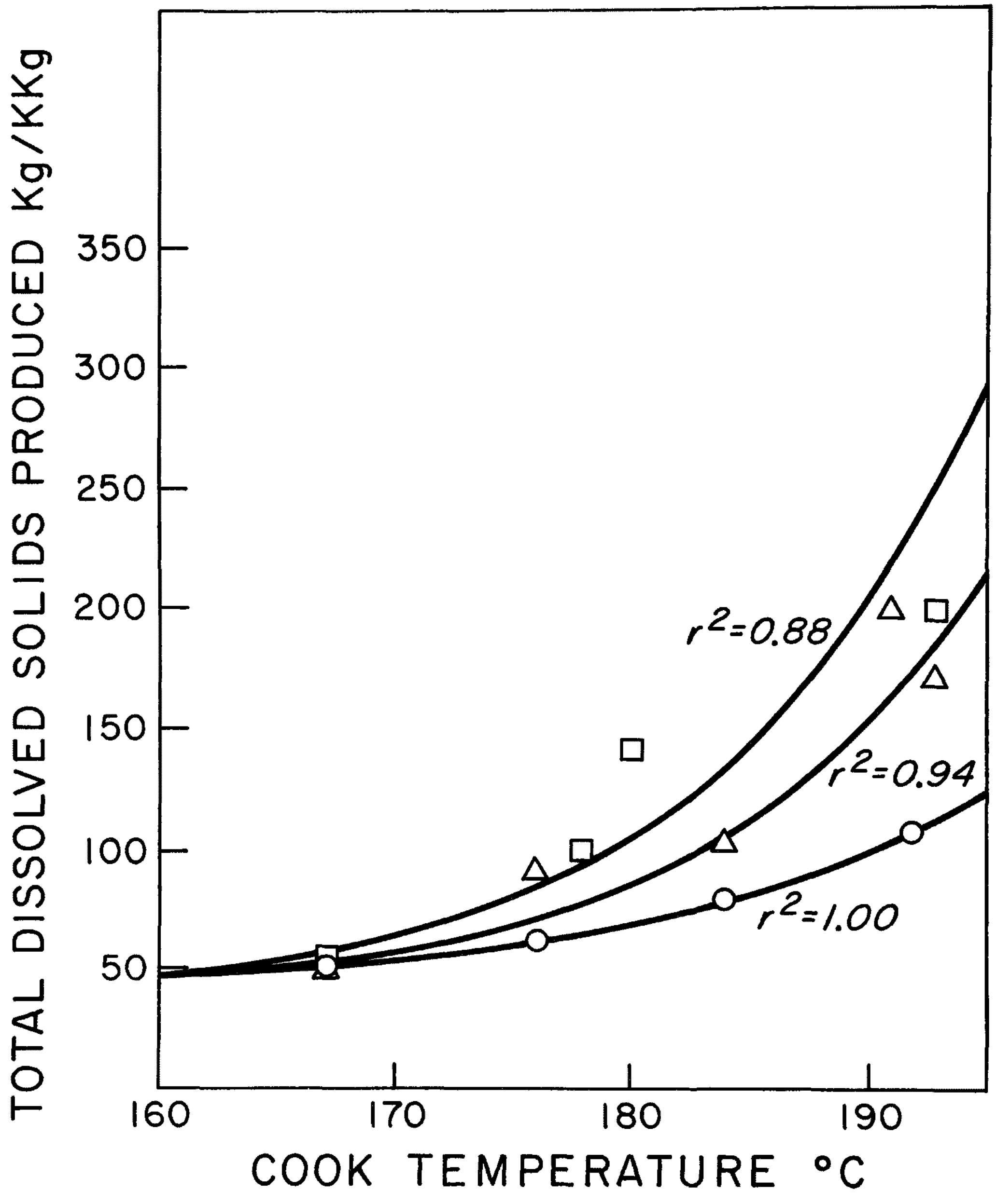

Figure 26. Total dissolved solids vs. cook temperature, southern yellow pine.

effluent remains approximately constant as the amount of recycle is increased.

TABLE 11. SUSPENDED SOLIDS DATA*

Wood Species	Average SS g/Kg pulp	Standard Deviation of SS g/Kg pulp	Average COD_{SS} g/Kg pulp	Standard Deviation of COD_{SS} g/Kg pulp	Average BOD_{SS} g/Kg pulp	Standard Deviation of BOD_{SS} g/Kg pulp
Aspen	63	14	104	26	14	10
Southern yellow pine	63	14	110	33	8	13
Plywood trim	82	22	133	32	3	5
Douglas fir	95	28	151	50	20	13
Oak	180	29	261	78	24	27

*All values as mg/l

Because the quantities of suspended solids being produced and reaching the effluent are affected by process variables other than cooking time and pressure, their influence on the raw waste are not determined in this study. The raw waste loads described in this paper are due to the soluble portions only. Inclusion of suspended solids waste load only increases scatter of the data. Soluble BOD_5 as grams per kilogram oven dry pulp produced vs. temperature at several lengths of cooks are presented in Figures 7 through 11. Soluble CODs as grams per kilogram oven dry pulp produced vs. temperatures, and yields vs. temperatures at several lengths of cooks are presented in Figures 12 through 16 and 17 through 21, respectively. Figures 22 through 26 show the quantities of dissolved solids released from the wood during cooking and refining.

A non-linear regression analysis was used to plot the constant time lines on the plots. The data fit well to the formula: Pollutant = A + B*exp(-C/T). The parameter "A" represents the level of pollutants that would be released with no cooking of the chips. T is the cook temperature and C is a constant for each wood species and cooking time. Correlation coefficients (r^2) were all greater than 0.85 for COD and 0.80 for yields; correlations were not determined for BOD. Scarcity of data for some BOD_5 regression analyses would have resulted in perfect correlation and thereby be misleading. BOD_5 data were more scattered than data for other parameters.

Yields were calculated by four different methods: (1) by dividing the original dry weight of wood minus the total dissolved solids by the original dry weight of wood, (2) by dividing pulp consistency times the volume by the original dry weight of wood, (3) by dividing the pulp consistency by the pulp consistency plus the concentration of total dissolved solids, (4) and by dividing the weight of the collection of all fiber produced by the original dry weight of the wood. Methods 1 and 3 were in close agreement, whereas method 2 showed considerable scatter and method 4 gave consistently lower results. Summation of the concentration of dissolved solids and the consistency showed an overall experimental recovery of 1003 grams (2.21 lb) material for each 1000 grams (2.20 lb) dry wood processed. The yield reported is the consistency in the press pit divided by the sum of the consistency and the total dissolved solids.

Results of the survey conducted as part of this project, plus additional information from the forest products industry, are listed in Table 12. Experimental values for soluble COD and BOD_5 are shown for the typical cooking conditions used by the hardboard industry.

TABLE 12. MILL COOKING DATA AND CORRESPONDING SOLUBLE COD AND BOD LOADINGS

Mill	Product	Pressure psig	Time min	Soluble COD g/kkg	Soluble BOD5 g/kkg
Aspen					
1	S1S	140	2	72	38
2	S1S	150	2	78	41
3	S1S	180-185	0.75	78	38
4	S2S	180-185	2-2.5	120	70
Oak					
1	S1S	100	3-4	120	60
2	S2S	100	15-25	225-300	150
Southern yellow pine					
1	S2S	150	8-14	120-130	90
2	S2S	175-200	5-6	140-190	75
Douglas fir					
1	S1S	95-120	3-5	85-120	55-75
2	S1S	95	3-3.5	85	60
3	S2S	200	2.66	160	95
Plywood trim					
1	S1S	120-130	3-4	82-90	38

DISCUSSION

BOD is not as reliable an indicator of raw waste loading as COD because of greater scatter of the BOD data. Also the BOD does not measure the total load to the waste treatment system. In Figure 27 an extended time BOD on a hardboard mill's effluent shows that the ultimate BOD approached the COD which was 2680 mg/l for the press pit, and 5350 mg/l for the white water. After 5 days only 60% of the BOD from the press pit was utilized and only 40% of the BOD from the white water was utilized. The press pit water contained 288 mg/l suspended solids and the white water contained 1250 mg/l suspended solids. Because BOD is not a good indicator of the total load to the waste treatment system, is subject to scatter and other inadequacies of the BOD tests, COD is a better indicator of raw waste loads resulting from the use of different wood species.

The data can be separated into two distinct groups corresponding to S1S production or S2S production as shown in Table 13. BOD values and COD values for the S1S board were consistently lower than those for the S2S board. Differences in pollutional loading between individual species are apparent in the data for both S1S and S2S boards, with the S2S board having the greatest variation. The ranking of wood species for the quantity of pollutants released is the same for both S1S and S2S boards.

TABLE 13. AVERAGE EXPERIMENTAL COD AND BOD_5 LOADINGS FOR EACH WOOD SPECIES

Wood Species	SS g/kg	COD g/kg S1S	COD g/kg S2S	BOD_5 g/kg S1S	BOD_5 g/kg S2S
Aspen	66	75	120	39	70
Plywood trim	84	85	--	38	--
Southern yellow pine	63	--	145	--	82
Douglas fir	96	95	160	63	95
Oak	185	120	225	60	150

The ranking of wood species in Table 11 is not according to which species inherently has more pollution producing potential in a hardboard mill. When the wood species are compared at constant cooking conditions the ranking is different. For example, at 8.84 atm (130 psia) for 5 minutes, the ranking from highest to lowest COD loading is southern yellow pine, plywood trim, aspen, Douglas fir, and oak. The ranking in Table 11 results from the particular cooking conditions used in the mills for each wood species. Woods that have a potential of causing high pollution loading may rank low on Table 13 because the wood softens at less severe conditions and/or the mills are making an attempt to reduce their pollution load by reducing the severity of cooking conditions.

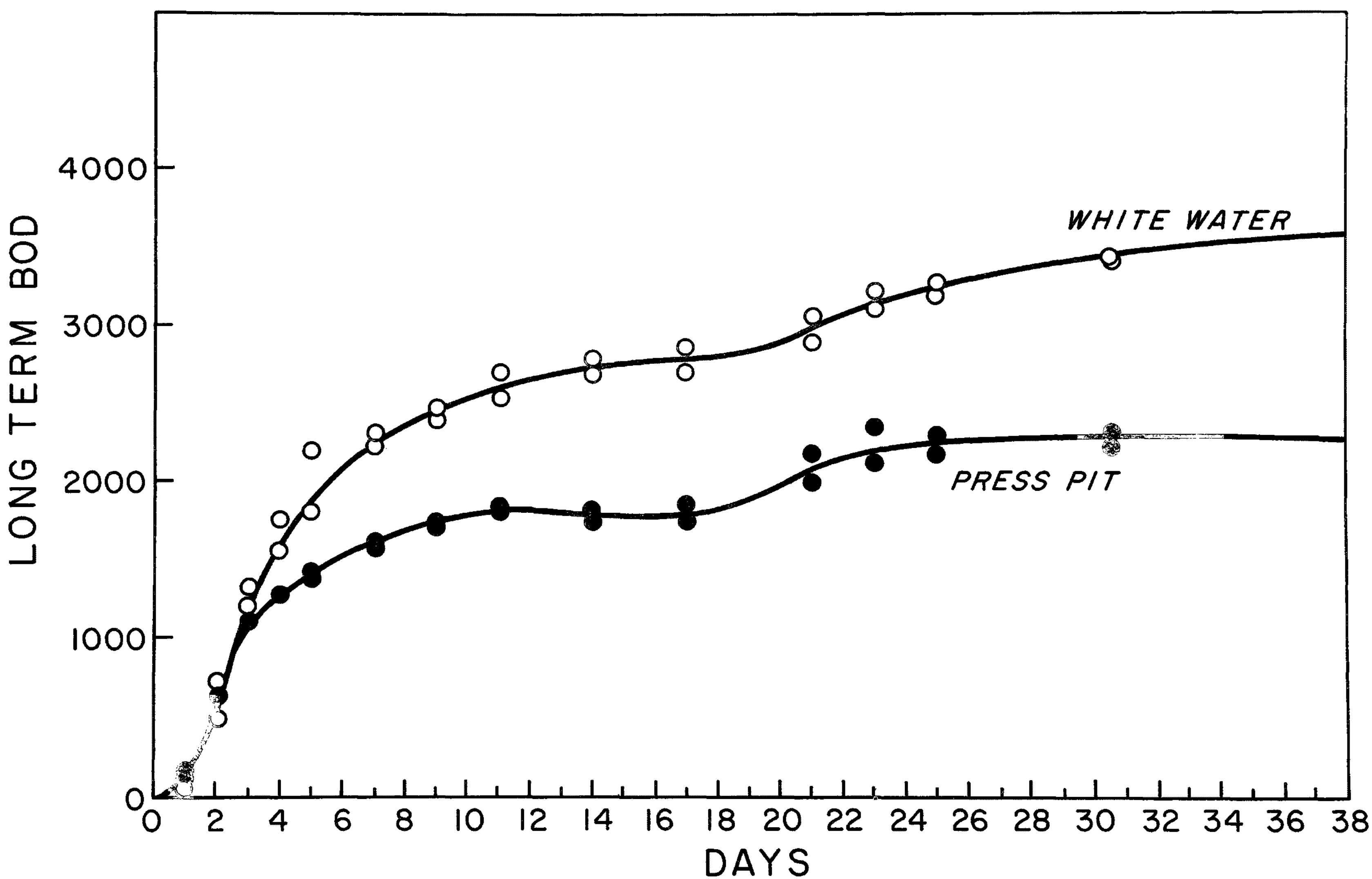

Figure 27. Long term BODs for hardboard mill wastewater.

