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Aerobic Secondary Treatment of Plywood Glue Wastes

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April 1973

AEROBIC SECONDARY TREATMENT OF PLYWOOD GLUE WASTES

By

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ABSTRACT

An activated sludge treatment system, consisting of an aeration tank, a tube-settler clarification module and a waste solids lagoon, was constructed at Klamath Plywood Corporation in Klamath Falls, Oregon to treat urea-formaldehyde glue and steam vat condensate wastewater. Operation of the system was studied over a period of 18 months. Prior to operation of the system, several in-plant changes were made to reduce the flow and BOD loading. The flow to the treatment system was reduced from about 40,000 gallons per day to about 8,000 gallons per day and BOD from 500-1,100 pounds per day to 100-400 pounds per day. During the period of greatest efficiency, the flow averaged 6,700 gallons per day and the BOD averaged 182 pounds per day. The results of the study indicate that activated sludge treatment of urea-formaldehyde glue waste alone is not feasible (average BOD removal of 8 percent). The combined wastewater is amenable to treatment by activated sludge, but requires the addition of phosphorus. Without nutrient addition, the average BOD removal was 38 percent. During the period when phosphorus was added to the system, the BOD removal averaged 78 percent. The flow averaged 9,800 gallons per day during the latter period. Treatment efficiency was adversely affected by cold weather during part of the study period.

This report was submitted in fulfillment of Grant No. 12100 EZU under the partial sponsorship of the Office of Research and Monitoring Environmental Protection Agency.

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SECTION I
CONCLUSIONS

Operation of a completely mixed activated sludge system designed to provide secondary treatment of glue and steam vat condensate wastes at Klamath Plywood Corporation, has been studied during the period from 15 February 1970 through 17 November 1972.

The following conclusions have been reached, based on the results of the study presented in this report:

1. Activated sludge treatment of urea-formaldehyde glue wastes alone is not feasible.

2. Combined glue and steam vat condensate wastewater is phosphorus deficient and produces a poorly settling activated sludge.

3. The combined wastewater is amenable to completely mixed activated sludge treatment with the addition of phosphorus.

4. Variations in MLSS levels had no significant effect on BOD removal efficiency when treating the combined waste without nutrient addition.

5. Foaming has little influence on operation of the system.

6. Freezing of the aeration basin surface occurs during cold weather periods.

7. The system has adequate buffering capacity so that pH adjustment is not necessary.

8. The tube settler unit performed adequately during periods when reasonably good settling activated sludge was present.

9. The tube settler module anchorage was not adequate to withstand the uplift force during periods when the unit surface was frozen.

10. Substantial quantities of slowly degradable or non-degradable solids accumulate in the system and are carried out in the effluent flow.

11. BOD removals from 55 to 95 percent can be achieved with this type of system.

12. Treatment of these wastes by activated sludge can be accomplished at a cost of $0.38 per thousand BFM (Scribner C) of logs processed.

SECTION II
RECOMMENDATIONS

Analysis of the data obtained during this study showed several areas where further studies would be desirable.

No direct comparison of the tube settler performance with conventional settling methods was made. Information of this type would provide valuable criteria for design of future systems of this kind.

Further analysis of the basin cooling problem and possible solutions would be desirable.

A more comprehensive study of the nutrient requirements for this type of waste would be valuable in view of the trend toward more stringent effluent discharge standards.

The following items should be carefully considered in the future evaluation of a biological system for treating glue and steam vat condensate wastewaters:

- The application of primary settling prior to the aeration basin. This concept results in a solids handling problem; however, if sufficient boiler capacity is available, the waste solids could be disposed of by spraying on the hog fuel prior to burning.

- The use of surge protection to reduce the detrimental effect of large fluctuations in flow to the activated sludge system.

SECTION III
INTRODUCTION

SCOPE

A completely mixed activated sludge secondary treatment system designed to treat wastes from the glue spreader operation and condensate from the log holding vats was constructed at Klamath Plywood Corporation in Klamath Falls, Oregon. The system was studied through the periods from February 1970 to April 1971, and June 1972 through November 1972, to establish the feasibility of aerobic secondary treatment for this type of waste. This project was financed with the aid of a demonstration grant provided by the Environmental Protection Agency (EPA), under grant number 12100 EZU.

The grant objectives were to:

1. Demonstrate the feasibility of secondary treatment for glue waste, utilizing completely mixed activated sludge.

2. Determine the BOD removal efficiency and effluent characteristics at various mixed liquor suspended solids concentrations.

3. Determine the quality and character of excess biological sludge.

4. Define the influence of foaming, ice, and temperature on system operation.

5. Determine the effect of nutrient supplementation on BOD removal efficiency and sludge settleability.

6. Determine the buffering capacity of the mixed liquor, and the effect of pH adjustment on BOD removal efficiency and sludge settleability.

7. Determine the operating costs for the methods of treatment demonstrated.

8. Evaluate the performance of the tube settler overflow system.

BACKGROUND

Klamath Plywood Corporation produces both interior hardwood faced plywood and exterior plywood. Total production exceeds 7 million square feet per month (3/8" basis). About 2.2 million BFM of logs are processed each month.

Nearly all face and back veneer is hardwood and is purchased, dry and ready to lay up, from U.S., Canadian or Far East sources. The core veneer is softwood (White Fir) and is processed at the Klamath Plywood mill. Most of the product is interior grade plywood utilizing urea-formaldehyde glue. Only minor quantities of Melamine and phenolic exterior glues are used.

Prior to beginning this project, from 20,000 to 60,000 gallons per day of untreated glue spreader and log holding vat wastes were being discharged to the Klamath River. A program to correct this problem was initiated in March 1967, at the direction of the Oregon State Department of Environmental Quality (OSDEQ).

Klamath Plywood Corporation was directed to provide wastewater treatment capable of 85 percent BOD removal prior to discharge to the Klamath River.

The program developed included in-plant changes to reduce the quantity of wastewater requiring treatment, and aerobic biological treatment of the wastewater prior to discharge to the river.

Two recycle systems were installed which reduced the wastewater flow from an average of about 40,000 gallons per day to about 8,000 gallons per day and the BOD load from 500-1,100 pounds per day to 100-400 pounds per day.

Glue Waste Recycle System. The glue spreader washdown water is recycled and used for a portion of the glue make-up water and replaces most of the fresh water previously used for washdown. A small quantity of the concentrated urea-formaldehyde glue washdown water is discharged to the treatment system. Melamine and phenolic exterior glue wastes are removed in a completely separate system and are trucked from the mill site for disposal.

Vat Waste Recycle System. The debarked White Fir blocks are heated in steam vats for several hours before peeling. Water is added to the steam to provide a heat carrying medium. A system was installed which provides for recycle of the condensates from these vats to replace the fresh water which was previously added to the steam. The excess condensates are discharged to the treatment system.

Treatment System. The completely mixed activated sludge process was selected for treatment of these wastes because it appeared to be economically favorable and bench-scale studies indicated a reasonable possibility of successful operation.

Klamath Plywood Corporation applied to EPA for a demonstration grant to help finance the system because aerobic biological treatment had not previously been used to treat this type of waste. Construction of the facility was completed in March 1970.

A complete list of definitions of the technical terms used in this report may be found in the WPCF Glossary [1], and a list of abbreviations and symbols used is contained in Section XII.

THEORETICAL CONSIDERATIONS

Microbiology. The living organisms found in activated sludge are classified as either plants or animals. The plants consist of bacteria and fungi and the animals are primarily protozoa, rotifers and nematodes.

Hawkes [2] stated that bacteria are normally dominant as primary feeders on organic wastes, with different holozoic protozoa being secondary feeders, and rotifers and nematodes are found at the higher levels in the food chain. Fungi cannot normally compete with bacteria, but they may predominate as primary feeders if certain conditions exist, such as: low pH, nitrogen deficiency, or low dissolved oxygen [3]. High carbohydrate wastes are also reported to stimulate fungi growth.

Metabolism. The metabolic reactions which occur within activated sludge can be divided into three phases: (1) oxidation, (2) synthesis, and (3) endogenous respiration. These three-phase reactions have been illustrated with general equations formulated by Weston and Eckenfelder [4].

In the presence of enzymes, produced by living microorganisms, about one-third of the organic matter removed is oxidized to carbon dioxide and water, to provide energy for synthesis to cell material of the other two-thirds of the organic matter removed [5]. The cell material is also oxidized to carbon dioxide, water, etc., by endogenous respiration (auto-oxidation).

Kinetics. Several authors [6,10,11] have formulated mathematical equations for design and operation of complete-mix activated sludge plants. Some of these formulations are more easily used for evaluation of full-sized plant operation than others. Eckenfelder's basic equations [11,12] are of this nature and are presented below.

BOD Removal. The microbial growth rate and steady-state substrate removal in a completely mixed system can be defined by use of the Michaelis-Menton relationship. A simplified equation for substrate removal was developed from this relationship:

$$kS_e = \frac{S_a - S_f}{X_a} = \frac{S_r}{X_a}$$

Where:

S_r = BOD removed, lb/day

S_a = Influent BOD, lb/day

S_f = Soluble effluent BOD, lb/day

S_e = Soluble effluent BOD, mg/l

X_a = Average mixed liquor suspended solids

k = Removal rate coefficient (lb BOD/day/lb MLSS) per mg/l BOD

NOTE: See Appendix A for further explanation.

The equation shows that BOD removal is proportional to the product of the MLSS and the aeration time. However, the validity of this equation is limited to conditions where the actual substrate concentration is much less than the concentration at one-half the maximum reaction rate (Michaelis Constant). A properly operating completely mixed system, producing a low soluble effluent BOD would satisfythis condition since the effluent soluble BOD is the same as the soluble BOD in the aeration basin. However, as effluent soluble BOD approaches the concentration at one-half the maximum reaction rate, BOD removal becomes less predictable by this simplified form of the Michaelis-Menton kinetics.

SECTION IV
TREATMENT FACILITIES

GENERAL DESCRIPTION

Figure 1 is a schematic plan of the treatment system showing the flow pattern through the plant. Wastewater from washdown of the glue spreaders flows by gravity through a screening facility to the raw waste pump station.

Condensate collected from the log holding vats flows through a screening facility into a holding tank which forms a portion of the vat recycle system. Overflow from the holding tank flows by gravity to the raw waste pump station.

The combined waste is pumped by a submersible sump pump through a 3-inch diameter pressure line to the aeration basin inlet box. The pump is controlled by means of a level sensing device in the sump.

The aeration basin inlet box serves two functions. It provides a location for sampling the raw waste and for flow measurement. The wastewater flows out of the box over a 90 degree "V"-notch weir. The flow is measured, totalized and recorded by means of a float-operated flowmeter.

Samples are pumped from the inlet box by a progressing cavity-type pump which is controlled by a signal from the flow recorder. Composite samples, proportional to the flow into the aeration basin are stored under refrigeration in a building adjacent to the aeration basin. This building also houses the electrical control panel.

The raw waste flow enters the aeration basin where two 10-horsepower pump type, floating aerators provide oxygen for biological growth, and mixing of the basin contents to maintain the solids in suspension.

Effluent from the aeration basin flows upward through a tube settler unit and overflows into a channel connected to the outfall pipe. Solids settle in the tubes and are recirculated into the basin contents.

Excess, or waste, solids are removed from the aeration basin by pumping from a trough beneath the tube settler. These waste solids are pumped to the solids storage pond where they are concentrated by settling. Overflow from the pond is combined with the tube settler effluent prior to discharge to the river. The pond is also used, occasionally, as an effluent polishing pond.

