DESIGN REPORT

FOR A

WASTE DISPOSAL SYSTEM

FOR

SOUTHLAND PAPER MILLS, INC.

LUFKIN, TEXAS

BROWN & ROOT, INC.
Engineers and Consultants
April, 1965

PREFACE

This report is intended to characterize clearly the waste of the Lufkin mill and determine the most economical treatment to bring the effluent within what the State of Texas might require for effluent standards. The design is based on the treatment producing a 20 ppm B.O.D. or less, and 20 ppm Suspended Solids, or less, effluent.

This report must be considered in the light of its two prime limitations which are (1) there is no provision for color removal except that color removal could be accomplished in the primary clarifier with a very heavy chemical dosage that would not be economical for full time operation and (2) the facilities as designed do not provide for fiber removals over about 50 ppm in the primary clarifier.

If the fibers are not recovered ahead of the primary clarifier, the excess fibers will cause problems throughout the plant which will result in a very poor effluent.

The tests results show that the mill effluent contains fibers in amounts varying from 170 to 550 ppm. This represents fiber losses from the mill of 14.16 tons to 45.82 tons per day. The average during the test period from February 6 thru February 16, 1965, was 25.72 tons per day. These fibers seriously interfere with the primary clarification process, make the biological process virtually uncontrollable, and prevent the effluent from the aeration units from settling in the final clarifier and consequently degrading the effluent.

With these limitations we believe this report represents a thorough analysis of the mill wastes, a proven process for treatment, and equipment to accomplish the process most economically.

SECTION I

SUMMARY

This engineering report represents a great deal of detailed study for waste treatment facilities for Southland Paper Mill's Lufkin, Texas plant. The process recommended for the treatment of this waste is clarification followed by biological oxidation. This method of treatment is recommended as a result of extensive research by agencies cited in this report.

The recommended process flow for treating the Southland mill waste is (a) primary clarification to remove, as far as possible, all suspended materials, (b) aeration for biological oxidation and (c) final clarification. Settled sludge for final clarification will be returned to the aeration stage for complete mixing with the incoming raw waste. Waste activated sludge will be thickened and combined with sludge from primary clarification for disposal.

Primary clarification will be accomplished with a combined reactor-clarifier unit. Aluminum sulfate and activated silica will be added at this stage to aid flocculation.

Aeration, for biological oxidation, will be done by mechanical, turbine-type surface entrainment aerators in large open aeration basins. Nutrients in the form of liquid ammonia and phosphoric acid will be added in the aeration basins to promote biological oxidation.

Special final clarification equipment must be used in the final clarifier. That is, a vacuum type sweep for rapid sludge return.

Return activated sludge will be removed by three non-clog centrifugal pumps.

Excess activated sludge, and sludge from the primary clarifiers will be

gravitied to a sludge thickener before being wasted in existing oxidation ponds.

All flow through the plant other than return activated sludge will be by gravity.

Total project cost will be about $1,987,000. A summary of this project cost is as follows:

Site Preparation	$208,000.00
Entrance Structures	2,325.00
Influent Flow Divider	1,760.00
Primary Clarification	168,400.00
Chemical Feed Wells	2,900.00
Aeration Basins	367,000.00
Final Clarification	184,000.00
Sludge Thickener	31,400.00
Sludge Return	27,000.00
Chemical Storage	43,500.00
Chemical Feed Building	60,000.00
Yard Piping	80,300.00
Effluent Pipeline	185,000.00
	$1,361,585.00
10% Contingencies	136,415.00
Overhead & Indirect	222,000.00
Profit	172,000.00
Total Construction	$1,892,000.00
Engineering @ 5%	95,000.00
TOTAL PROJECT	$1,987,000.00

It is recommended that sludge disposal be accomplished by wasting to the existing oxidation ponds only until the necessary tests can be made to determine the dewaterability and fuel value of the thickened sludge. It is then recommended that disposal be handled by incineration. The incinerator will cost approximately $300,000 installed.

SECTION II

INTRODUCTION

The Lufkin, Texas mill operations of Southland Paper Mills, Inc. consists of kraft and groundwood facilities. At the present time (1965), the mill produces 20 million gallons per day (MGD) of total mill effluent which includes rejects, miscellaneous storm and sanitary sewers and wastes from all components of the mill.

The mill effluent is treated for fiber recovery by a Sveen-Peterson flotation unit and then discharged to a series of lagoons for the settling or retention of non-recoverable fibers and possible reduction of biochemical oxygen demand (BOD) through stabilization. The effluent is eventually discharged to the Angelina River. The discharged effluent is high in BOD and has the dark color characteristic of kraft mill waste. Table II-1 shows the flow contributions of the various plant components, together with the contributed BOD.

TABLE II-1

BIOCHEMICAL OXYGEN DEMAND BALANCE
(Furnished by Southland Paper Mills, Inc.)

Stream	Volume MGD	BOD_5 lbs/day
Rejects	0.3	---
Machine Sewer	2.0	1,250
Groundwood White Water	5.75	5,750
Pulp Mill	4.5	6,400
Bleach Plant	3.6	3,000
Evaporator Condensate	0.6	2,500
Miscellaneous Sewers	3.25	---
TOTAL	20.00	18,900

The raw mill waste contains approximately 46,000 lbs/day of suspended solids, and it is estimated that approximately 36,000 lbs/day are removed in the lagoons, so that the effluent discharged to the river contains about 10,000 lbs/day.

It is proposed to construct waste treatment facilities that will produce an effluent containing not more than 20 ppm of BOD (3,300 lbs/day) and 20 ppm of suspended solids (3,300 lbs/day). No color removal is to be provided.

This report contains the results of research, process and design investigations carried out in order to determine the recommended treatment plant layout and component sizes. Section I is a summary of the report and findings and Section II is the introduction, in which a recapitulation of existing conditions is made. Section III presents the process analysis and design, together with a discussion of the recommended process. Section IV presents a detailed engineering design of the treatment plant. Section V is a detailed cost estimate of the recommended layout. Section VI is a bibliography noting all references cited in the report. Section VII is the appendix which contains an investigation of incineration processes and an investigation of possible conversion of the existing activated sludge treatment unit into a chemical pretreatment plant.

SECTION III

PROCESS DESIGN

RESEARCH

The Lufkin mill of Southland Paper Mills, Inc., is a fully integrated operation and the waste includes streams from groundwood, pulping, bleaching and paper making operations plus the miscellaneous equipment and processes. Research[1,2] has been accomplished and an analysis of four waste streams and the total effluent indicated that all waste streams were amenable to biological treatment. Although the waste treatment criteria are established in terms of BOD removal, the research and design criteria for industrial waste treatment at the Lufkin mill have been established in terms of the total biological oxygen demand (T_bOD)[3].

T_bOD provides a more reliable, absolute and more easily determined measure of the biochemically available soluble organics in the waste streams. The T_bOD test measures the degradable organic content by the change in chemical oxygen demand (COD) before and after aeration in the presence of an acclimated culture of microbial organisms (activated sludge). The measured T_bOD is approximately 1.5 times the BOD of a given sample.

Laboratory analysis of the mill waste showed the T_bOD for the total effluent to be 38,300 lbs/day, or 230 ppm. Ninety percent of the total T_bOD is furnished by effluent from the groundwood mill, the pulp mill, the bleach plant and the evaporator condensate.

On January 29, 1962, a seven day composite sample of total mill effluent was analyzed by Curtis Laboratories, analytical and consulting chemists, to determine the chemical constituents of the waste. The results of this analysis are shown on Table III-1.

TABLE III-1

RESULTS OF ANALYSIS
(Furnished by Curtis Laboratories)

	Milligrams per Liter
Total Alkalinity as $CaCO_3$	152
Chlorides as NaCL	412
Sulphates as Na_2SO_4	154
Chemical Oxygen Demand	71
BOD	225
pH	7.1

Analysis of these results and the comments of A. W. Busch[4] indicates that there are two characteristics of the waste that deserve special emphasis.

1. The waste is essentially devoid of the primary nutrients, nitrogen and phosphorus and will require supplementary feeding.

2. There is a critical concentration of the waste which is toxic to the micro-organisms used in biological treatment, and the process design must give cognizance to this fact.

Examination and study of the research results leads to the following conclusions concerning the process design:

1. Pretreatment will be Required for Solids Removal. Based on data furnished by Southland, approximately 10,000 lbs/day of suspended solids are being discharged in the final effluent to the Angelina River. In the raw effluent (after treatment in the Sveen-Peterson flotation unit), there are approximately 46,000

lbs/day of suspended solids. Effective biological treatment is extremely difficult when the waste introduces 5 tons of solids per day to the process, and is certainly so when 23 tons per day are introduced. The existing ponds or lagoons are heavily loaded and clogged with fiber, and their efficiency can be seriously questioned. It is apparent, therefore, that some sort of pretreatment will be required in order to remove these suspended solids before biological treatment begins. The suspended solids are nearly all tiny cellulose fibers which have no nutrient value and which can damage seriously any aerobic process.

2. Biological Treatment is most Desirable. The waste is readily degraded by biological processes. A biological treatment process should be used so that maintenance problems will be reduced and excessive chemical costs avoided.

3. The Process must be Relatively Insensitive to Shocks. The toxicity of certain contributors to the waste requires that the treatment process be able to absorb relatively mild shock loads without upsetting the microbial culture.

4. Nutrients must be Added. The primary nutrients, nitrogen and phosphorous, must be added to the waste in order to develop a satisfactory microbial culture. The recommended nitrogen source is anhydrous ammonia (NH_3) and the recommended phosphorous source is phosphoric acid (H_3PO_4).

RECOMMENDED PROCESS

There are several possible methods of treating wastes biologically. The most common are the use of trickling filters, oxidation ponds (lagoons) or variations of the activated sludge process. The trickling filter is not recommended because of its extreme sensitivity to toxic material and shocks, and because of the highly empirical and relatively uncertain nature of its design and operation. Oxidation ponds are not recommended because of the space requirements and because the process kinetics of oxidation ponds are not suited to the particular situation in question.

Activated sludge is the general name given to the process whereby sewage is aerated with an admixture of previously aerated sludge. The sludge, which is light and flocculent, serves as a vehicle for aerobic bacteria. The bacteria oxidize the organic matter both in solution and suspension and the sludge, as it moves rapidly through the sewage, absorbs suspended and colloidal matter[5]. Aeration may be provided by either forced air or mechanical aerators.

It is recommended that mechanical aeration be used. An inherent disadvantage to forced-air is the possibility of clogged diffusers, since the diffusers are always submerged. Although manufacturers advertise "non-clog" diffusers they do, nevertheless, clog. When this happens, they must be removed from the sewage and cleaned, resulting in an interruption in the treatment process. Mechanical aerators, on the other hand, are much more easily maintained and there is no possibility of clogging.

In most sewage treatment processes the problem of sludge digestion is solved by the use of anaerobic digesters. These are large, covered tanks where the sludge is drawn and held in order to be digested by anaerobic bacteria. This method of sludge digestion produces problems of gas generation and disposal, corrosion, maintenance and other nuisances that render its usefulness subject to serious question. Sludge digestion using aerobic bacteria has the advantages of eliminating many corrosion problems, producing no obnoxious gases and producing a more stable sludge for disposal. It is recommended that all phases of the

Southland waste treatment plant be aerobic.

The completely-mixed activated sludge process satisfied all of the conditions outlined above and is the recommended treatment process. Completely-mixed activated sludge is the process whereby the untreated wastes are instantaneously mixed throughout the entire aeration tank. In effect, the organic load on the aeration tank is uniform from one end to the other and produces a uniform oxygen demand and a uniform biological growth. This is the ideal case, of course, which is rarely equalled in the field. The process kinetics are such that these conditions can be closely approximated, however, in several ways. Analysis of the mathematics of the system[6] and of the fundamental biochemistry have shown that the aeration tank actually behaves as a surge tank, enabling the system to absorb shock loads and certain toxic loads without upsetting the process.

Moreover, in the completely-mixed system, control of the mixed liquor suspended solids ratio (MLSS) in the aeration tank will determine time required to stabilize and treat the waste. This makes it possible to combine waste treatment and sludge digestion in a single basin in a completely aerobic process. McKinney[7] has given an excellent description of the microbiology that accomplishes this.

The recommended process flow pattern fcr treating the Southland mill waste is (a) primary clarification to remove, as far as is possible, all suspended materials, (b) aeration for biological oxidation and (c) final clarification. Settled sludge from final clarification will be returned to the aeration stage for complete mixing with the incoming raw waste. Waste activated sludge will be thickened and combined with the sludge from primary clarification for disposal. Sludge disposal will be either by incineration or lagooning. Figure I shows the process flow diagram. The final, treated effluent will be conveyed for eventual discharge into the Angelina River.

PROCESS DESIGN

Busch[4] has made the recommendations in Table III-2, based on data obtained in the cited research.

TABLE III-2

RECOMMENDED DESIGN CRITERIA

Flow:	20 million gallons per day
T_bOD (Removable COD):	42,500 lbs/day
Effluent quality:	20 mg/l BOD_5 35 mg/l T_bOD 20 mg/l suspended solids
Mixed liquor suspended solids (M.L.S.S.) required:	24,500 lbs
Aeration Volume Recommended:	2.5 MG
M.L.S.S. concentration:	1,200 mg/l
Clarification area:	33,333 ft^2 (600 gpd/ft^2)
Solids produced (excess):	7,340 lbs/day
Oxygen required:	26,500 lbs/day
Nitrogen requirement:	1,500 lbs N.; 1,800 lbs NH_3/day
Phosphorus requirement:	300 lbs P; 950 lbs H_3PO_4/day

Busch further recommends that the aeration volume be divided into at least two units. This will give the plant a desired degree of operational flexibility. A thickener will be provided to concentrate excess solids.

The T_bOD remaining in a 35 ppm effluent is:

$$35 \text{ ppm} \times 20 \text{ MGD} \times 8.345 \text{ lbs/MG} = 5,841 \text{ lbs/day.}$$

Therefore, the T_bOD removal required to produce a 35 ppm effluent is (42,500 - 5,841.5) lbs/day = 36,658.5 lbs/day. Consequently, the minimum plant efficiency must be $\frac{36,658.6}{42,500} = 0.8625 = 86.25$ percent. A 35 ppm T_bOD is roughly equal to a 20 ppm BOD_5, since $BOD_5 = 2/3\ T_bOD$.

To complete the process design, a detention time of 3 hours will be used in the design of the aeration basins and a surface loading of 600 gallons per square foot per day will be used in the design of final clarification.

SECTION IV

FACILITIES DESIGN

PRIMARY CLARIFICATION

Primary clarification, to remove the load of suspended solids from the raw waste, is required. Fiber recovery prior to the facilities shown in this report must be effected so that not more than 50 ppm of fibers enter into the primary clarifier.

Tests show that the final effluent from the existing mill contains 170 to 550 ppm of fibers. This is an average of 25.72 tons of fiber per day in the waste effluent. If allowed to enter the waste treatment plant, these fibers would seriously interfere with the primary clarification process, making the biological process virtually uncontrollable and making biological solids removal very inefficient.

These solids are, for the most part, tiny cellulose fibers, much like soda straws, which contain air that is trapped and held by surface tension. These particles are very light and are not readily settleable, so that chemical coagulation and sedimentation must be provided.

The most obvious and probably the easiest method of doing this is to use a combined reactor-clarifier unit. It is proposed to add aluminum sulfate (alum), in the reactor-clarifier as a flocculating agent. Because of the lightness of the suspended solids, it will be necessary to add a flocculating aid. Activated silica will be used for this purpose.

Alum will be fed as aluminum sulfate solution by chemical feed units. Chlorine activated silica will be added from a Fischer and Porter chlorine activated silica feeder.

The location of the chemical feed equipment, in the chemical feed building, is shown by Figure II. In general, this solution will be fed by Fischer and Porter indicating rotameters, with a low flow differential pressure transmitter and recorder. Alum liquor will be stored in a large poxyglas tank adjacent to a railroad siding, gravity fed to the chemical feed building, and transferred from the chemical feed building by a small chemical feed pump to the reactor-clarifier.

Activated silica will be formed by a chemical reation between sodium silicate (a liquid) and chlorine. Sodium silicate will be stored in a tank adjacent to the alum tank, and will flow by gravity from this tank to the chemical feed building. After being mixed with the chlorine, the activated silica will be pumped to the reactor-clarifier.

The proposed reactor clarifier is shown by Figure III.

The reactor-clarifier proposed for this project is the Type IS Accelator unit manufactured by the Infilco Co. of Tucson, Arizona. Using an upflow rate of 0.75 gpm/ft^2, a reactor-clarifier 98'-0" in diameter with a 15'-3" side liquor depth will be necessary.

AERATION BASIN SIZING

Total aeration basin volume as recommended by Busch is 2.5 MG. This is an equivalent volume of 334,200 cubic feet. An aeration volume of this amount would give a detention time of three hours. Busch further recommends that this aeration basin be broken up into two cells having a volume of 167,100 cubic feet each. On Figure IV is shown the dimensions and layout of the aeration basins. Effluent from the primary clarifier is fed by gravity to these aeration basins. The layout of this gravity feed system is also shown by Figure IV.

Primary to flowing into the aeration basins, the waste is fed with nutrients. The two nutrients, liquid ammonia and phosphoric acid, will be fed to the waste through a chemical feed well. The two feed wells are located between the primary clarifiers and the aeration basins.

The liquid ammonia, and phosphoric acid will be stored in two poxyglas tanks next to the alum and silica tanks, gravitied to the chemical feed building and pumped from the chemical building by two small solution pumps.

Aqueous ammonia will be purchased in tank car lots with a maximum concentration of 29.4% ammonia by weight. The amount of ammonia fed will be controlled by a Fischer and Porter recorder and controller. This device both controls and indicates.

Phosphoric acid feed will be controlled with a device similar to that used for alum feed. The amount of phosphoric acid fed will be recorded on a continuous strip chart indicator and totalizer.

Another design criteria to be met in aeration basin sizing, is to assure that the aeration volume is adequate to meet the requirements of the Mixed Liquor Suspended Solids (MLSS) ratio. Busch states in his recommended process design that 24,500 lbs/day of MLSS are required for oxidation. Based on an MLSS concentration of 1,200 mg/l the aeration volume required is:

$$\frac{24{,}500 \text{ lbs/day}}{1200 \text{ ppm}} \times \frac{1}{8.345 \text{ lbs/day}} = 2.45 \text{ MG}$$

This requirement is less than the 2.5 MG available.

The Engineers propose to design the two aeration cells from earthen levees, and to pave the levee slopes with concrete.

SURFACE AERATOR DESIGN

To supply the oxygen requirement for biological degradation, the Engineers will install mechanical, turbine-type surface entrainment aerators in the aeration basins.

From the information obtained from technical publications, it has been indicated that the horsepower necessary for the mixing process in the aeration basin is one horsepower per 1000 cubic feet or basin. As previously shown, each cell will have a volume of 167,100 cubic feet. Based on this criteria, approximately 167 horsepower is necessary for each basin.

As recommended by Busch, the oxygen uptake required to satisfy the total demand is 26,500 lbs/day. Assuming that two pounds of oxygen per horsepower per hour can be supplied by the mixers, a total requirement of:

$$\frac{26{,}500 \text{ lbs/day}}{2 \text{ lbs/hp/hr} \times 24 \text{ hrs}} = 550 \text{ hp}$$

is necessary for mixing. Because of the size range of these aerators, eight seventy-five horsepower mixers will be required. Turbine-type aerators, similar to the units manufactured by either the Infilco Co. or the Yeomans Co. are quite adequate to supply oxygen requirements.