The mill reporting the lowest cooking pressure for aspen (S1S) made a special effort to reduce its pollution load by reducing the cooking time. This mill reduced its raw waste load by 25% by reducing the cooking time from 4 to 2 minutes. Most mills using aspen cook their chips for 2 minutes or less, whereas mills using other species of wood cook their chips for 3 minutes or more. It is because aspen is cooked for a shorter time than other wood species that the raw waste load from aspen is lower.

The high value for the raw waste load from oak from a S1S mill is also an anomaly. The mill that reported the cooking conditions for oak does not normally use oak, but did so when other wood was not available, using equipment normally used for another wood species and not attempting to optimize or shorten the cooking time. The long time used to cook oak at the S2S mill is probably also unnecessary. Time required to homogeneously heat a chip is seldom more than 3 minutes.

The degree to which the severity of cooks could be reduced has not been explored. Factors such as increased refining energy, board strength, board dimensional stability, board water absorption, swelling thickness, and pulp shive content need to be explored. Black and Larson (2) have taken a preliminary look at these factors. A reduction in cooking time appears most possible in S2S board production. The limit to shortening the cooking time in S2S production is the time at which the production of shives reaches an unacceptable level. Severe cooking is used to ensure that no shives appear on the board surface. Shives are likely to occur when the chips are not homogeneously heated.

If those mills that have not already done so were to reduce the severity of their cooks by as much as their product specifications will allow, the raw waste loads within each classification (S1S or S2S) would probably be closer to each other. There would be little variation in raw waste loads between S1S mills using different species of wood. Raw waste loads from S2S mills would probably have greater variation between mills producing S2S board from different wood species. The difference in loading between S1S and S2S mills would also be much less if the severity of cooks were reduced.

Special note should be taken of the results for Douglas fir and Douglas fir plywood trimmings. Douglas fir chips produce a substantially higher raw waste load than Douglas fir plywood trimmings. The plywood trimmings contain an alkaline phenolic glue, have a smaller size distribution, have a lower moisture content, and have a processing history. The glue should have minimal effect on the raw waste load as it makes up very little of the chip mass. The pH of the solution apparently played no part since there was no difference in the pH's of the liquid resulting from cooks of other species. If the size of the chips was responsible for the difference, one would expect a higher raw waste load from the samples with the smaller chips. The opposite occurred.

To check if the differences in the moisture content of chips was the cause of the differences in raw waste loadings, further experimentation was performed. Two samples of Douglas fir taken from the same batch of chips used earlier in this study were dried, one to 35% moisture and the other to 25% moisture. The 2 samples were then cooked at 8.8 atm (130 psia) for 5 minutes and processed by the methods used in the experimental work reported on in this paper. The results showed no difference from earlier cooks of Douglas fir at the same pressure and time. Drying of the chips has no effect on the raw waste load from a hardboard mill. The effect on the raw waste load of drying the chips to oven dryness has not been investigated. Plywood trimmings would have been dried to oven dryness in earlier processing.

The most likely reason that the raw waste loading from plywood trim was lower than that from Douglas fir is the previous processing history of the plywood trimmings. The exact history of the plywood trimmings could not be traced because the mill from which the chips were obtained has a large number of sources for its wood supply. In the plywood process round wood is often heated in a hot water bath or steamed. Part of the soluble material present in the wood is leached into the water bath or condensate. By the time plywood trimmings reach a hardboard mill, a portion of the water soluble materials that contribute to the raw waste load have been removed from the wood.

Comparison of Results to Mill Values--

Raw waste BOD averages from Figure 4 are listed in Table 14 with predicted BOD_5 values. Considerable differences between mill BOD data and experimental BOD_5 data exist.

TABLE 14. COMPARISON OF MILL BODs TO PREDICTED BODs

Mill	Wood Species	Mill BOD_5 Kg/t pulp	Predicted BOD_5 Kg/t pulp
B	Plywood trim	57	44
C	Douglas fir	61	96
E	Aspen	115	49
G	Aspen	225	70

Predictions of dissolved solids loadings to hardboard mill white water systems were compared to measured values for three mills as shown in Table 15.

All of the predicted dissolved solids values are between 17% and 20% higher than the measured values. The lower measured values are probably due to precipitation of tannin materials onto the board when the pH is lowered and alum added.

TABLE 15. COMPARISON OF MILL DISSOLVED SOLIDS LOADINGS TO PREDICTED DISSOLVED SOLIDS LOADINGS

Wood Species	Cook Temperatures °C	Cook Time Min	Predicted Dissolved Solids Kg/KKg	Measured Dissolved Solids Kg/KKg
Aspen	165	2	60	50
Plywood trim	175	3	70	60
Southern yellow pine	187	5	130	110

All chips used in the experiment were fresh chips. No attempt was made to quantify increases in raw waste load due to aging of the chips. For instance, if chips were used that had been stored in a pile and had undergone fungal and thermal degradation, the raw waste load would surely be higher than shown in this study.

CONCLUSION

Significant differences existing in the raw waste load resulting from the manufacture of hardboard can be related to either the production of S1S or S2S board and to the wood species used. Actual loads from hardboard mills deviate from the experimentally determined values because of process variations such as the amount of recycle. A reduction in excessively severe cooking conditions at some mills could reduce the S2S average raw waste load. Differences in the soluble raw waste load between wood species used is of smaller magnitude than differences for S1S and S2S production. Suspended solids in the raw waste load proved to be independent of the cooking conditions but highly dependent on the species of wood used. The quantity of suspended solids reaching the effluent is partially regulated by the amount of white water recycle and the use of retention aids.

SECTION 6

EFFECTS OF WHITE WATER RECYCLE

Evans Products, Corvallis, Oregon, invited EPA personnel in the wood products research section to monitor water characteristics within the Evans Products hardboard mill while the company made process changes to decrease water usage by increasing recycle of white water. EPA's role was that of collecting and analyzing samples.

METHOD

Water use was measured throughout the mill at all locations by both EPA and mill personnel. Effluent flows from the white water tank, press pit, and total effluent were measured. Flow from the white water tank was measured by recording the level in the tank. Excess white water overflowed through a twelve-inch diameter pipe. The flow from the white water tank at any tank level was calibrated by filling the tank with the overflow pipe plugged, then pulling the plug and measuring the level at short time intervals. The slope of the line resulting from plotting the level-time data is the flow at any particular tank level. The resulting curve was cross checked by adding a known flow of water to the tank with all other exits blocked. The calibration curve flows came quite close to the known flows. The slope of the calibration curve fit very well to the theoretical flow equations for flow into a circular pipe.

Flow from the press pit area was measured by calibration of the pump capacity volumes by dumping a known flow into the press pit for a day when no production was taking place. The pump was operated by a level control switch. The total amount of time the pump was on that day was automatically recorded. By recording the amount of time the pump was on during production, the flow could be determined.

Flow from the aerated lagoon settling pond was determined by measurement of the pond level. The pond drained through a V notch weir.

Other water flows in the mill were calculated by collection of the total flow for a set amount of time and measuring the volume, or by consistency measurements and water balances.

The white water and press pit flows were sampled. Composite samples were taken from the white water system by a Hydragard sampler. The sampler took a 100 ml sample about every 15 minutes. The Hydragard sampler operates by blowing the contents of a sample chamber into the collection chamber with air on a set time interval. When the air pressure ceases, the sample chamber fills up with liquid again. The press pit was sampled with a dip-stick type sampler. The sampler periodically dipped a pipe with a stop at one end and hole in the top into the water stream. When the pipe returns to its normal position, the collected sample flows to a collection bottle.

The collected samples were analysed for total BOD, soluble BOD, total COD, soluble COD, suspended solids, dissolved solids, and volatile dissolved solids.

In addition, grab samples were collected at various process locations. Samples were taken out of the head box, wire drain, press rolls, overlay and cyclone.

Extent of White Water Recycle

Closing up of the white water system was approached on a step-by-step basis. First, freshwater usage at the cyclones was replaced by white water. Then the consistency regulators were tied into the white water system. The system was run for several months in this mode to record any changes.

Next the freshwater to the secondary refiner that prepared finely reformed pulp for the overlay was converted to white water usage. Then the shower water was connected to the white water system. This brought the percent recycle to nearly 90%.

The remaining freshwater usages were at the freshwater feed to the digestor (steaming chamber), vacuum pump seal water, and some high pressure showers. These were not converted to white water usage because of feared abrasion in the close tolerance high pressure pump for the digestor feed and in the close tolerance vacuum pumps.

OBSERVATIONS AND RESULTS

Data obtained from this study were from both company records and EPA tests. The data was analysed to attempt to determine the causes of raw waste load variation, process water compositions, effects of process water recycle on process conditions and effluent loading, and the effects of decreasing flows on the waste water treatment system.

Waste Load Variation

Production records were compared with raw waste loadings and flows. Raw waste loads and flows showed no dependence upon the thickness of board being produced. Flows of excess white water also did not depend upon the production for the day. During days of low production the Fourdrinier machine was operated as normal, with the unused mat going to broke. Water discharges are dependent on water reuse practices rather than production dictates.

Measurements were made of the quantity of dissolved solids entering the white water system from the cyclone and of the quantity of dissolved solids being discharged from the mill. Figure 28 shows the frequency of occurrence of quantities of dissolved solids loaded to the white water system and quantities of dissolved solids discharged. The figure illustrates that nearly all of the effluent raw waste load is due to variations in the refining process or wood supply. The two high points on the line for dissolved solids loading from the cyclone came at a time when the wood was being cooked for a longer time than normal.

Processes Water Composition

Evans Products took samples of process water at various locations throughout the mill. These samples were analysed for suspended solids, dissolved solids, non-volatile dissolved solids, sugars, and tannins. The results of the investigation are shown in Table 16, as % sugars, % tannins and % unaccounted for material in the volatile portion of the dissolved solids.

TABLE 16. PROCESS WATER COMPOSITION

Location	Sugars $\overline{X}$* %	Sugars s* %	Sugars n*	Tannins $\overline{X}$ %	Tannins s %	Tannins n	Unaccounted for $\overline{X}$ %
Cyclone							
Plywood trim before recycle	60.0	2.7	3	14.7	0.5	2	15.9
Oak before recycle	75.1	3.8	2	14.5	3.3	2	10.4
Oak after recycle	74.8	5.8	5	13.5	2.3	5	11.7
Stock chest	72.5	21.4	3	10.7	8.8	2	16.8
Head box	78.4	5.2	10	13.4	1.2	10	8.2
Fourdrinier roller sections	72.1	6.2	4	14.1	1.4	4	13.9
Vacuum	78.1	3.1	2	15.2	--	1	6.7
Press rolls	74.9	6.9	4	15.5	1.2	9	9.6
White water tank	71.9	5.2	11	13.3	1.4	12	14.8
Hot press pit	62.1	9.2	9	19.7	3.8	9	18.2

* $\overline{X}$-mean, s-standard deviation, n-number of samples

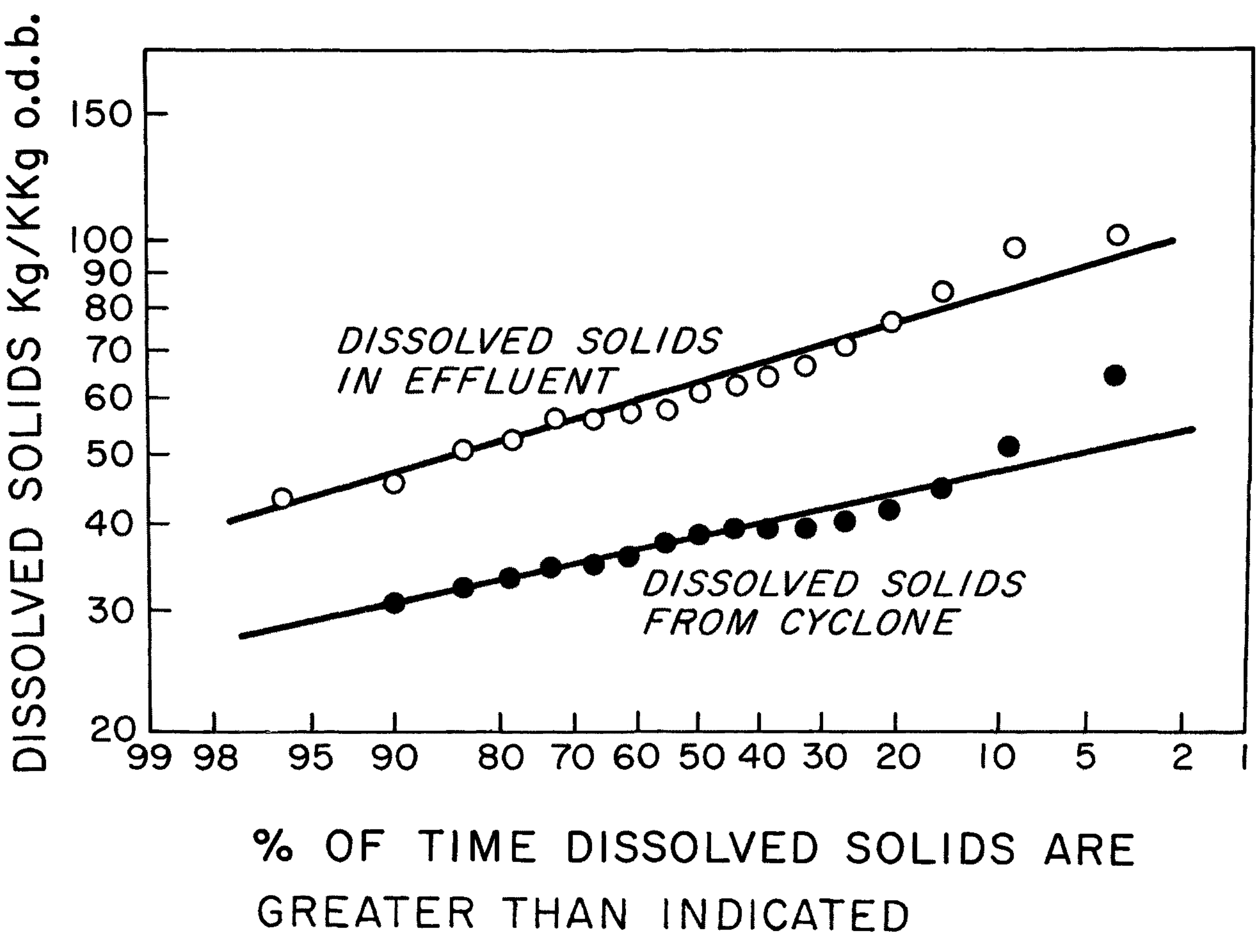

Figure 28. Frequency of occurrence of dissolved solids levels

A difference between the proportion of sugars in the water between the cyclones using plywood trim and the cyclone using oak is apparent. The portion of sugars in the cyclones was 75.1% for oak and 60.4% for Douglas fir. These differences became obscure once recycling of white water to the cyclone sprays was installed.