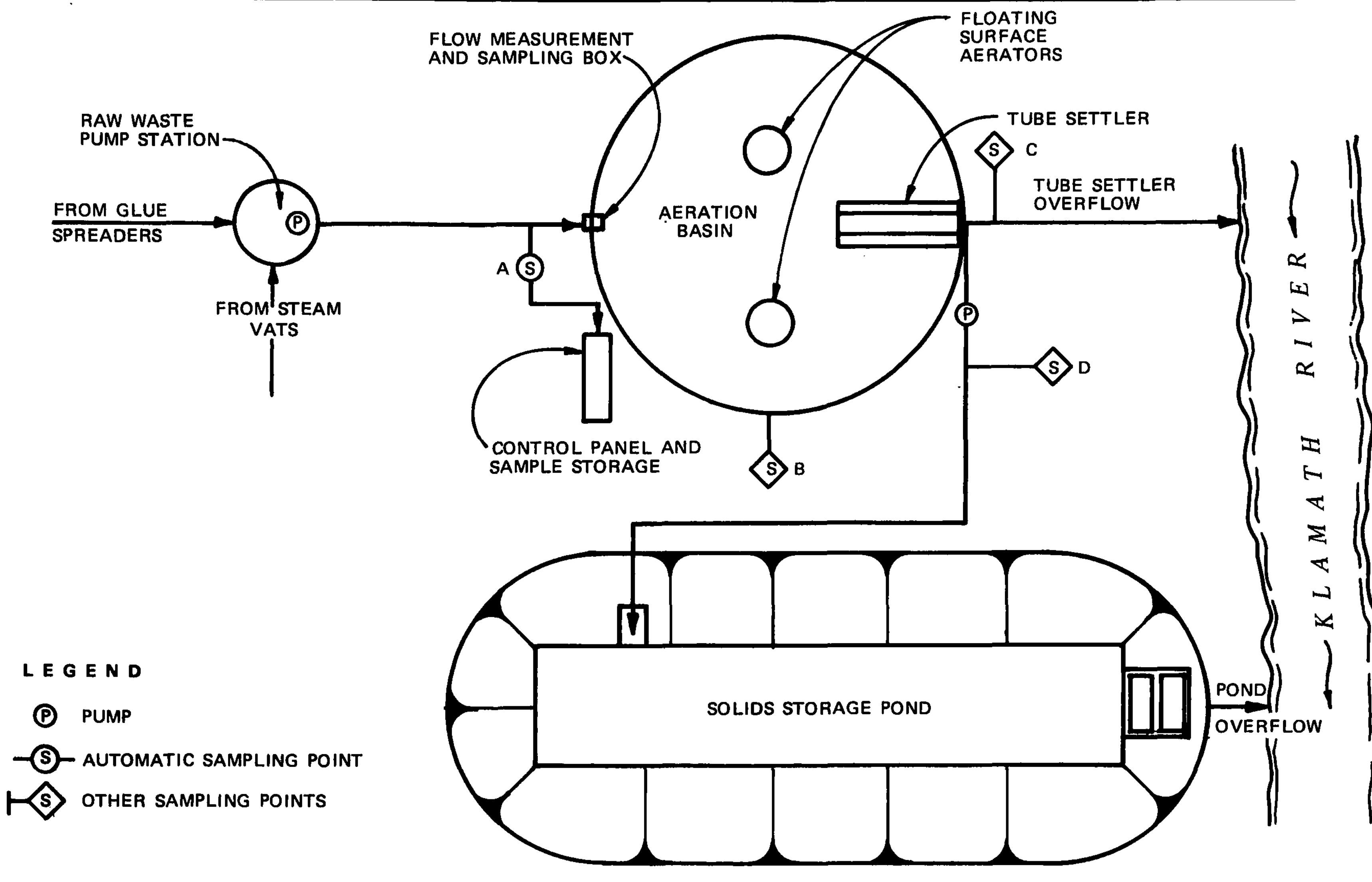

FIGURE 1

SCHEMATIC PLAN

DESIGN CRITERIA

Table 1 lists the criteria used for design of the Klamath Plywood Corporation wastewater treatment system.

DESIGN FACTORS

The design factors used for the major unit and equipment selection are listed in Table 2. The manufacturers of the major equipment items are listed in Table 3. The treatment units are described below.

The aeration basin has a volume of 80,000 gallons. This volume provides a detention time at design flow (8,000 gal/day) of 10 days. The basin was constructed as a tank with a steel ring wall and a PVC liner. Oxygen is supplied to the basin by two Ashbrook 10 horsepower, floating, pump type surface aerators.

TABLE 1
TREATMENT SYSTEM DESIGN CRITERIA

Average Daily Flow (gpd)		
Glue Waste		200
Vat Waste		7,800
	Total	8,000
Peak Flow (gpm)		
Glue Waste		5
Vat Waste		15
	Total	20
Average Daily BOD Loading (lb/day)		
Glue Waste		30
Vat Waste		700
	Total	730
Average Daily TSS Loading (lb/day)		
Glue Waste		12
Vat Waste		13
	Total	25
pH		
Glue Waste		6-7
Vat Waste		5
Effluent Requirements		85% BOD Removal

TABLE 2
DESIGN FACTORS

Raw Wastewater Pump	
Number	1
Type	Submersible, nonclog
Capacity	50 gpm
Aeration Basin	
Number	1
Volume	80,000 gal.
Detention Time	10 days @ design flow
Design Organic Loading	68 lb BOD/1,000 ft^3/day
Aeration Equipment	
Number of Aerators	2
Type	Floating, surface, pump type
Size	10 hp
Clarification Unit	
Number	1
Type	Tube settler in aeration basin
Area	24 ft^2
Depth	24 inches
Flow Measurement	
Type	Float operated, totalizing recording
Waste Solids Pump	
Number	1
Type	Progressing cavity
Capacity	27 gpm
Solids Storage Pond	
Number	1
Type	Earth embankment
Volume	40,000 ft^3
Solids Detention Time	2 years

TABLE 3
PROCESS EQUIPMENT

Equipment	Model	Manufacturer
Raw Wastewater Pump	SP 50A	Hydromatic Pump Co.
Flowmeter	TF-61-5M	Leupold & Stevens Instruments, Inc.
Aerators	MSA-10	Ashbrook Corp.
Aeration Basin	---	Plasti-Steel, Inc.
Tube Settler	---	Neptune MicroFLOC, Inc.
Waste Sludge Pump	FS-56 C	Robbins and Meyers, Inc.
Sample Pump	FS-11 E	Moyno Pump Division

The clarification unit consists of a tube settler module mounted in the aeration basin. The unit was designed for an overflow rate of 0.23 gpm per square foot of tube area at average design flow. Sludge is recycled by the mixing action of the tank contents. A portion of the settled solids which accumulate beneath the tube settler are resuspended by this action. A trough mounted beneath the module isolates a portion of the solids so that they will become concentrated prior to pumping to the waste solids pond.

The solids storage pond has a volume of about 40,000 ft^3. The pond is of earth construction with a baffled, concrete overflow structure.

SECTION V
DEMONSTRATION PROCEDURES

PLANT STARTUP

Startup of the plant was initiated on 17 February 1970. The tank had previously been filled with water to test the operation of the aerators. About 3,500 gallons of raw wastewater consisting only of glue spreader waste was pumped into the aeration basin and the aerators were started. By the following day, a substantial blanket of foam had developed on the surface of the basin. The basin was seeded with approximately 150 gallons of solids taken from the river bank at the point where the raw waste had previously been discharged to the river. Approximately 1,500 gallons per day of raw waste was added to the basin for a period of 10 days and total suspended solids analyses were made on the mixed liquor to monitor the buildup of biological solids. No apparent biological growth occurred during this time. The raw wastewater pump was shut off on 27 February and no wastewater was added to the system through 5 March. An extremely heavy buildup of foam persisted during this period.

On 9 March, 500 gallons of activated sludge from the Klamath Falls airport sewage treatment plant was added to the aeration basin as seed. Raw wastewater feed was again started and the system was monitored through 30 March. The system did not become acclimated during this period.

The decision was made at this time to restart the system. This was accomplished by displacing the entire basin contents with river water, reseeding with activated sludge, and adding glue waste in controlled amounts such that the system would not be overloaded. The system was operated in this fashion through 17 June.

During this time the system did not appear to acclimate properly, even though several oxygen uptake tests indicated that biological activity was taking place. The biological solids formed were of a dispersed nature and would not settle in the tube settler.

Analysis of the test results and operating procedures produced the conclusion that the system could not be efficiently operated with raw wastewater from the glue spreaders alone. The decision was made at this point to begin running all of the required tests, in order to document the failure of the system to operate, and then proceed with the remainder of the demonstration program.

OPERATION

The demonstration program was set up for three operation phases: (1) operation on glue waste alone, (2) operation on glue and vat waste without nutrient supplementation, and (3) operation on glue and vat waste with nutrient supplementation. The system was operated continuously, except for periods when the mill was shut down, from 15 July 1970 to 4 April 1971 and the operation was monitored throughout this period. The operation covered both cold and warm weather periods.

Table 4 lists the demonstration program operation schedule which was established for this project. The development of this schedule was based on the results of the pilot study conducted by the FWPCA, which were summarized in an interim report of October 1968 [7].

After completion of the scheduled three phases of operation, a thorough analysis of the data was made. The results of this analysis showed that further operation and data collection would be required to provide a complete report. A fourth phase of operation was set up, to provide the required information.

Phase IV consisted of operation on glue and vat waste with nutrient supplementation, and was conducted in two parts. Phase IV-1 covered the periods from 12 June 1972 through 24 June 1972 and 21 August 1972 through 11 September 1972. The system was operated at a MLSS concentration of about 3000 mg/l during this period. Phase IV-2 covered the period from 2 October 1972 through 17 November 1972, with the MLSS concentration maintained at about 5000 mg/l.

SAMPLING SCHEDULE AND PROCEDURES

Samples were taken at various locations throughout the system. These sample point locations are shown on Figure 1, and are described below. Table 5 lists the sampling and testing schedule used during Phases I, II and III. The sampling and testing schedule for Phase IV is listed in Table 6.

Plant Influent. Automatic 24-hour composite samples, proportional to plant flow, were obtained by pumping from the influent pressure line upstream from the aeration basin inlet box. This location is shown as sample point A on Figure 1. The automatic sampler, sample pump and storage refrigerator are housed in a small building adjacent to the aeration basin, which also contains the electrical control panel.

TABLE 4

DEMONSTRATION PROGRAM OPERATION SCHEDULE

OPERATION PERIOD	PHASE	ITEM	METHOD OF OPERATION
15 JULY 1970 – 15 SEPTEMBER 1970	I	–	GLUE WASTE ONLY – 4,000 mg/l MLSS
16 SEPTEMBER 1970 – 23 NOVEMBER 1970	II	1	GLUE AND VAT WASTE – ACCLIMATION PERIOD
24 NOVEMBER 1970 – 4 JANUARY 1971	II	2	MLSS LESS THAN OPTIMUM* (3,000 mg/l)
5 JANUARY 1971 – 11 JANUARY 1971	II	3	ADJUSTMENT PERIOD
12 JANUARY 1971 – 3 FEBRUARY 1971	II	4	OPTIMUM MLSS (4,000 mg/l) – MINIMUM POWER REQUIREMENT DETERMINATION
4 FEBRUARY 1971 – 9 FEBRUARY 1971	II	5	ADJUSTMENT PERIOD
10 FEBRUARY 1971 – 8 MARCH 1971	II	6	MLSS GREATER THAN OPTIMUM (6,000 mg/l)
9 MARCH 1971 – 22 MARCH 1971	III	1	GLUE AND VAT WASTE WITH NUTRIENT SUPPLEMENTATION ADJUSTMENT PERIOD
23 MARCH 1971 – 3 APRIL 1971	III	2	OPTIMUM MLSS (4,000 mg/l) – MINIMUM POWER REQUIREMENT DETERMINATION

* AS DETERMINED BY THE PILOT STUDY (7).