FINAL CLARIFIER DESIGN

In the design criteria, a surface loading of 600 gallons per square foot per day was proposed for the final clarifier. Then, the necessary clarifier surface area is:

$$\frac{20{,}000{,}000 \text{ gal/day}}{600 \text{ gals/ft}^2\text{/day}} = 33{,}400 \text{ sq ft.}$$

If final clarification surface area is divided into two units, the area per unit is 16,700 sq ft. The diameter of each clarifier is $\frac{\pi d^2}{4} = 16{,}700$ sq ft,

then $\pi d^2 = 66{,}800$ sq ft

$$\text{or} \quad d^2 = 21{,}250 \text{ sq ft} \quad \text{or } d = 145 \text{ ft.}$$

Using a 145 foot diameter clarifier unit with a 10 foot side liquor depth gives a clarifier volume of:

$$\frac{\pi \times (145 \text{ ft})^2}{4} \times 10 \text{ ft} = 165{,}500 \text{ cu ft.}$$

Based on a flow of 20 MGD, a detention time of 2.95 hours would be allowed by the final clarifier.

Therefore, it is recommended by the Engineers that a final clarifier having a tank diameter of 145 feet and a side liquor depth of 10 feet be utilized for final clarification. It is also recommended that mechanical clarifier equipment similar to the Rex Unitube Tow-Bro Sludge Remover as manufactured by the Chain Belt Co. be used. The installation of this equipment in a final clarifier tank is shown by Figure V. As with the primary clarifier and aeration basin, it is proposed to construct the final clarifier basin from earthen embankments with sides and bottom paved with concrete.

SIZING OF SLUDGE TRANSFER PUMPS

Sludge transfer from each final clarifier to each aeration basin is equal to Q/4 = 3500 gpm. Pumping arrangement and capacity must be provided so that each clarifier will be provided with at least one standby pump available. To meet this requirement, three pumps with a capacity of 3500 gpm each will be required. To transfer this sludge, it is recommended that non-clog centrifugal pumps be used.

SLUDGE THICKENER DESIGN

The sludge thickener will be designed on the basis of a surface loading of 200 pounds per square foot per ton of solids produced per day. Based on this criteria, it is recommended that a 65 foot diameter thickener, with a 10 foot side liquor depth, similar to a Type H thickener as manufactured by Dorr-Oliver, Incorporated be installed. Figure VI shows the installation of this equipment in an earthen paved basin. The basin sides will be on a 1:1 slope.

SLUDGE DISPOSAL

Excess sludge is thickened and combined with the sludge from primary clarification for disposal.

Sludge disposal may be carried out in either of two ways: incineration or lagooning. The use of sludge drying beds has been dismissed because of the large area required (approximately 1.75 acres).

Lagooning can be done in the existing aeration ponds, but the ponds will have to be cleaned of the existing heavy accumulation of fiber. However, it is recommended that sludge disposal initially be carried out by wasting into these existing aeration ponds. It will be necessary to run tests on the sludge to determine the degree to which it can be dewatered before a final recommendation on sludge incineration can be made. The problem of sludge disposal by incineration is discussed in some detail in the appendix of this report.

EFFLUENT DISPOSAL

The final treated effluent will be conveyed, by gravity pipe line, around the existing aeration ponds to a discharge point on Mill Creek for eventual disposal into the Angelina River. The location of this proposed pipeline is shown by Figure VIII.

All gravity pipe line should be designed for 1.50 times the normal flow in order to assure adequate capacity during storm water surges. Therefore, for an average flow of 20 MGD, the design flow is 30 MGD. Using an n value of 0.013, would require a minimum pipe size of 36-inches to handle the design flow. The effluent pipe will be laid on a grade that would maintain a minimum velocity of 2.0 feet per second.

The layout of each treatment component as it exists at the proposed plant site is shown by Figure VII.

SECTION V

COST ESTIMATE

The following is a detailed cost estimate for the waste treatment facilities at the Lufkin mill.

A. SITE PREPARATION		
1. Excavation; 150,000 cu yd @ $0.50		$ 75,000.00
2. Steel Crib-Type Retaining Wall;		
a. 6'-12' high, 850' @ $50.00	$42,500.00	
b. 12'-16' high, 325' @ $85.00	$27,500.00	
c. 16'-18' high, 300' @ $110.00	$33,000.00	
3. Roads and Misc.	$30,000.00	
		$ 103,000.00
B. ENTRANCE STRUCTURE		
1. Excavation; 50 cu yd @ $1.50	$ 75.00	
2. Reinforced Concrete; 22 cu yd @ $90.00	$ 2,000.00	
3. Accessories and Misc.;	$ 250.00	
		$ 2,325.00
C. INFLUENT FLOW DIVIDER		
1. Excavation; 54 cu yd @ $1.50	$ 80.00	
2. Reinforced Concrete; 21 cu yd @ $90.00	$ 1,680.00	
		$ 1,760.00
D. PRIMARY CLARIFICATION		
1. Excavation; 11,800 cu yd @ $1.00	$11,800.00	
2. Reinforced and Misc. Concrete; 456 cu yd @ $80.00	$36,600.00	
3. Reactor-Clarifier Mechanisms; 2 each @ $57,500	$115,000.00	
4. Electrical	$ 5,000.00	
		$168,400.00
E. CHEMICAL FEED WELLS (2)		$ 2,900.00

F. AERATION BASINS

1. Excavation; 14,000 cu yd @ $1.00	$14,000.00	
2. Reinforced and Misc. Concrete; 1,400 cu yd @ $80.00	$112,000.00	
3. Mechanical Aerators, Starters and Motors; 8 each @ $17,750	$142,000.00	
4. Misc. Piping, Walkways and Equipment	$24,000.00	
5. Electification	$75,000.00	
		$367,000.00

G. FINAL CLARIFICATION

1. Excavation; 13,000 cu yd @ $1.00	$13,000.00	
2. Reinforced and Misc. Concrete; 321 cu yd @ $80.00	$26,000.00	
3. Clarifier Mechanisms; 2 each @ $71,500	$143,000.00	
4. Electrification	$ 2,000.00	
		$184,000.00

h. SLUDGE THICKENER

1. Excavation; 2,000 cu yd @ $1.00	$ 2,000.00	
2. Reinforced and Misc. Concrete; 130 cu yd @ $80.00	$10,400.00	
3. Thickener Mechanism	$17,000.00	
4. Electrical	$ 2,000.00	
		$ 31,400.00

I. SLUDGE RETURN

1. 3500 gpm Pumps and Motors; 3 each @ $4,000.00	$12,000.00	
2. Foundations and Misc.	$15,000.00	
		$ 27,000.00

J. CHEMICAL STORAGE		
1. 16,000 Gal. Poxyglas Storage Tanks; 4 @ $3,000	$12,000.00	
2. Foundation	$ 4,000.00	
3. Unloading Apparatus	$15,000.00	
4. Piping and Fittings	$ 5,000.00	
5. Railroad Spur	$ 7,500.00	
		$ 43,500.00
K. CHEMICAL FEED BUILDING		
1. Building; 670 sq ft @ $12.00	$ 8,000.00	
2. Chemical Feeders, Pumps and Instrumentation	$36,000.00	
3. Chlorine Shed and Misc. Equipment	$11,000.00	
4. Utilities	$ 5,000.00	
		$ 60,000.00
L. YARD PIPING		
1. 42" Concrete Pipe; 550 lin ft @ $21.00	$11,600.00	
2. 30" A-C Pipe; 580 lin ft @ $18.00	$10,400.00	
3. 30" C.I. Pipe; 200 lin ft @ $20.00	$ 4,000.00	
4. 18" A-C Pipe; 300 lin ft @ $14.00	$ 4,200.00	
5. 16" C.I. Pipe; 80 lin ft @ $15.00	$ 1,200.00	
6. 12" A-C Pipe; 1,080 lin ft @ $8.50	$ 9,200.00	
7. 12" C.I. Pipe; 300 lin ft @ $14.00	$ 4,200.00	
8. 6" C.I. Pipe; 1,500 lin ft @ $7.00	$10,500.00	
9. Misc. Valves, Fittings and Meters	$25,000.00	
		$ 80,300.00

M. EFFLUENT PIPELINE

1. 36" Gifford-Hill Concrete Pretensioned Pipe; 7,600 lin ft @ $18.00 — $145,000.00

2. Structures and Clearing — $ 40,000.00

		$185,000.00
Sub-Total		$1,361,585.00
Contingencies @ 10%		136,415.00
Sub-Total		$1,498,000.00
Overhead & Indirect		222,000.00
Sub-Total		1,720,000.00
Contractor's Profit @ 10%		172,000.00
TOTAL CONSTRUCTION		$1,892,000.00
Engineering @ 5%		95,000.00
TOTAL PROJECT COST		$1,987,000.00

SECTION VI

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7. McKinney, Ross E.; Microbiology for Sanitary Engineers, McGraw-Hill Book Company, New York; 1962; pp. 216-219.

SECTION VII

APPENDIX

SLUDGE DISPOSAL

The solution to the problem of sludge disposal at the Lufkin mill is dependent on two factors: the dewaterability and the BTU value of the sludge. Neither of these qualities can be determined until the treatment plant is in actual operation and the thickened primary and activated sludge from the thickener can be sampled and tested. In this report, it has been recommended that sludge disposal be accomplished by wasting to the existing oxidation ponds until these sludge qualities can be determined. If it can be shown that the sludge can be dewatered sufficiently and that it has a BTU value that will support reasonable combustion, it is recommended that the sludge be incinerated.

Waste activated sludge is notoriously difficult to dewater. The reason is that the sludge is very low in suspended solids (in the normal sense of the term) and consists almost entirely of microbes. These tiny animals are themselves over 95% water and are very light. Some activated sludges, however, prove more amenable to dewatering than others, depending on the character of the sludge (the types and characteristics of the microbes present).

Primary sludge, on the other hand, is much easier to dewater because it is relatively high in suspended solids and very low in microbial content. Again, however, the dewaterability will vary depending on the sludge in question. A sludge that is high in floatables will have different dewatering characteristics than a heavy sludge with few floatables. When the primary sludge and waste activated sludge are combined for disposal, as at the Lufkin mill, then the sludge characteristics are a combination that can only be determined by testing the combined sludge as it comes from the thickener.

Economical incineration also depends on the BTU value of the sludge. Incinerator operation is usually based on some utilization of the heat value of the waste in the burning process. The channelling of this heat back into the burning cycle makes it possible, after a time, to turn off the external fuel supply and to use this recycled heat to consume the incoming waste. The heat produced by the burning of the incoming waste is in turn, recycled and the process begins again. In a real sense, the incinerator "runs itself".

If the BTU value of the waste is very low, however, then the heat produced during combustion is very low. The length of time during which fuel must be supplied to the process varies inversely as the BTU value of the waste being burned.

The BTU value of activated sludge is dependent on the types of microbes present but is usually low. Primary sludge, on the other hand, usually has a relatively high BTU value. The BTU value of any combination of the two sludges, therefore, cannot be determined until the combination is actually produced.

It is recommended that testing of the thickened sludge begin as soon as the treatment plant is placed in operation so that the burning characteristics can be determined.

<u>ADDITIONAL REPORTS</u>

The following is a reproduction of a report prepared by Arthur W. Busch, Consulting Engineer, containing the process recommendations for waste treatment at the Lufkin mill.

A.W. BUSCH
CONSULTING ENGINEER
P.O. BOX 1892 HOUSTON, TEXAS 77001

March 31, 1965

Mr. R. M. Millwee, Jr.
Project Engineer
Brown & Root, Inc.
P. O. Box 3
Houston, Texas 77001

Dear Mr. Millwee:

Attached is my report on Waste Treatment Process Design for Southland Paper Mills, Inc., Lufkin and Sheldon, Texas Plants as authorized in your letter of October 22, 1964.

As a result of the extensive laboratory study made by Southwest Research Institute in cooperation with Southland Mills personnel, an effective, economical process design is possible.

If there are questions regarding the contents, I shall be pleased to discuss these with you.

Yours very truly,

A. W. Busch

AWB:tr
Attachment

A REPORT ON

WASTE TREATMENT PROCESS DESIGN FOR SOUTHLAND PAPER MILLS, INC., LUFKIN AND SHELDON, TEXAS PLANTS

Prepared for
Brown & Root, Inc.
P. O. Box 3
Houston, Texas 77001

by
A. W. Busch
Consulting Engineer
P. O. Box 1892, Houston, Texas

March, 1965

TABLE OF CONTENTS

SUMMARY

This report, authorized by Mr. R. M. Millwee, Jr., of Brown & Root, Inc., on October 22, 1964, has as its purpose the presentation of process design recommendations for waste treatment at two Southland Paper Mills, Inc., plants. The scope is limited to the removal of organic matter and biological solids.

The recommended process, biological oxidation (activated sludge), is based on analytical and experimental data contained in two Southwest Research Institute reports, dated December 18, 1964, and March 11, 1965. The data presented in these reports have permitted the design of waste treatment processes to meet the effluent requirements imposed by the Texas Water Pollution Control Board.

Recommendations are made for treatment process design, fiber removal studies, and consideration of start-up and operation of the treatment plants.

PURPOSE AND SCOPE

This report was authorized by a letter, dated October 22, 1964, from Mr. R. M. Millwee, Jr., Project Engineer, Brown & Root, Inc. The purpose of the report is to present process design recommendations based on the analytical and experimental data contained in the Southwest Research Institute reports of December 18, 1964 and March 11, 1965.

The scope of this report encompasses treatment of wastes at two plants:

1) The existing integrated mill at Lufkin, Texas, 20 M.G.D. flow; and

2) The new groundwood mill to be built at Sheldon, Texas, 2.5 M.G.D. flow.

The effluent criteria for both treatment processes are 20 mg/l $B.O.D._5$ and 20 mg/l suspended solids. The color problem is specifically excluded from the scope of this report. The process design calculations presented are based on prior removal of fiber. While fiber removal processes are not within the scope of the report, comments regarding recommended procedures are included.

GENERAL WASTE CHARACTERISTICS

Lufkin Mill

The Lufkin plant of Southland Paper Mills, Inc. is a fully integrated mill and the waste includes streams from groundwood, pulping, bleaching, and paper making operations plus the miscellaneous ancillary equipment and processes. The design flow used in this report is 20 M.G.D. Detailed analyses of this waste are presented in a joint report of the writer and Southwest Research Institute, dated December 18, 1964, and in the Southwest Research Institute report of March 11, 1965. The waste is amenable to biological treatment without prior adjustment of pH. Two characteristics of the waste deserve special emphasis:

1) The waste is essentially devoid of the primary nutrients, nitrogen and phosphorus and will require supplementary feeding.

2) There is a critical concentration of the waste which is toxic to the micro-organisms used in biological treatment. The process design must give cognizance to this factor.

Sheldon Mill

The mill to be built at Sheldon will initially produce only groundwood. The waste characteristics are fully detailed in the two previously referenced reports. The only critical factor in biological treatment of this waste is the need for supplementation of nitrogen and phosphorus for bacterial nutrition.

PROCESS DESIGN

General

The experimental data obtained by the Southwest Research Institutes are of excellent consistency and lend themselves to a rigorous process design for the production of an effluent of specified quality. The major limitation of the data (common to all laboratory studies) is that they were obtained under conditions of only one, uniform, temperature. Because the micro-organisms operative in biological oxidation are temperature sensitive, this parameter can not be neglected. Of greatest significance is the temperature of the mixed liquor during winter operation for lower temperatures decrease the rate at which the organisms accomplish their work.

A brief summary of biological oxidation is pertinent for effective process design evaluation. Biological oxidation is simply a conversion process wherein dissolved organic compounds are converted into bacterial cells which can then be removed from the waste water. The process is discrete and can be described by stoichiometric equations. In an aerobic environment not limited by mixing or nutrients the unit rate of conversion, or removal, of organics is proportional to the concentration of organics present. Thus, a fixed mass of organisms is required to remove a predetermined number of pounds of organics per unit time for a specific effluent quality. In contrast to this rigid requirement, the hydraulic environment is immaterial. That is, the required mass of or ganisms may be dispersed in any volume which can be adequately mixed and aerated. Thus the hydraulic hold-up time is not a fundamental parameter of design.

Once the organism mass has been determined, the rate of net increase of the population can be evaluated. This rate is a function of process environment and is of significance in controlled solids operation and in predicting excess solids production.

Controlled solids operation can meet temperature effects readily by simply increasing the population concentration to compensate for a decrease in unit rate of removal.

Recommended Process Design

The following recommendations are based on the waste criteria presented below and on the experimental data contained in the Southwest Research Institute report of March 11, 1965:

Lufkin Mill

Flow: 20 million gallons per day
$T_bO.D.$ (Removable COD): 42,500 lb./day
Effluent quality: 20 mg/l BOD_5
35 mg/l T_bOD
20 mg/l suspended solids
M.L.S.S. required: 24,500 lb.
Aeration volume recommended: 2.5 MG

M.L.S.S. concentration: 1,200 mg/l
Clarification area: 33,333 $ft.^2$ (600 gpd/ft^2)
Solids produced (excess): 7,340 lb/day
Oxygen required: 26,400 lb/day
Nitrogen requirements: 1500 lb. N; 1800 lb. NH_3/day
Phosphorus requirement: 300 lb. P; 950 lb. H_3PO_4/day

The aeration volume should be divided into at least two units. The volume of the waste stream carrying the excess solids will, of course, depend on the concentration of the solids. If a single unit system such as the Aero-Accelator is used, a thickener should be provided to concentration excess solids. This unit should be sized to handle 7340 lbs. of solids per day in a flow of 515 gpm. The underflow from the thickener, containing the excess solids would be about 30 gpm (2% solids concentration).

If separate aeration and clarification units are used, the underflow from the excess solids unit would amount to about 60 gpm (1% solids concentration) and no thickener would be required. The separate clarifier for excess solids should be sized for 0.8 MGD at a surface loading of 600 gpd/ft^2.

A schematic drawing of the two flowsheets is presented in Figure 1.

Sheldon Mill

Flow: 2.5 million gallons per day
T_bOD (Removable COD): 6000 lb/day
Effluent quality: 20 mg/l BOD_5
35 mg/l T_bOD
20 mg/l suspended solids
M.L.S.S. required: 3,000 lb.
Aeration volume recommended: 0.36 M.G.
M.L.S.S. concentration: 1,000 mg/l
Clarification area: 4,200 ft^2 (600 gpd/ft^2)
Solids produced (excess): 1,600 lb./day
Oxygen required: 3,100 lb./day
Nitrogen required: 200 lb. N; 240 lb. NH_3/day
Phosphorus required: 40 lb. P; 125 lb. H_3PO_4/day

Again two units are preferable for the provision of the aeration volume. If Aero-Accelators are used the excess solids stream to the thickener would be approximately 135 gpm and the under flow at 2 per cent solids would be about 7 gpm.

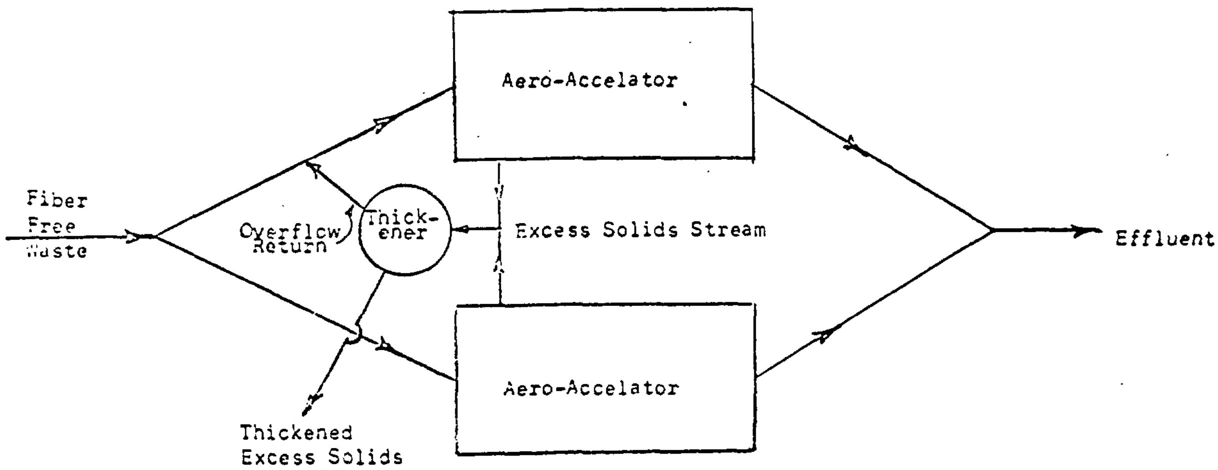
If separate aeration and clarification units are used, the underflow from the excess solids unit would be about 15 gpm. The separate clarifier for excess solids should be sized for 135 gpm at the recommended surface loading of 600 gpd/ft^2.