The composition of the white water changed throughout the processes. Variations in the sugar concentration occurred at various locations along the forming line. The proportion of tannins in the liquid phase increased along the forming line. The composition of the hot press discharge was considerably different. The proportion of sugars significantly decreased while the proportion of tannins and unaccounted for materials increased. An explanation for this is either that more material was released from the wood due to the pressure and temperature, or that the soluble wood sugars were charred due to the high temperatures encountered. A material balance about the hot press showed there was little or no change in the quantity of dissolved sugars due to hot pressing. The amount of dissolved tannins present increased by about 58%, and the amount of unidentified soluble material present in the press pit water increased by about 50% when the board passed through the hot press. There was a 25% increase in total materials dissolved after passing through the hot press. The material balance indicates that more materials are dissolved from the fibers during hot pressing, and that if any sugars are dissolved, they or an equivalent amount of sugars were degraded or oxidized.

Effects of Increased Recycle on Water Properties

Suspended Solids--

As the amount of recycle was increased, the quantity of suspended solids going to the effluent decreased as shown in Figure 29. When the white water discharge was between 20.9 to 29.2 Kl/KKg (5000 to 7000 gal/Ton), suspended solids in the raw effluent averaged 28.8 Kg/KKg (57.6 lbs/Ton). After a reduction in flow to 10.4 to 18.8 Kl/KKg (2500 to 4500 gal/Ton), suspended solids in the raw effluent dropped to 16.4 Kg/KKg (32.8 lbs/Ton). Further reduction of flow to 4.2 to 10.4 Kl/KKg (1000 to 2500 gal/Ton) resulted in 9.1 Kg/KKg (18.2 lbs/Ton) suspended solids in the raw effluent. The concentration of suspended solids in the white water increased after less than 12 Kl/KKg (50,000 gal/Ton) white water was discharged, as shown in Figure 30.

A change in the nature of the suspended solids in the white water occurred as more white water was recycled. Settleable solids dropped from an average of 840 mg/l to nil. This reduction in settleable solids is attributed to the increased overall retention of larger solids due to repeated passes through the fiber mat. The nature of the solids in the press pit effluent remained unchanged when recycling was increased. Most of the suspended and settleable solids in the press pit effluent originate from blown board or other mishaps in the pressing process, and from dust and fibers from handling of the pressed boards.

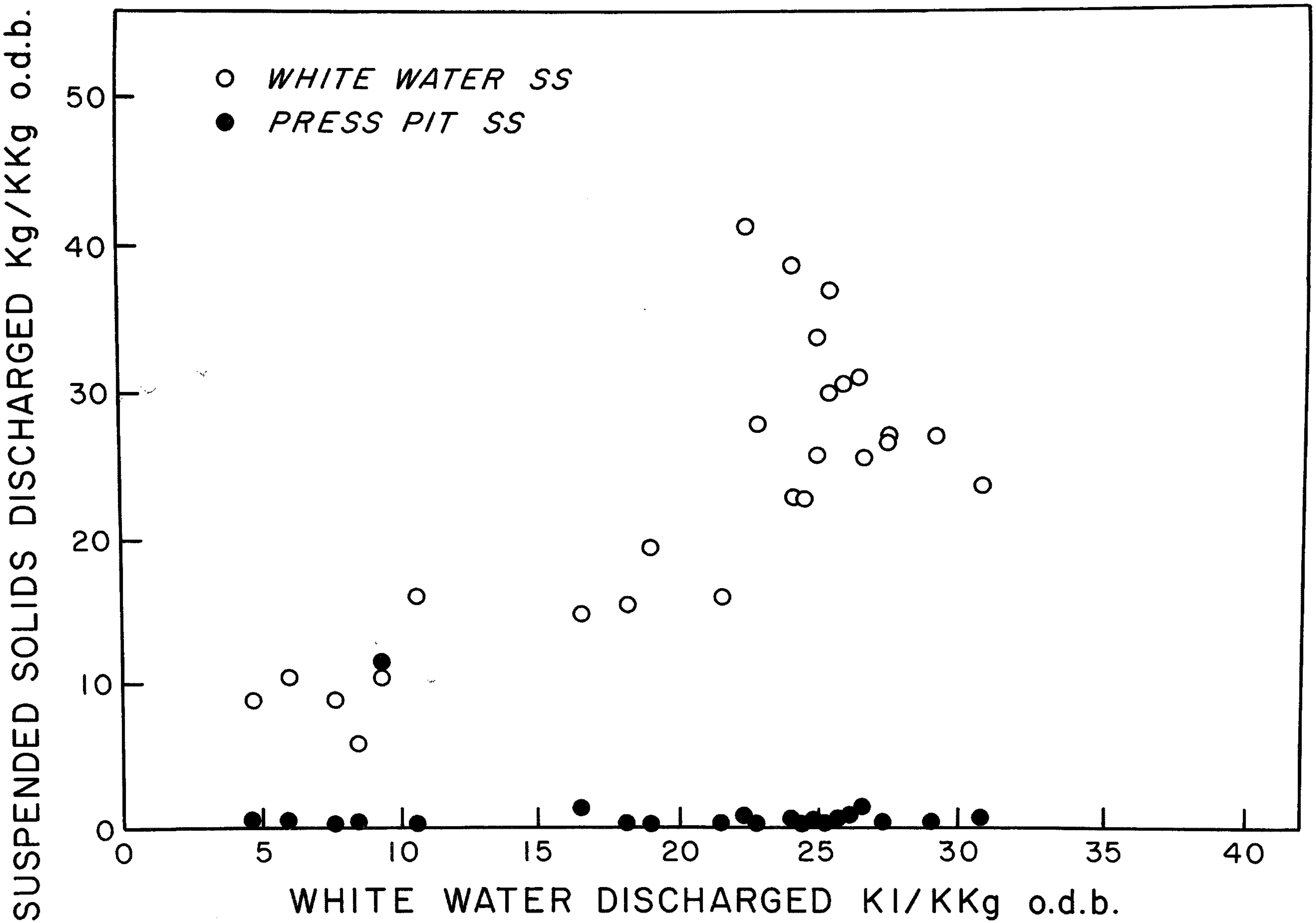

Figure 29. Discharge of suspended solids vs. white water discharge.

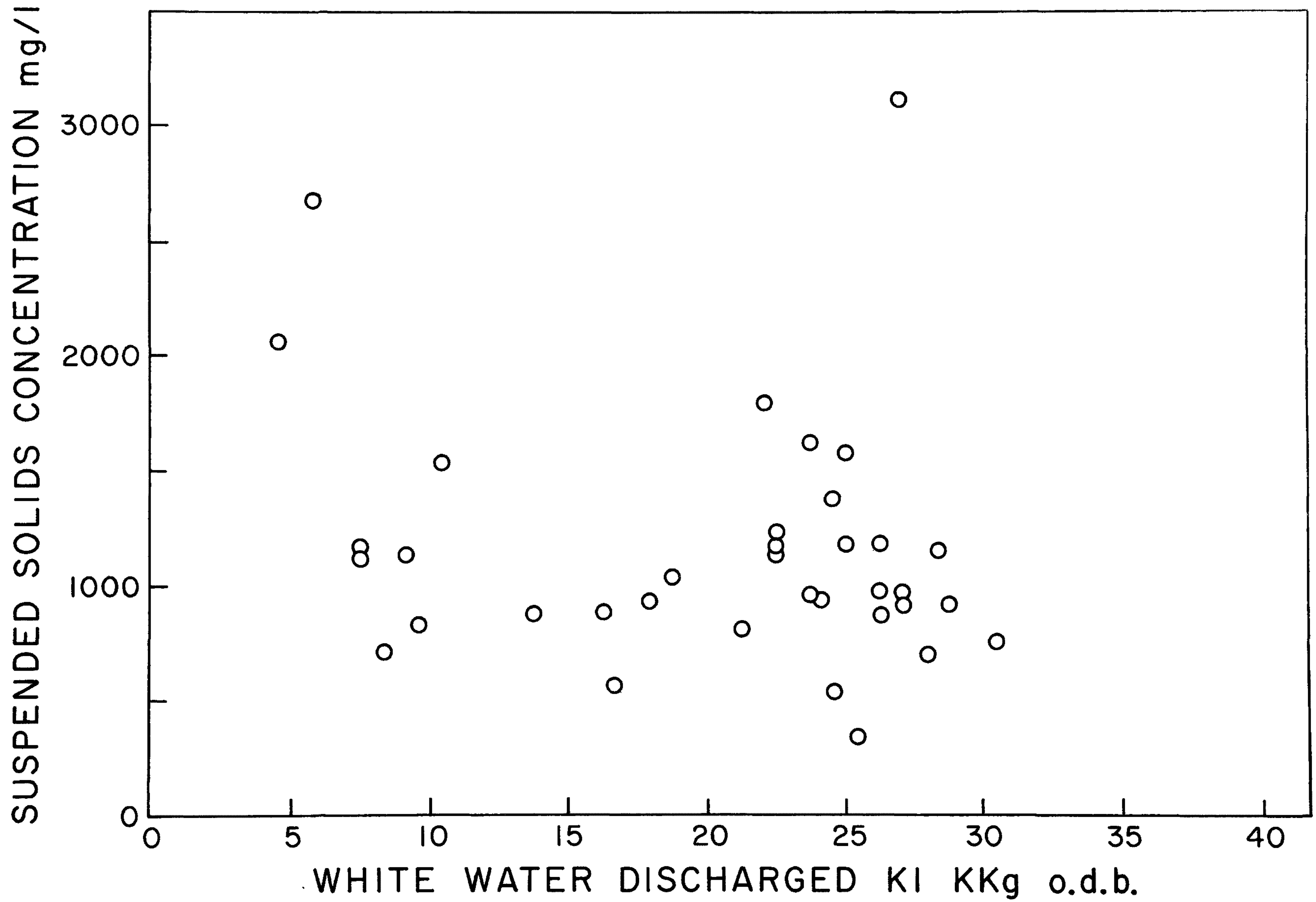

Figure 30. White water suspended solids concentration vs. white water discharge.

Dissolved Solids--

An increase in the amount of recycle causes in increase in the total dissolved solids concentration. A material balance yields the equation $Cm = \frac{L}{Wm+E}$ describing the relationship between the white water concentration (Cm) and the quantity of effluent (E). L is the loading of dissolved organic solids to the white water system and Wm is the water contained in the mat. The equation does not include the press pit discharge. Data taken at Evans Products fit very well to this equation, as shown in Figure 31, with a correlation-coefficient of 0.96. Three data points were excluded from the correlation because hog fuel containing bark was being processed at the time, significantly increasing the dissolved solids loading to the white water system. The quantity of dissolved solids going to the effluent is shown in Figure 32.

As a side note, the loading of dissolved solids to the white water system as predicted using data obtained in the comparison of pollution loads resulting from different species of wood was 73 g/Kg pulp (146 lb/Ton). The loading found in the measurements in Evans Products white water system was 61 g/Kg (122 lb/Ton) pu lp. The difference may be caused by precipitation of some of the tannins dissolved during cooking by addition of alum. Alum is added to help precipitate waxes. Many of the tannins dissolved are phenolic compounds.

Chemical Oxygen Demand (COD)--

One of the objectives of increasing the amount of recycle is to decrease the raw waste loading to the treatment system. The total mill raw waste load COD was plotted as a function of total mill discharge in Figure 33.

Figure 33 shows that the quantity of soluble COD discharged changes very little as the amount of recycle of white water increases. The total COD, including the contribution due to suspended solids, decreases with increasing recycle. BOD_5 raw waste loads behaved similarly, as shown in Figure 34, except that the Total BOD_5 was not as responsive to the increase in recycle. The BOD_5 of suspended solids does not exert itself until later in the BOD test, sometime after the 5 day time allotment in the test.

Temperature--

Temperatures rose from about 42°C (108°F) to about 65°C (150°F) in the head box when recycle was increased from about 50% recycle to about 90% recycle. This temperature rise was not enough to cause any noticeable problems.

Board Quality Changes--

Increasing the white water did not change the board strength or dimensional stability. A decrease in water adsorption was noticed, so use of a starch additive to lower water adsorption was discontinued. No sticking on the hot press occurred.