TABLE 5

SAMPLING AND TESTING SCHEDULE PHASES I, II AND III

(NUMBER OF TESTS PER WEEK)

SAMPLE POINT		COD	BOD_5	SUSPENDED SOLIDS		TEMPERATURE	pH	DISSOLVED OXYGEN	NITROGEN			TOTAL PHOSPHATES	DISSOLVED PHOSPHATES	SLUDGE VOLUME INDEX	SLUDGE AGE	ALKALINITY
				TOTAL	VOLATILE				TOTAL	AMMONIA	NITRATES					
A	PLANT INFLUENT	3	3	3	3	3	3	–	1	1	1	1	–	–	–	–
B	AERATION BASIN	–	–	3	3	2	2	2	–	–	–	–	–	3	2	1
C	TUBE SETTLER EFFLUENT	3	3	3	3	–	–	–	1	1	1	1	1	–	–	–
D	WASTE SLUDGE	1	1	3	–	–	1	–	–	–	–	–	–	–	–	–

TABLE 6

SAMPLING AND TESTING SCHEDULE
PHASE IV

(NUMBER OF TESTS PER WEEK)

	SAMPLE POINT	BOD_5	TOTAL SUSPENDED SOLIDS	TEMPERATURE	pH	DISSOLVED OXYGEN	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPHATES
A	PLANT INFLUENT	6	6	6	6	6	1	1
B	AERATION BASIN	6	6	6	6	6	1	1
C	TUBE SETTLER EFFLUENT	6	6	6	6	6	1	1

Aeration Basin. Grab samples were obtained from the surface of the aeration basin. The location is shown as sample point B.

Tube Settler Effluent. These samples were obtained by manually compositing grab samples during the day shift. Sample point C indicates the location of these samples.

Waste Sludge. Sample point D indicates the location of these grab samples taken from the waste sludge discharge line.

ANALYTICAL METHODS

All analyses were performed in the Oregon Technical Institute Laboratory in Klamath Falls, Oregon. All testing was done in accordance with the FWPCA manual [8] or the twelfth edition (1965) of "Standard Methods for the Examination of Water and Wastewater" by the American Public Health Association[9].

SECTION VI
WASTEWATER CHARACTERISTICS

GENERAL

The wastewater originates from two sources in the mill: the glue spreader operation and the log holding vats.

Glue Spreader Wastes. Excess glue is steam cleaned from the spreader equipment during the washdown operation. The washdown water is recycled to the glue mixer, with the excess being discharged to the treatment system. The wastewater also contains excess glue from the hot press operation.

Log Holding Vat Wastes. After the barking operation and before peeling, the logs are placed in vats where they are steamed for several hours. The steam condensate from these vats is collected in channels and flows to a holding tank from which the flow is recycled over the logs. Overflow from the holding tank is discharged to the treatment system. This wastewater contains wood sugars, dissolved lignins, tannins and other constituents.

TREATMENT SYSTEM

Figures 2 and 3 are chronological plots of influent flow, BOD and suspended solids data for the entire demonstration period. These figures show that the flow to the treatment system was highly variable and exceeded the design conditions much of the time. The variability of the flow can be attributed to the nature of the mill operation which causes intermittent discharges of wastewater.

Maximum, minimum and average values of all Phase I, II, and III influent data are listed in Table 7. These data are separated according to the various phases of operation. Table 8 lists both influent and effluent data for Phase IV.

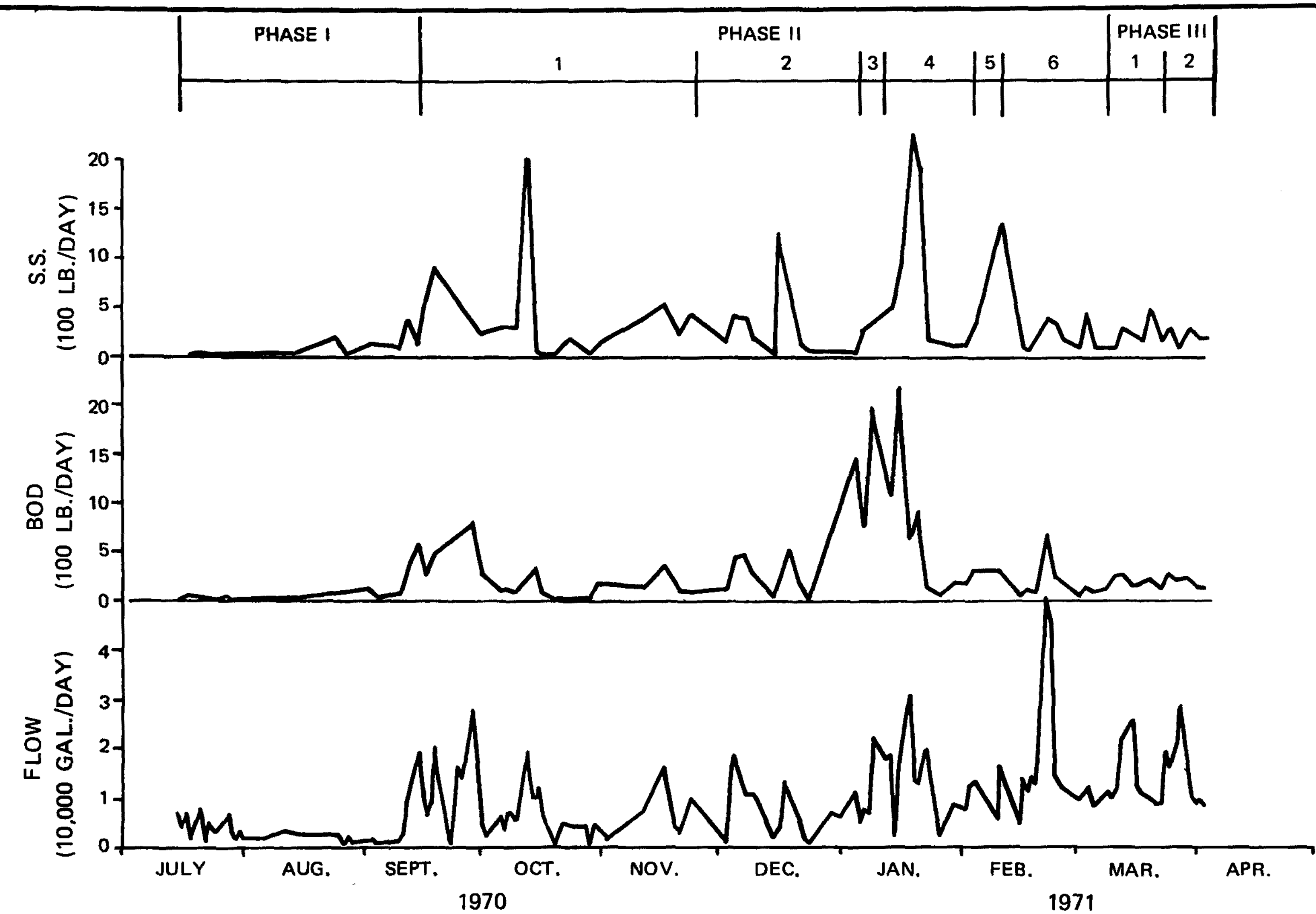

FIGURE 2

WASTEWATER CHARACTERISTICS
PHASES I, II, AND III

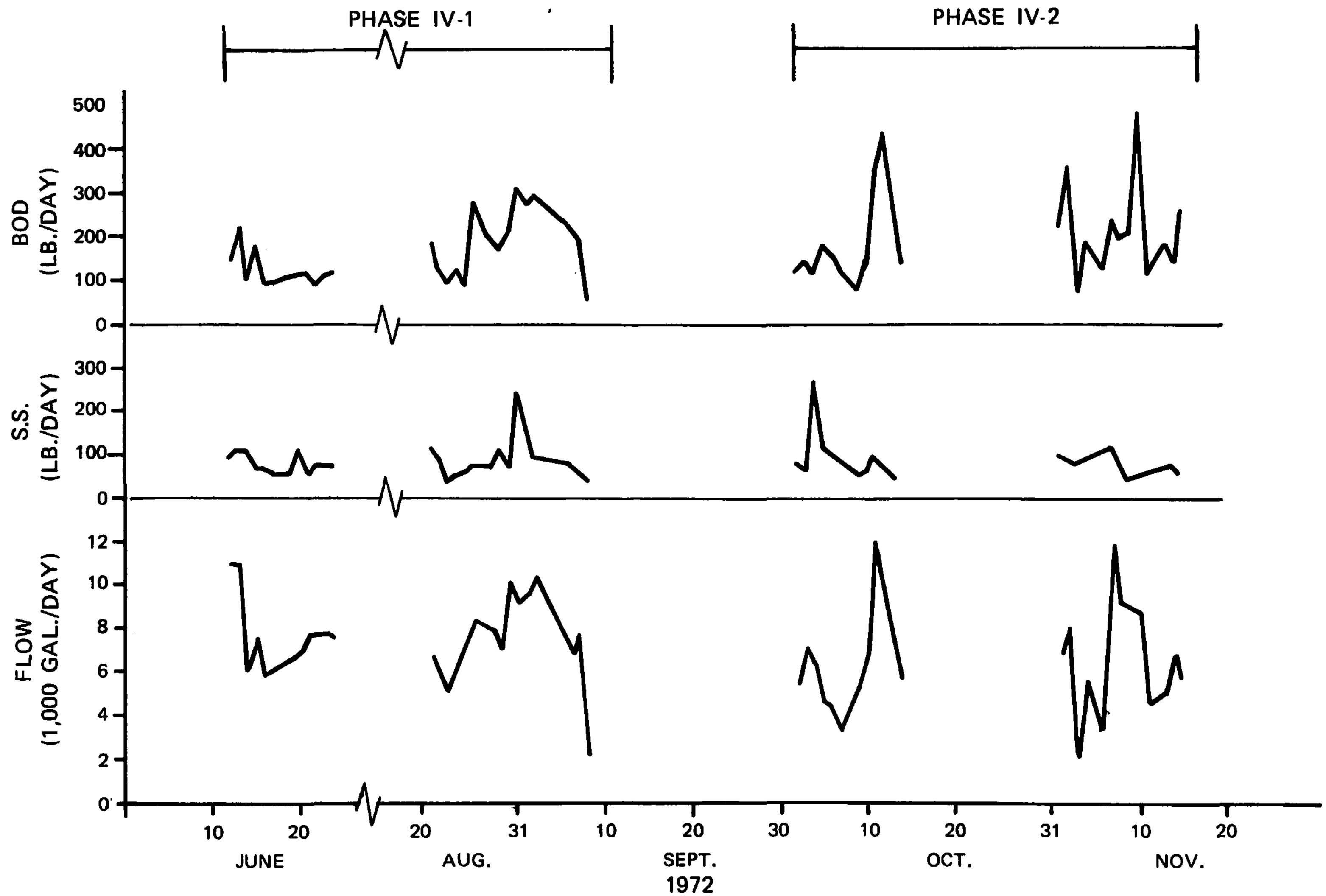

FIGURE 3

WASTEWATER CHARACTERISTICS
PHASE IV

TABLE 7

INFLUENT CHARACTERISTICS
PHASES I, II AND III

PARAMETER	PHASE I			PHASE II–2			PHASE II–4			PHASE II–6			PHASE III–2		
	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.
FLOW (GAL./DAY)	3,885	19,000	500	7,675	18,850	800	13,505	19,400	1,900	15,810	50,350	4,150	15,030	28,000	8,650
COD (LB./DAY)	572	1,605	72	522	1,080	68	1,566	5,885	373	790	2,511	191	780	875	586
BOD (LB./DAY)	93	562	9	387	1,415	30	610	2,131	42	172	689	39	181	254	116
TSS (LB./DAY)	65	356	6	384	1,250	23	761	2,235	77	280	1,332	39	193	281	68
VSS (LB./DAY)	65	352	6	372	1,220	23	752	2,220	77	272	1,332	32	193	281	68
TEMP. (^{o}C)	26.6	37.8	20.5	32.4	44.1	18.1	36.8	50.2	25.6	36.8	41.9	32.0	31.2	36.8	25.0
pH	5.2	6.9	2.0	4.6	5.6	3.6	4.6	5.1	4.1	4.6	5.2	4.3	4.5	4.8	4.3
TOTAL KJELDAHL N (mg/l)	635	650	620	600	612	590	607	610	601	596	609	589	588	590	586
NH_3–N (mg/l)	430	450	420	413	423	410	411	415	409	404	412	400	399	401	397
NO_3–N (mg/l)	71	75	68	63	68	58	48	60	26	26	28	25	24	25	23
TOTAL P (mg/l)	30	31	28	23	27	20	21	21	20	20	23	19	19	20	18