OTHER RECOMMENDATIONS

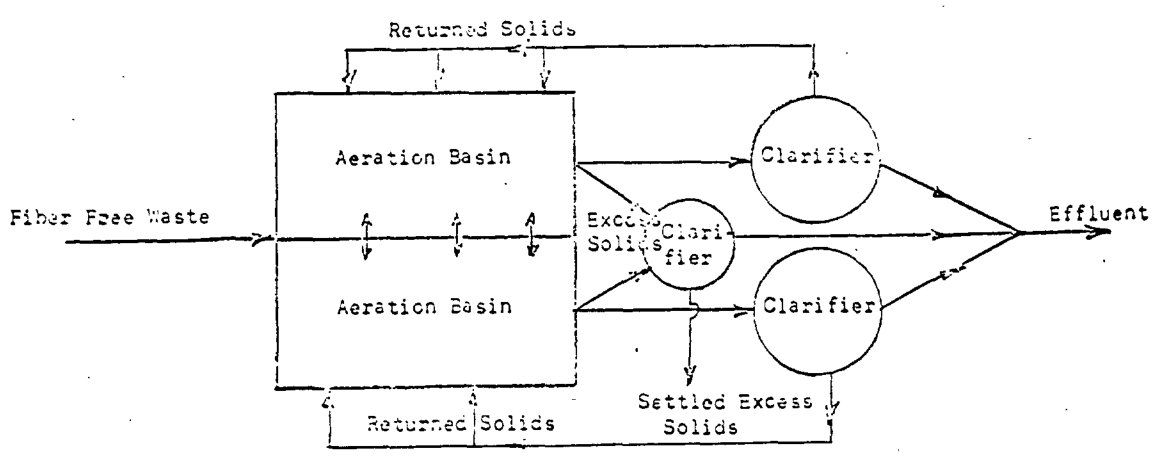
Fiber Removal

The problem of fiber removal is so vital to effective control of the

BY AWB DATE 3/27/65 SUBJECT Southland Paper Mills, Inc. SHEET NO. ____ OF ____
CHKD. BY ____ DATE ____ JOB NO. ____



INTEGRAL AERATION AND CLARIFICATION
WITH EXTERNAL THICKENING

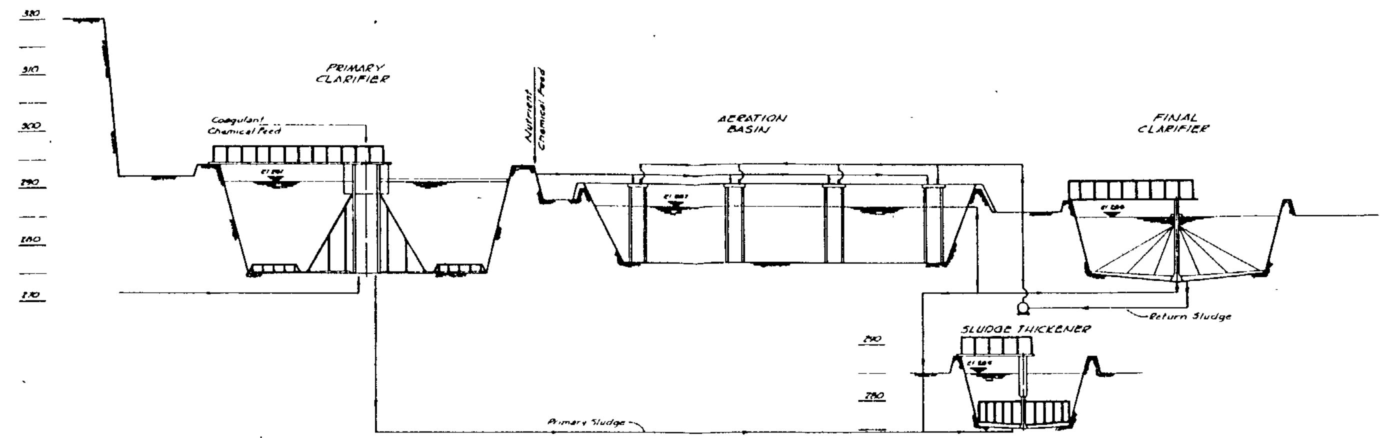


SEPARATE AERATION AND CLARIFICATION
WITHOUT THICKENING

FIGURE I - SCHEMATIC DRAWINGS OF ALTERNATE FLOWSHEETS biological treatment process that further comment is felt justified. Experience at numerous mills has shown that plain sedimentation is not effective for fiber removal. The only methods which have proved workable involve chemical treatment, either in flotation or gravity units. It is strongly recommended tha laboratory studies be made to determine the chemical costs involved and to provide a basis for process and equipment design. It is furthermore recommended that fiber removal be made an inherent part of the waste treatment plant design.

Plant Start-up and Operation

Because of the stringent effluent quality criteria which must be met, proper start-up and operation of the treatment process is especially significant. While a detailed discussion of these points is not within the scope of this project, continued emphasis on these important factors is recommended.



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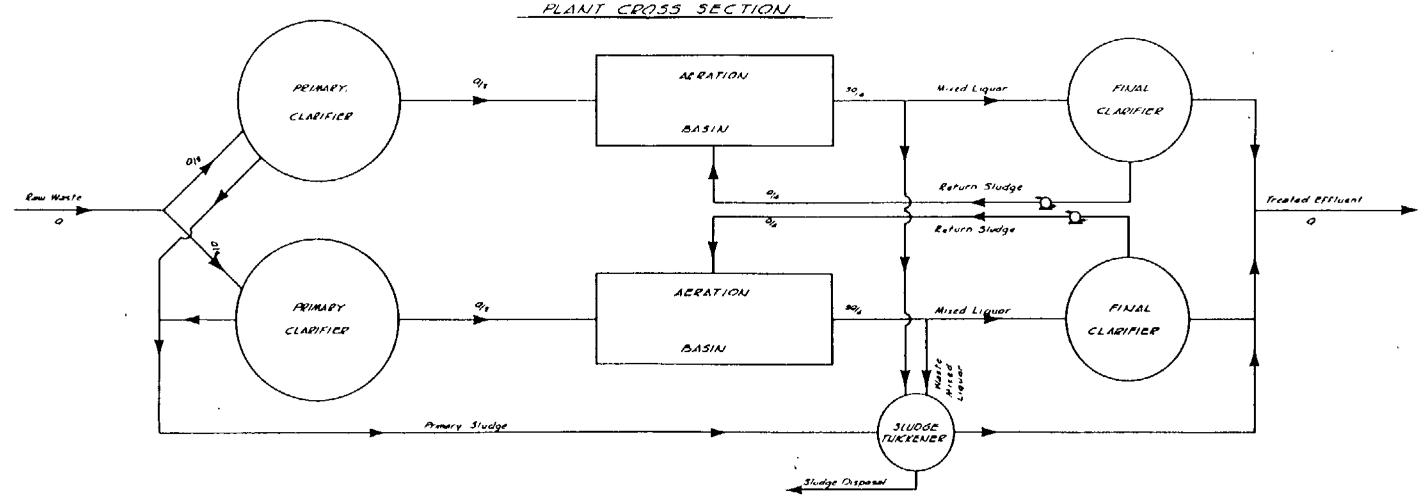


PLANT FLOW DIAGRAM

NOTES	REVISIONS / BY / DATE	REVISIONS / BY / DATE

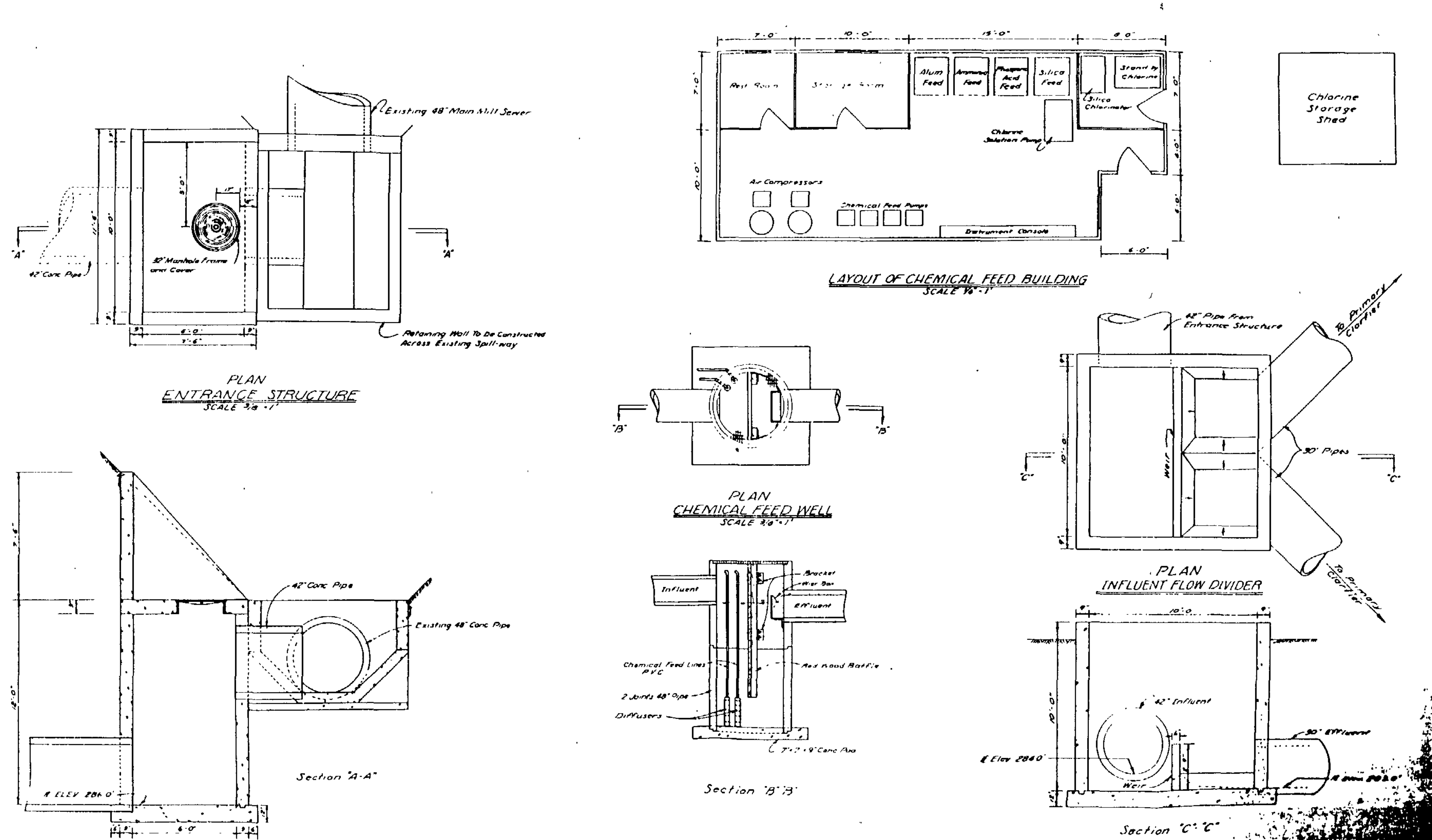
BROWN-BILT

BROWN & ROOT, INC.
ENGINEERS AND CONSULTANTS
HOUSTON, TEXAS

DRAWN BY:	CHK'D BY:	APPROVED	SCALE
DATE:	DATE:		

TITLE OF DRAWING: PROCESS FLOW DIAGRAMS
WASTE TREATMENT FACILITIES
NAME OF OWNER: SOUTHLAND PAPER MILLS, INC
LOCATION OF PROJECT: LUFKIN, TEXAS

CONTRACT NO: E-367
B&R DWG NO: FIGURE I
SHEET I OF VIII



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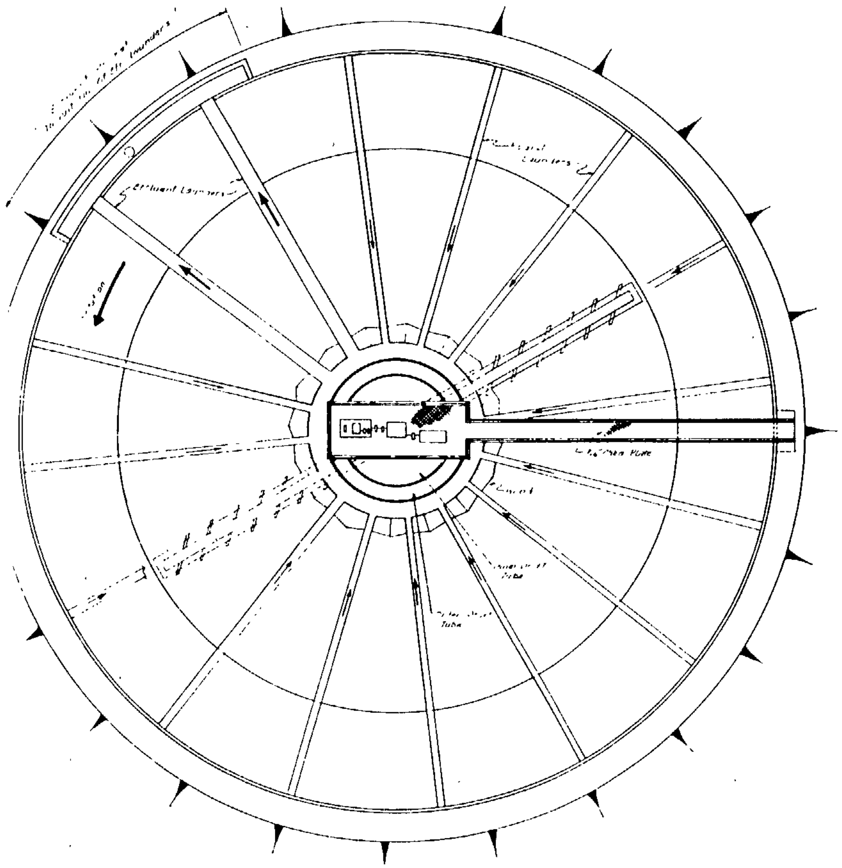
CHK'D BY: J M A — DATE: 4-65
APPROVED
SCALE: AS SHOWN

TITLE OF DRAWING: CHEMICAL FEED BUILDING
WASTE TREATMENT
NAME OF OWNER: SOUTHLAND
LOCATION OF PROJECT: LUFKIN



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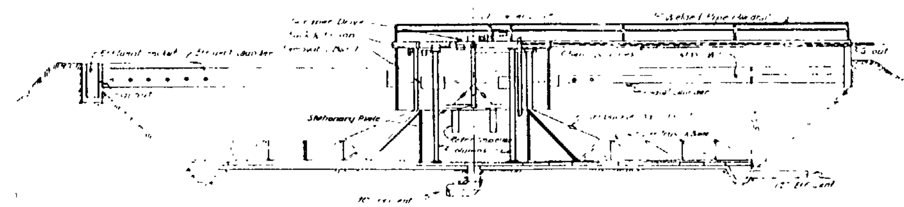

ELEVATION

NOTES	REVISIONS • BY • DATE	REVISIONS • BY • DATE

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HOUSTON, TEXAS

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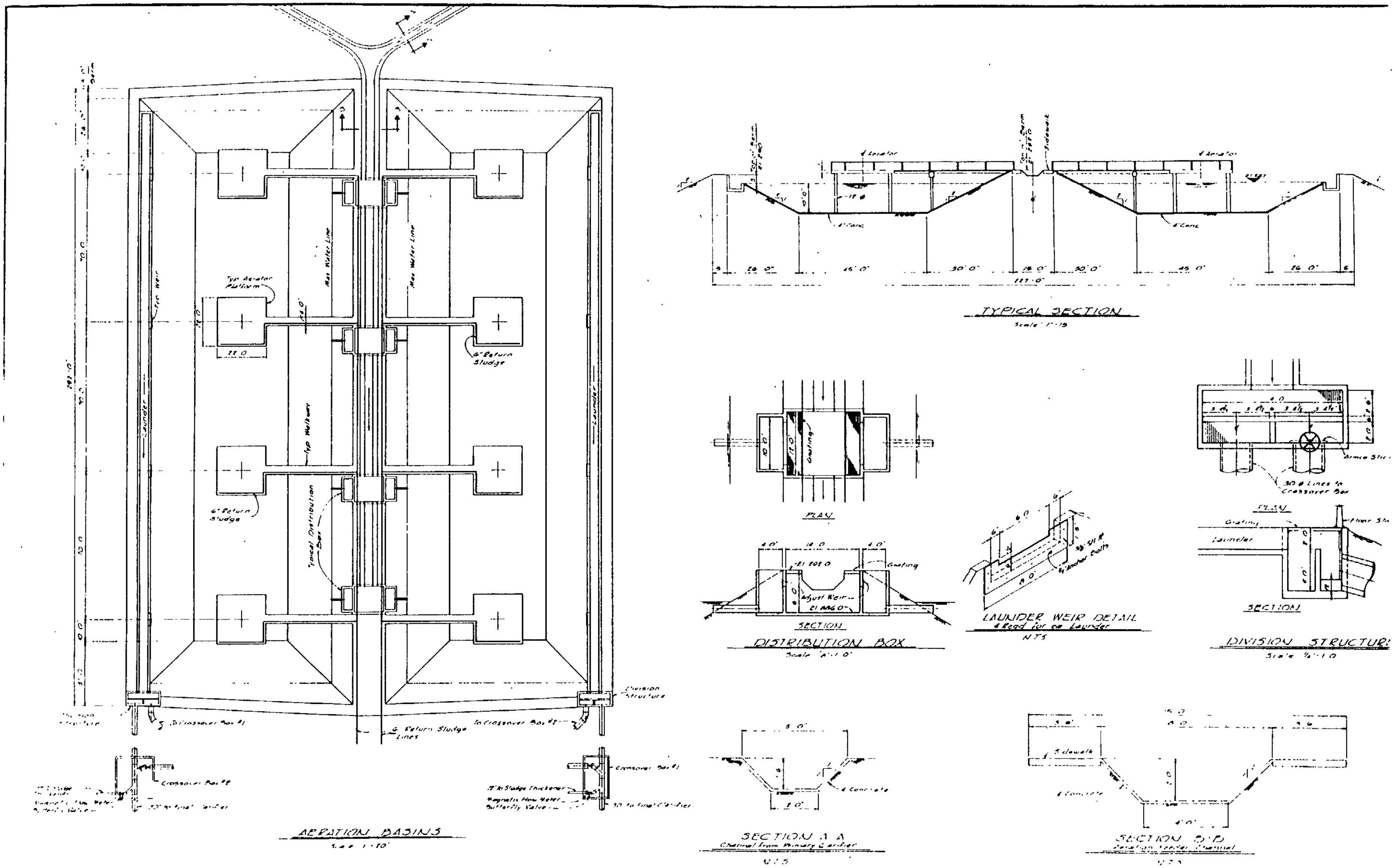
[illegible]			AS SHOWN
DATE 4-55	DATE		