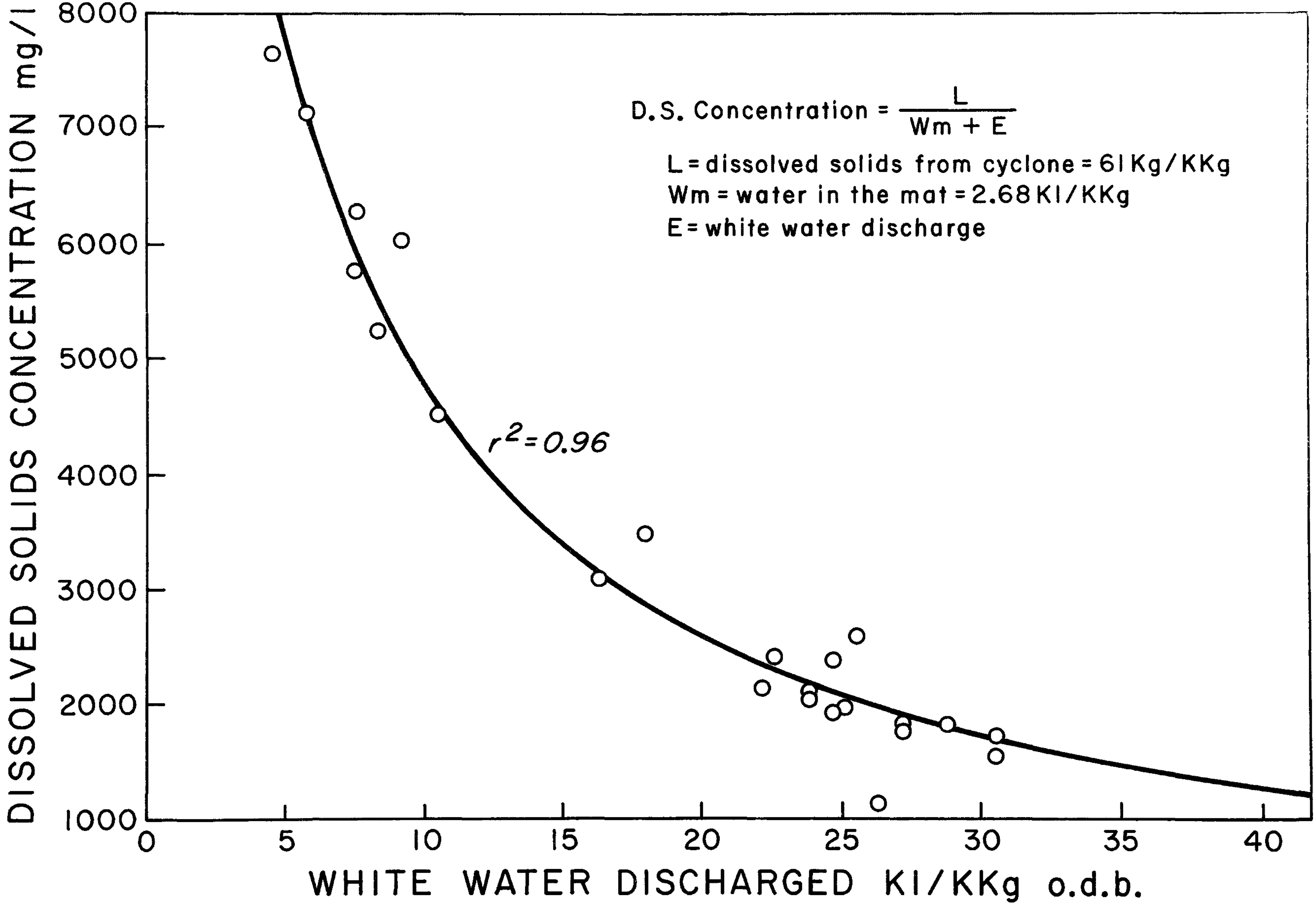

Figure 31. White water dissolved solids concentration vs. white water discharge.

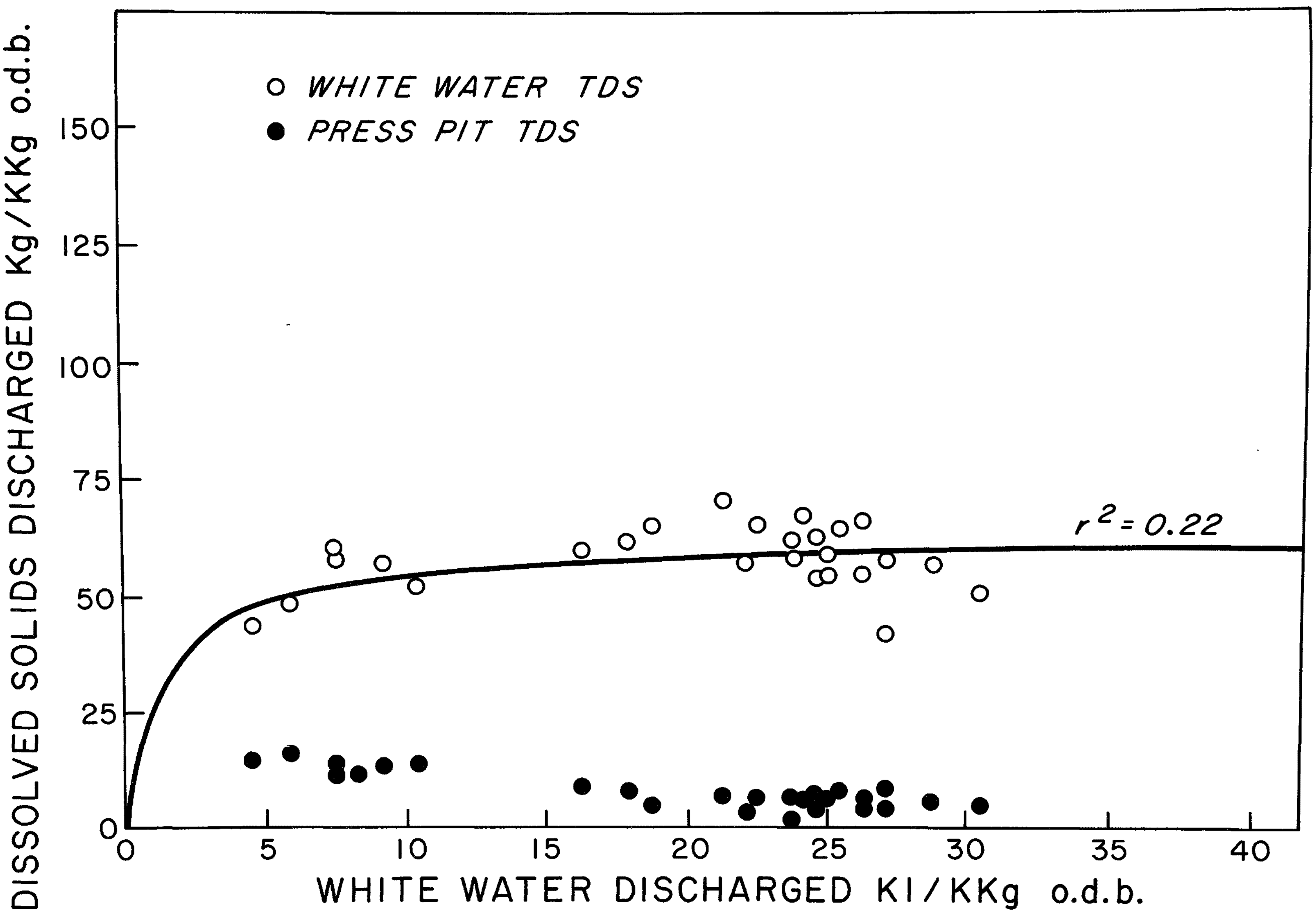

Figure 32. Discharge of dissolved solids vs. white water discharged.

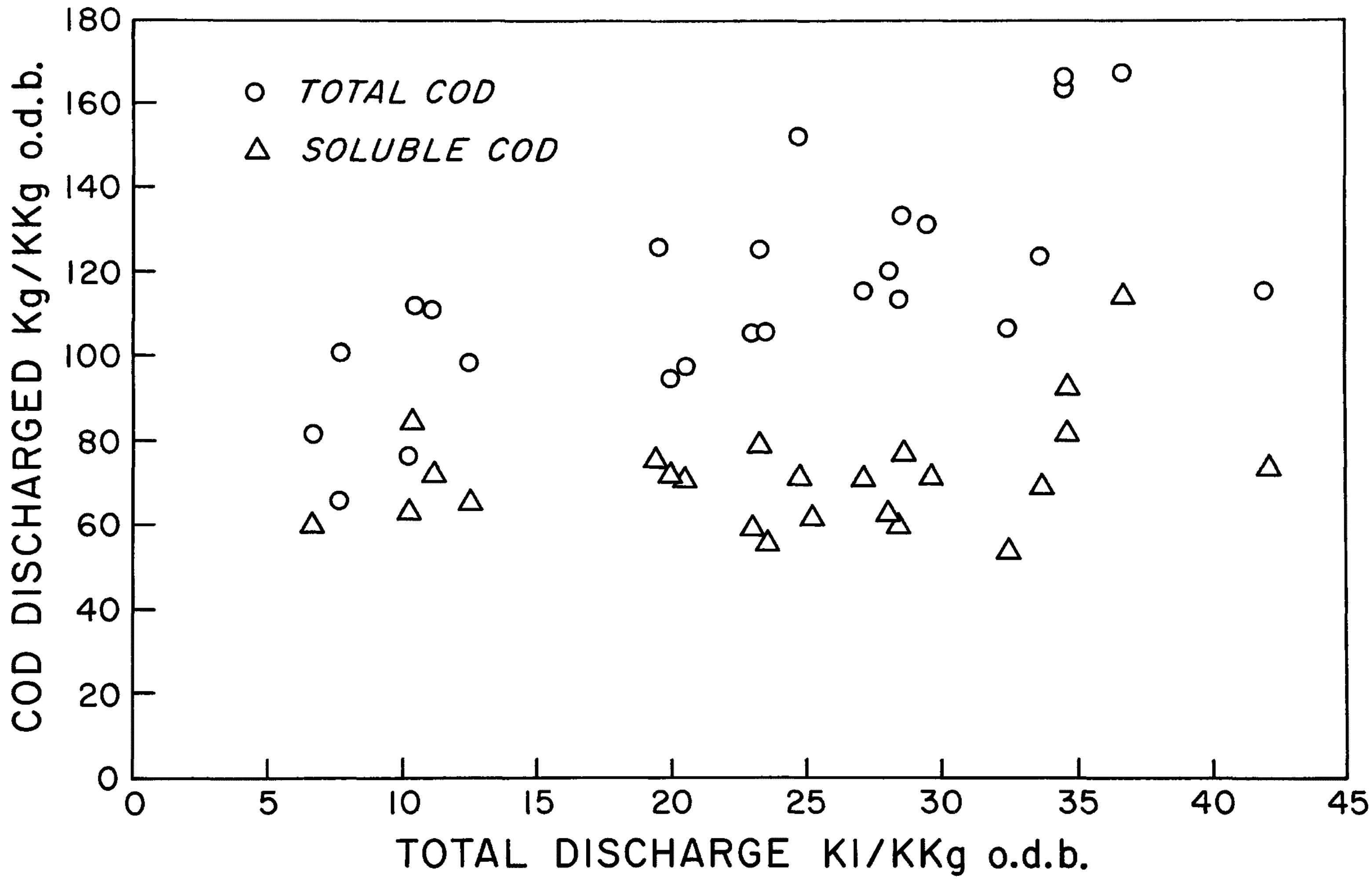

Figure 33. Discharge of COD vs. discharge.

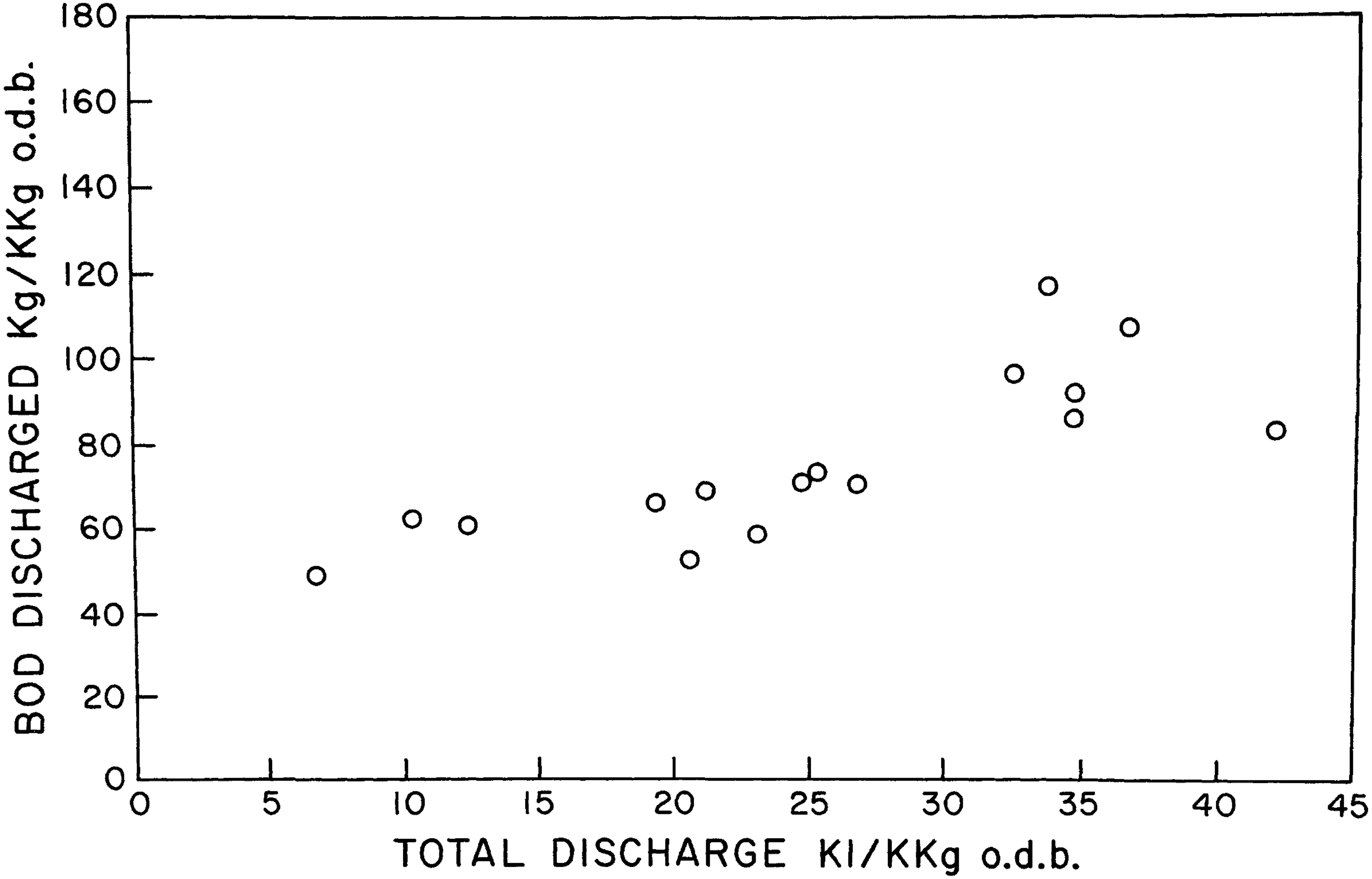

Figure 34. Discharge of BOD vs. discharge.