TABLE 8

INFLUENT AND EFFLUENT DATA
PHASE IV

PARAMETER	PHASE IV-1						PHASE IV-2					
	INFLUENT			EFFLUENT			INFLUENT			EFFLUENT		
	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.
TEMPERATURE (^{o}C)	34	43	26	16	20	9	30	41	13	12	18	6
pH	4.7	5.2	4.5	7.3	7.7	7.0	4.7	5.2	4.3	7.1	7.4	6.6
BOD_5 (MG/L)	2450	3980	1260	512	900	195	3250	6500	1279	459	1090	100
TSS (MG/L)	1380	3040	760	2110	3200	1580	1860	5720	500	1860	4000	250
TOTAL PHOSPHATE (MG/L)	16.8	26.4	12.1	21.0	24.2	14.1	61.2	262	9.4	33.9	107	8.8
TOTAL KJELDAHL N (MG/L)	220	301	125	285	356	197	100	160	25.0	310	565	6.0
BOD REMOVAL (%)	78.1	93.4	43.5				82.9	95.0	54.6			
ORGANIC LOADING (LB BOD/LB MLSS)	0.071	0.130	0.039				.058	0.118	0.022			
FLOW (GAL/DAY)	7610	11,100	2240				6730	12,200	3590			

SECTION VII
TREATMENT PLANT PERFORMANCE

GENERAL

Influent and effluent COD, BOD and suspended solids and aeration basin MLSS data were collected three times per week for each of the first three phases of operation. Influent and effluent BOD and suspended solids and MLSS data were collected 6 times per week during Phase IV. Additional data such as temperature, pH, and nutrient levels, were recorded on a less frequent basis. Table 9 lists average, maximum and minimum values of the effluent data for Phases I, II and III. Effluent data for Phase IV are listed in Table 8.

BOD REMOVAL AND EFFLUENT CHARACTERISTICS

Figure 4 is a chronological plot of plant flow, percent BOD removal, aeration basin MLSS and effluent suspended solids data for the first three phases of the demonstration period. These curves were plotted as a three-day moving average of the raw data. This approach results in a more meaningful plot, showing longer range trends, since the data for these Phases were extremely variable.

Figure 5 is a plot of the same parameters using Phase IV raw data. These data were much less variable, hence three day moving averages were not used.

Phase I. Operation of the system on glue waste alone resulted in generally poor BOD removals. The maximum BOD removal during this period was 27 percent, which occurred near the end of the Phase I operation. BOD removals of less than 10 percent were recorded throughout most of the period. The effective detention time during this period was about 20 days, and the average BOD load was about 13 percent of the design loading.

The center curves of Figure 4 show the aeration basin MLSS data plotted on the same axes with the effluent suspended solids data. The relative magnitude of these values serve as an indication of the settleability of the activated sludge. These values show that poorly settling biological sludge was produced throughout the Phase I operation period.

Wastewater flow ranged from 500 to 19,000 gallons per day during Phase I. For most of this period, the flow was uniform on a daily basis, and averaged 3,900 gallons per day for the entire period. However, substantial diurnal variation in the flow rate was a common occurrence. These variations in flow rate, coupled with the poor sludge settleability, resulted in substantial solids carryover into the plant effluent. This is reflected by the variation in effluent suspended solids shown on Figure 4.

TABLE 9

EFFLUENT CHARACTERISTICS
PHASES I, II AND III

PARAMETER	PHASE I			PHASE II–2			PHASE II–4			PHASE II–6			PHASE III–2		
	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.	AVG.	MAX.	MIN.
BOD REMOVAL (%)	8	27	0	56	69	46	40	85	0	18	49	0	72	86	54
COD (LB./DAY)	185	527	57	321	562	61	1142	1718	660	614	2091	251	351	616	161
BOD (LB./DAY)	24	39	8	64	89	14	590	2872	95	128	588	33	55	91	19
TSS (LB./DAY)	83	365	17	221	393	32	533	903	301	367	1134	153	175	276	48
VSS (LB./DAY)	81	362	17	221	392	32	515	887	265	343	1134	150	173	276	48
pH	7.3	8.0	5.6	7.0	7.2	6.8	6.6	7.1	6.0	6.8	7.4	6.4	6.9	7.0	6.7
TOTAL KJELDAHL N (mg/l)	467	480	423	405	410	405	408	423	401	387	390	381	373	375	372
NH_3 – N (mg/l)	265	278	255	276	298	255	288	295	278	281	283	279	277	280	274
NO_3 – N (mg/l)	33	39	28	35	40	30	26	30	19	22	27	19	20	21	19
TOTAL P (mg/l)	20	22	18	22	24	22	16	17	15	14	14	13	40	40	39

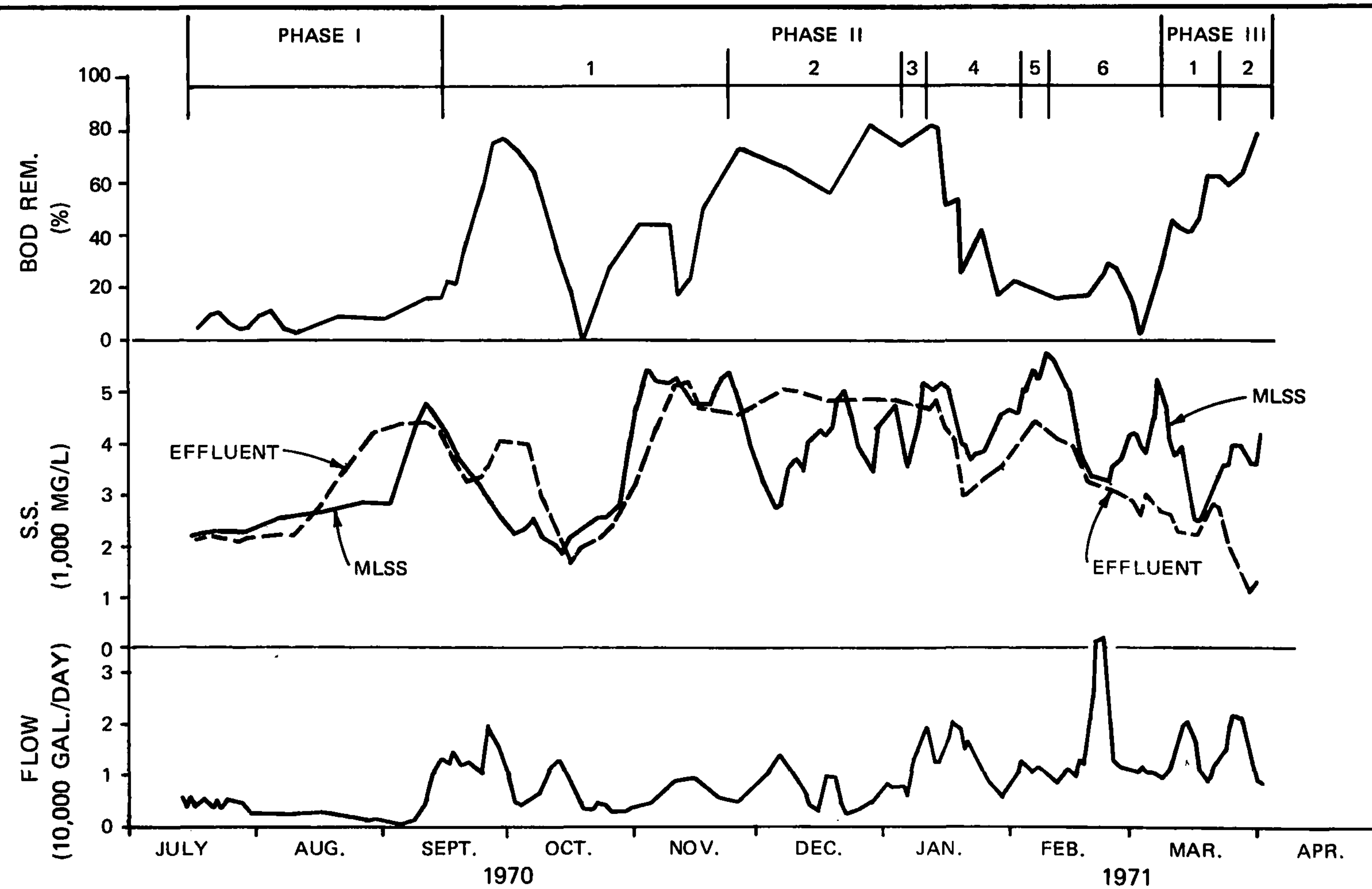

FIGURE 4

BOD REMOVAL AND EFFLUENT CHARACTERISTICS

(3 DAY MOVING AVERAGE DATA)