TITLE OF DRAWING: PRIMARY CLARIFIER
WASTE TREATMENT FACILITIES
NAME OF OWNER: SOUTHLAND PAPER MILLS, INC
LOCATION OF PROJECT: LUFKIN, TEXAS

CONTRACT NO. E - 367
DRAWING NO. FIGURE III
SHEET III OF XIII

[redacted]

CONTRACT NO F-367



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BROWN-BILT

BROWN & ROOT, INC.
ENGINEERS AND CONSULTANTS
HOUSTON, TEXAS

DRAWN BY	CHK'D BY	APPROVED	SCALE
M. J. DATE 4-65	DATE 4-65		

TITLE OF DRAWING: AERATION BASINS
WASTE TREATMENT FACILITIES
NAME OF OWNER: SOUTHLAND PAPER MILLS, INC
LOCATION OF PROJECT: LUFKIN, TEXAS

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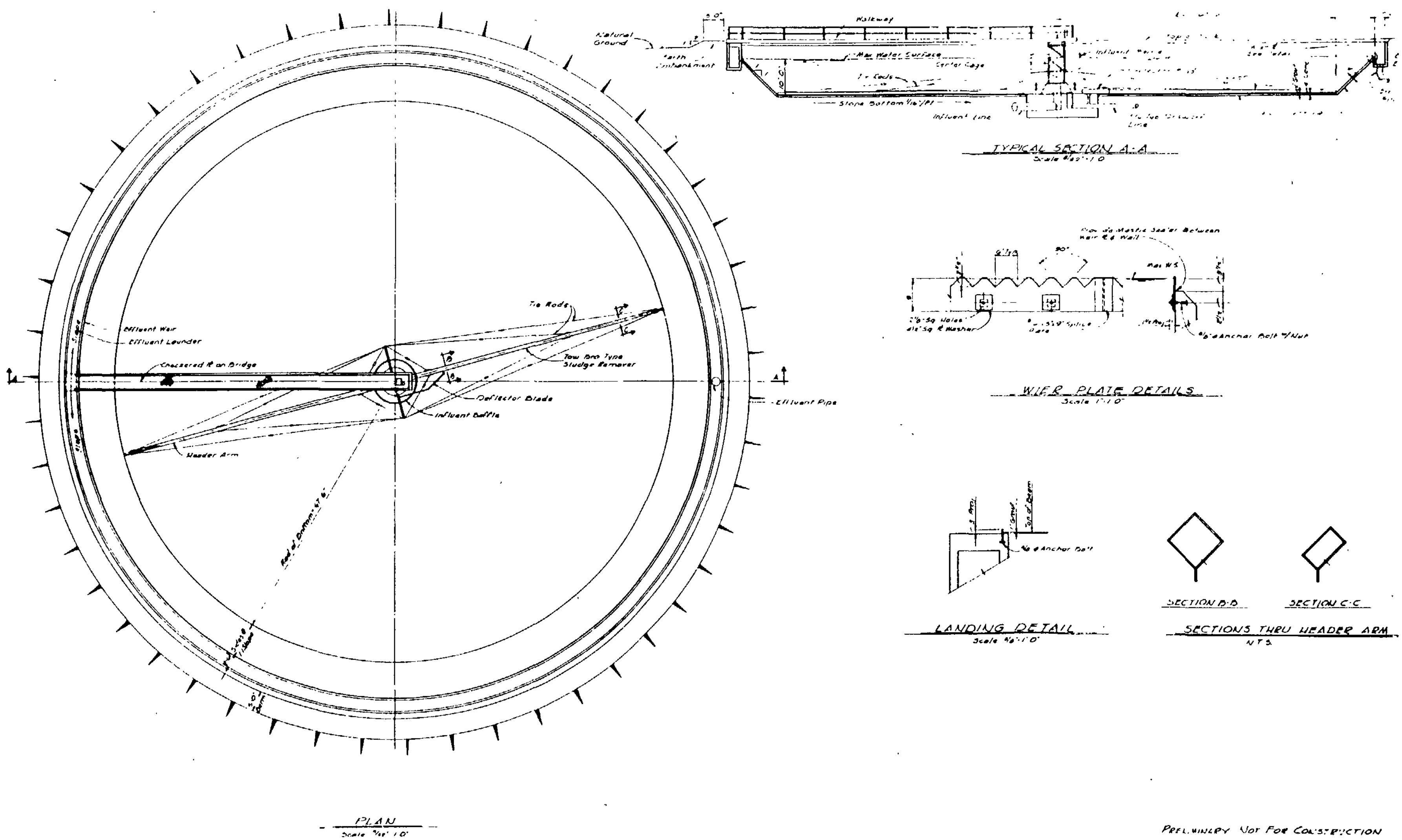

PRELIMINARY NOT FOR CONSTRUCTION

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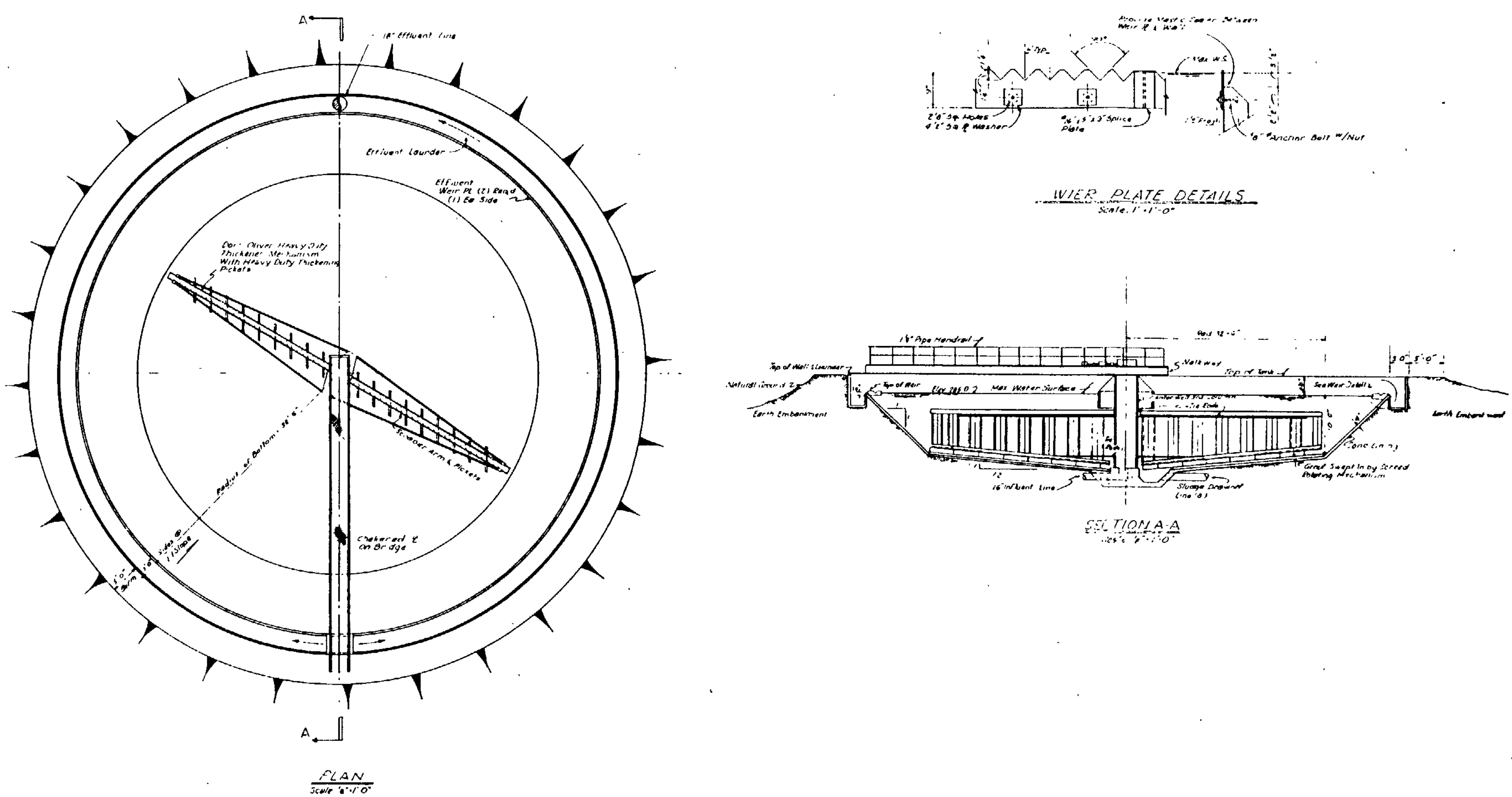
HOUSTON, TEXAS

DRAWN BY: M.J.J. DATE 4-62 — CHK'D BY: DATE 4-62 — APPROVED — SCALE

TITLE OF DRAWING: FINAL CLARIFIER
WASTE TREATMENT FACILITIES
NAME OF OWNER: SOUTHLAND PAPER MILLS, INC
LOCATION OF PROJECT: LUFKIN, TEXAS

FIGURE



BROWN & ROOT, INC.
ENGINEERS AND CONSTRUCTORS
HOUSTON, TEXAS

BROWN-BILT

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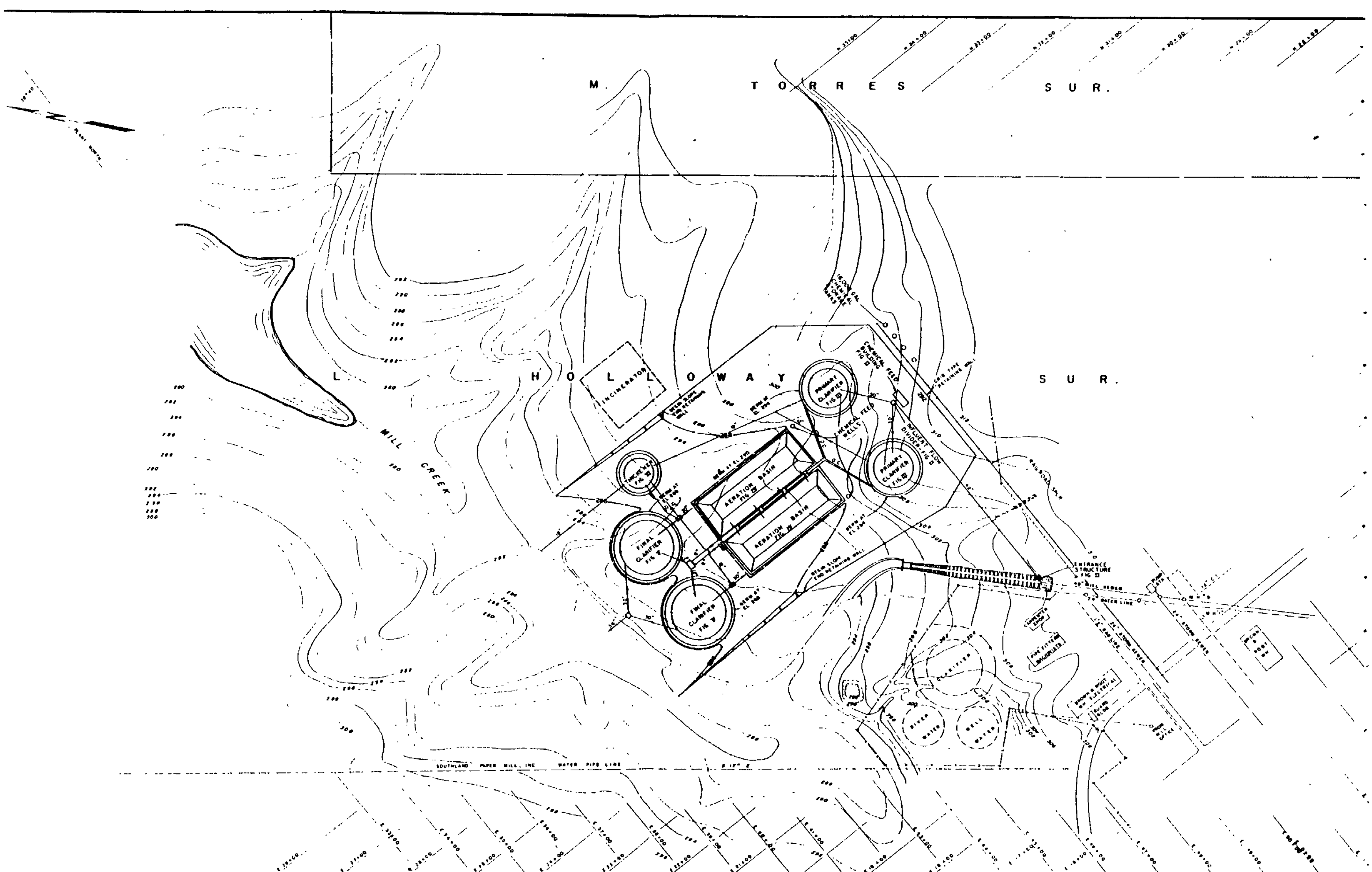
DATE: 4-65	DATE:			

TITLE OF DRAWING: SLUDGE THICKENER
WASTE TREATMENT FACILITIES
NAME OF OWNER: SOUTHLAND PAPER MILLS, INC.
LOCATION OF PROJECT: LUFKIN, TEXAS

CONTRACT NO. E-367
DRAWING NO. FIGURE XI
SHEET XI OF XII

NOTES

REVISIONS	BY	DATE	REVISIONS	BY	DATE



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BROWN & ROOT, INC.
ENGINEERS AND CONSULTANTS
HOUSTON, TEXAS

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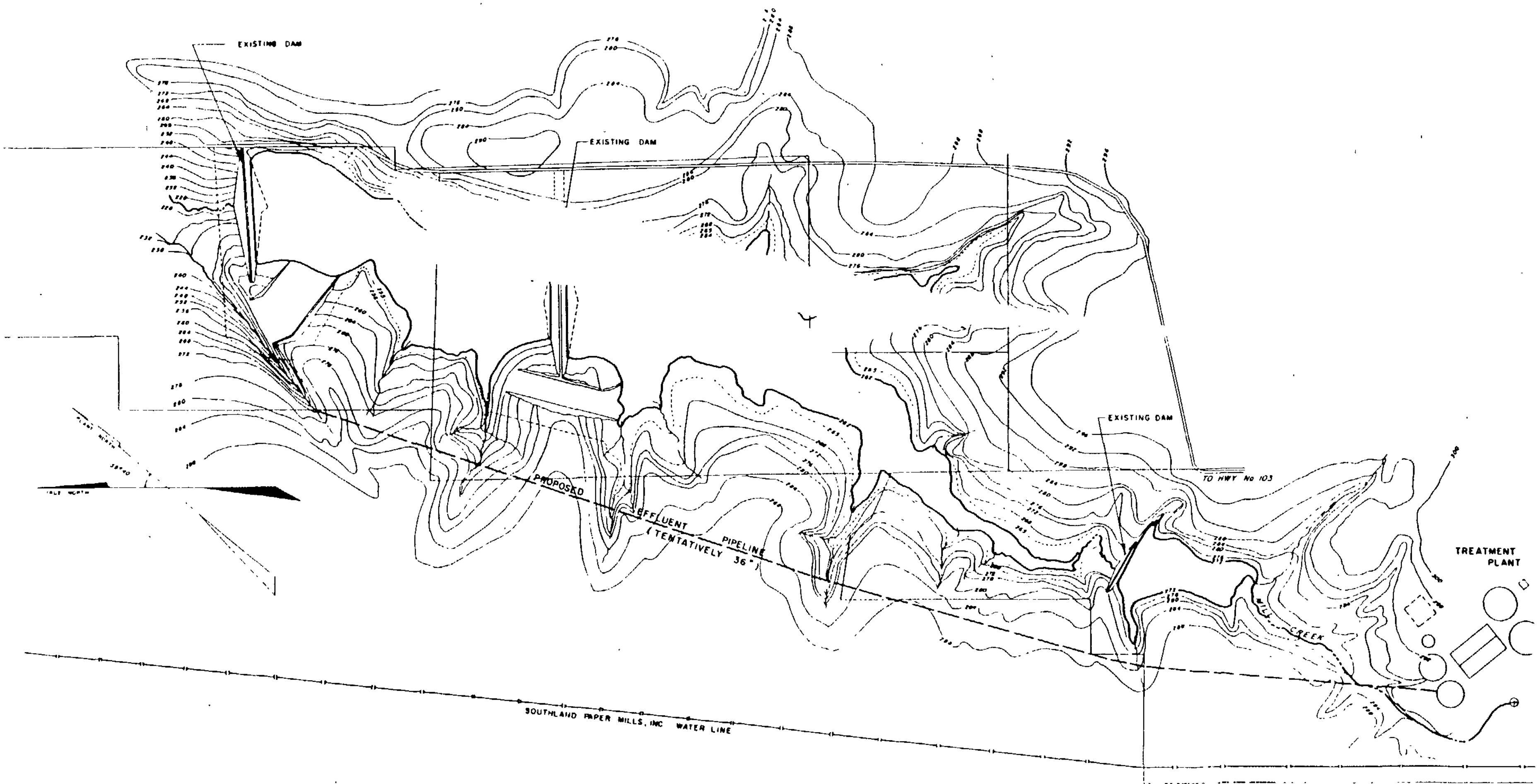
G. MONEYHUN DATE 2-16-62	J.E.H. DATE 4-62		1" = 100'

TITLE OF DRAWING: PLANT LAYOUT
WASTE TREATMENT FACILITIES
NAME OF OWNER: SOUTHLAND PAPER MILLS, INC
LOCATION OF PROJECT: LUFKIN, TEXAS

CONTRACT E-3
DRAWING FIGURE
SHEET III



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REVISIONS	BY	DATE	REVISIONS	BY	DATE

BROWN-BILT

BROWN & ROOT, INC.
ENGINEERS AND CONSULTANTS
HOUSTON, TEXAS

DRAWN BY	CHK'D BY	APPROVED	SCALE
T.D.B.			
DATE 6-15	DATE		

TITLE OF DRAWING: EFFLUENT PIPE LINE LOCATION
WASTE TREATMENT FACILITIES
NAME OF OWNER: SOUTHLAND PAPER MILLS, INC.
LOCATION OF PROJECT: LUFKIN, TEXAS

CON. E
DWG. FIGURE
SHEET

A REPORT ON WASTE TREATMENT PROCESS DESIGN FOR SOUTHLAND PAPER MILLS, INC., LUFKIN AND SHELDON, TEXAS PLANTS

By: A. W. Busch

A. W. BUSCH
CONSULTING ENGINEER
P. O. BOX 1802   HOUSTON, TEXAS 77001

RESIDENCE PHONE
MO 7-4807

BUSINESS PHONE
JA 8-4141

March 31, 1965

Mr. R. M. Millwee, Jr.
Project Engineer
Brown & Root, Inc.
P. O. Box 3
Houston, Texas 77001

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A. W. Busch

AWB:tr
Attachment.

A REPORT ON

WASTE TREATMENT PROCESS DESIGN FOR SOUTHLAND PAPER MILLS, INC., LUFKIN AND SHELDON, TEXAS PLANTS

Prepared for

Brown & Root, Inc.

P. O. Box 3

Houston, Texas 77001

by

A. W. Busch

Consulting Engineer

P. O. Box 1892, Houston, Texas

March, 1965

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The scope of this report encompasses treatment of wastes at two plants:

1) The existing integrated mill at Lufkin, Texas, 20 M.G.D. flow; and
2) The new groundwood mill to be built at Sheldon, Texas, 2.5 M.G.D. flow.

The effluent criteria for both treatment processes are 20 mg/l $B.O.D._5$ and 20 mg/l suspended solids. The color problem is specifically excluded from the scope of this report. The process design calculations presented are based on prior removal of fiber. While fiber removal processes are not within the scope of the report, comments regarding recommended procedures are included.