EFFECTS OF RECYCLE ON THE WASTE TREATMENT SYSTEM

Evans Products treats its waste water by primary settling, aeration in a lagoon, and by final settling. Primary settling consists of two ponds in series with capacities of about 9.5 million liters (2.5 million gallons) each. Sludge is periodically pumped to a sludge drying basin when the settling ponds become filled. The aeration basin holds about 37.8 million liters (10.0 million gallons), and has 5 aerators with a combined total of 268 Kilowatts (360 horsepower). The final settling pond also holds 18.9 million liters (5.0 million gallons). Sludge is pumped from the settling lagoon when the suspended solids in the effluent becomes too high.

This waste treatment pond also receives waste water from a battery separator plant which is largely cooling water. The battery separator plant began to recycle its process and cooling water about a year after the hardboard plant had completed its recycle program. Since the battery separator plant waste water contains much less BOD than the hardboard mill, it mainly acted as a dilutant to the hardboard mill waste.

As recycle in the hardboard mill is increased, the BOD loading to the treatment system does not decrease substantially until 80 to 90% recycle is obtained. However, the total organic raw waste load, as measured by the COD, does decrease with increasing recycle. The waste treatment system largely benefits from the reduced flow. Increased detention time in the aeration basin allows more time for biological degradation of the wastes and thereby results in increased treatment efficiency. Reduction of the raw waste load results in an additional improvement of the effluent quality. Figure 35 shows the BOD of the effluent following the final settling pond at various flows. Figure 36 shows the percent BOD removal for the different flows.

Suspended solids are not substantially decreased by the longer detention time in the aeration basin. Suspended solids removal is improved in the final settling pond because of the increased detention time. Some improvement in the final suspended solids discharged results from the lower loading of suspended solids and organic materials to the lagoon. Figure 37 shows effluent suspended solids as a function of flow. Figure 38 shows that the reduction in suspended solids in the treated effluent is not due to a reduction of input BOD, but is due to improved settling in the final lagoon.

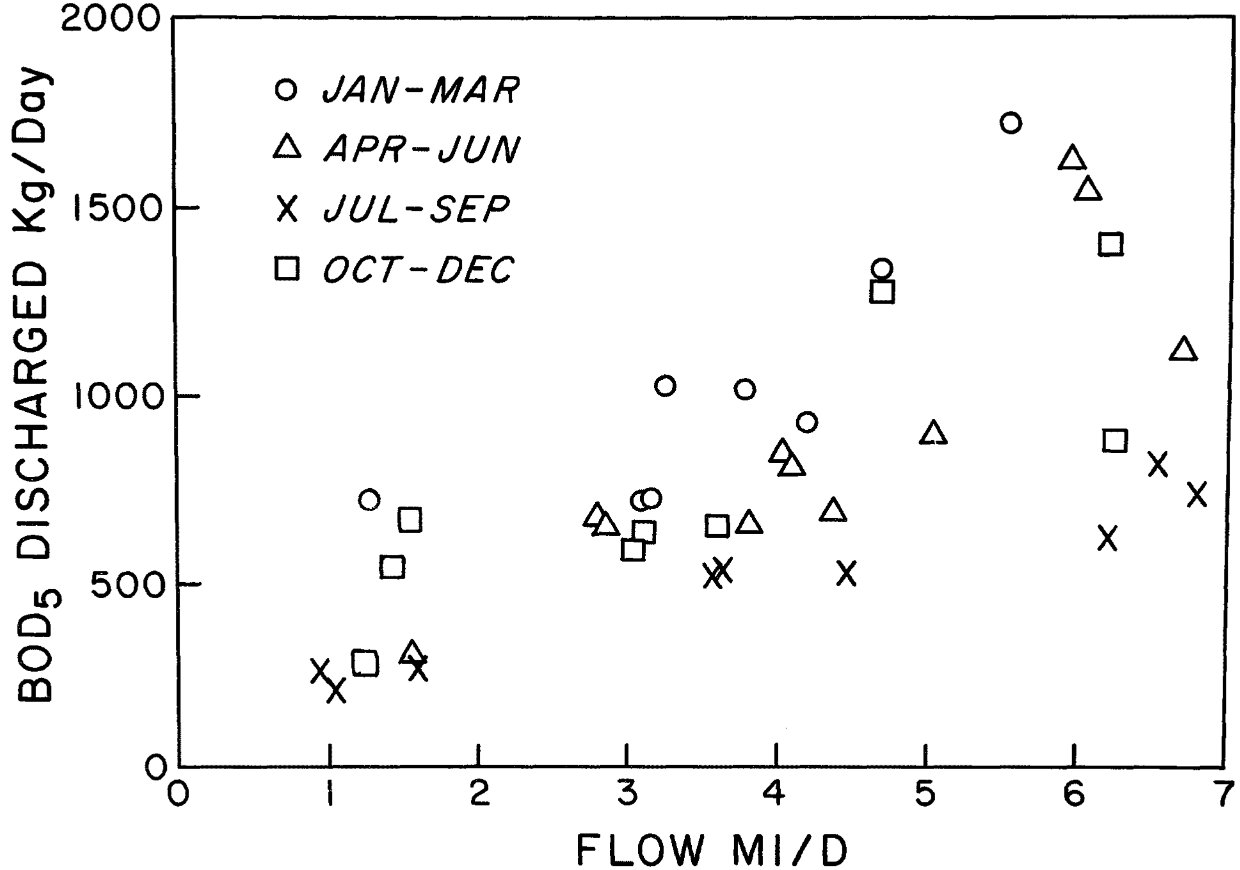

Figure 35. BOD discharged from final settling pond vs. effluent flow.

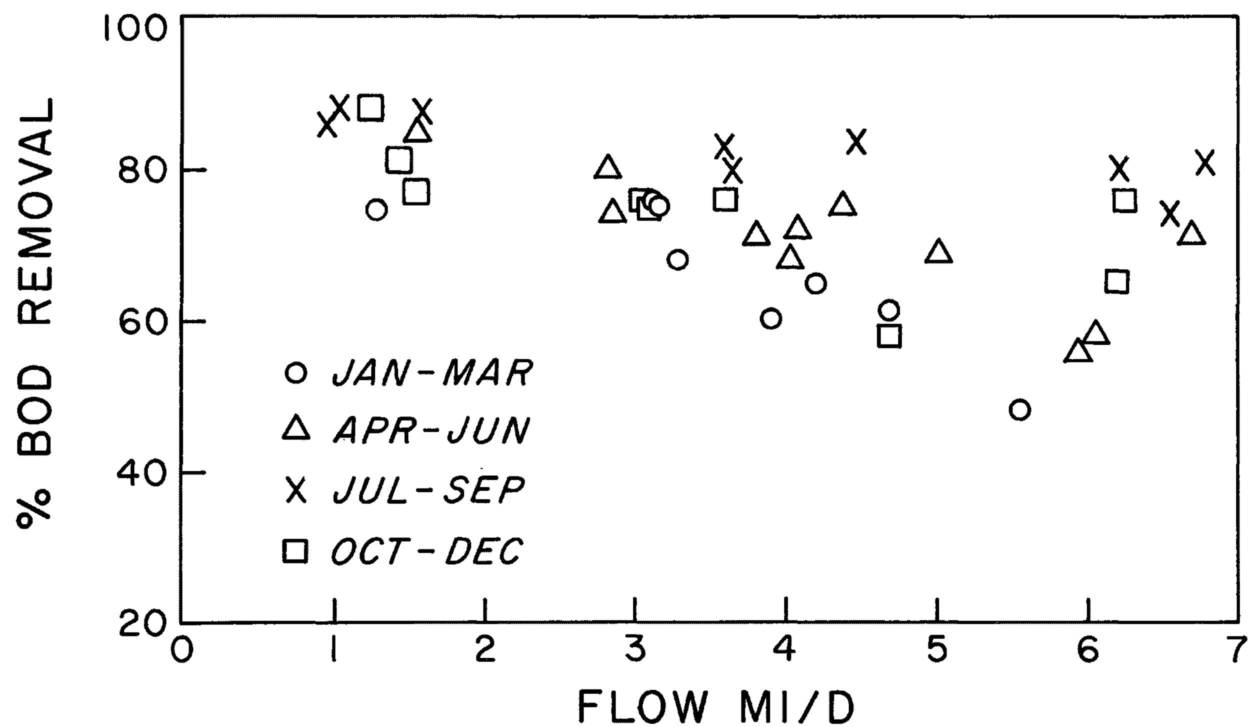

Figure 36. % BOD removal vs. effluent flow.

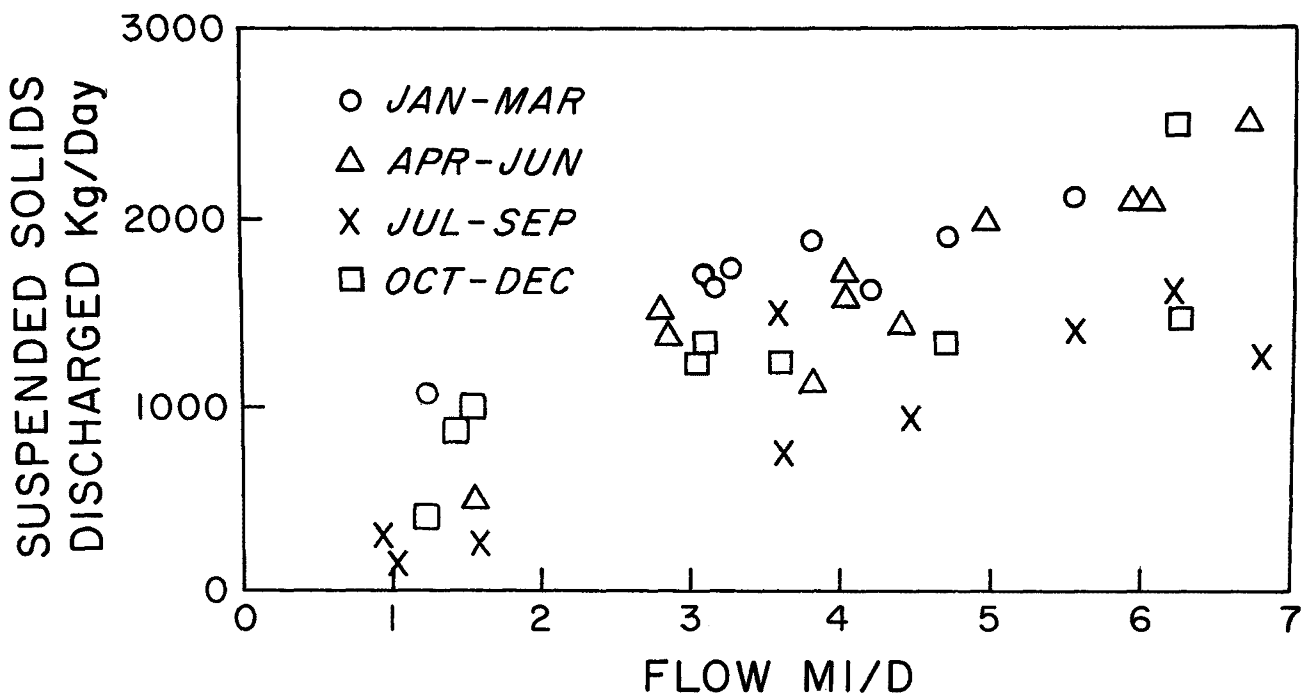

Figure 37. Suspended solids discharged from final settling pond vs. effluent flow.