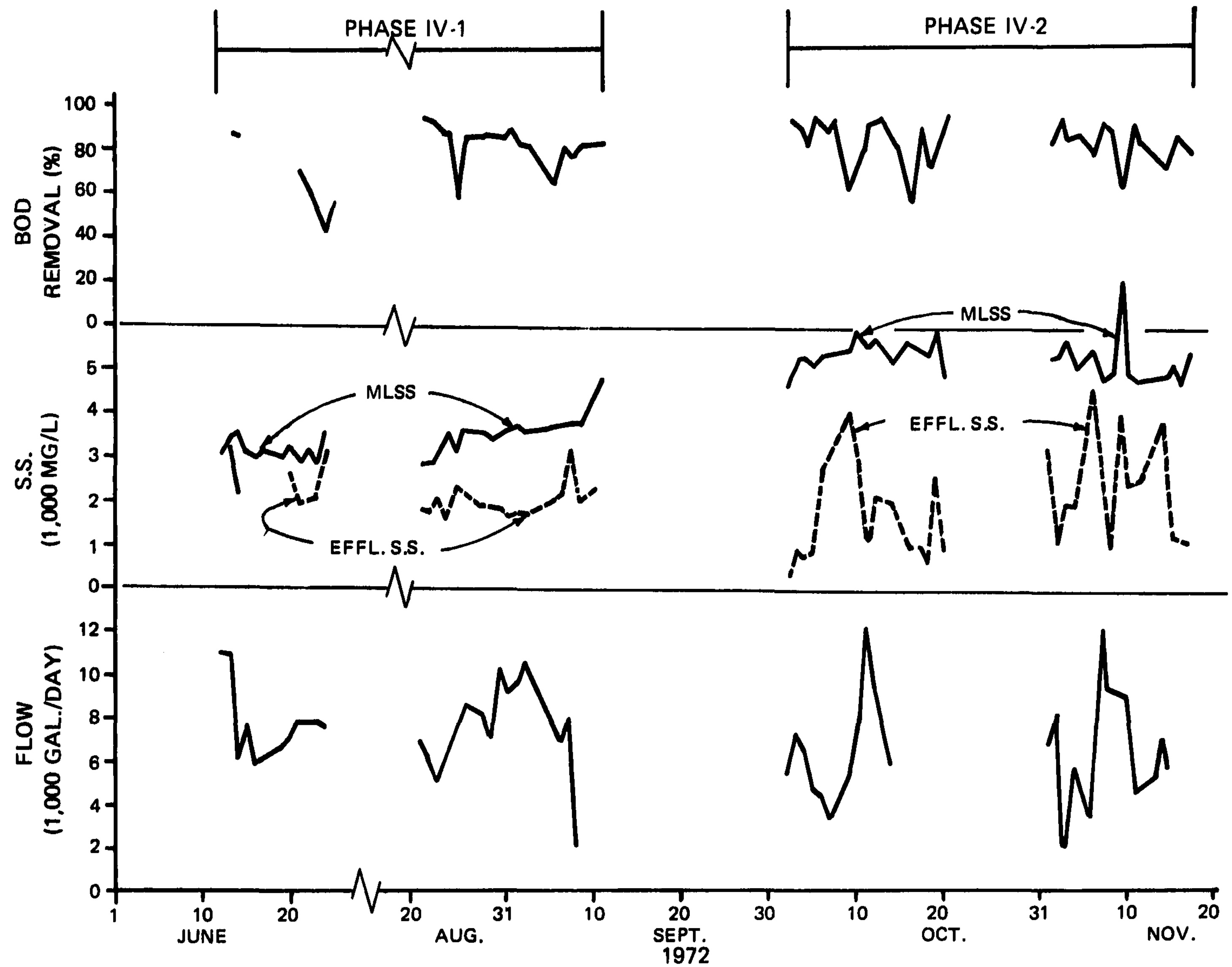

FIGURE 5
BOD REMOVAL AND EFFLUENT CHARACTERISTICS

Phase II. The initiation of Phase II (operation on glue and vat waste without nutrient supplementation) resulted in a substantial increase in flow rate to the system. The flow averaged 8,000 gallons per day during the acclimation period.

The Phase II operation period was accomplished in three parts as discussed in a previous section and as shown on Figure 4. The first part (Phase II-2) was to cover operation at a lower MLSS level (3,000 mg/l) than the optimum. The average MLSS level during this period was 4,000 mg/l. During the second part of Phase II (II-4), the system was to be operated at the optimum MLSS level (4,000 mg/l), and during the third part (II-6), a higher than optimum MLSS level (6,000 mg/l). The MLSS level averaged 4,500 mg/l during II-4 and 4,000 mg/l during II-6. The average BOD removal during these three periods was as follows: II-2, 56 percent; II-4, 40 percent; and II-6, 18 percent.

The biological sludge produced during the entire Phase II operating period had poor settling characteristics resulting in high effluent suspended solids. This is again indicated by the data plotted on Figure 4.

Phase III. The effluent quality appeared to improve substantially during the Phase III operation period (operation on glue and vat waste with nutrient supplementation.) The addition of nutrients to the aeration tank in the form of a phosphoric acid fertilizer (Simplot 0-20-0) caused a marked improvement in the settleability of the activated sludge. The data plotted on Figure 4 show a reduction in effluent suspended solids with an increase in MLSS and a corresponding improvement in BOD removal percentage after Phase III was begun. The average BOD removal during this time was 72 percent.

The average flow during this period was 15,000 gallons per day and the MLSS averaged 3,900 mg/l.

Phase IV. The performance of the treatment system improved during the Phase IV operation period. The average BOD removal during the period of operation at 3000 mg/l MLSS was about 78%. The BOD removal increased to about 83 percent during operation at 5000 mg/l MLSS. However, as shown on Figure 5, there was a significant variation in BOD removal throughout the period.

Figure 5 also indicates a general trend toward reduced BOD removals at higher flows. This is likely due to the reduction in aeration time at higher flows.

There was also a substantial variation in effluent suspended solids values through this period. However, the MLSS concentration remained reasonably uniform.

The flow to the treatment system averaged 7,610 gallons per day during Phase IV-1 and 6,730 gallons per day during Phase IV-2.

pH CONTROL AND SYSTEM BUFFERING

The system provided adequate buffering capacity throughout the demonstration program. Influent and aeration basin pH data are listed in Table 10 for each of the various operating conditions. This data shows that the buffering capacity in the aeration basin was sufficient to maintain a neutral pH, with influent pH consistently in the 4 to 5 range.

TABLE 10
INFLUENT AND AERATION BASIN pH DATA - AVERAGE VALUES

	PHASES						
	I	II-2	II-4	II-6	III-2	IV-1	IV-2
Influent	5.2	4.6	4.6	4.6	4.5	4.7	4.7
Aeration Basin	7.3	7.0	6.6	6.8	6.9	7.3	7.1

SECTION VIII
PROJECT COSTS

The total capital cost for construction of the treatment system was $40,370. A capital cost breakdown is listed in Table 11. Table 12 lists demonstration, operation and maintenance costs for a 12-month operation period. The Research and Development portion of these costs totaled $12,047. Operation and maintenance costs were $3,900 resulting in a total of $15,947 for the 12-month period.

Table 13 lists the total annual cost of the system. These figures include operation and maintenance costs and capital cost amortized at 9 percent for 15 years. The operation and maintenance costs were based on those recorded during the Research and Development period and exclude costs related to the demonstration program.

TABLE 11
TREATMENT SYSTEM CAPITAL COST

Item	Total Cost
Vat Waste Holding Tank	$ 675
Raw Waste Pump Station	2,327
Raw Waste Pressure Line	2,755
Sampling Equipment	1,470
Aeration Basin	6,912
Aeration Equipment	5,690
Tube Settler	2,829
Solids Storage Pond and Piping	5,738
Outfall Piping	509
Plant Piping and Valves	335
Electrical	4,055
Engineering	6,729
Legal and Administration	54
Contingency	243
Preliminary Site Engineering	49
TOTAL CAPITAL COST	$40,370

TABLE 12
DEMONSTRATION, OPERATION AND MAINTENANCE COSTS

RESEARCH AND DEVELOPMENT

Item	Total Cost
Demonstration Program Supervision	$ 4,432
Laboratory Testing (including Plant Operation)	3,600
Sample Shipping	15
Final Report	4,000
	$12,047

OPERATION AND MAINTENANCE

Operation	Included in Lab Testing
Chemicals and Lab Equipment	$ 900
Maintenance	1,200
Power	1,500
Office and Administrative	300
Subtotal	$ 3,900

TOTAL - DEMONSTRATION, OPERATION AND MAINTENANCE COSTS	$15,947

NOTE: Costs based on operation from April 1970 to April 1971.

TABLE 13
TOTAL ANNUAL COST

Item	Cost
Capital Cost	$40,370
Amortized Capital Cost (9% - 15-yr)	5,000
Operation and Maintenance	5,100
TOTAL ANNUAL COST	$10,100

SECTION IX
DISCUSSION

ACTIVATED SLUDGE SYSTEM

General. Many limitations of completely mixed activated sludge systems for treatment of this type of wastewater were encountered during the course of this project. The major limitations were related to the type of waste, temperature effects, nutrient deficiency, and the highly variable wastewater flow. The extremely poor treatment results obtained during Phase I indicate that aerobic biological treatment of urea-formaldehyde glue waste alone is not feasible at this location. Treatment efficiency improved considerably with the addition of steam vat condensate to the system and reduction of the glue waste to a minimum flow. However, it appears that phosphorus addition is necessary for this system to successfully treat the combination wastewater.

Acclimation problems during startup of the system resulted principally from the poor treatability of the waste and the cold weather during this period. Biological reaction rates are sharply reduced at low temperatures. The combination of a slowly degrading waste and low reaction rates prevented a normal startup of the system.

Treatment Efficiency. The low BOD removal efficiency observed during Phase I was partially due to the poor settling characteristics of the activated sludge. This problem was also encountered during the pilot plant study [7]. The pilot study also showed no apparent BOD removal increase by adding nutrients.

Similar problems with sludge settling occurred during Phase II. Low temperatures were also a problem during this period. The changes in MLSS level and several oxygen uptake tests showed the presence of biological activity in the basin but poorly settling sludge was produced. This characteristic made close control of the MLSS level very difficult because of the washout of solids in the effluent during high flow periods. Uncontrolled wasting of activated sludge was the result. The design provided for MLSS control by wasting sludge at a rate which could be preset on a timer controlling the waste sludge pump. The MLSS levels shown in the planned operation schedule for the various phases were not closely maintained because of the control problems described above. However, during portions of these planned phases, the system was operated at the MLSS levels indicated. Operation at these various MLSS levels had no apparent effect on BOD removal efficiency or effluent characteristics.

BOD Removal. BOD removal in the activated sludge system as discussed previously, is described by the equation

$$kS_e = \frac{S_r}{X_a} .$$

However, this simplified form of the Michaelis-Menton kinetics is limited to use only where the substrate concentration in the reactor is much less than the concentration at one-half the maximum reaction rate. The concentration in the reactor is the same as the effluent soluble BOD concentration in a completely mixed system. This relationship was used to evaluate the performance of the treatment system.

Data from Phase IV-2 only, were used for this analysis because the most consistent operation was achieved during this period. Soluble BOD was not measured directly, but was calculated from effluent total BOD and effluent total suspended solids data. This method is described in Appendix A.

Effluent soluble BOD varied from 20 to 300 mg/l during Phase IV-2, with an average of 140 mg/l. Eckenfelder's data [11] for domestic sewage and certain industrial wastes, indicate that effluent BOD values up to 80-90 mg/l fall within the required limits. Lawrence and McCarty [13] have shown the one-half maximum reaction rate substrate concentration to be highly variable. They show a variation of 65 to 355 mg/l, based on BOD measurements, for various wastewater compositions.

Eckenfelder's simplified equation for BOD removal, therefore, appears to be of questionable validity for analysis of this treatment system.

The BOD removal rate, k, is equal to the slope of the first order curve passing through the origin, on a plot of total pounds of BOD removed per day per pound of MLSS vs. mg/l of effluent soluble BOD. Figure 6 is such a plot, using the data from Phase IV-2. This plot shows that the data is quite scattered. This can be attributed to large fluctuations in BOD loading to the system, as well as highly variable effluent suspended solids concentrations which directly affected the soluble BOD values in this analysis (see Figures 3 and 5).

The curve shown on Figure 6 was drawn through the mean coordinates of the data points because of the scattered data.