GENERAL WASTE CHARACTERISTICS

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The Lufkin plant of Southland Paper Mills, Inc. is a fully integrated mill and the waste includes streams from groundwood, pulping, bleaching, and paper making operations plus the miscellaneous ancillary equipment and processes. The design flow used in this report is 20 M.G.D. Detailed analyses of this waste are presented in a joint report of the writer and Southwest Research Institute, dated December 18, 1964, and in the Southwest Research Institute report of March 11, 1965. The waste is amenable to biological treatment without prior adjustment of pH. Two characteristics of the waste deserve special emphasis:

1) The waste is essentially devoid of the primary nutrients, nitrogen and phosphorus, and will require supplementary feeding.
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The experimental data obtained by the Southwest Research

Institute are of excellent consistency and lend themselves to a rigorous process design for the production of an effluent of specified quality. The major limitation of the data (common to all laboratory studies) is that they were obtained under conditions of only one, uniform, temperature. Because the microorganisms operative in biological oxidation are temperature sensitive, this parameter can not be neglected. Of greatest significance is the temperature of the mixed liquor during winter operation for lower temperatures decrease the rate at which the organisms accomplish their work.

A brief summary of biological oxidation is pertinent for effective process design evaluation. Biological oxidation is simply a conversion process wherein dissolved organic compounds are converted into bacterial cells which can then be removed from the waste water. The process is discrete and can be described by stoichiometric equations. In an aerobic environment not limited by mixing or nutrients the unit rate of conversion, or removal, or organics is proportional to the concentration of organics present. Thus, a fixed mass of organisms is required to remove a predetermined number of pounds of organics per unit time for a specific effluent quality. In contrast to this rigid requirement, the hydraulic environment is immaterial. That is, the required mass of organisms may be dispersed in any volume which can be adequately mixed and aerated. Thus the hydraulic hold-up time is not a fundamental parameter of design.

Once the organism mass has been determined, the rate of net increase of the population can be evaluated. This rate is a function of process environment and is of significance in controlled solids operation and in predicting excess solids production.

Controlled solids operation can meet temperature effects readily by simply increasing the population concentration to compensate for a decrease in unit rate of removal.

Recommended Process Design

The following recommendations are based on the waste criteria presented below and on the experimental data contained in the Southwest Research Institute report of March 11, 1965:

Lufkin Mill

Flow: 20 million gallons per day
$T_bO.D.$ (Removable COD): 42,500 lb./day
Effluent quality: 20 mg/l BOD_5
35 mg/l T_bOD
20 mg/l suspended solids
M.L.S.S. required: 24,500 lb.
Aeration Volume recommended: 2.5 MG.
M.L.S.S. concentration: 1,200 mg/l
Clarification area: 33,333 ft^2 (600 gpd/ft^2)
Solids produced (excess): 7,340 lb/day
Oxygen required: 26,400 lb/day
Nitrogen requirement: 1500 lb.N; 1800 lb. NH_3/day
Phosphorus requirement: 300 lb.P; 950 lb. H_3PO_4/day

The aeration volume should be divided into at least two units. The volume of the waste stream carrying the excess solids will, of course, depend on the concentration of the solids. If a single unit system such as the Aero-Accelator is used, a thickener should be provided to concentrate excess solids. This unit should be sized to handle 7340 lbs. of solids per day in a flow of 515 gpm. The underflow from the thickener, containing the excess solids would be about 30 gpm (2% solids concentration).

If separate aeration and clarification units are used, the underflow from the excess solids unit would amount to about 60 gpm (1% solids concentration) and no thickener would be required. The separate clarifier for excess solids should be sized for 0.8 MGD at a surface loading of 600 gpd/ft^2.

A schematic drawing of the two flowsheets is presented in Figure 1.

Sheldon Mill

Flow: 2.5 million gallons per day
T_bOD (Removable COD): 6000 lb/day
Effluent quality: 20 mg/l BOD_5
35 mg/l T_bOD
20 mg/l suspended solids
M.L.S.S. required: 3,000 lb.
Aeration volume recommended: 0.36 M.G.
M.L.S.S. concentration: 1,000 mg/l
Clarification area: 4,200 ft^2 (600 gpd/ft^2)
Solids produced (excess): 1,600 lb./day
Oxygen required: 3,100 ld./day
Nitrogen required: 200 lb.N; 240 lb. NH_3/day
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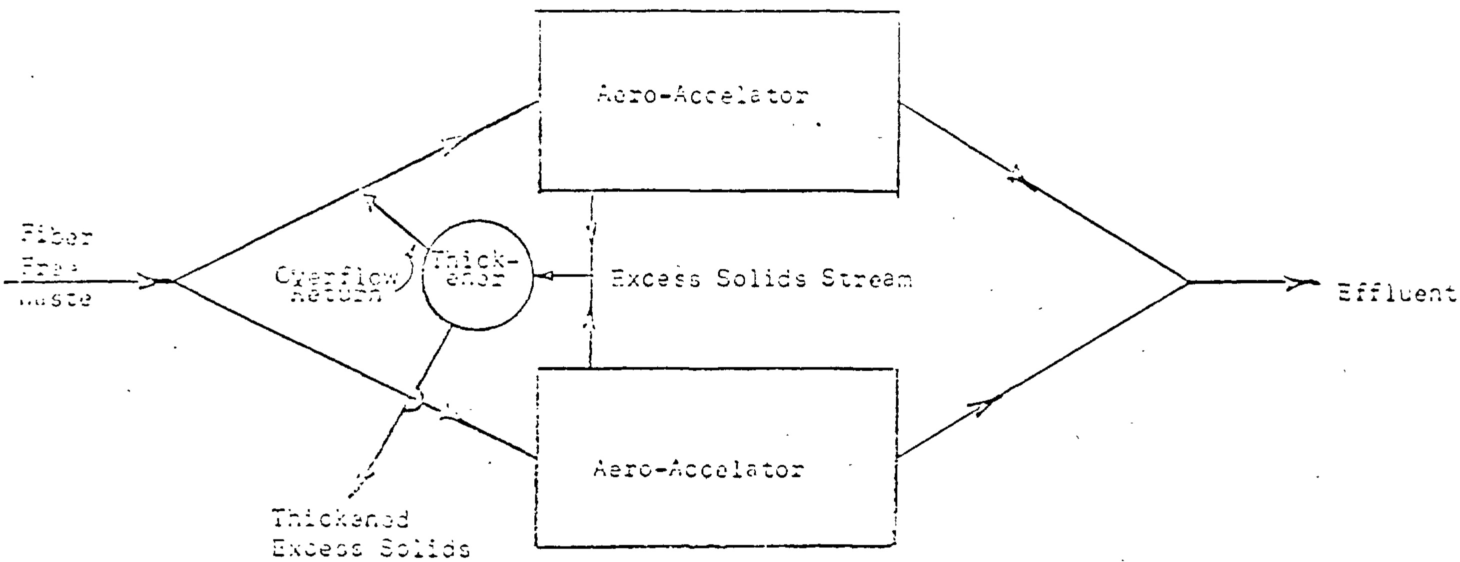
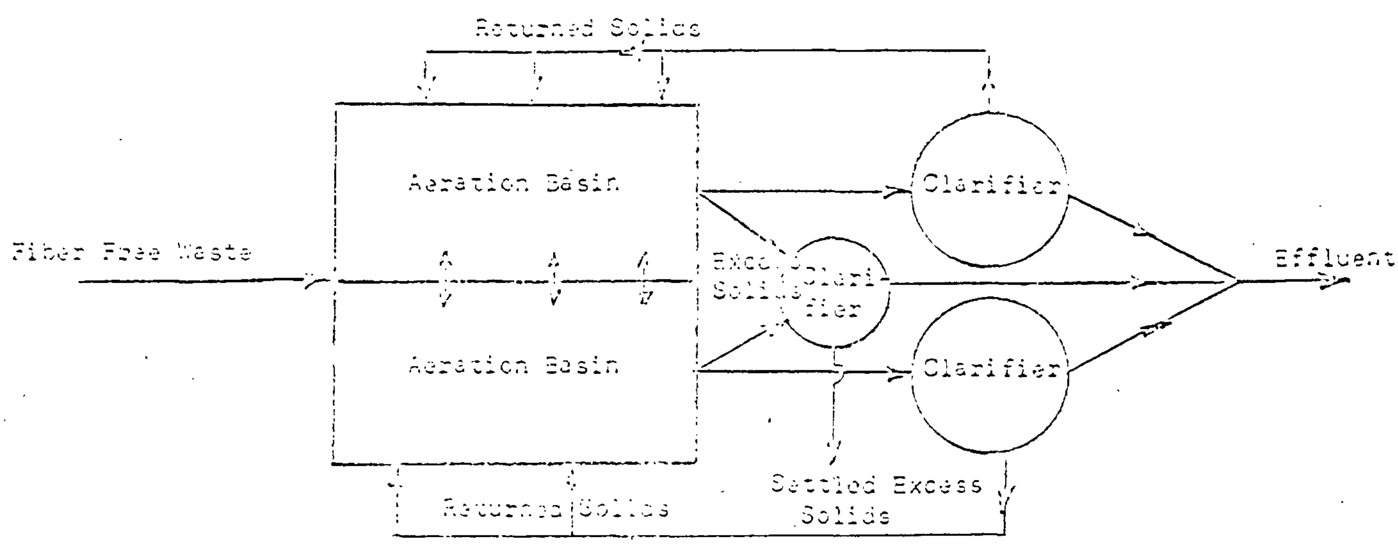
Again two units are preferable for the provision of the aeration volume. If Aero-Accelators are used the excess solids stream to the thickener would be approximately 135 gpm and the



INTEGRAL AERATION AND CLARIFICATION
WITH EXTERNAL THICKENING



SEPARATE AERATION AND CLARIFICATION
WITHOUT THICKENING

FIGURE I - SCHEMATIC DRAWINGS OF ALTERNATE FLOWSHEETS underflow at 2 per cent solids would be about 7 gpm.

If separate aeration and clarification units are used, the underflow from the excess solids unit would be about 15 gpm. The separate clarifier for excess solids should be sized for 135 gpm at the recommended surface loading of 600 gpd/ft^2.

OTHER RECOMMENDATIONS

Fiber Removal

The problem of fiber removal is so vital to effective control of the biological treatment process that further comment is felt justified. Experience at numerous mills has shown that plain sedimentation is not effective for fiber removal. The only methods which have proved workable involve chemical treatment, either in flotation or gravity units. It is strongly recommended that laboratory studies be made to determine the chemical costs involved and to provide a basis for process and equipment design. It is furthermore recommended that fiber removal be made an inherent part of the waste treatment plant design.

Plant Start-up and Operation

Because of the stringent effluent quality criteria which must be met, proper start-up and operation of the treatment process is especially significant. While a detailed discussion of these points is not within the scope of this report, continued emphasis on these important factors is recommended.

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STUDY OF WASTE WATER STREAMS FOR SOUTHLAND PAPER MILLS, INC.

Technical Report - Phase II
SwRI Project No. 21-1617

by

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to

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Job No. E-367 & E-518

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I. SUMMARY

Laboratory experiments were conducted at the Research Laboratory of Southland Paper Mills Inc., Lufkin, Texas to provide the data needed for waste treatment plant design. This report contains the necessary information concerning treatment plant process kinetics for 20 MGD of total mill waste at the Lufkin Mill and for 2.5 MGD of groundwood mill waste from the proposed Sheldon Mill near Houston.

Pretreatment for removal of fibers was considered for both waste systems. It was concluded that fiber removal was necessary prior to biological treatment of these wastes.

Use of completely mixed aerobic systems is recommended for biological treatment of both wastes. Completely mixed systems provide optimum steady-state conditions for the biological culture and inherent protection from sudden shock loads and high concentration levels which might impede culture metabolism.

Both wastes were found to be deficient in nitrogen and phosphorus. Therefore, nutrient feed must be provided for the biological treatment systems.

Treated effluent standards of 20 mg/l BOD and 20 mg/l suspended solids are reasonable for these wastes. Proper design and operation should produce effluents of this quality without difficulty.

Color reduction of total mill wastes was specifically excluded from this study. However, a record was made of color before and after biological treatment and showed that essentially no change was effected. It is felt that color will be of major concern in the receiving waters of the Lufkin mill effluent. It is therefore recommended that studies be initiated to reduce the color of that effluent. Color should not be a problem in groundwood mill effluent at the Sheldon site.

II. PURPOSE AND SCOPE

This study was authorized by letter from Mr. R. M. Millwee, Jr., Project Engineer, Brown & Root, Inc.. This study completes Phase II of this project. Technical Report, Phase I of December 18, 1964 characterized the wastes involved as to the magnitude and difficulty of the problem anticipated in producing an effluent low in oxygen demand.

The purpose of this study was to provide the rate data necessary for the complete design of adequate treatment facilities for mill waste at two locations. The first consideration was for the existing mill at Lufkin, Texas and second was for the new mill to be constructed at the Sheldon site, near Houston, Texas. The Lufkin treatment plant was to be designed for biological treatment of 20 MGD of the total mill waste effluent. Treatment plant design for the new mill at the Sheldon site was to handle 2.5 MGD of groundwood mill waste only, as it is understood that the initial construction will complete the groundwood section only.

The scope of the study was limited to process and design kinetics required for satisfaction of biological oxygen demand of the waste and removal of suspended matter produced in the biological system. Total suspended matter (non-filtrable residue) and BOD standards for the treated effluents at both sites were each set at 20 mg/l. Any requirement for color removal was specifically excluded from the scope of this study.

III. EXPERIMENTAL PROCEDURE

A. General

Technical Report, Phase I provided a background of information as to the feasibility of biological treatment of the wastes involved in this study. Description of the TbOD test technique and COD determination methods is contained in that report. The requirement of this study was to provide the rate data necessary for the proper sizing of mixed aeration basins, design of sludge wastage systems, selection of final clarifier overflow rates, and other design parameters.

Two waste streams were studied--total mill waste for Kufkin and groundwood waste for Sheldon. Separate studies were made on each of these wastes to evaluate the effect of fiber content on treatment plant design and operation. To do this, each waste was filtered through a Buchner funnel and laboratory filter paper to simulate pretreatment for suspended solids removal. Comparison was then made between the treatment kinetics of filtered and unfiltered waste. Thus, in total, four separate systems were studied.

The equipment necessary for these studies was set up in the Southland Paper Mills Research Laboratory in Lufkin, Texas. This equipment consisted primarily of two continuous flow biological reactor units with the necessary feed and effluent systems. Batch rate equipment was already on hand in the Research Laboratory. Equipment was also provided for sample filtering and solids determinations and for the COD determinations required.

The temperature at which laboratory studies were made was somewhat lower (5° - 10° C) than actual waste temperature. However, waste temperatures are well below the maximum allowable for biological activity. Since this high temperature would, if anything, improve treatment efficiency, it was accepted as a safety factor on design data.

The efforts of Mr. Fred Bishop and David Tarazi and the other research personnel were instrumental in the success of this study.

B. Continuous Flow Reactor Studies[1]

The bench scale reactors were used for a twofold purpose in this study. First, they provided a simulated treatment plant in the laboratory which

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[1] A. W. Busch, "Laboratory Units for Bench Scale Bio-Oxidation Studies," Water and Sewage Works 106, 1959, p. 254.

could be closely controlled and monitored. Second, they provided a means for hydraulic classification of the active culture for use in batch rate studies. A detailed procedure was set up for operation of these units. This procedure and schematic flow diagram are included as the Appendix to this report.

The continuous flow reactors were operated 24 hours a day, seven days a week. This continuous operation is necessary since living organisms are involved and they require continuous feeding for proper results. Grab samples of the particular waste being studied were prepared each morning, and nutrients (nitrogen and phosphorus) were added in excess. The change in COD between influent and effluent composite sample was used as the measure of biological treatment through the system. The TbOD [2] test was set up on the effluent composite from each day's run.

A solids balance was obtained on the system each day by measuring suspended matter in the reactor feed, reactor mixed liquor, and reactor effluent. However, it was found that the Chain-O-Matic balance in the laboratory was not sensitive enough to produce as close a solids balance as can normally be obtained. While this might have seriously impaired short term data, the rate studies were continued for a sufficient time to average out this factor. The volume of one continuous flow reactor was 5.25 liters and the other 5.9 liters. These numbers are used in all calculations involving MLSS according to the reactor used.

It should be noted also that on January 31 the existing pulp mill biological treatment system was discontinued in order to reflect this load in the total mill effluent. Previously, the TbOD load being removed in the pulp mill treatment system amounted to approximately 10% of the total mill effluent TbOD.

C. Batch Rate Studies

The batch rate study procedures were very similar to the TbOD tests used in Phase I of this study for characterization of the waste. The difference was that classified organisms were used from the continuous flow reactors at sufficient concentration to remove all soluble materials within a few hours. This removal was followed closely by taking samples of the completely mixed system every 15 to 30 minutes. Total suspended matter and soluble COD determinations were made on these samples. Thus, a removal rate per unit of mixed liquor solids as well as solids growth was measured during the batch studies. Membrane filters (0.45 micron pore size) were used for suspended solids determinations. It was assumed that any material passing through these filters was soluble. All COD determinations were made on filtered samples.

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[2] L. L. Hiser and A. W. Busch, "An 8-Hour Biological Oxygen Demand Test Using Mass Culture Aeration and COD," Journal Water Pollution Control Federation, 36, April 1964, pp. 505-515.

IV DISCUSSION AND RESULTS

A Total Mill Waste

1 General

Tables I and II record the laboratory data obtained from the continuous flow reactor units for the period December 22, 1964 through February 23, 1965. Tables III and IV list the variables computed from Tables I and II and are used in constructing the curves in Figures 1 through 16

During the initial period from December 22 through January 16, the reactor was operated on filtered grab samples from the total mill effluent sewer. Reactor effluent volume varied from 8 to 24 liters/day during this period The first week of this period was spent in acclimating the culture and smoothing operating and laboratory techniques. Building up the mixed liquor culture was difficult at first and a solids balance could not be achieved due to the complication of returning unknown quantities of solids carried over to the effluent each day The data prior to January 6, although listed in the Tables, for the most part were ignored in subsequent computations and descriptions For all practical purposes the test period on filtered total mill waste (with one feed pump in operation) was from January 6, 1965 to January 16, 1965. On January 19 a batch removal and growth rate study was made using the culture classified during the preceding period in the continuous flow reactor.

On January 20 two feed pumps were installed on the continuous flow reactor to essentially double the feed rate The reactor was continued on filtered waste at this higher feed rate through January 28, at which time another batch rate study was made The initial waste concentration in this batch study exceeded toxic limits of the culture and no COD removal or solids growth was measured in the system. A discussion of this phenomenon is included later

The total mill reactor was then continued at the high flow through February 4 1965 and a batch rate study was completed on February 5, 1965 This completed work on the filtered waste.

On February 5 the continuous flow reactor was started on unfiltered total mill effluent Two feed pumps were operated during the period February 5 through February 16 to give a direct comparison with the preceding study on filtered waste. On February 17 a batch rate study was made using culture from the unfiltered waste system. This rate study completed laboratory work on the total mill effluent waste

2 Unit Removal and Loading Rates

Figure 1 is a plot of the unit removal rate (gm TbOD removal/gm MLSS/day) as a function of the reactor effluent TbOD concentration. Two sets of data are plotted on this curve. the first set for the period during which only one feed pump was being used with the reactor, and the second set of data for the period when two feed pumps were being used.