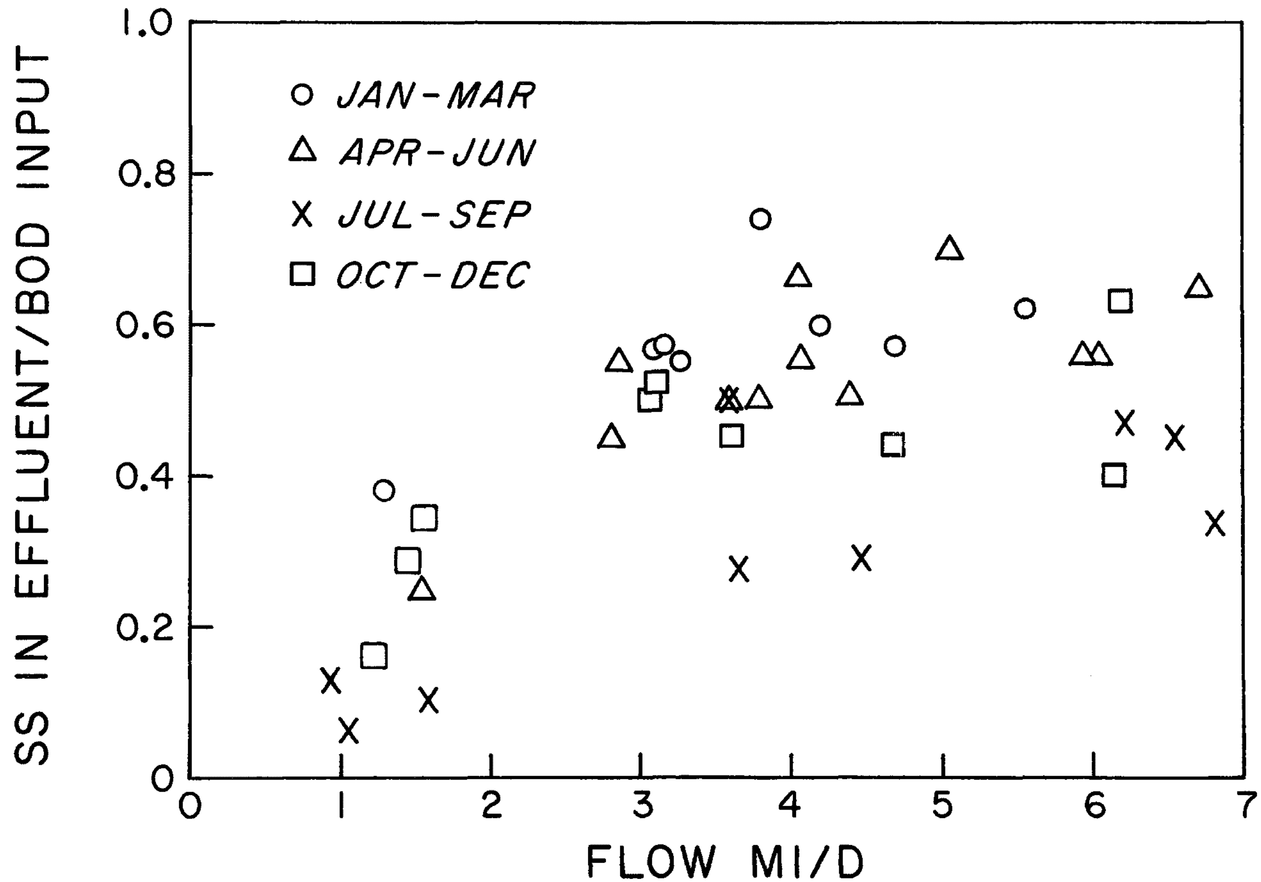

Figure 38. Suspended solids in effluent/BOD input vs. effluent flow.

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APPENDICES

APPENDIX A. DIGESTER PRESSURE, TEMPERATURE, TIME, AND RECOVERY DATA

Department of Forest Products
Oregon State University
Corvallis, Oregon 97331

December 29, 1975

Mr. Victor Dallons
Industrial Treatment & Control
200 SW 35th Street
Corvallis, OR 97330

Dear Vic:

Enclosed are the tabulated data for the wood steaming experiments which we performed for you under Project F-818-100. We ran the experiments as closely as possible according to the schedule in your letter of July 31, 1975. Briefly, the various chip and wood samples were steamed at the indicated pressure in our 2-pound digester for the specified time, and the effluents were delivered to you for BOD and other analyses. We determined the resulting yields from these treatments, and this is the only test which we performed in our lab on the products (solid or liquid) of the experiments.

We subjected the yield data to multiple regression analysis, with the results given in the accompanying table. Combining all 70 experiments in one pool, both pit yields and flatbox yields have poor correlation with the 3 independent variables, steaming time, temperature (actual or recorded), and pressure.* Pressure was the most significant variable for prediction of pit yield, closely followed by temperature, while steaming time was the most significant variable for flatbox yield. In view of the low overall multiple correlation coefficients (.27 and .20 respectively), little significance should be attached to these relationships.

---

* Originally, both theoretical and recorded temperatures were included in the regression analysis. Since the pressures and theoretical temperatures were perfectly correlated (r=1), there was no value in keeping both variables in the analysis, and the theoretical temperature was dropped out.

By analyzing the data for each wood sample individually, the regressions become more meaningful.** The (r^2)'s generally improve to a maximum of .76 for aspen, although the r^2 for plywood trim is only .27. With some exceptions, steaming time generally rates secondary in importance to steaming pressure in terms of influencing the yields, and again the temperature follows the pressure closely in terms of influence. Since the pressure and temperature are so closely correlated, and the pressure precedes the temperature in the regression analysis, the apparent significance of the temperature is lower than it might otherwise be.

In summary, we can state that, within the ranges of the independent variables tested, temperature seems a bit more influential in determining yield than time. Steam pressure and temperature are highly correlated, but it seems most likely that it is the temperature that is responsible for loss of wood substance in these experiments rather than the steam pressure *per se*. While the pressure may be important in promoting penetration of moisture into the wood, the temperature of the steam is the factor that determines the rate of breakdown and ultimate solution of woody material into the aqueous effluent.

If you have further questions on this, please do not hesitate to contact us. It has been a pleasure working with you on this project, and we hope that we may conduct future cooperative work on other projects.

Yours truly,

Walt

Walter J. Bublitz
Associate Professor
Pulp and Paper

klm
enc.
cc: Resch
Hull
Currier

** Only pit yield was thus analyzed, since flatbox yield showed poorer correlation with independent variables from the pooled analysis.

Multiple Regression Data for Digester Yields

Yield data from	Flat-box	Pit					
Species	All	All	Pine	Douglas fir	Oak	Plywood trim	Aspen
# of tests	70	70	14	14	14	14	14
Simple Correlation With:							
X(1)	-.31	-.26	-.11	-.58	-.33	-.37	-.34
X(2)	-.31	-.45	-.59	-.46	-.79	-.02	-.84
X(3)	-.29	-.41	-.59	-.45	-.75	-.03	-.86
Multiple Correlation (All):							
r^2	.20	.27	.37	.59	.73	.28	.76
Regression Coefficients:							
B(0)	131.5	56.8	331.7	86.3	163.4	-207.5	220.5
B(1)	-1.22	-.693	-.398	-1.17	-.730	-.323	-.504
B(2)	-.067	-.185	.222	-.123	-.039	-.494	-.064
B(3)	-.084	.178	-.760	.074	-.212	1.06	-.338
"t" Value, Regression Coefficients:							
t(1)	-2.8	-2.3	-.58	-3.1	-2.0	-.67	-1.1
t(2)	-.37	-1.5	+.36	-.90	-.27	-1.4	-.46
t(3)	-.20	.62	-.55	.23	-.61	1.3	-1.0

Independent Variables:
X(1) Steaming time, minutes
X(2) Steaming pressure, psi
X(3) Steaming temperature, °F

SOUTHERN YELLOW PINE

COOK NO.	COOK TIME MIN.	COOK PRESS. PSIG	TEMPERATURE DEGREES F THEO.	ACTUAL	-----TIME, MINUTES----- TO PRESS.	TO REFINER	IN PIT	CONSISTENCY, % ON SCREEN	IN PIT	---YIELD, %-- FROM PIT	FROM FLATBOX	REMARKS
42	2	100	338	(1)	0.58	3.5	16	6.22	6.82	93.1	93.6	(1) TEMP. RECORD. PROB.
26	2	130	356	348	0.75	4.5	14	6.69	7.16	97.7	95.3	
34	2	160	370	363	0.75	3.5	17	6.54	6.85	93.5	89.9	
12	2	200	388	378	1.25	3.5	15	6.43	6.69	91.3	82.7	
25	5	100	338	333	0.50	4.5	17	6.60	7.08	96.6	97.6	DUPLICATE COOKS
52	5	100	338	332	0.58	3.0	13	6.99	6.71	91.5	92.6	DUPLICATE COOKS
39	5	130	356	348	0.75	3.5	16	6.78	6.80	92.8	87.9	
28-A	5	160	370	363	1.00	3.0	16	5.72	6.82	93.1	84.6	REPEAT COOK
15	5	200	388	376	1.50	4.3	13	5.90	6.63	90.5	81.4	DUPLICATE COOKS
44	5	200	388	379	1.17	3.5	17	7.12	6.71	91.6	83.2	DUPLICATE COOKS
68	10	100	338	332	0.50	3.5	17	7.97	8.18	111.6	101.2	
13	10	130	356	350	0.50	4.0	13	6.58	6.85	93.5	84.0	
37	10	160	370	356	0.92	3.5	16	5.95	6.62	90.4	84.9	
55	10	200	388	379	0.75	3.0	13	5.91	5.70	70.8	77.8	

DOUGLAS FIR

COOK NO.	COOK TIME MIN.	COOK PRESS. PSIG	TEMPERATURE DEGREES F THEO.	TEMPERATURE DEGREES F ACTUAL	TIME, MINUTES TO PRESS.	TIME, MINUTES TO REFINER	TIME, MINUTES IN PIT	CONSISTENCY, % ON SCREEN	CONSISTENCY, % IN PIT	YIELD, % FROM PIT	YIELD, % FROM FLATBOX	REMARKS
7	2	100	338	328	0.42	3.0	17	6.42	7.13	97.3	91.1	
53	2	130	356	348	0.83	3.3	22	6.28	6.99	95.4	91.9	
70	2	160	370	363	1.08	3.3	15	5.93	6.74	92.0	85.0	DUPLICATE COOKS
27	2	160	370	363	1.08	3.5	18	5.59	6.38	87.1	87.9	DUPLICATE COOKS
17	2	200	388	366	1.08	3.5	20	6.57	6.55	89.4	89.7	
36	5	100	338	333	0.50	3.5	16	6.23	6.36	86.8	90.4	
22	5	130	356	(1)	0.92	4.3	22	6.76	6.78	92.5	87.0	(1) TEMP. RECORD. PROB.
35	5	160	370	355	1.00	4.3	18	5.93	6.53	89.1	86.4	
19	5	200	388	378	1.50	3.8	18	5.32	6.16	84.0	76.8	
45	10	100	338	331	0.67	2.3	16	5.79	6.00	81.9	86.1	
54	10	130	356	348	0.67	3.3	21	6.33	6.61	90.3	87.5	DUPLICATE COOKS
23	10	130	356	348	0.75	3.5	17	6.53	6.79	92.7	84.9	DUPLICATE COOKS
2	10	160	370	363	1.17	4.0	17	5.20	5.81	79.3	76.3	
33	10	200	388	372	1.25	4.0	17	4.72	5.33	72.8	78.2	

OAK

COOK NO.	COOK TIME MIN.	COOK PRESS. PSIG	TEMPERATURE DEGREES F THEO.	ACTUAL	------TIME, MINUTES----- TO PRESS.	TO REFINER	IN PIT	CONSISTENCY, % ON SCREEN	IN PIT	---YIELD, %-- FROM PIT	FROM FLATBOX	REMARKS
4-A	2	100	338	331	0.42	3.0	19	5.00	5.97	81.5	86.4	REPEAT COOK
18	2	130	356	348	0.83	3.5	22	5.72	6.10	83.3	88.5	
38	2	160	370	358	0.75	3.0	13	5.09	6.03	82.3	86.3	
21	2	200	388	377	1.17	3.5	18	5.07	5.57	76.1	77.5	
61-A	5	100	338	332	0.33	3.3	15	5.66	6.41	87.5	85.7	
41	5	130	356	348	0.67	3.5	17	5.52	6.17	84.1	84.2	DUPLICATE COOKS
48	5	130	356	349	0.67	3.0	17	5.48	6.09	83.1	84.3	DUPLICATE COOKS
69	5	160	370	363	1.08	3.3	17	4.77	5.38	73.4	71.1	DUPLICATE COOKS
20	5	160	370	358	1.00	3.5	18	5.30	5.68	77.6	78.6	DUPLICATE COOKS
1	5	200	388	378	0.92	4.0	17	4.38	5.00	68.2	60.3	
66	10	100	338	333	0.25	2.8	17	5.23	6.16	84.1	79.9	
63	10	130	356	344	0.58	3.5	17	(1)	5.39	73.4	(1)	(1) FIRE DESTROY SAMP.
16	10	160	370	350	1.00	4.0	17	4.82	5.58	76.2	74.5	
46	10	200	388	370	1.25	3.3	14	4.29	5.14	70.2	70.2	

PLYWOOD TRIM

COOK NO.	COOK TIME MIN.	COOK PRESS. PSIG	TEMPERATURE DEGREES F THEO.	ACTUAL	----TIME, MINUTES---- TO PRESS.	TO REFINER	IN PIT	CONSISTENCY, % ON SCREEN	IN PIT	---YIELD, %-- FROM PIT	FROM FLATBOX	REMARKS
57-A	2	100	338	332	0.25	3.3	14	6.20	6.70	91.5	88.3	
43-A	2	130	356	351	0.42	3.0	13	6.07	7.04	96.1	91.4	REPEAT COOK
24	2	160	370	365	0.92	4.0	18	6.97	7.53	102.8	97.0	
3	2	200	388	378	1.50	3.5	30	6.33	6.57	89.7	85.2	DUPLICATE COOKS
59-A	2	200	388	381	1.33	3.0	18	7.03	7.32	99.9	89.9	DUPLICATE COOKS
62-A	5	100	338	332	0.50	3.0	13	6.56	6.99	95.4	90.5	
6	5	130	356	351	0.83	4.5	21	7.48	7.67	104.7	90.2	
47	5	160	370	364	0.83	3.0	16	6.92	6.47	89.3	91.4	
67	5	200	388	378	1.25	3.0	17	7.08	7.03	95.6	84.2	
50	10	100	338	332	0.33	3.0	15	6.42	6.73	91.9	93.0	DUPLICATE COOKS
60-A	10	100	338	332	0.25	3.3	14	6.52	6.89	94.0	89.5	DUPLICATE COOKS
8	10	130	356	349	0.58	4.0	20	6.39	7.01	95.7	89.8	
10	10	160	370	362	0.58	3.5	13	5.82	6.12	83.5	88.8	
14	10	200	388	376	1.33	4.3	14	6.32	6.82	93.1	84.9	