Figure 6 also shows that the BOD removal rate was very low. This is due to the large accumulation of non-degradable, or very slowly degradable, influent suspended solids in the aeration tank. The use of "active mass" in the system, if

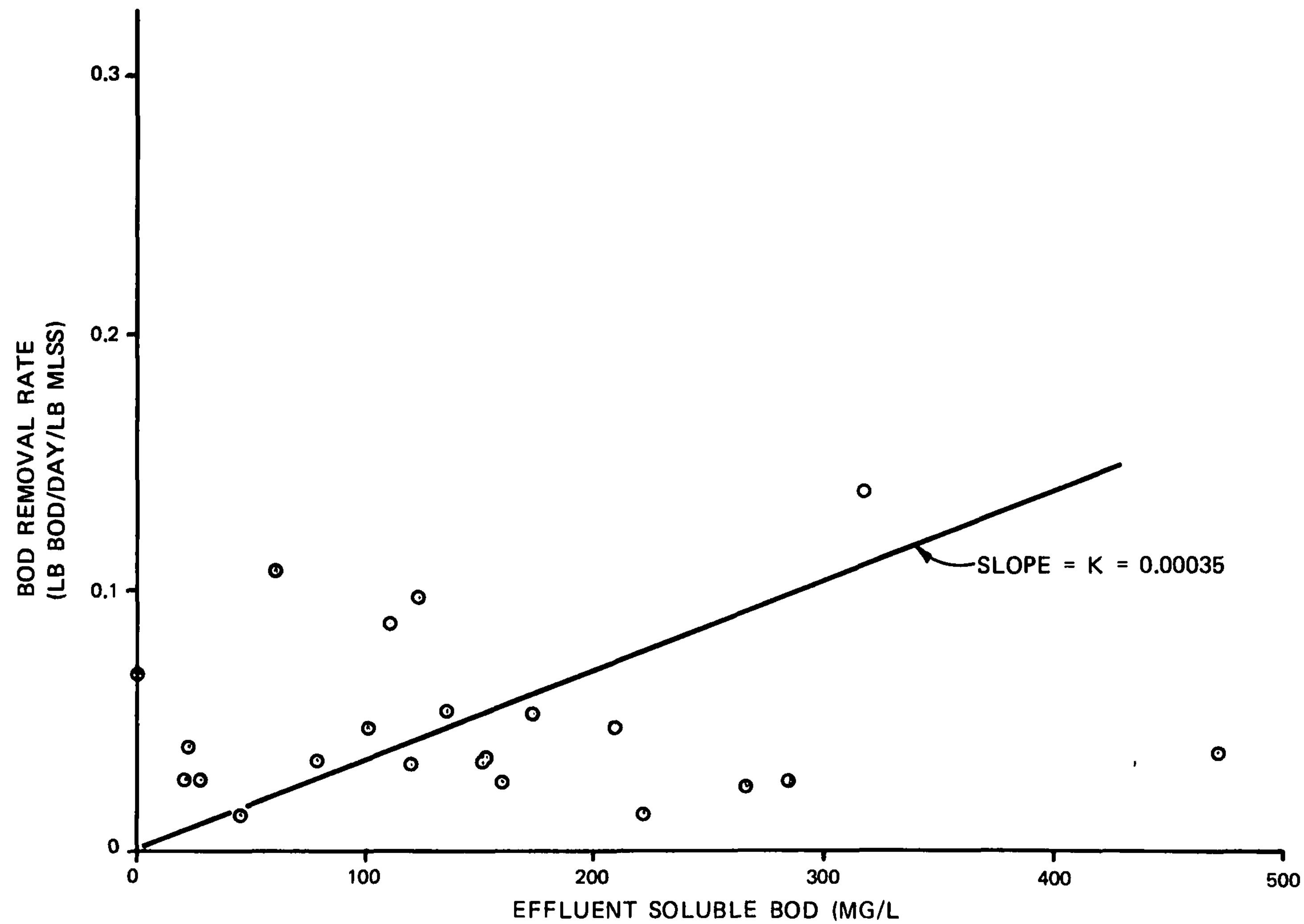

FIGURE 6

**BOD REMOVAL RATE
PHASE IV–2**

such data were available, or possibly data for MLSS due to BOD removed, to calculate the BOD removal rate, would likely improve the reliability of the k rate obtained from this type of plot. In general, it appears that the accumulation of these biodegradably resistant solids tends to obscure the kinetics evaluation. The BOD removal coefficient, k, resulting from this analysis was 0.00035 per day. This is much lower than Eckenfelder's data [11] for various types of wastewater. However, it must again be emphasized that this method of analysis is of questionable validity because of the marginal conditions encountered.

Figure 7 is a plot of percent BOD removal and organic loading during Phase IV. In general, the BOD removal appeared to increase with increasing organic loading, and to decrease with decreasing organic loading. This indicates that the average organic loading on the system was lower than that required for the most efficient operation. Again, the accumulation of poorly degrading influent solids in the aeration basin resulted in calculated loadings which were probably much lower than the actual loadings.

TEMPERATURE EFFECTS

Basin Temperature. Figure 8 shows aeration basin temperature, air temperature, MLSS and percent BOD removal through the first three phases of the demonstration period. This data was plotted as a three-day moving average to show the trends rather than daily variations, thus providing a better opportunity for data comparison. The aeration basin temperature closely paralleled the air temperature nearly all the time. Deviations from this pattern were caused by high influent flows of vat waste, which raised the basin temperature for short periods.

Temperature, BOD removal and MLSS data for Phase IV are plotted on Figure 9. Raw data rather than three-day moving averages, were plotted for this phase because the operation, and the resulting data, were much more uniform than during the first three phases. The most significant observation from this figure is the apparent reduction in BOD removal with lowering basin temperature, at the end of Phase IV-2.

No definite relationship between basin temperature and BOD removal or MLSS level can be established from this data. However, biological activity appears to have been retarded by temperatures consistently below 10 degrees C.

Freezing Problems. The plant is located in an area subject to extremely cold winter weather. A layer of ice formed on the surface of the aeration basin on several occasions. This caused a blockage of the tube settler effluent, effectively

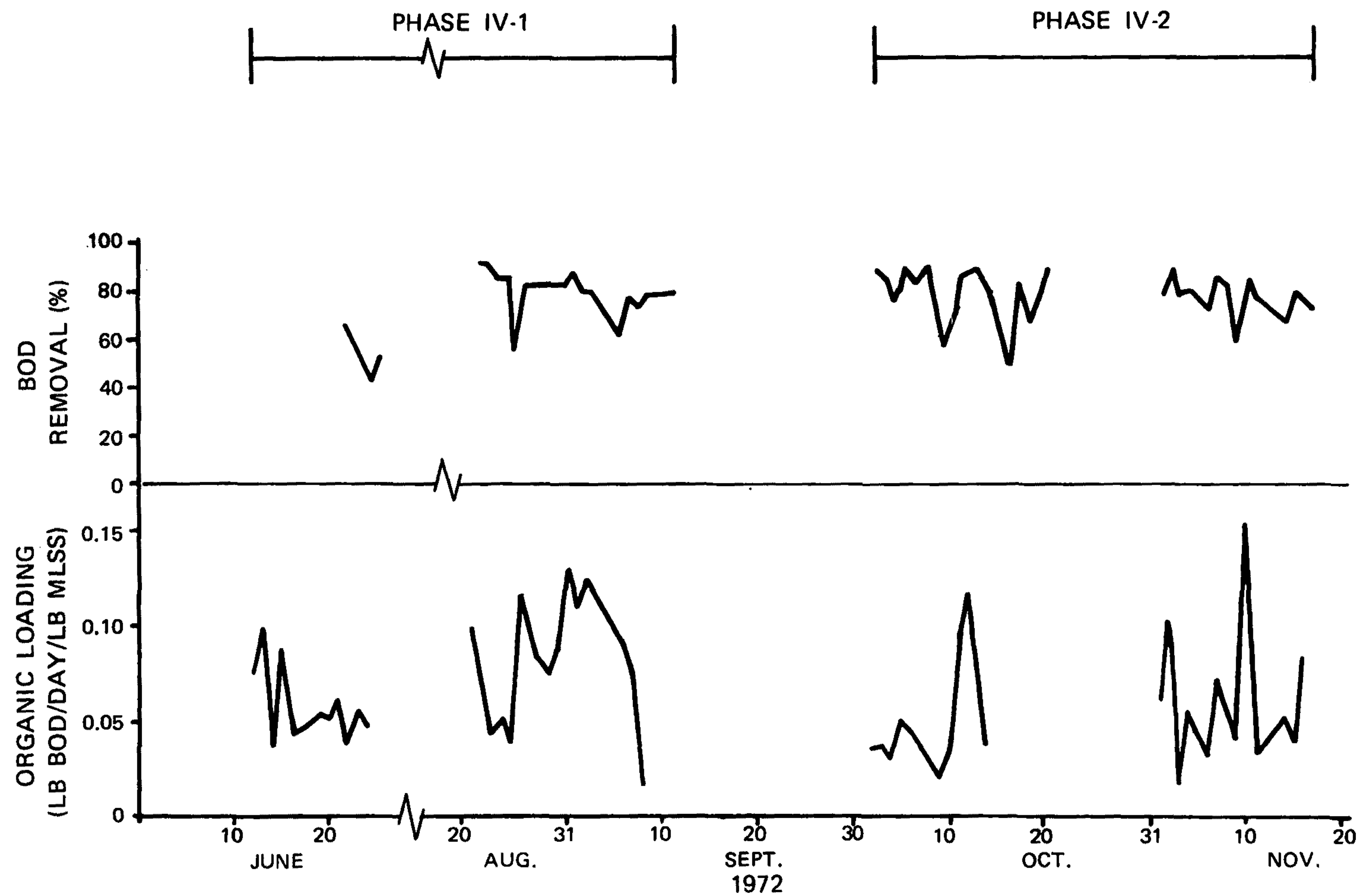

FIGURE 7

EFFECT OF ORGANIC LOADING ON BOD REMOVAL
PHASE IV

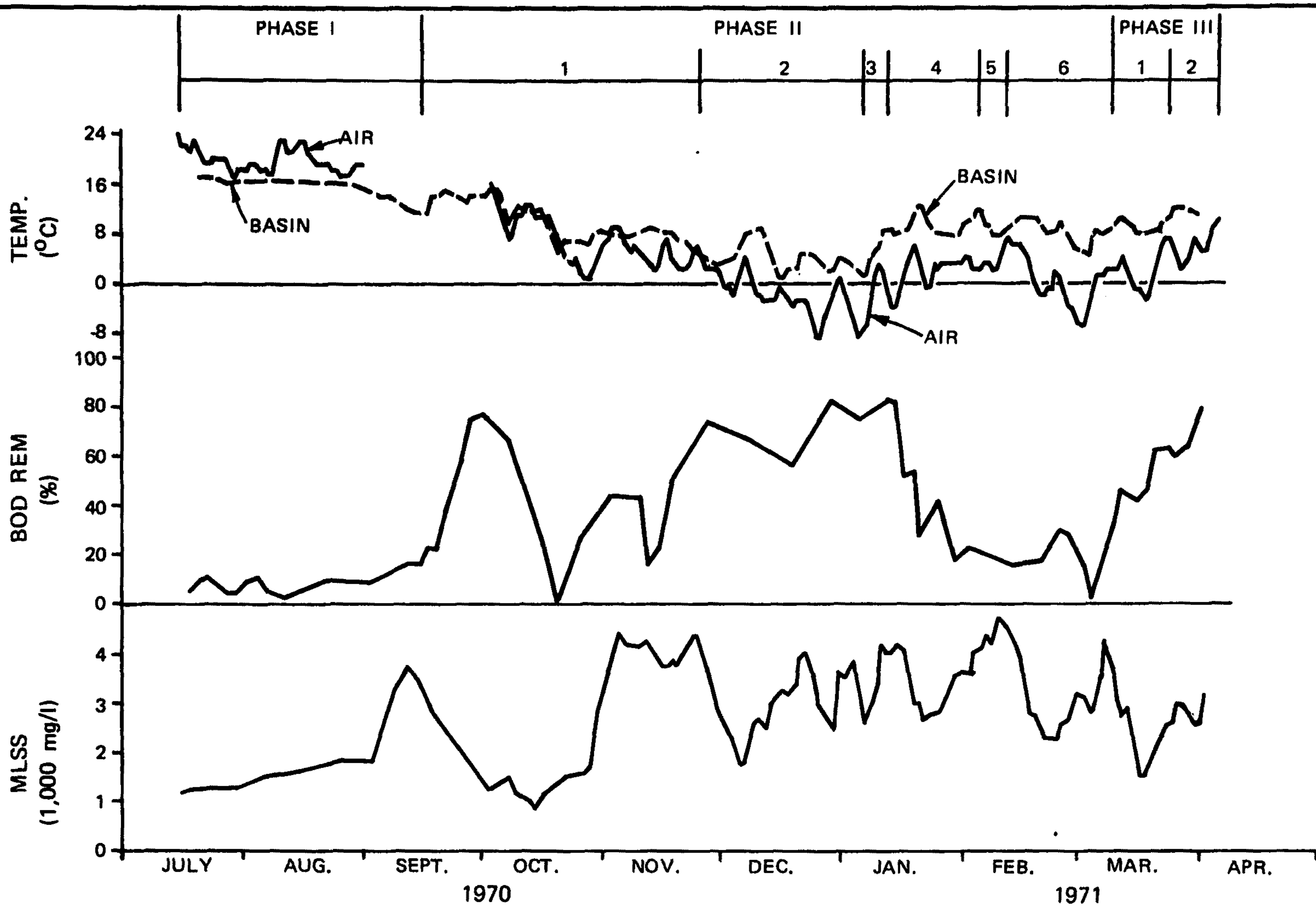

FIGURE 8

TEMPERATURE EFFECTS
(3 DAY MOVING AVERAGE DATA)