The removal rate curve is higher for the low flow period than for the high flow period This is probably explained by the fact that the low flow culture was quite dispersed This provides relatively more reaction sites than are apt to be found in an equal concentration of a more flocculated culture. During the high flow rates the non-flocculant or dispersed portions of a culture are washed out in the effluent It is precisely for this classification purpose that continuous flow units are indispensable to biological rate studies The low flow culture was selected at a clarifier overflow rate of about 200 gal/day/ft^2 clarification area while the high flow culture was selected at a clarifier overflow rate of 650-700 gal/day/ft^2

Figure 2 is a plot of the same variables as in Figure 1 for the unfiltered waste. The unfiltered culture was selected at a lower overflow rate (approximately 550 gal/day/ft^2 than the filtered waste culture.

Figures 3 and 4 relate unit loading (gm TbOD applied/gmMLSS/day) as a function of reactor effluent TbOD concentration. These curves are similar to Figures 1 and 2 except that "applied" TbOD is used rather than "removed" TbOD These figures are important in the sizing of aeration basins for biological systems. Figure 3 plots two curves for the filtered waste system. one for the low flow period and one for the high flow period. Figure 4 plots the relationship for the unfiltered waste.

Figures 5 and 6 plot unit removal as a function of unit loading for the continuous flow reactors. The slope of the curve is a measure of the efficiency of the system. It will be noted that the filtered waste system maintains its efficiency at loadings up to 2.2 gm/gm/day. The unfiltered waste system efficiency shows a tendency to become irregular at higher loadings although only 3 loadings are plotted over 1.0 gm/gm/day.

3. Growth Rates and Solids Production

Biolgoical waste treatment is essentially a process by which soluble organic contaminants are converted to bacterial cell materials. In this form they may be removed from the system hydraulically. Thus, an excess of solids is always produced which must be removed from the system. Figures 7 and 8 plot growth rate (Δ MLSS/Avg MLSS/day) as a function of unit loading It can be seen on Figure 7 that, at unit loadings from 1 to 3 gmTbOD /gmMLSS/day, growth rate was fairly constant between 0.1 and 0.2 day^{-1}. The effect of the waste fiber content of the unfiltered waste is seen quite readily by comparison to Figure 8. In this system, growth rate varied from 0.8 to 1.5 day^{-1} over a unit loading range of 0.5 to 1.5 gm/gm/day. This reflects, of course, the accumulation of inert fiber in the culture rather than growth rate, per se.

Data on solids produced as gm per gm of filtrate COD destroyed is shown on Tables III and IV. Solids production varied considerably during the low flow rate period shown on Table III. This was due to the fact that the entire system was operating at a solids level below sensitivity of the laboratory balance. Further the culture exhibited the poor settling qualities characteristic of food limited cultures and varying quantities of mixed liquor solids were carried over to the effluent.

The solids production as shown on Table IV is a better measure of what is expected during plant operation. Here again the effect of effluent solids (fiber) was seen. Solids produced varied from 0.1 to 0.3 gm per gm COD destroyed with fiber free waste feed. When fed unfiltered waste solids production rose ten fold for a range of 1.0 to 2.1 gm/gm COD destroyed. This higher figure again reflects the accumulation of fiber in the culture which masks the solids production due to cell synthesis.

The accumulation of fiber in the active culture presents a very real problem in the control of a waste treatment plant Since the operator cannot tell what fraction of the MLSS is inert fiber, he cannot adequately control the solids level in the treatment plant and therefore will have no control on unit loading of the active fraction. This lack of control will be reflected in the treated waste quality.

4. Batch Rate Studies

Results of total mill batch rate studies are shown on Figure 9A. TbOD and MLSS progressions with time are shown for filtered and unfiltered waste batch studies. These curves are typical of batch rate curves. There is one anomaly which may be seen in the batch rate study of February 5 (without fiber). A "false" plateau of short duration was noted in the TbOD progression. This plateau was also noted in the filtered waste batch study run January 19 (culture classified at low overflow rate) and with the groundwood effluent systems.

Figure 9B plots the unit removal rate as a function of TbOD concentration on all three total mill waste batch studies. Unit removal rates for both filtered cultures were more than 1.5 times higher than the unfiltered culture rate at 30 mg/l TbOD concentration. However, all three rates are considerably higher than observed in continuous flow units. Further discussion of this variance between batch and continuous flow rate data and the TbOD progression anomaly mentioned above is included later in section IV B4.

No attempt was made to determine growth rate on these batch studies due to laboratory balance insensitivity.

5. <u>Toxicity and Nutrients</u>

Two instances of toxicity were noted during this study. The first was on January 28 when a batch study was set up on total mill effluent. A waste to culture proportion of 1:1 was used in setting up this particular study. This apparently exceeded the toxic limit of the culture such that no COD reduction was observed after 24 hours of operation.

The second instance occurred with the continuous flow reactor on January 12. A grab sample with an exceptionally low pH of 3.1 was fed to the unit for that day's run. As can be seen in Table I and III, the reactor efficiency was seriously impeded for the next three days.

The first instance of toxicity would not be met in a completely mixed biological system as the influent waste is immediately diluted to effluent concentration levels. However, this factor precludes the use of the conventional plug flow design for the aeration basin unless a large recirculation flow volume were included in the system.

The problem of low pH is again handled in the completely mixed system by dilution. If, however, such a problem continued for a considerable time the biological system could be seriously impaired.

Nitrogen and phosphorus determinations showed the total mill waste to be almost completely devoid of these necessary nutrients. Total nitrogen was less than 2 mg/l and total phosphorus (after alum precipitation) was 8 mg/l. Therefore, it will be necessary to provide for nutrient feed in any biological treatment system.

6. Solids Separation Rate

Another effect of fiber content on the biological culture is seen in Figure 10 which shows typical settling curves. Settling rate data was carefully selected for these curves in order to present a valid comparison. The two cultures are practically identical in total suspended solids content and prior environmental conditions. The major difference is that one is almost entirely a biological culture while the other is a mixture of fiber and biological culture, in unknown proportions. Two factors are important in this comparison. First, the unfiltered waste culture settling rate is about 1/10th that of the filtered waste culture and therefore will require a much larger final clarifier for proper separation of solids. Second, the unfiltered waste will require a larger volume of sludge wastage for disposal of a given amount of sludge due to poor compaction properties. Compounding this problem would be the added weight of fiber brought in continually with the raw waste. Maximum settling rates (inches/minute) of system Mixed Liquor are listed on Tables I and II.

7. Color

Equivalent APHA color was run daily on the influent and effluent of the continuous flow reactor during the period January 7 to January 30, 1965. The values obtained are recorded in Tables I and II. The purpose of this procedure was to determine the effect of complete biological treatment on mill effluent color. No consistant change was observed in waste color as a result of this treatment.

All color measurements were made on membrane-filtered samples to eliminate turbidity. Some small fraction of the color was undoubtedly absorbed on the membrane filter but this factor was of no consequence since only a relative comparison was made.

Color was run by comparing absorbance at 425 mμ wave length to a standard curve. This curve was made using APHA color standards. Highly colored waste samples were diluted with distilled water where necessary.

B. Groundwood Waste

1. General

Laboratory data obtained from the continuous flow reactor are recorded on Table V. Table VI is a tabulation of the variables computed from the raw data in Table V. All rate calculations involving solids are based on average MLSS.

One reactor was operated on filtered waste at low flow (one feed pump) from December 30, 1964 to January 16, 1965. Two reactors were then operated concurrently at high flow (two feed pumps on each reactor, for the period February 18 to February 23, 1965. One reactor treated filtered groundwood mill waste and the other unfiltered waste during this latter test period.

All reactors were fed continuously on grab samples collected daily from the groundwood mill effluent clarifier (Sveen-Pederson). Cultures developed rapidly on this waste, so that the entire operating period provided valid data.

One batch rate study was run on January 19 using filtered waste culture hydraulically classified at 290 to 390 gal/ft^2/day. Two batch rate studies were made concurrently on February 24, 1965. One used the filtered waste culture and the other used the unfiltered waste culture. The first culture was hydraulically classified at about 700 gal/ft^2/day and the second at about 400 gal/ft^2/day. These rate studies completed the laboratory work on the groundwood mill waste.

2. Unit Removal and Loading Rates

Figure 11 shows the relation of unit removal rate to reactor effluent TbOD for all three groundwood waste systems studied. The effect of fiber on unit removal rate is even more pronounced here than with the total mill waste systems. At comparable flows the culture system without fiber is capable of more than double the unit removal rate capacity of the culture system containing fiber. At an effluent TbOD concentration of 30 mg/l (equivalent to BOD of 20 mg/l) unit removal rates are about 0.8 and 1.8 gm TbOD/gm MLSS/Day for unfiltered and filtered waste respectively.

Figure 12, relating unit loading to effluent TbOD, is very similar to Figure 11 as the system efficiency is high. This is shown clearly by Figure 13, where unit removals are nearly equivalent to unit loading.

3. Growth Rate

Figure 14 is of a plot of growth rate as a function of unit loading for the three systems studied. The filtered waste data for high and low flow merges into one curve as it should. Of significance is the fact that with fiber the "apparent" growth rate is several times that without fiber, due to the effect of the fibers accumulating in the culture.

Solids production as gm/gm filtrate COD destroyed is listed on Table VI During the low flow period, solids produced varied from 0.1 to 0.2 gm/gm COD. However, it was felt the high flow period of February 18 through 23 reflected a truer range of expected solids production on fiber free waste - 0.2 to 0.3 gm/gm COD destroyed

The solids production figures for unfiltered groundwood waste varied from 0.4 to 1.2 gm/gm COD destroyed. These figures reflect the fiber content of the waste which accumulates in the culture. Therefore they are not a true measure of cell synthesis when applied to waste with a high fiber content.

4. Batch Rate Studies

COD and MLSS progressions are shown on Figure 15A for the two batch rate studies made on February 24, 1965 The January 19 study is not shown to avoid confusion, but similar results were obtained.

Both of the COD curves of Figure 15A show the two step progression noted in Figure 9A of the total mill waste systems. Sequential substrate utilization is one possible reason for this phenomenon. However, it was felt further exploration of this point was beyond the scope of this study

Unit removal rates for all three batch studies are plotted as a function of TbOD concentration in Figure 15B. The filtered waste unit removal rate (high flow) is again several times those exhibited in the continuous flow units. The two step progression of the batch removal curve is the probable answer to this. The second step of this removal is at a higher rate and lower TbOD concentration than the first step. It is this higher rate that is reflected in Figure 15B. More of an over-all rate is probably obtained in the continuous flow reactor operating at steady state conditions. This emphasizes the need for continuous flow data to properly design waste treatment systems.

5. Toxicity and Nutrients

No evidence of toxicity was noted with regard to the groundwood mill waste.

This waste is deficient in nutrients. Total phosphorus (after alum flocculation) is about 2 mg/l and total nitrogen content is less than 2 mg/l. Supplemental nutrient feed must be supplied for biological treatment of this waste.

6. Solids Separation Rates

Maximum settling rates (inches/minute) are listed on Table V for mixed liquor from the filtered (high flow) and unfiltered systems. Culture with fiber content from the unfiltered system settles at 1/3 to 1/10 the rate of the filtered waste mixed liquor.

Figure 16 is a comparison of typical settling curves of the cultures from the filtered and unfiltered systems. Slower settling and poor compaction of the unfiltered waste culture would require considerably larger final clarifiers and increase sludge volume wastage. Further, fiber going to this system cannot be recovered for use. It is recommended that fiber recovery be complete prior to biological treatment.

7. Color

Color is not a problem with groundwood waste and was not considered in this study.

V. CONCLUSIONS

Both Total Mill Waste and Groundwood Waste are amenable to biological removal of soluble organic materials. This study has shown this by the operation of laboratory bench scale treatment units and has provided the necessary information to enable complete design of treatment facilities.

The effect of fiber content in the wastes is sufficiently detrimental to require removal of fiber prior to the biological systems.

The Total Mill Waste exhibits a concentration toxicity which requires consideration in biological treatment. The completely mixed aeration basin is recommended as it provides an immediate dilution along with its other advantages.

Both Total Mill Waste and Groundwood Waste will require nutrient feed (nitrogen and phosphorus) to satisfy the nutritional requirements of the microorganisms

The color of Total Mill Waste is not appreciably affected by aerobic biological treatment. It is felt that the "apparent" color level in this waste will be found objectionable, and it is recommended that steps be taken to develop methods of color reduction. Color will not be a problem at the Sheldon Mill with groundwood effluent only.

TABLE I. TOTAL MILL EFFLUENT REACTOR CONTINUOUS FLOW DATA

Date	Effluent Volume Liters	Clarifier Overflow Rate gpd/ft^2	pH - UNITS Raw Waste	pH - UNITS Reactor M. L.	pH - UNITS Effluent	COD Raw Waste mg/l	COD Reactor Effluent mg/l	TBOD Raw Waste mg/l	TBOD Reactor Effluent mg/l	TOD Raw Waste mg/l	TOD Reactor Effluent mg/l	SOLIDS DATA Raw Waste SS mg/l	SOLIDS DATA Reactor Effluent SS mg/l	SOLIDS DATA Reactor Initial MLSS mg/l	COLOR-APHA UNITS Raw Waste	COLOR-APHA UNITS Reactor Effluent	REMARKS
Filtered Waste																	
Dec 22	8.7	82	7.1	8.1	7.7	514	301					22	52	210			One feed pump "on" for period 12/22/65 - 1/6/65
23	7.9	74	7.4	8.1	7.9	451	297					74	46	218			
24	17.1	161	6.6	7.5	7.3	602	328					14	124	262			
26	18.0	169	6.7	7.1	7.0	483	306					-	43	120			
28	8.3	78	5.1	6.9	6.8	463	281					-	26	238			
29	8.6	81	6.9	6.9	7.0	366	278					8	12	346			
30	17.0	160	5.3	6.6	6.6	459	265					8	23	460			
31	17.3	161	6.5	6.8	6.9	491	243					-	43	344			
Jan 1	17.1	161	5.9	7.0	6.8	523	294					4	43	164			
2	16.0	150	5.6	6.4	6.4	535	316					4	48	352			
3	17.3	163	4.5	6.4	6.2	477	294			136	25	4	60	384			
4	16.0	150	4.3	6.1	5.9	516	283					4	72	338			
5	16.7	157	4.5	6.7	6.2	411	242	184	15			4	80	192			Reactor M. L. blended.
6	21.8	205	6.2	6.7	6.4	496	296	239	39	120	18	4	4	344			Reactor M. L. blended.
7	23.2	218	6.8	7.2	6.9	398	229	159	-			4	40	524	1280	1390	
8	23.3	219	6.2	6.7	6.7	416	219	182	14	108	12	4	24	492	1328	1430	
9	16.0	150	6.5	7.0	6.8	613	322	298	7			4	12	600	2000	1580	
10	17.3	163	6.0	6.0	6.6	464	286	179	1			4	24	676	1352	1520	
11	23.1	220	6.1	6.3	5.3	394	216	178	1	195	12	4	20	632	1040	1240	
12	23.7	223	3.1	3.1	3.3	418	313	135	30			4	44	660	640	300	Reactor M. L. blended. Low pH Effect evident thru January 14
13	22.5	212	6.2	6.2	5.2	411	398	105	59	129	90	4	32	608	1372	1080	
14	23.8	224	5.8	6.1	6.3	505	432	186	113			4	60	584	1440	1460	
15	22.9	215	6.4	6.8	6.5	498	318	204	54			4	-	308	1690	1560	
16	16.3	153	6.3	6.7	6.6	444	288					4	44	388	1344	1340	

TABLE II. TOTAL MILL EFFLUENT REACTOR CONTINUOUS FLOW DATA

Date	Effluent Volume Liters	Clarifier Overflow Rate, gpd/ft²	pH - UNITS Raw Waste	pH - UNITS Reactor M. L.	pH - UNITS Effluent	COD Raw Waste avg mg/l	COD Reactor Effluent mg/l	TbOD Raw Waste mg/l	TbOD Reactor Effluent mg/l	SOLIDS DATA Raw Waste SS mg/l	SOLIDS DATA Reactor Effluent SS mg/l	SOLIDS DATA Reactor Initial MLSS mg/l	COLOR-APHA UNITS Raw Waste	COLOR-APHA UNITS Reactor Effluent	Maximum settling rate inch/min	REMARKS
Filtered Waste																
Jan. 20	42.0	664	5.9/6.9	7.0	7.1	402	289	180	67	4	36	152	1440	1230		Two feed pumps on
21	46.2	730	6.0/6.7	7.4	6.8	496	293	215	12	16	0	368	1588	1440		
22	41.5	703	8.0/8.4	7.3	7.7	270	201	91	22	19	16	419	1010	1040		Heavy rain dilution
23	37.0	585	6.1/6.6	7.2	7.0	423	276	175	28	--	56	448	1548	1570		Reactor overflowed
24	41.0	618	6.1/6.8	7.0	7.1	393	291	121	9	30	32	620	1680	1770		
25	45.9	711	5.2/6.0	6.9	6.8	497	333	207	43	24	12	706	1374	1700		
26	40.2	635	6.2/6.5	7.1	6.9	412	323	154	35	16	4	800	1714	1740		
27	22.5	576	6.2/7.4	7.2	7.0	500	353	<147	--	8	72	1047	1680	--		One feed pump out of service
28	36.2	650	5.9/--	6.3	7.3	431	297	148	11	6	32	796	--	1700		
29	42.7	675	5.2/6.1	6.9	6.8	470	313	185	28	29	24	940	1440	1700		
30	35.7	564	5.4/5.9	7.0	7.0	415	257	167	9	24	44	1130	1372			
31	36.0	560	7.0/7.4	7.3	7.4	458	272	207	21	64	44	1220				Pump mill waste treatment plant taken service Jan. 31 for balance of tests
1	35.1	555	5.2/6.1	6.5	6.9	453	259	202	8	26	40	1132				
2	40.0	637	5.8/6.6	7.1	6.8	508	291	240	23	24	68	1653			4.4	3.1 ML wasted
3	40.5	640	6.5/7.2	7.2	7.3	497	326	206	35	60	48	850			1.3	
4	42.7	675	5.4/6.5	7.0	6.9	432	288	165	21	48	48	1387			5.3	
Unfiltered Waste																
5	33.5	527	6.4/6.8	7.1	7.1	503	303	209	14	40	48	555			4.2	Reactor started on unfiltered waste
6	31.8	502	6.4/7.0	7.2	7.3	500	331	213	44	515	76	1050			2.5	2.5 to 4.5 l ML wasted per day for
7	36.2	572	5.5/6.2	6.9	6.8	424	287	171	34	430	104	1360			2.0	balance of tests
8	35.2	556	6.2/6.7	7.4	7.2	433	244	165	16	210	68	760			0.8	
9	36.6	578	5.8/6.3	6.8	6.8	497	316	212	41	220	68	310			0.4	
10	35.9	567	5.7/6.2	7.2	6.8	519	344	217	42	340	116	240			2.1	
11	34.3	542	8.0/8.4	7.7	7.5	591	343	248	0	250	120	640			0.7	
12	36.0	569	7.0/7.3	7.8	7.6	552	300	257	5	550	116	650			0.5	
13	35.5	561	5.8/6.4	7.1	7.0	557	351	234	28	210	184	1490			2.0	
14	27.5	435	5.8/6.2	6.9	6.7	417	278	140	1	200	112	710			3.5	
15	34.7	548	5.3/6.0	6.9	6.7	485	323	171	9	170	56	730			1.8	
16	34.5	545	5.9/6.2	6.6	6.3	412	215	197	0	270	88	660			1.4	