ASPEN

COOK NO.	COOK TIME MIN.	COOK PRESS. PSIG	TEMPERATURE DEGREES F THEO.	ACTUAL	TIME, MINUTES TO PRESS.	TO REFINER	IN PIT	CONSISTENCY, % ON SCREEN	IN PIT	YIELD, % FROM PIT	FROM FLATBOX	REMARKS
11	2	100	338	332	0.67	3.5	12	6.92	7.20	98.3	96.9	DUPLICATE COOKS
40	2	100	338	332	0.42	2.5	19	6.59	6.91	94.3	96.5	DUPLICATE COOKS
58-A	2	130	356	349	0.92	3.0	15	6.63	6.68	90.5	89.9	
49	2	160	370	346	1.08	3.5	14	6.20	6.90	94.2	93.0	
32	2	200	388	372	1.17	3.5	16	6.32	6.31	86.1	88.0	
29	5	100	338	332	0.42	4.0	16	6.73	7.20	98.3	93.7	
51	5	130	356	349	0.67	3.3	15	6.92	7.15	97.6	90.2	
56-A	5	160	370	363	1.00	3.5	18	6.08	6.67	91.0	88.3	
30	5	200	388	376	1.25	3.5	18	5.46	5.43	74.1	76.6	
9	10	100	338	332	0.50	4.0	20	6.82	7.73	105.5	94.4	
64	10	130	356	337	0.75	3.0	14	5.92	6.69	91.3	84.9	
5	10	160	370	362	1.25	4.5	20	5.53	5.62	75.5	77.4	
31	10	200	388	368	1.17	4.3	21	5.29	5.47	74.7	77.3	DUPLICATE COOKS
55-A	10	200	388	373	1.42	3.5	14	5.32	5.69	77.7	72.5	DUPLICATE COOKS

APPENDIX B. TEST RESULTS FROM DIGESTOR COOKS

TABLE B-1. TEST RESULTS FROM DIGESTER COOKS

t-p	TDS	VDS	NVDS	SS	TS	BOD_S	BOD_T	COD_S	COD_T	pH
					Loading, g/Kg					
Aspen										
2-100	56	47	11	62	122	27	66	53	151	6.36
2-130	66	52	14	57	123	18	39	66	151	6.53
2-160	69	48	21	68	145	--	--	73	235	6.36
2-200	126	116	10	46	172	84	95	149	219	6.06
5-100	73	56	17	76	155	41	49	70	165	6.23
5-130	94	77	21	59	153	56	66	104	196	5.41
5-160	151	133	17	57	209	97	110	165	279	6.39
5-200	264	247	17	64	327	178	187	289	382	4.71
10-100	78	70	8	74	162	--	--	81	194	4.68
10-130	116	99	13	57	--	75	84	138	227	5.27
10-160	229	206	23	50	275	139	143	299	377	--
10-200	284	260	25	60	354	188	209	333	428	4.62
2-100	57	46	11	103	163	41	49	60	212	6.45
10-200	219	200	19	53	272	--	--	303	420	5.52
Southern Yellow Pine										
2-100	52	41	11	85	142	41	49	51	180	6.65
2-130	63	49	7	71	138	28	46	64	194	6.57
2-160	79	71	9	63	146	49	62	90	194	6.08
2-200	107	98	9	44	155	58	31	111	192	6.50
5-100	53	45	8	59	116	26	40	57	163	6.22
5-130	91	81	10	65	157	71	73	101	208	5.93
5-160	101	36	15	40	127	36	46	111	191	6.70
5-200	171	157	13	80	271	--	--	192	360	5.68
10-100	55	44	10	47	101	--	--	60	140	4.68
10-130	97	90	7	57	158	--	68	100	214	6.12
10-160	142	124	18	81	238	89	116	140	298	6.54
10-200	191	181	10	76	276	123	135	217	348	5.45
5-100	52	40	12	67	119	44	55	66	181	6.61
5-200	153	142	10	47	192	98	105	171	227	6.09

TABLE B-1. TEST RESULTS FROM DIGESTER COOKS (Continued)

t-p	TDS	VDS	NVDS	SS	TS	BOD_S	BOD_T	COD_S	COD_T	pH
					Loading, g/Kg					
Oak										
2-100	92	68	24	196	296	50	61	130	391	--
2-130	120	103	17	205	333	312	--	129	423	6.20
2-160	170	147	22	230	430	103	159	186	523	6.03
2-200	266	248	17	173	465	--	160	290	626	4.87
5-100	92	68	24	196	296	50	61	130	391	--
5-130	177	167	10	174	373	152	170	202	366	5.25
5-160	235	216	19	126	384	--	--	272	440	5.12
5-200	338	296	41	158	544	166	247	377	648	--
10-100	153	144	9	170	323	102	107	175	369	4.89
10-130	229	207	14	184	412	157	160	272	475	4.95
10-160	275	257	18	196	514	--	--	308	638	4.57
10-200	357	336	21	228	656	245	267	410	834	4.32
5-130	179	166	13	163	362	121	139	207	444	4.59
5-160	243	245	13	174	417	--	--	298	542	4.68
Douglas Fir										
2-100	67	57	10	91	166	--	--	79	216	5.68
2-130	80	67	13	75	155	61	63	97	218	6.70
2-160	152	126	22	146	320	87	102	152	322	6.24
2-200	141	119	22	86	226	--	--	155	277	6.40
5-100	100	92	9	117	220	71	82	108	296	5.92
5-130	106	94	13	71	178	--	--	121	229	6.62
5-160	141	135	6	96	251	97	110	161	335	5.43
5-200	175	163	13	111	314	--	--	192	389	6.44
10-100	120	109	10	124	248	85	102	129	312	5.84
10-130	138	123	15	52	196	77	108	155	256	6.16
10-160	227	182	46	77	331	74	123	233	354	--
10-200	212	209	8	135	375	147	176	249	509	5.64
2-160	101	86	15	72	173	58	72	116	223	6.12
10-130	134	120	14	73	207	94	115	161	274	6.28

TABLE B-1. TEST RESULTS FROM DIGESTER COOKS (Continued)

t-p	TDS	VDS	NVDS	SS	TS	BOD_S	BOD_T	COD_S	COD_T	pH
					Loading, g/Kg					
Plywood Trim										
2-100	60	51	9	116	177	39	44	72	252	6.54
2-130	72	62	10	128	205	47	54	80	267	6.32
2-160	73	63	10	109	188	44	52	84	263	6.47
2-200	92	--	--	88	183	44	36	126	250	--
5-100	70	52	18	64	134	31	37	79	182	6.95
5-130	71	62	9	67	140	--	--	72	178	--
5-160	92	76	16	61	148	56	53	104	200	6.47
5-200	115	105	10	74	199	75	80	137	258	6.00
10-100	61	45	16	89	153	--	--	77	213	6.37
10-130	92	80	12	87	188	--	--	96	229	6.16
10-160	109	90	19	78	193	58	59	110	245	6.54
10-200	135	118	18	73	219	--	--	151	281	6.11
10-100	71	58	13	59	131	39	45	86	179	6.53
2-200	83	56	16	61	144	46	50	97	185	6.40

APPENDIX C. DATA COLLECTED AT EVANS PRODUCTS CORPORATION

TABLE C-1. WHITE WATER SOLIDS DATA

Date	Excess White Water Flow MGD	Total Dissolved Solids mg/l	Total Dissolved Solids lbs/day	Volatile Dissolved Solids mg/l	Volatile Dissolved Solids lbs/day	Non-Volatile Dissolved Solids mg/l	Non-Volatile Dissolved Solids lbs/day	Suspended Solids mg/l	Suspended Solids lbs/day
3/19/74	.51	--	--	--	--	--	--	803	3415
3/20/74	.59	2384	11730	--	--	--	--	641	5154
3/21/74	.53	2128	9406	1747	7722	382	1688	1880	8310
3/26/74	.63	2638	13860	2318	12179	320	1681	1186	6231
3/27/74	.57	2039	9692	1775	8438	264	1255	1632	7758
3/28/74	.59	1920	9447	1669	8212	251	1235	1380	6790
4/02/74	.57	2115	10054	1851	8799	264	1255	969	4606
4/03/74	.54	4366	19662	4070	18329	296	1333	1244	5602
4/04/74	.58	3650	17655	3357	16238	293	1417	944	4566
4/09/74	.61	2202	11202	1967	10007	235	1196	1206	6135
4/10/74	.60	3163	15828	2813	14076	350	1751	1199	6000
4/11/74	.60	1968	9847	1727	8641	240	1200	1490	7456
4/16/74	.63	2029	1066	1792	9415	236	1240	973	5112
4/17/74	.65	1825	9893	1529	8289	296	1605	984	5334
4/18/74	.69	1822	10484	1524	8770	218	1715	934	5374
4/24/74	.73	1570	9558	1336	8134	234	1425	776	4724
4/25/74	.65	1770	9595	1520	8239	250	1355	993	5383
12/20/74	.43	3482	12487	3019	10827	463	1660	869	3116
2/05/75	.39	3098	10076	2856	9289	242	787	892	2901
2/12/75	.22	6006	11020	5120	9394	886	1626	1135	2082
2/19/75	.45	2102	7880	1896	7116	206	773	1040	3903
3/05/75	.25	4588	9566	3916	8165	672	1401	1534	3198
3/12/75	.18	6296	9452	5524	8292	772	1159	1185	1779
3/19/75	.11	7636	7005	6776	6216	860	789	2154	1976
4/02/75	.14	7148	8346	6136	7164	1012	1182	2667	2114
4/23/75	.2	5218	8704	4616	7699	602	1004	708	1173
6/04/75	.18	5736	8610	--	--	--	--	1204	1807

TABLE C-2. PRESS PIT SOLIDS DATA

Date	White Water Flow MGD	Total Dissolved Solids		Volatile Dissolved Solids		Non-Volatile Dissolved Solids		Suspended Solids	
		mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day	mg/l	lbs/day
3/19/74	.51	2603	911	2025	709	578	202	180	63
3/20/74	.59	2722	953	--	--	--	--	312	109
3/21/74	.53	2911	1019	2618	916	293	102	451	158
3/26/74	.63	2460	861	1913	670	298	104	891	312
3/27/74	.57	2441	854	2221	777	220	77	235	82
3/28/74	.59	3086	1080	2841	994	245	86	236	83
4/02/74	.57	2929	1025	2624	918	305	107	401	140
4/03/74	.54	822	288	576	202	246	86	246	86
4/04/74	.58	2581	903	2357	825	224	78	174	61
4/09/74	.61	3094	1083	2846	996	284	99	349	122
4/10/74	.60	2967	1039	2684	939	609	213	300	105
4/11/74	.60	2874	1006	2626	919	246	86	206	72
4/16/74	.63	2362	827	2158	755	204	71	507	177
4/17/74	.65	2724	954	2355	824	369	129	214	75
4/18/74	.69	2505	876	2257	790	248	87	231	81
4/24/74	.73	2605	911	2340	819	265	93	266	93
4/25/74	.65	2335	817	2115	740	220	77	260	91
12/20/74	.43	3995	1398	3601	1260	394	138	158	55
2/05/75	.39	2202	770	1988	696	214	75	826	289
2/12/75	.22	4640	1624	4188	1466	452	158	6692	2343
2/19/75	.45	2256	780	2088	730	168	59	144	50
3/05/75	.25	4992	1572	4356	1525	636	272	188	66
3/12/75	.18	8212	2875	7374	2581	838	293	88	31
3/19/75	.11	6426	2249	5722	2003	704	246	299	105
4/02/75	.14	7470	2615	6534	2287	936	327	332	116
4/23/75	.2	5440	1904	4654	1629	786	275	221	77
6/4/75	.18	--	--	--	--	--	--	189	66

TABLE C-3. CYCLONE DISSOLVED SOLIDS DATA

Date	Cyclone Total Dissolved Solids mg/l	Cyclone Total Dissolved Solids g/kg	Cyclone Spray Dissolved Solids mg/l	Cyclone Spray Dissolved Solids g/kg	Dissolved Solids Loading to Cyclone g/kg
4/09/74	1988	34.7	0	0	34.7
4/10/74	3687	64.4	0	0	64.4
4/16/74	2275	39.7	0	0	39.7
4/17/74	2420	42.3	0	0	42.3
4/24/74	2060	36.0	0	0	36.0
4/25/74	1880	32.8	0	0	32.8
5/01/74	2170	37.9	0	0	37.9
1/31/75	2748	48.0	1898	28.6	19.4
2/04/75	4348	75.9	2412	36.4	39.6
2/05/75	4420	77.2	3098	46.7	30.5
2/12/75	7518	131.3	6006	90.5	37.1
3/05/75	5966	104.2	4588	69.1	35.0
3/19/75	9166	160.0	7636	115.1	45.0
4/02/75	9044	157.9	7148	107.7	50.2
4/16/75	4660	81.4	3386	51.0	30.3
4/23/75	6768	118.2	5218	78.6	39.5
4/30/75	6814	119.0	5676	85.5	33.4
6/04/75	7150	124.8	5736	86.4	38.4