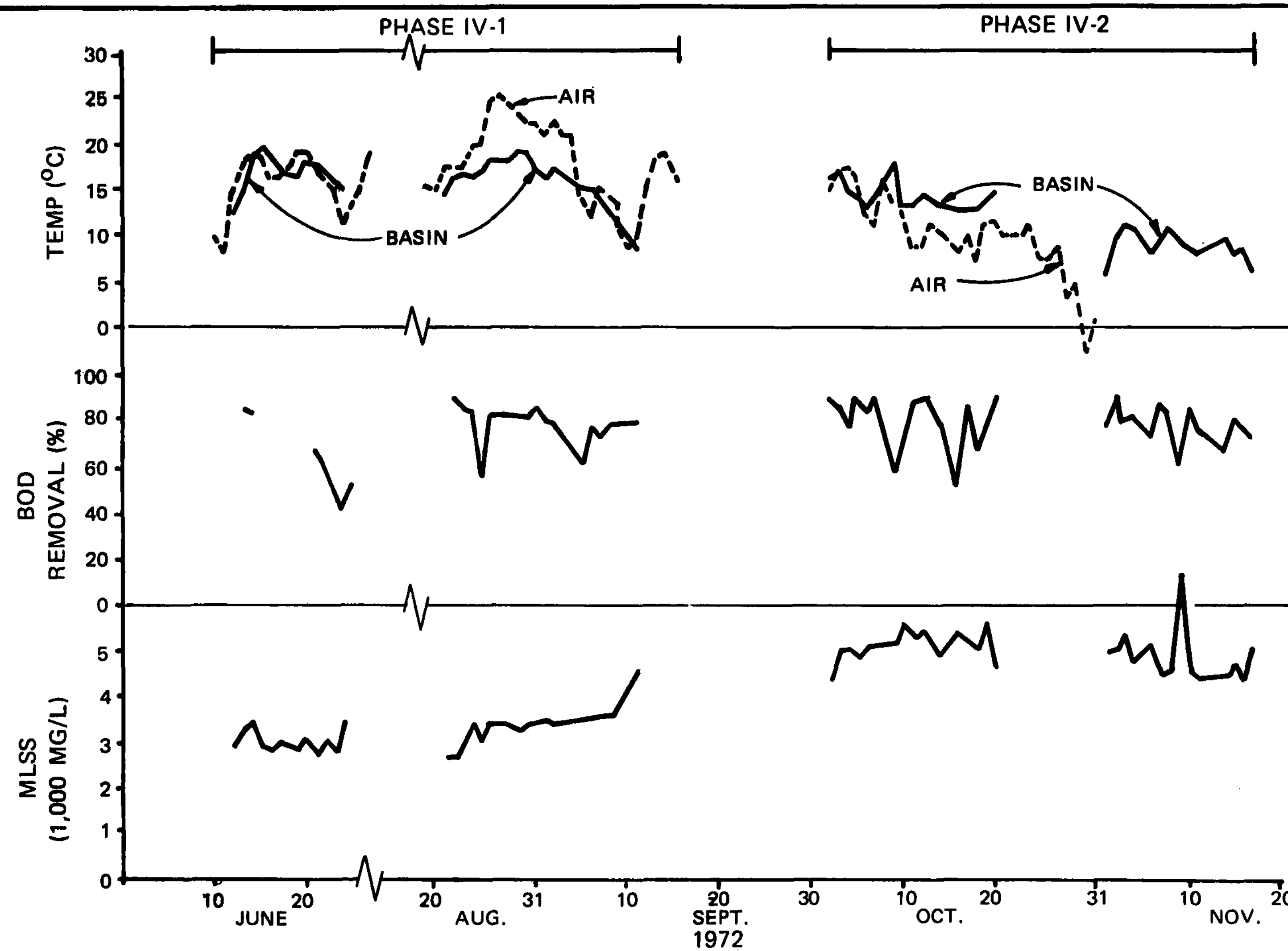

FIGURE 9

TEMPERATURE EFFECTS
PHASE IV

stopping the plant operation. The uplift force beneath the ice layer in the tube settler module lifted it from its foundation twice.

Foaming. A layer of foam developed on the surface of the aeration basin several times. No problems arose from the presence of the foam. The worst condition occurred during the startup period, when the foam layer spilled over onto the ground around the basin.

However, this foam quickly dissipated. The foaming generally occurred after a period when no wastewater was pumped through the system, such as when the mill was down for several days.

Near the end of December 1970, the aeration basin contents became very viscous and slimy. The reason for this condition was not definitely established. However, it was very likely due to a nutrient deficiency which affected the metabolism of the microorganisms, a common occurrence for high strength wastes with nutrient imbalance. The slimy condition disappeared with the addition of phosphorus to the system at the start of Phase III.

NUTRIENT EFFECTS

The pilot plant data indicated that the combined glue and vat wastewater was deficient in phosphorus. The effect of nutrient supplementation was determined during Phase III by adding 0.2 pounds of phosphorus, as Simplot 0-20-0 fertilizer, to the system each week.

The BOD:N:P ratio was 100:15:0.5 during Phase II, before nutrient addition was started. This ratio shows a low phosphorus content which would retard the biological growth. With the addition of phosphorus during Phase III, the ratio improved to 100:40:1.3.

Two principal effects of the nutrient addition were observed. The viscosity of the mixed liquor returned to normal as the slimy condition disappeared, and the settling properties of the activated sludge improved markedly. The BOD removal efficiency increased steadily until Phase III of the demonstration program was ended on 3 April 1971.

Visual observations after completion of Phase III indicated the continuance of this trend. The improved settleability of the activated sludge was corroborated by the steady reduction in effluent suspended solids during a period of widely varying flow to the treatment system. During prior operation phases, substantial washout of activated sludge solids occurred during periods of high flow. These observations led to the initiation of Phase IV to obtain additional data.

The operation during Phase IV corroborated the visual observations made after Phase III was terminated. No problems with increased viscosity of the mixed liquor were encountered during this period. The BOD removal efficiency increased slightly above that which was observed at the end of Phase III. This level was maintained throughout Phase IV. The effluent suspended solids stayed well below MLSS levels, but, as shown on Figure 5, fluctuated widely.

Figure 5 and Table 8 show that the effluent suspended solids concentration was very high throughout Phase IV. No definite reason for this has been established. However, it could be due to either the accumulation of poorly degradable, poorly settling, influent solids or inadequate performance of the tube settler module, or both.

TUBE SETTLER

A qualitative evaluation of the tube settler performance was attempted. A definite conclusion about the effectiveness of this unit was not reached. The unit appeared to do an adequate job on the activated sludge with good settling properties. However, high solids carryover was observed with the poorly settling sludge during periods of high flow to the system. This problem may or may not be related to the efficiency of the tube module since no comparison with conventional methods of clarification was possible. Displacement of the unit from its foundation due to ice buildup in the module was a definite problem. However, this could be avoided by using a different type enclosure. The high effluent suspended solids levels observed during Phase IV would indicate a poor performance by the tube settler. The average loading rate during this period was about 0.21 gallons per min per square foot of tube settler area. However, this could not be substantiated with the data available.

OXYGEN UPTAKE

Figure 10 is a typical plot of oxygen uptake data taken during Phase II. The actual uptake rate at this time was 19.2 mg/l/hr. An oxygen transfer rate of 35 lb/hr at zero D.O. and standard temperature (20 degrees C) was calculated from this data. This results in an oxygen transfer efficiency of 1.75 lb/hp/hr based on the total aeration capacity of 20 horsepower. No correction for the alpha or beta factors was made in these calculations.

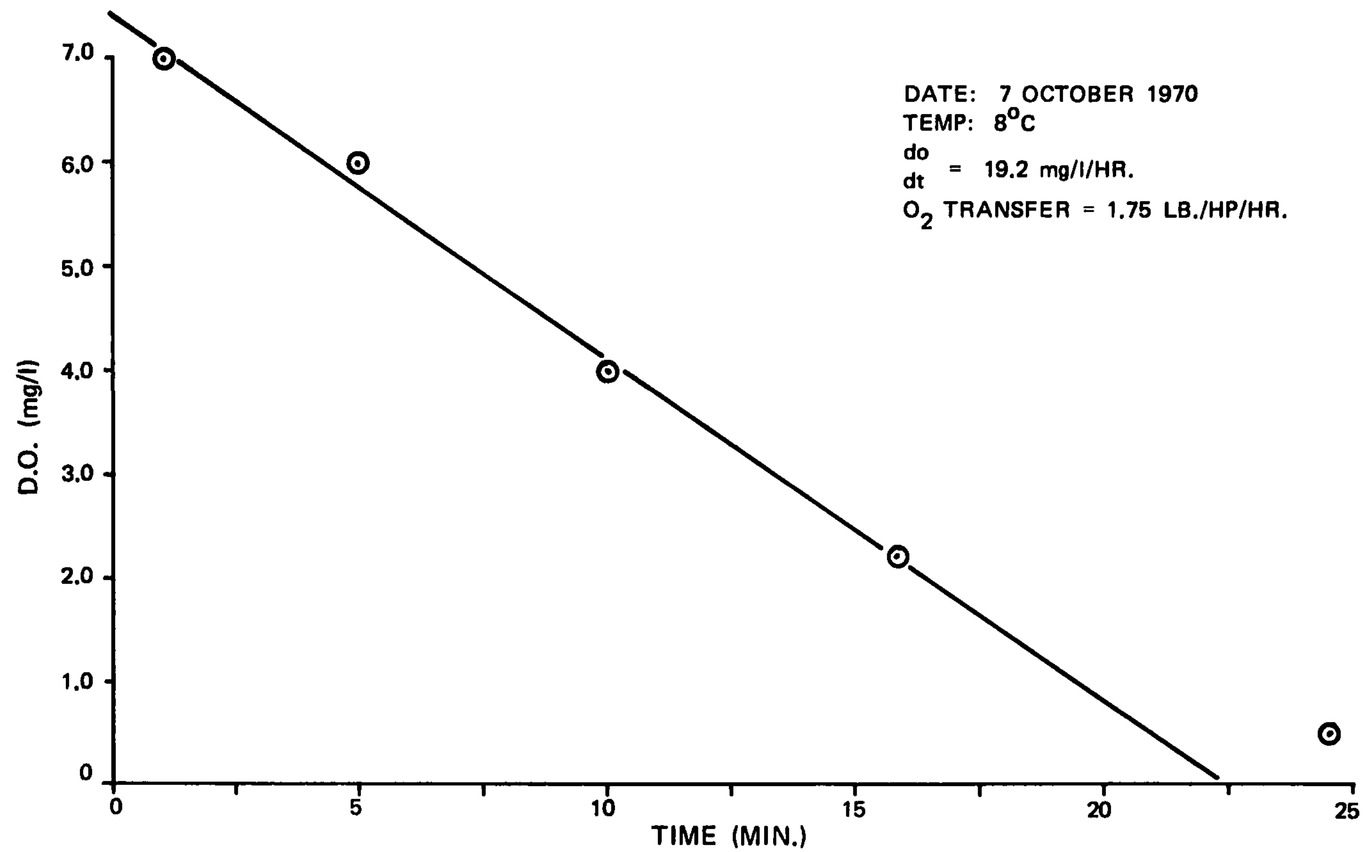

FIGURE 10

OXYGEN UPTAKE

SOLIDS STORAGE POND

Very little sludge was pumped to the storage pond during the demonstration period because of the presence of poorly settling sludge and the resultant difficulty in maintaining the desired MLSS level. Most of the solids removed from the system during this period were in the tube settler effluent. However, during the period between the end of Phase III and the beginning of Phase IV, the storage pond was used as a polishing lagoon, with the entire effluent passing through it prior to discharge to the river. This approach has worked very well in terms of effluent quality, and has been resumed since the end of Phase IV.