TABLE III - TOTAL MILL EFFLUENT REACTOR KINETICS DATA

Date	Effluent mg/l	ThOD gm	Δ COD mg/l	Δ COD gm	Δ MLSS mg/l	Δ MLSS gm	Avg. MLSS mg/l	Avg. MLSS gm	Growth Rate Day -1	Solids Age Days	Solids Produced g/g COD removed	Unit Loading g/g Day	Unit Removal g/g Day
Filtered Waste													
Dec. 22			213	1.9	8	.0	214	1.1	.0	.0	.0		1.7
23			154	1.2	44	.2	240	1.3	.2	5.0	.2		0.9
24			274	4.7	-142	-.7	191	1.0	-	-	-		4.7
26			177	3.2	168	.9	204	1.1	.8	1.3	.3		2.9
28			182	1.5	58	.3	317	1.7	.2	5.0	.2		0.9
29			88	0.8	114	.6	403	2.1	.3	3.3	0.8		0.4
30			194	3.3	-116	-.6	402	2.1	-	-	-		1.6
31			153	2.6	-180	-.9	254	1.3	-	-	-		2.0
Jan 1			229	3.9	188	1.0	258	1.4	.7	1.4	.3		2.8
2			219	3.5	32	.2	368	1.9	.1	10.0	.1		1.8
3			185	3.2	4	.0	386	2.0	.0	.0	.0		1.6
4			227	3.6	-196	-1.0	290	1.5	-	-	-		2.4
5	15	.3	169	2.8	152	.8	268	1.4	5.7	.2	.3	2.2	2.0
6	39	.9	200	4.4	180	.9	434	2.3	.4	2.5	.2	2.3	1.9
7	Neg	-	159	3.7	-32	-.2	508	2.7	-	-	-	1.4	1.4
8	14	.3	168	3.9	108	.6	546	2.9	.2	5.0	.2	1.4	1.3
9	7	.1	291	4.7	76	.4	638	3.4	.1	10.0	.1	1.4	1.4
10	1	.0	178	3.1	-44	-.2	654	3.4	-	-	-	.9	0.9
11	1	.0	177	4.1	28	.2	646	3.4	.1	10.0	<0.1	1.2	1.2
12	30	.7	105	2.5	-52	-.3	634	3.3	-	-	-	1.0	0.8
13	59	1.3	46	1.0	-24	-.1	596	3.1	-	-	-	.8	0.3
14	113	2.7	73	1.7	-276	-1.5	446	2.4	-	-	-	1.8	0.7
15	54	1.2	150	3.4	80	.4	348	1.8	.2	5.0	.1	2.6	1.9
16	-	-	156	2.5	28	.2	402	2.1	.1	10.0	.1		1.2

TABLE IV - TOTAL MILL EFFLUENT REACTOR KINETICS DATA

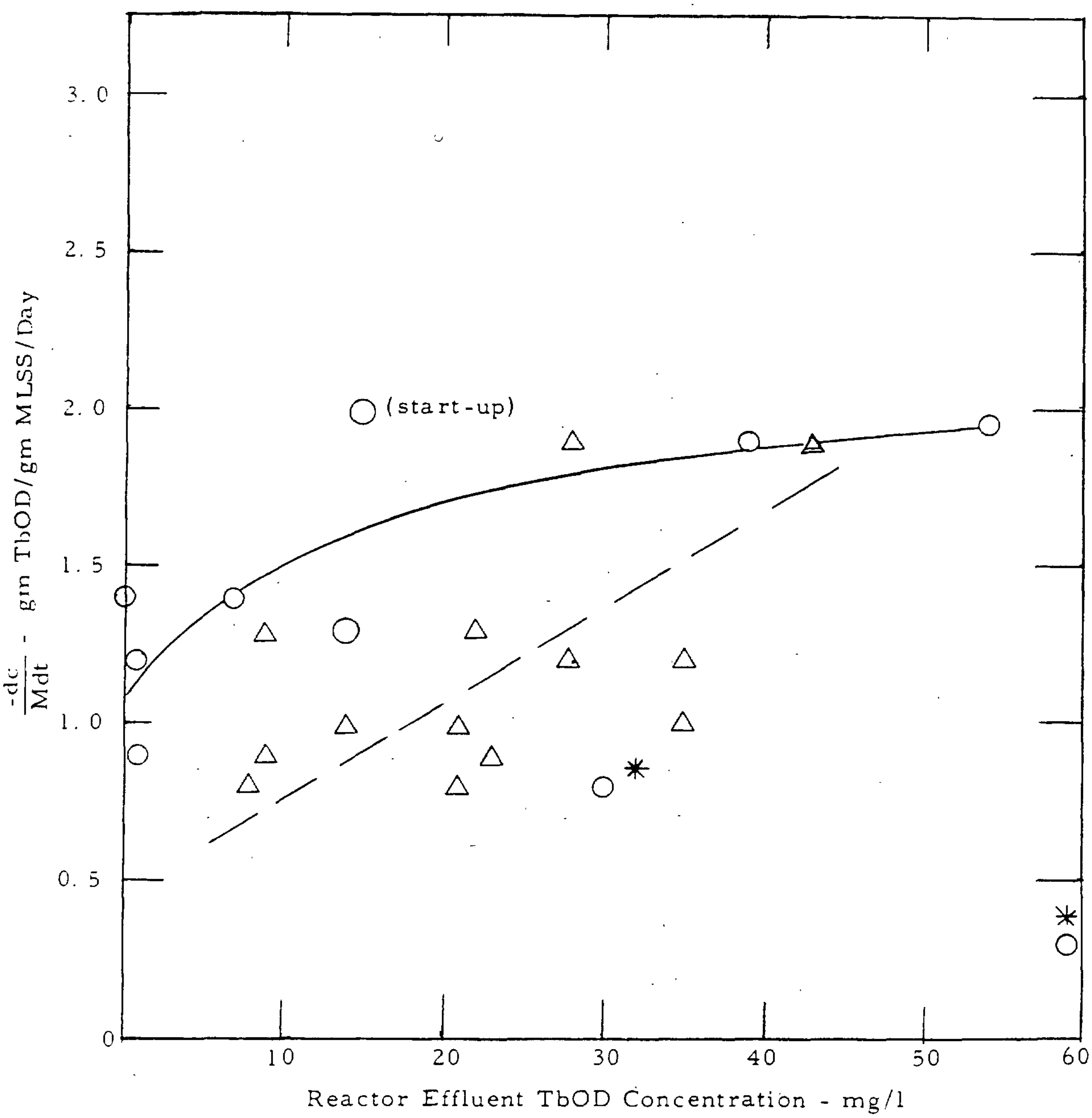
Date	Effluent mg/l	TbOD gm	△ COD mg/l	△ COD gm	△ MLSS mg/l	△ MLSS gm	Avg. MLSS mg/l	Avg. MLSS gm	Growth Rate Day^{-1}	Solids Age Days	Solids Produced g/g COD removed	Unit Loading g/g Day	Unit Removal g/g Day
Filtered Waste													
Jan 20	67	2.8	113	4.7	216	1.1	260	1.4	.8	1.3	.2	5.4	3.4
21	12	.6	203	9.4	72	.4	400	2.1	.2	5.0	.0	4.7	4.5
22	22	1.0	69	3.1	48	.3	460	2.4	.1	10.0	.1	1.7	1.3
23	28	1.0	147	5.4	132	.7	550	2.9	.2	5.0	.1	2.2	1.9
24	9	.4	112	4.6	86	.5	660	3.5	.1	10.0	.1	1.4	1.3
25	43	1.9	164	7.4	94	.5	750	4.0	.1	10.0	.1	2.3	1.9
26	35	1.4	119	4.8	247	1.3	920	4.9	.3	3.3	.3	1.3	1.0
27	-	-	147	3.3	-	-	920	4.8	-	-	-	.7	.7
28	14	.5	134	4.7	144	.8	870	4.6	.2	5.0	.2	1.1	1.0
29	28	.4	157	6.7	240	1.3	1060	5.6	.2	5.0	.2	1.4	1.2
30	9	.7	158	5.6	40	.2	1200	6.3	.0	.0	.0	1.0	.9
31	21	.3	186	6.7	212	1.1	1330	7.0	.2	5.0	.2	1.1	1.0
Feb 1	8	.8	194	6.8	221	1.2	1540	8.1	.1	10.0	.2	.9	.8
2	23	1.4	217	8.7	247	1.3	1820	9.5	.1	10.0	.1	1.0	.9
3	35	.9	171	6.9	537	2.8	1120	5.9	.5	2.0	.4	1.4	1.2
4	21	.6	144	6.1	65	.3	1420	7.5	.0	.0	.0	.9	.8
Unfiltered Waste													
5	14	.5	195	6.5	1450	7.6	1280	6.7	1.1	.9	1.2	1.0	1.0
6	44	1.4	169	5.4	2130	11.2	2110	11.1	1.0	1.0	2.1	.6	.5
7	34	1.2	137	5.0	1840	9.7	2280	12.0	.8	1.3	1.9	.5	.4
8	16	.6	149	5.2	1420	7.4	1470	7.7	1.0	1.0	1.4	.8	.7
9	41	1.5	171	6.3	1330	7.0	980	5.1	1.4	.7	1.1	1.5	1.2
10	42	1.5	175	6.3	1670	8.8	1070	5.6	1.6	.6	1.4	1.4	1.1
11	0	0	248	8.5	1320	6.9	1300	6.8	1.0	1.0	.8	1.3	1.3
12	5	.2	252	9.1	3580	18.8	2440	12.8	1.5	.7	2.1	.7	.7
13	28	1.0	206	7.3	650	3.4	1810	9.5	.4	2.3	.5	.9	.5
14	1	< .1	139	3.8	1490	7.8	1460	7.7	1.0	1.0	2.1	.5	.5
15	9	.3	162	5.6	1230	6.4	1350	7.1	.9	.1	1.1	.8	.8
16	0	0	197	6.8	1300	6.8	1300	6.8	1.0	1.0	1.0	1.0	1.0

TABLE V. GROUND WOOD EFFLUENT REACTOR CONTINUOUS FLOW DATA

Date	Effluent Volume Liters	Clarifier Overflow Rate, gpd/ft^2	pH - UNITS: Raw Waste	pH - UNITS: Reactor M. L.	pH - UNITS: Effluent	COD: Raw Waste avg mg/l	COD: Reactor Effluent mg/l	TBOD: Raw Waste mg/l	TBOD: Reactor Effluent mg/l	SOLIDS DATA: Raw Waste SS. mg/l	SOLIDS DATA: Reactor Effluent SS mg/l	SOLIDS DATA: Reactor Initial MLSS mg/l	Maximum settling rate inch/min	REMARKS
Filtered Ground Wood														
Dec. 30	17.7	280	5.6	6.4	6.0	369	84			4	42	452		One feed pump "on" for period
31	17.8	281	5.3	6.0	6.0	304	73			--	6	592		12/30/64 - 1/16/65
Jan. 1	18.5	292	5.3	6.0	5.9	371	84			4	26	812		
2	17.3	273	5.2	6.0	5.9	349	84			4	96	938		
3	18.6	294	5.2	6.1	5.7	357	80			10	149	833		
4	18.0	284	5.1	5.9	5.9	353	87			4	24	940		
5	18.1	286	5.1	6.1	6.4	338	100			20	20	993		
6	23.9	378	6.4	6.5	6.2	356	37	319	0	32	48	1033		
7	24.3	384	7.0	6.4	6.3	342	79	277	14	16	104	1240		
8	24.0	379	7.1	6.6	6.4	293	84	227	18	12	300	1187		
9	18.6	294	7.0	6.3	6.0	364	66	298	0	64	64	706		
10	18.5	292	6.9	6.1	6.1	348	74	274	0	44	108	933		
11	24.0	379	7.2	6.3	6.5	286	77	214	5	24	56	793		
12	23.8	376	7.1	6.5	6.0	332	74	266	8	28	48	800		
13	23.5	371	7.1	6.4	6.2	369	69	304	4	32	12	927		
14	21.5	342	7.1	6.4	6.4	342	65	277	0	4	76	1053		
15	24.1	381	7.2	6.5	6.3	362	64	300	2	24	44	1087		
16	18.6	294	7.3	6.4	6.5	381	63	--	--	4	80	1012		
Feb. 18	45.0	711	5.7/7.1	6.2	5.5	370	120	266	16	4	40	630	4.0	Two feed pumps "on" for period
19	45.0	711	5.1/6.8	6.0	5.5	350	107	250	7	4	244	1290	1.0	2/18/65 - 2/23/65
20	41.0	648	5.2/7.1	6.4	6.2	328	111	217	0	16	16	1150	0.3	2.0 liters of ML wasted
21	46.0	727	5.0/6.7	5.4	5.2	350	111	255	16	4	160	1330	5.6	1.0 liter of ML wasted, MLSS lost to effluent
22	45.5	719	5.0/6.3	5.2	5.1	320	116	238	34	16	36	950	2.1	1.0 liter of ML wasted
23	41.2	651	5.0/6.2	5.2	5.4	225	58	167	0	16	28	980	--	
Unfiltered Ground Wood														
Feb. 18	42.1	396	5.6/7.0	5.5	5.5	368	150	252	34	120	69	1110	0.4	
19	41.3	388	5.2/6.8	5.4	5.2	345	108	237	0	48	80	2340	0.1	
20	27.0	207	5.2/7.1	6.6	6.1	322	82	240	0	116	80	1440	0.1	3.0 liters of ML wasted
21	24.0	216	5.0/6.7	5.4	5.2	252	97	163	10	52	40	2080	0.1	1.0 liter of ML wasted
22	33.5	407	5.0/6.1	5.3	5.0	275	111	196	32	88	112	1840	0.3	2.0 liters of ML wasted
23	30.1	364	5.0/6.2	5.2	5.5	212	63	179	0	176	100	1540	--	2.0 liters of ML wasted

TABLE VI - GROUNDWOOD EFFLUENT REACTOR KINETICS DATA

Date	Effluent mg/l	TbOD gm	Δ COD mg/l	Δ COD gm	Δ MLSS mg/l	Δ MLSS gm	Avg. MLSS mg/l	Avg. MLSS gm	Growth Rate Day^{-1}	Solids Age Days	Solids Produced g/g COD removed	Unit Loading g/g Day	Unit Removal g/g Day
Filtered Groundwood													
Dec 30			285	5.0	140	.8	522	3.1	.3	3.3	.2		1.6
31			231	4.1	220	1.3	702	4.1	.3	3.3	.3		1.0
Jan 1			287	5.3	126	.7	875	5.2	.1	10.0	.1		1.0
2			265	4.6	-105	-.6	886	5.2	-	-	-		.9
3			277	5.2	107	.6	887	5.2	.1	10.0	.1		1.0
4			266	4.8	53	.3	967	5.7	.1	10.0	.1		.8
5			238	4.3	40	.2	1013	6.0	.0	.0	.0		.7
6	0	-	319	7.6	207	1.2	1130	6.7	.2	5.0	.2	1.13	1.13
7	14	.3	263	6.4	-53	-.3	1220	7.2	-	-	-	0.93	0.89
8	18	.4	209	5.0	-481	-2.8	950	6.5	-	-	-	0.83	0.77
9	0	-	298	5.5	227	1.3	820	4.8	.3	3.3	.2	1.15	1.15
10	0	-	274	5.1	-140	-.8	810	4.8	-	-	-	1.06	1.06
11	5	.1	209	5.0	7	.0	800	4.7	.0	.0	.0	1.09	1.06
12	8	.2	258	6.1	127	.7	860	5.1	.1	10.0	.1	1.24	1.20
13	4	.1	300	7.1	126	.7	990	5.8	.1	10.0	.1	1.24	1.22
14	0	-	277	6.8	34	.2	1070	6.3	.0	.0	.0	1.08	1.09
15	2	.0	298	7.2	-75	-.4	1050	6.2	-	-	-	1.16	1.16
16	0	-	318	5.9	161	.9	1090	6.4	.1	10.0	.2	0.92	0.92
Feb 18	16	.7	250	11.3	660	3.5	960	5.0	.7	1.4	.3	2.40	2.26
19	7	.3	243	10.9	560	2.9	1220	6.4	.5	2.0	.3	1.75	1.70
20	0	.0	217	8.9	500	2.6	1240	6.5	.4	2.5	.3	1.37	1.37
21	16	.7	239	11.0	-380	-2.0	1140	6.0	-	-	-	1.95	1.83
22	34	1.5	204	9.3	260	1.4	965	5.1	.3	3.3	.2	2.12	1.83
23	0	.0	167	6.9	270	1.4	1045	5.5	.3	3.3	.2	1.26	1.26
Unfiltered Groundwood													
Feb 18	34	1.4	218	9.2	1230	7.3	1725	10.2	.7	1.4	0.8	1.01	0.90
19	0	.0	237	9.8	590	3.5	1890	11.2	.3	3.3	0.4	0.87	0.87
20	0	.0	240	5.3	1070	6.3	1760	10.4	.6	1.6	1.2	0.51	0.51
21	10	.2	153	3.5	700	4.1	1960	11.6	.3	3.3	1.2	0.32	0.30
22	32	1.4	164	7.1	490	2.9	1690	10.0	.3	3.3	0.1	0.85	0.71
23	0	0	179	7.0	590	3.5	1780	10.5	.3	3.3	0.5	0.67	0.67



○ 1/5/65 - 1/16/65 - low flow rate
△ 1/20/65 - 2/4/65 - high flow rate
✳ Low pH shock