TABLE C-4. WHITE WATER, BOD DATA

Date	Flow	BOD, Total mg/l	lbs/day	BOD, Soluble mg/l	lbs/day
3/20/74	.51	1525	6486	--	--
3/21/74	.53	1518	6710	1162	5136
3/27/74	.57	1487	7069	--	--
3/28/74	.59	1262	6210	1298	6387
4/03/74	.54	1438	6476	--	--
4/04/74	.58	1462	7072	1470	7111
4/10/74	.60	1232	6165	--	--
4/11/74	.60	1305	6530	1035	5179
4/17/74	.65	1867	1012	--	--
4/18/74	.69	1747	10053	1507	8672
4/24/74	.73	963	5862	--	--
4/25/74	.65	1502	8142	894	4846
12/20/74	.43	2925	10489	1890	6778
2/05/75	.39	1675	5448	1675	5448
2/19/75	.45	1285	4823	1060	3978
3/05/75	.25	2488	5187	2256	4704
4/02/75	.14	3287	3838	2821	3294
4/23/75	.2	3188	5318	2962	4941

TABLE C-5. PRESS PIT, BOD DATA

Date	BOD, Total mg/l	BOD, Total lbs/day	BOD, Soluble mg/l	BOD, Soluble lbs/day
3/20/74	1525	534	--	--
3/21/74	1532	536	1525	534
3/27/74	1430	500	--	--
3/28/74	1735	605	1642	575
4/03/74	1517	531	--	--
4/04/74	1542	540	1405	492
4/10/74	1362	477	--	--
4/11/74	1650	577	1085	380
4/16/74	1438	503	--	--
4/18/74	1838	643	1865	653
4/24/74	1292	452	--	--
4/25/74	1500	525	1433	501
4/29/74	1400	490	--	--
12/20/74	2730	955	2070	724
2/05/75	2075	726	1700	595
2/19/75	1440	504	1365	478
3/05/75	2385	835	3090	1081
4/02/75	3028	1060	1942	680
4/16/75	2016	706	1965	688
4/23/75	2930	1028	2963	1037
4/30/75	2290	801	2250	787

TABLE C-6. SOLUBLE COD DATA

Date	White Water Flow MGD	White Water COD mg/l	White Water COD lbs/day	Press Pit COD mg/l	Press Pit COD lbs/day	Total COD lbs/day
3/19/74	.51	3355	14270	4165	1458	15728
3/20/74	.59	2640	12990	2146	751	13741
3/21/74	.53	2640	11669	2258	790	12459
3/26/74	.63	2560	13450	2247	787	14237
3/27/74	.57	2510	11932	1210	424	12356
3/28/74	.59	2270	11169	4570	1600	12769
4/02/74	.57	2560	12170	4210	1474	13644
4/03/74	.54	2990	13465	3900	1365	14830
4/04/74	.58	2865	13858	3630	1271	15129
4/09/74	.61	2570	13074	4440	1555	14629
4/10/74	.60	2420	12109	4150	1453	13562
4/11/74	.60	2220	11108	3900	1365	12473
4/16/74	.63	2150	11296	3310	1158	12454
4/17/74	.65	2040	11058	3350	1173	12231
4/18/74	.69	1990	11451	3330	1164	12615
4/24/74	.73	1650	10045	2830	991	11036
4/25/74	.65	1590	8619	2750	963	9582
12/20/74	.43	3520	12623	4380	1533	14156
2/05/75	.39	3776	12281	4930	1726	14007
2/12/75	.22	6370	11687	8100	2836	14523
2/19/75	.45	3555	13341	2600	910	14251
3/05/75	.25	5130	10696	6537	2289	12985
3/12/75	.18	8137	12215	7783	2724	14939
3/19/75	.11	9425	8644	8448	2957	11601
4/02/75	.14	8539	9970	9368	3279	13249
4/23/75	.2	6115	10199	6843	2395	12594

TABLE C-7. TOTAL COD DATA

Date	White Water Flow MGD	White Water COD mg/l	White Water COD lbs/day	Press Pit COD mg/l	Press Pit COD lbs/day	Total COD lbs/day
3/19/74	.51	5500	23400	3930	1376	24776
3/20/74	.59	4260	21000	4620	1618	22618
3/21/74	.53	4650	20600	4960	1737	22300
3/26/74	.63	4680	24600	4690	1642	26200
3/27/74	.57	5090	24200	--	--	--
3/28/74	.59	4570	22500	5090	1783	24300
4/02/74	.57	4680	22300	4690	1642	23900
4/03/74	.54	4490	20200	4545	1592	21800
4/04/74	.58	6420	31100	4120	1443	32500
4/09/74	.61	4670	23800	5015	1756	25600
4/10/74	.60	4790	24000	4670	1635	25600
4/11/74	.60	4720	23600	4350	1524	25100
4/16/74	.63	4320	22700	4540	1590	24300
4/17/74	.65	4050	22000	4020	1408	23400
4/18/74	.69	3680	21200	3840	1345	22500
4/24/74	.73	2670	16255	3460	1212	17500
4/25/74	.65	3300	17900	3240	1135	19000
1/20/75	.43	4770	17100	4640	1625	18700
2/05/75	.39	6250	20300	9147	3204	23500
2/12/75	.22	8985	16500	17000	5954	22459
2/19/75	.45	4890	18400	3810	1334	19734
3/05/75	.25	8206	17109	6925	2424	19533
3/12/75	.18	11370	17068	7783	2724	19792
3/19/75	.11	13820	12678	8965	3138	15816
4/02/75	.14	14590	17035	9989	3496	20531
4/23/75	.2	7856	13103	6885	2409	15512

TABLE C-8. PROCESS WATER SOLIDS COMPOSITION

Date	Board Thickness (in)	Location	Suspended solids (mg/l)	Dissolved solids (mg/l)	Non-Volatile solids (mg/l)	Sugars (mg/l)	Tannins (mg/l)	Sugars %	Tannins %	pH	Comments
10/14/74	1/4	Cyclone L	880	2202	332	1490	305	67.7	13.9	55.1	Plytrim
		Cyclone S	1714	5588	60	4350	682	77.8	12.2	3.8	Oak
		Head Box	1850	2452	142	1650	353	71.4	15.3	4.5	
		W.W. Chest	781	2254	108	1650	341	76.9	15.9	4.6	
		Baby Rolls	894	1726	134	1175	244	73.8	15.3	4.5	
		1st Big Roll	872	1828	146	1285	276	76.4	16.4	5.4	
		1st sec., Fordrineer	834	2494	230	1750	355	77.3	15.7	5.2	
10/21/74	1/4	Hot Press #1	174	3494	252	2160	587	61.8	16.8	5.2	
		Hot Press #2	272	3338	452	2000		59.9		4.8	
		2nd Headbox	2550	1428	204	860	137			5.3	
		#3 Vat	1878	3514	818	1800	157	51.2	4.5	3.6	
		W.W. Pit	972	2680	284	1810	335	67.5	12.5	5.1	
10/30/74	1/4	3rd Suc. Box	454	1476	156	1060	201	80.3	15.2	5.7	
		Press Roll Sect.	820	1996	288	1250	241	73.2	14.1	5.3	
		2nd Pan	1104	2018	434	1260	259	79.5	16.4	5.2	
		Fourdrinier roller section	798	3404	314	2100	385	68.0	12.5	5.2	
		Pit under roller section	154	424	32	210	36	53.6	9.2	6.2	
11/12/74	1/8	1st Pan of Press Rolls	1290	1480	258	800	184	65.5	15.0	5.0	
		2nd Pan of Press Rolls	1562	1302	246	790	182	74.8	17.2	4.9	
		Hot Press Pit #2	92	1468	158	850	323	51.2	22.0	5.5	
		White Water	1082	2218	288	1400	287	63.1	12.9		
11/18/74	1/8	Stock Chest	1824	3466	1084	2240	407	94.0	17.0	6.0	
		Head Box	2590	2732	348	1975	300	82.8	12.6	4.7	
		W.W. from roller sec.	1272	2612	348	1760	308	77.7	13.6	4.7	
		Suction Box	10	202	76	54	13			5.9	

TABLE C-8. PROCESS WATER SOLIDS COMPOSITION (Continued)

Date	Board Thickness (in)	Location	Suspended solids (mg/l)	Dissolved solids (mg/l)	Non-Volatile solids (mg/l)	Sugars (mg/l)	Tannins (mg/l)	Sugars %	Tannins %	pH	Comments
11/19/74	1/8	Cyclone, M	996	2102	212	1370	276	72.5	14.6	4.9	D.F.
		Cyclone, S	890	5846	218	5500	460	97.7	8.2	3.6	Oak
		Broke	1768	996	158	820	160	97.9	19.1	4.8	
		Overlay Slurry	3398	1478	404	1100	146	102.0	14.0	5.0	
11/25/74	1/8	W.W. Chest	486	2718	450	1725	273	76.1	12.0	4.6	Recycle
		Head Box	1806	2888	516	1910	293	80.5	12.4	4.6	of White
11/26/74	1/8	W.W. Chest (comp.)	644	3308	466	2050	309	72.1	10.9	4.6	Water In Cyclone
		Head Box	1926	4180	494	2630	438	71.4	11.8	4.5	Started
11/27/74	1/8	Hot Press	288	3510	318	2230	591	69.7	18.5	4.6	11/25/74
11/27/74	1/8	1st Head Box	2210	4250	666	2950	480	82.3	13.4	4.4	
		W.W. Chest (comp.)	1376	4102	454	2850	454	78.1	12.5	4.6	
12/05/74	1/4	Cyclone, M	1072	5706	736	4080	616	82.1	12.4	4.8	
		Head Box	2356	3590	550	2600	418	85.5	13.8	5.3	
		W.W. Chest (comp.)	1246	6304	1612	4000	670	85.3	14.3	5.2	
		Hot Press	182	3218	456	1950	544	70.6	19.7	5.5	
12/12/74	1/8	W.W. Composite	1654	4178	640	2710	521	76.6	14.7	5.9	
		Head Box	2366	4216	772	2220	487	79.0	14.1	5.0	
		Press Rolls, Baby	1354	2638	544	1650	318	78.8	15.2	5.0	
		Hot Press	260	3860	874	2350	793	78.7	26.6	5.7	
		Cyclone, M	630	5288	778	3500	673	77.6	14.9	5.2	
12/18/74	1/4	W. W. Pit	756	3886	638	2400	407	73.9	12.5	5.6	
		Head Box	3926	3498	576	2185	352	74.8	12.0	4.9	
	3/16	Cyclone M	1544	4906	754	2880	443	69.4	10.7	5.1	
	3/16	Press Roll	1496	1392	254	900	153	79.1	13.4	5.2	
		Hot Press	178	3614	716	1560	520	53.8	17.9	8.1	
12/19/74	3/16	W. W. Pit. Comp.	1252	2880	546	1660	317	71.1	13.6	5.9	
1/28/75	1/8	Cyclone S	1624	5500	290	3950	661	75.8	12.7	4.7	
		Cyclone M	2382	4514	876	2480	601	63.2	16.5	5.5	
		Head Box	2404	2470	362	1550	301	73.5	14.3	5.7	
		White Water, Comp	1242	2694	390	1560	324	67.7	14.1	5.8	
		Press Rolls	1634	1520	214	1004	217	76.9	16.6	5.6	
		Hot Press	200	2790	266	1270	491	50.3	19.5	5.8	

TABLE C-8. PROCESS WATER SOLIDS COMPOSITION (Continued)

Date	Board Thickness (in)	Location	Suspended solids (mg/l)	Dissolved solids (mg/l)	Non-Volatile solids (mg/l)	Sugars (mg/l)	Tannins (mg/l)	Sugars %	Tannins %	pH	Comments
1/21/75	1/8	Cyclone M	974	4700	1048	2810	609	76.9	16.7	4.6	
	1/8	Cyclone S	2014	5196	622	3100	577	67.8	12.6	4.0	
		Head Box	1822	2972	504	2040	363	82.7	14.7	3.8	
		White Water, Comp	1398	2708	476	1485	301	66.5	13.5	4.2	
		Press Roll, S	1548	1548	264	830	209	64.6	16.3	4.2	
		Hot Press	224	2876	284	1460	603	56.3	23.3	4.7	
1/14/75	1/8	Cyclone, M	1504	4032	1572	2550	545	103.7		5.2	
		Head Box	2728	2228	618	1295	209	80.4	13.0	5.4	
		Roller Sec.	354	2098	392	1120	248	65.7	14.5	4.4	
		Press Rolls	1432	1181	242	681	195	72.5	20.8	4.9	
		White Water (Comp.)	1412	2372	432	1330	276	68.6	14.2	5.1	
		Hot Press	198	3266	616	1960	642	74.0	24.2	4.5	
1/07/75	1/8	White Water (Comp.)	1296	2224	272	1410	254	72.2	13.0	6.1	
		Head Box	1946	2160	524	1275	248	77.9	15.2	5.6	
		Cyclone, M	1548	3600	1108	2220	415	92.8	17.3	5.0	
		Hot Press	206	2806	1080	1800	639	104.0	37.6	5.8	
		Roller Section	288	2086	626	1370	297	93.8	20.3	5.7	
		Press Rolls	1072	914	94	637	114	77.7	13.9	6.2	

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Raw waste loads from the hardboard industry are characterized. Factors that affect the raw waste load are studied. The raw waste load is most strongly affected by the wood cooking conditions. More of the wood is dissolved at the higher pressures and temperatures found in production of smooth on one side (S1S) board, which results in higher raw waste loads for smooth on two sides (S2S) production. Additional wood is dissolved in the hot press in the production of S1S board. Refining of the wood results not only in production of solids, but also in production of wood fines that add to the raw waste load.

Recycling of whitewater and press pit waters reduces the quantity of discharge from a hardboard mill. Raw waste loads are also decreased. Dissolved solids, suspended solids, and the temperature in the whitewater increase with increased recycling. The change in the raw waste load and whitewater characteristics are most dramatic when nearly all the process waters are being recycled.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Extraction Biochemical oxygen demand	Water reuse, hardboard industry, total suspended solids, whitewater, waste effluents	13B

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