Prior to the initiation of Phase IV of the demonstration program, the pond was drained. No solids concentration data were obtained at that time, but the concentration was estimated to be 8-9 percent solids. The estimated volume of sludge in the lagoon was about 13,000 cubic feet. Several truckloads of sludge were removed from the pond and spread on farmland.

The pond was drained again at the end of the second year of operation of the treatment system. The estimated volume of sludge in the pond at that time was about 20,000 cubic feet.

Since the end of the demonstration period the pond has been used as a storage basin for a portion of the effluent during the cold weather when the efficiency of the activated sludge system is reduced. Sufficient capacity to allow this type of operation is obtained by draining the pond during the warm weather when the system efficiency is greatest.

No odor problems from solids storage have been observed. An abundant algae growth has occurred on the pond surface during the spring and summer months, which tends to reduce the odor potential.

OPERATING PROBLEMS

Process. Most of the process operation problems have been discussed in previous sections of this report. These problems are summarized as follows:

> Cold temperatures affected the process in two ways: a reduction of the biological reaction rate; and ice formation on the aeration basin and tube settler surfaces. The poor treatability of glue waste alone resulted in very poor BOD removal during Phase I. The production of poorly settling activated sludge was largely responsible for high effluent suspended

solids concentrations and uncontrolled wasting of solids from the aeration basin. The wide variation in flow rate from day to day also added to this problem.

Mechanical. There were very few major mechanical problems during this demonstration program. Two items which were a continual problem were the flowmeter and the automatic sampler. A regular buildup of wood chips and other debris beneath the float, hampered the operation of the flowmeter. Several corrective methods, including a jet of water to keep these solids washed out, were tried with little success. A similar plugging problem from chips and glue solids affected the operation of the automatic sampler.

Plugging of the raw waste pump occurred during Phase I, but with the addition of the vat waste to the system, this problem was lessened.

SECTION X
ACKNOWLEDGMENTS

This project was supported in part by Environmental Protection Agency Research and Development Grant No. 12100 EZU. Appreciation is expressed to W. H. Ferry of Columbia Plywood Corporation and to Dr. H. K. Willard, EPA project officer, for their cooperation and assistance during this study.

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SECTION XII
ABBREVIATIONS

mg/l	milligrams per liter
BOD	biochemical oxygen demand (five day)
MLSS	mixed liquor suspended solids
mgd	million gallons per day
TSS	total suspended solids
D.O.	dissolved oxygen
O_2	oxygen
COD	chemical oxygen demand

SECTION XIII

APPENDIXES

APPENDIX A

SUPPLEMENTARY INFORMATION

BOD REMOVAL RELATIONSHIP

Eckenfelder [11, 12] has presented the following formulation, based on the Michaelis-Menton Kinetics, for defining microbial growth rate and steady state substrate removal:

$$kS_e = \frac{S_r}{X_a t}$$

Where: S_r = BOD removed, mg/l

X_a = Average MLSS, mg/l

t = Aeration time, days

S_e = Soluble effluent BOD, mg/l

k = Removal rate coefficient, (mg BOD/day/mg MLSS)/ mg/l BOD

The application of BOD removal and MLSS data in terms of lb/day was more convenient for data analysis for this report. Modification of the above equation was required to allow its use with the desired units. This was accomplished through a dimensional analysis of the equation.

Multiplying both numerator and denominator of the right side of the equation by a volume term gives the following result:

$$\frac{\text{Conc}}{\text{Conc. x time}} = \frac{\text{Conc}}{\text{Conc. x time}} \times \frac{\text{Vol}}{\text{Vol}}$$

$$= \frac{\text{Conc. x vol/time}}{\text{Conc. x vol}}$$

$$= \frac{\text{Wt/time}}{\text{Wt.}} \quad \text{or} \quad \frac{\text{lb/day}}{\text{lb}}$$

Therefore, the equation becomes:

$$kS_e = \frac{S_r}{X_a}$$

Where: S_r = BOD removed, lb/day

X_a = Average MLSS, lb

S_e = Effluent Soluble BOD, mg/l

k - Removal rate coefficient, $\frac{\text{(lb BOD/day/lb MLSS)}}{\text{mg/l BOD}}$

SOLUBLE BOD DETERMINATION

As indicated in Section IX, effluent soluble BOD measurements were not made during this project. Effluent soluble BOD values were approximated, however, as described in this section, to provide data for the attempted evaluation of the BOD removal rate coefficient. It must be kept clearly in mind that these data are only approximations, and do not necessarily represent the actual conditions prevailing in the treatment system.

The effluent total BOD consists of two fractions: that BOD contributed by the solids in the effluent flow; and that BOD which is soluble.

The slope of the first order curve obtained by plotting effluent BOD vs. effluent suspended solids, gives the fraction of BOD contributed by a unit quantity of suspended solids.

Effluent soluble BOD is then obtained by use of the following equation:

$$S_e = S_t - y(X_e)$$

Where: S_e = Effluent soluble BOD, mg/l

S_t = Effluent total BOD, mg/l

X_e = Effluent suspended solids, mg/l

y = Fraction of BOD per unit solids, mg BOD/mg X_e

Figure 11 is a plot of effluent total BOD vs. effluent suspended solids for all Phase IV-2 data. The slope of the curve (y) equals 0.17 mg BOD per mg suspended solids. Therefore the above equation becomes:

$$S_e = S_t - 0.17X_e$$

This equation was used to calculate the effluent soluble BOD data plotted on Figure 6.

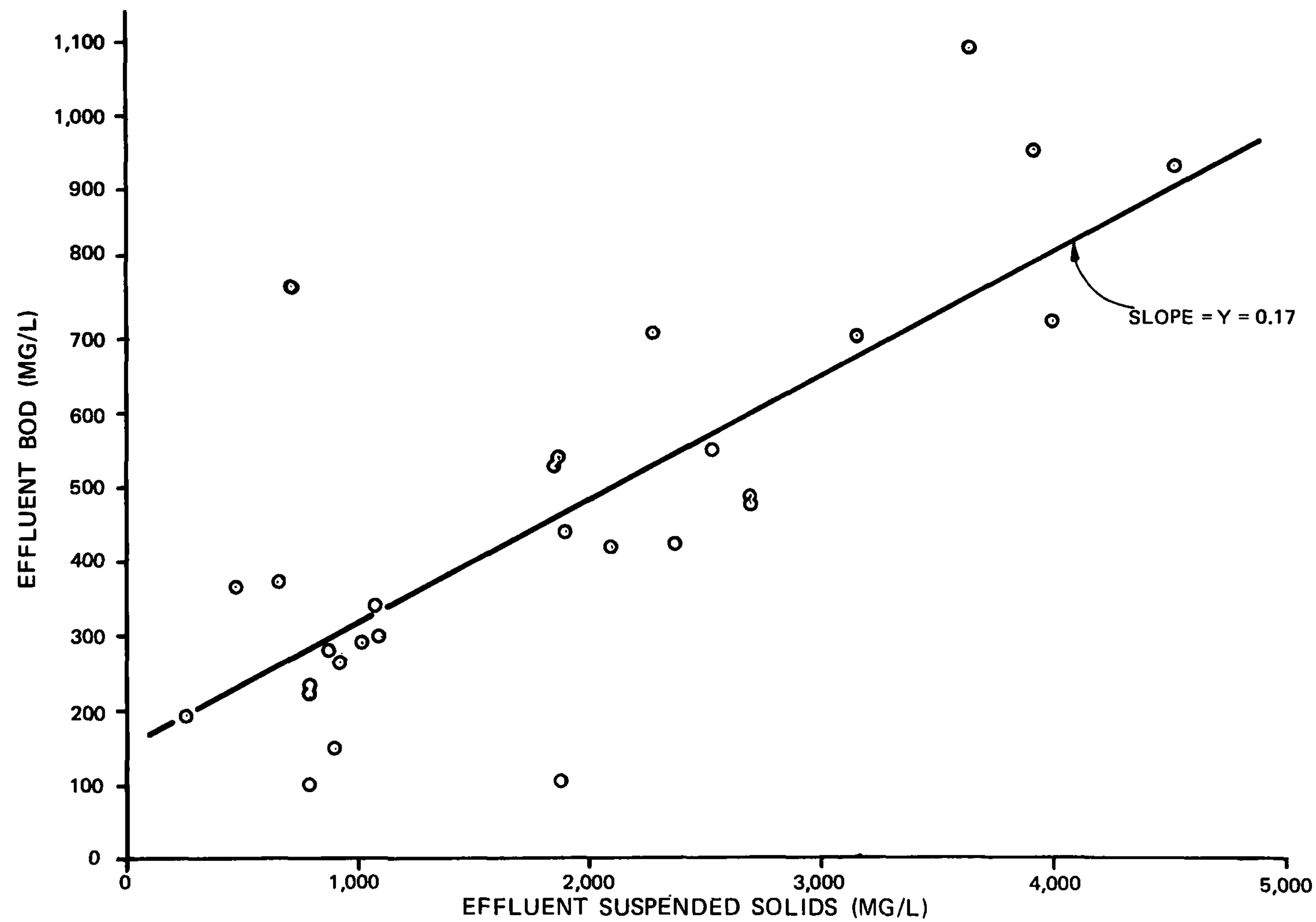

FIGURE 11

FRACTION OF BOD FROM SUSPENDED SOLIDS
PHASE IV–2

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8. Performing Organization Report No.

7. Author(s)

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Columbia Plywood Corporation
Portland, Oregon

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13. Type of Report and Period Covered

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15. Supplementary Notes

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16. Abstract

An activated sludge treatment system, consisting of an aeration tank, a tube-settler clarification module and a waste solids lagoon, was constructed at Klamath Plywood Corporation in Klamath Falls, Oregon to treat urea-formaldehyde glue and steam vat condensate wastewater. Operation of the system was studied over a period of 18 months. Prior to operation of the system, several in-plant changes were made to reduce the flow and BOD loading. The flow to the treatment system was reduced from about 40,000 gallons per day to about 8,000 gallons per day and BOD from 500-1,000 pounds per day to 100-400 pounds per day. During the period of greatest efficiency, the flow averaged 6,700 gallons per day and the BOD averaged 182 pounds per day. The results of the study indicate that activated sludge treatment of urea-formaldehyde glue waste alone is not feasible (average BOD removal of 8 percent). The combined wastewater is amenable to treatment by activated sludge, but requires the addition of phosphorus. Without nutrient addition, the average BOD removal was 38 percent. During the period when phosphorus was added to the system, the BOD removal averaged 78 percent. The flow averaged 9,800 gallons per day during the latter period. Treatment efficiency was adversely affected by cold weather during part of the study period.

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17a. Descriptors

*Waste Treatment, *Industrial Wastes, *Aerobic Treatment Activated Sludge, Biological Treatment, Wood Wastes

17b. Identifiers

*Plywood Glue Wastes, Tube Settler

17c. COWRR Field & Group 05D

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