FIGURE 1. TOTAL MILL REACTOR - WITHOUT FIBER
UNIT REMOVAL RATE VS TbOD CONCENTRATION

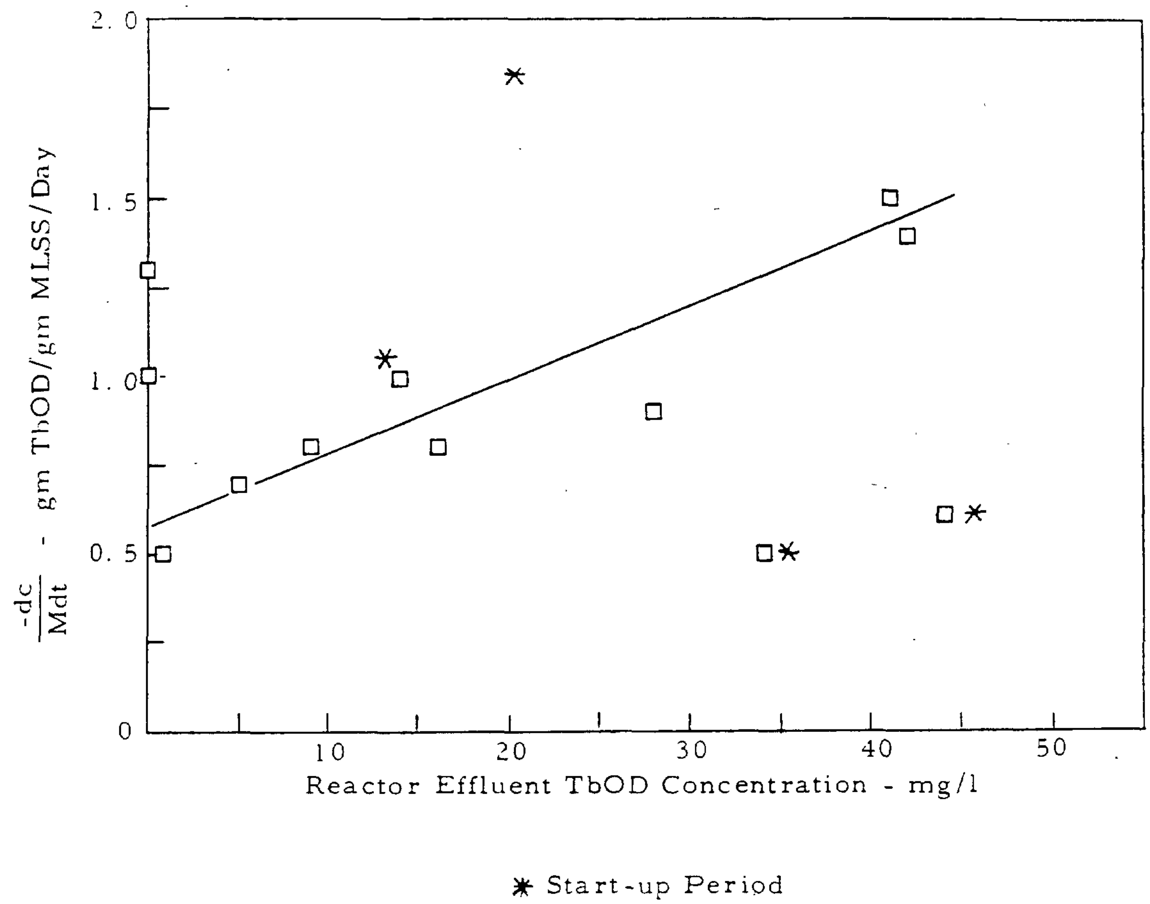
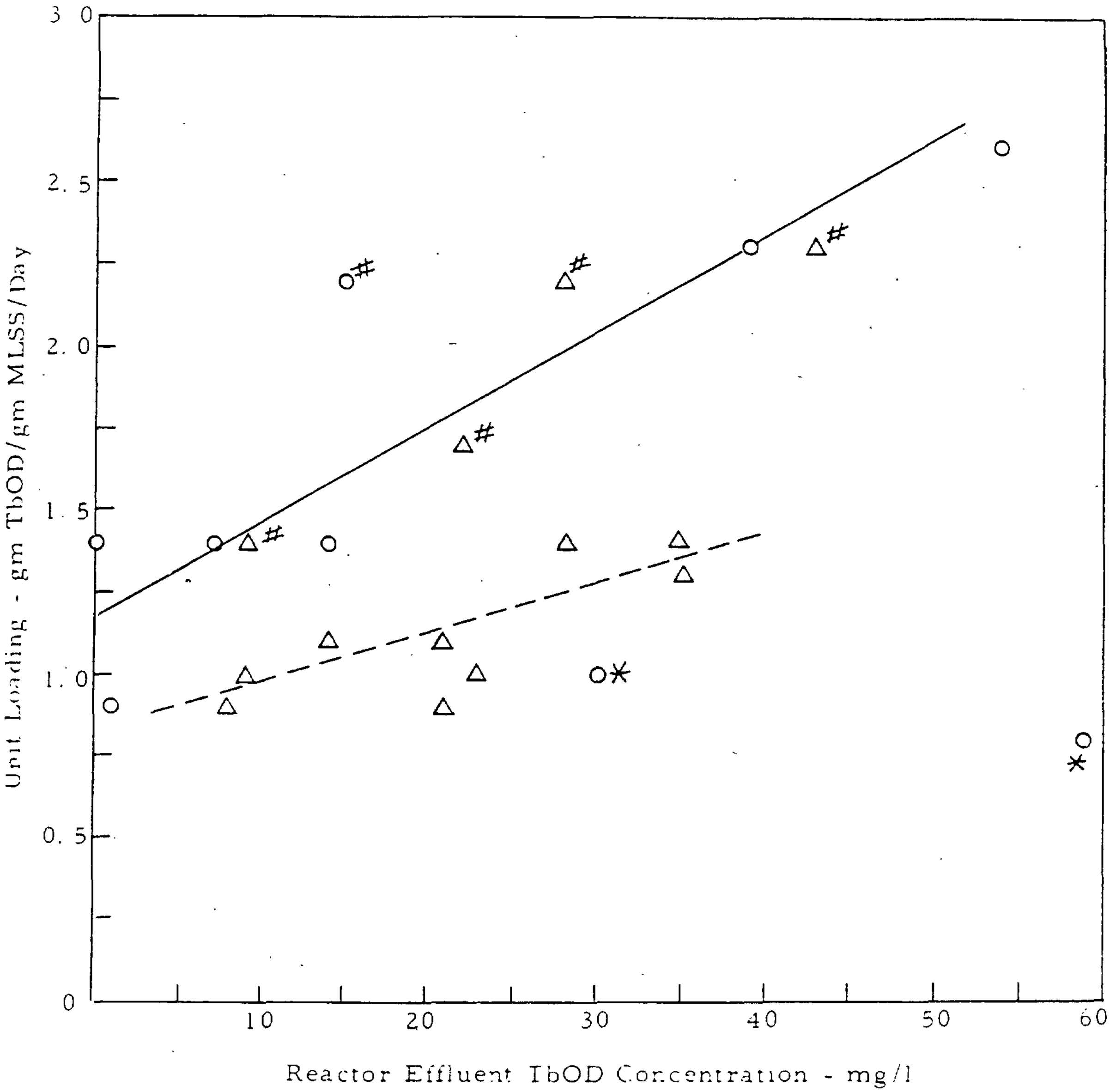


FIGURE 2. TOTAL MILL REACTOR - WITH FIBER
UNIT REMOVAL RATE VS TbOD CONCENTRATION
2/5/65 - 2/16/65



O 1/5/65 - 1/16/65 - low flow
Δ 1/20/65 - 2/4/65 - high flow
start-up period
* low pH shock

FIGURE 3. TOTAL MILL REACTOR - WITHOUT FIBER
UNIT LOADING VS TbOD CONCENTRATION

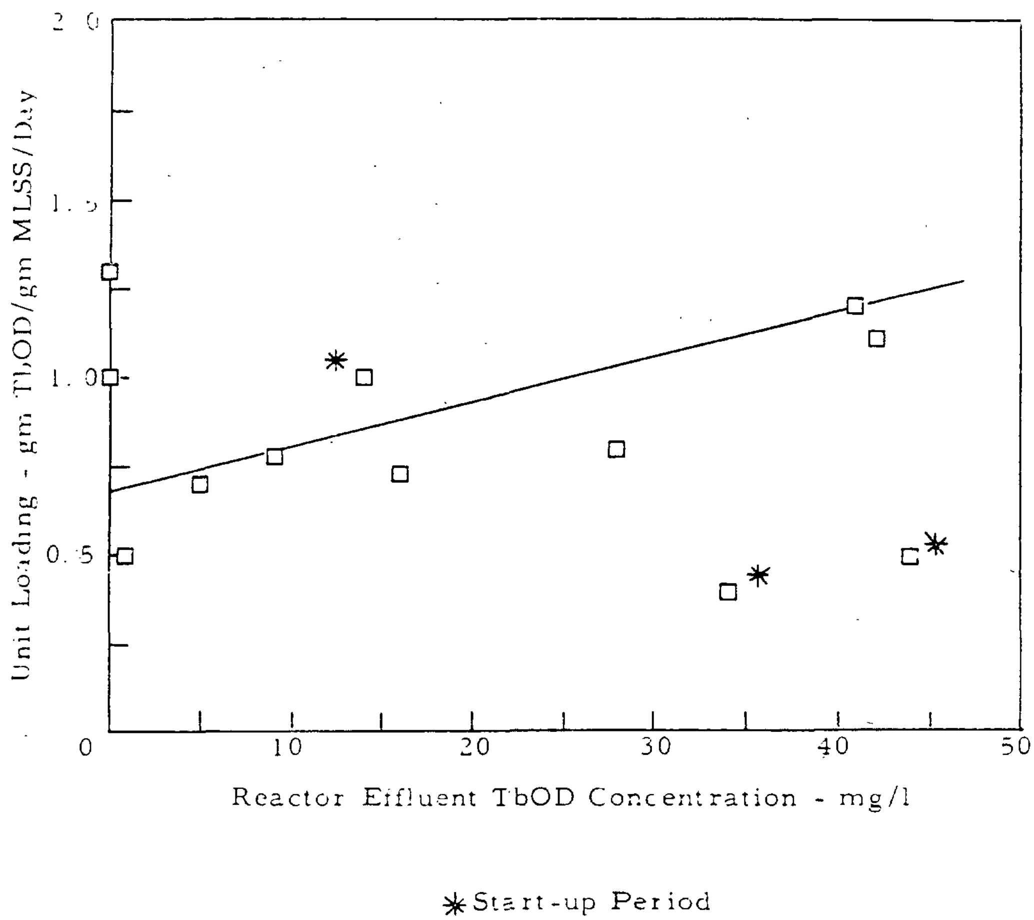


FIGURE 4. TOTAL MILL REACTOR - WITH FIBER
UNIT LOADING VS TbOD CONCENTRATION
2/5/65 - 2/16/65

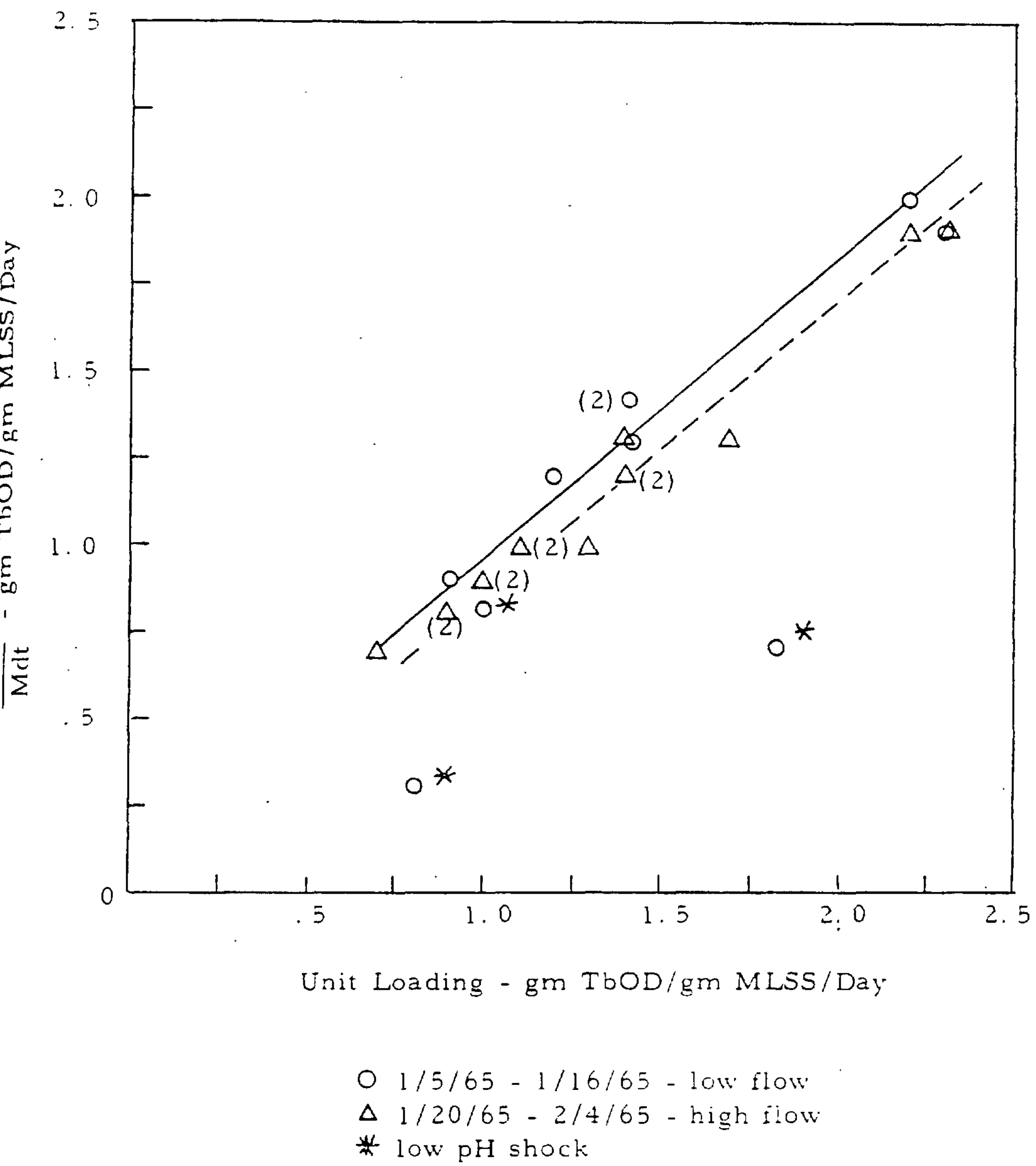


FIGURE 5. TOTAL MILL REACTOR - WITHOUT FIBER
UNIT REMOVAL RATE VS UNIT LOADING

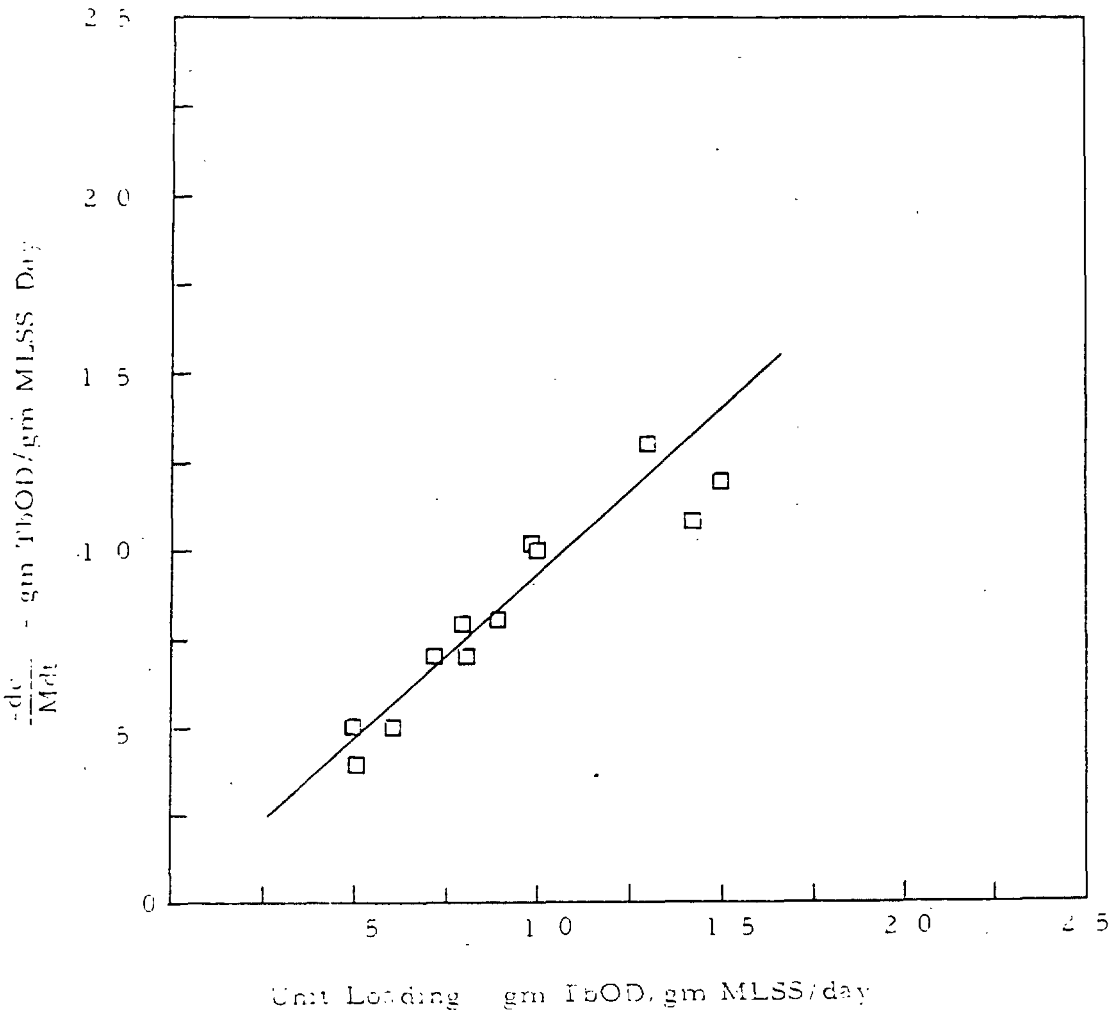


FIGURE 6 TOTAL MILL REACTOR - WITH FIBER
UNIT REMOVAL RATE VS UNIT LOADING
2/3/65 - 2/16/65

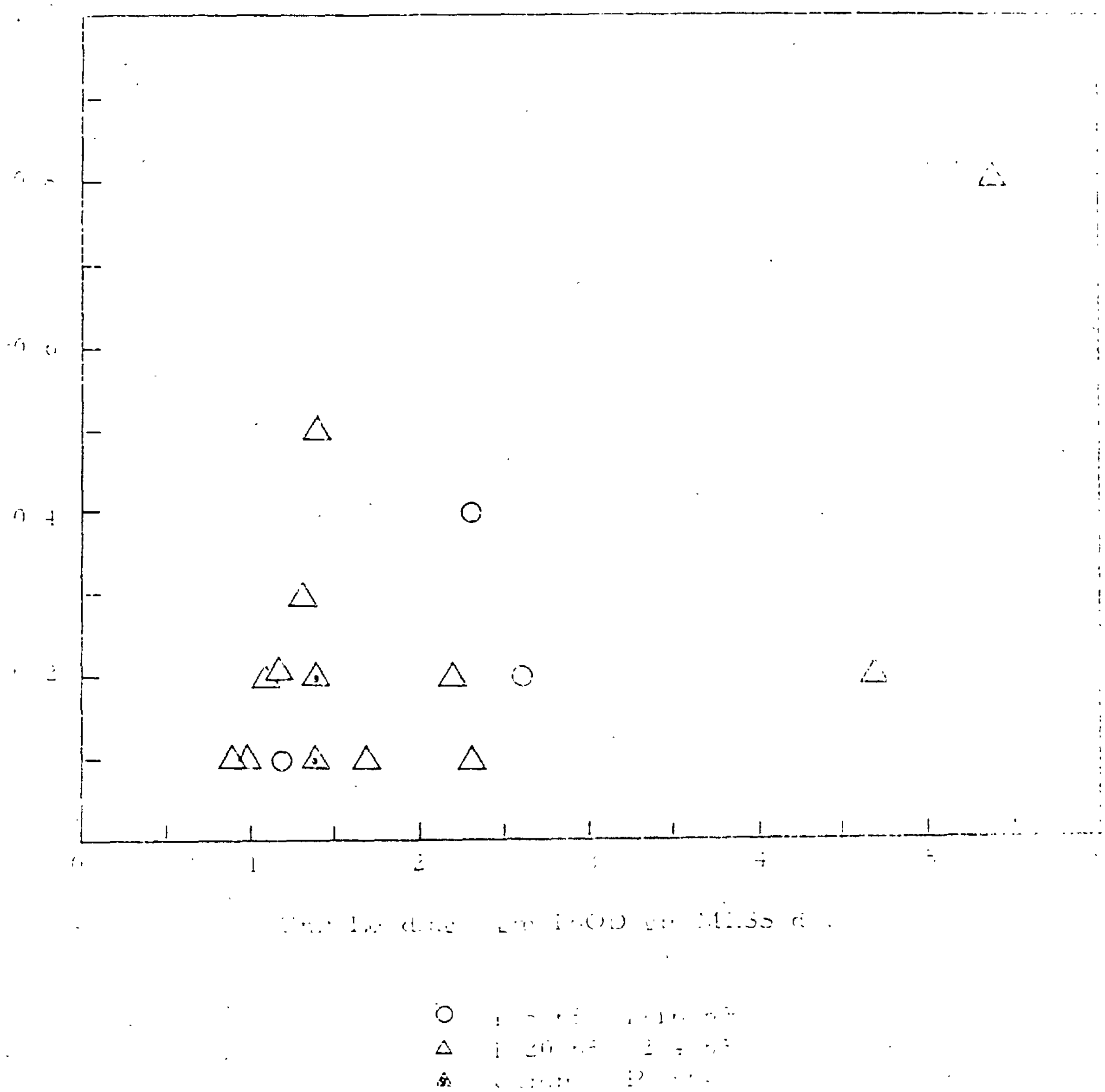


FIGURE 7. TOTAL M[illegible] [illegible] GROWTH RATE [illegible] LOAD [illegible]

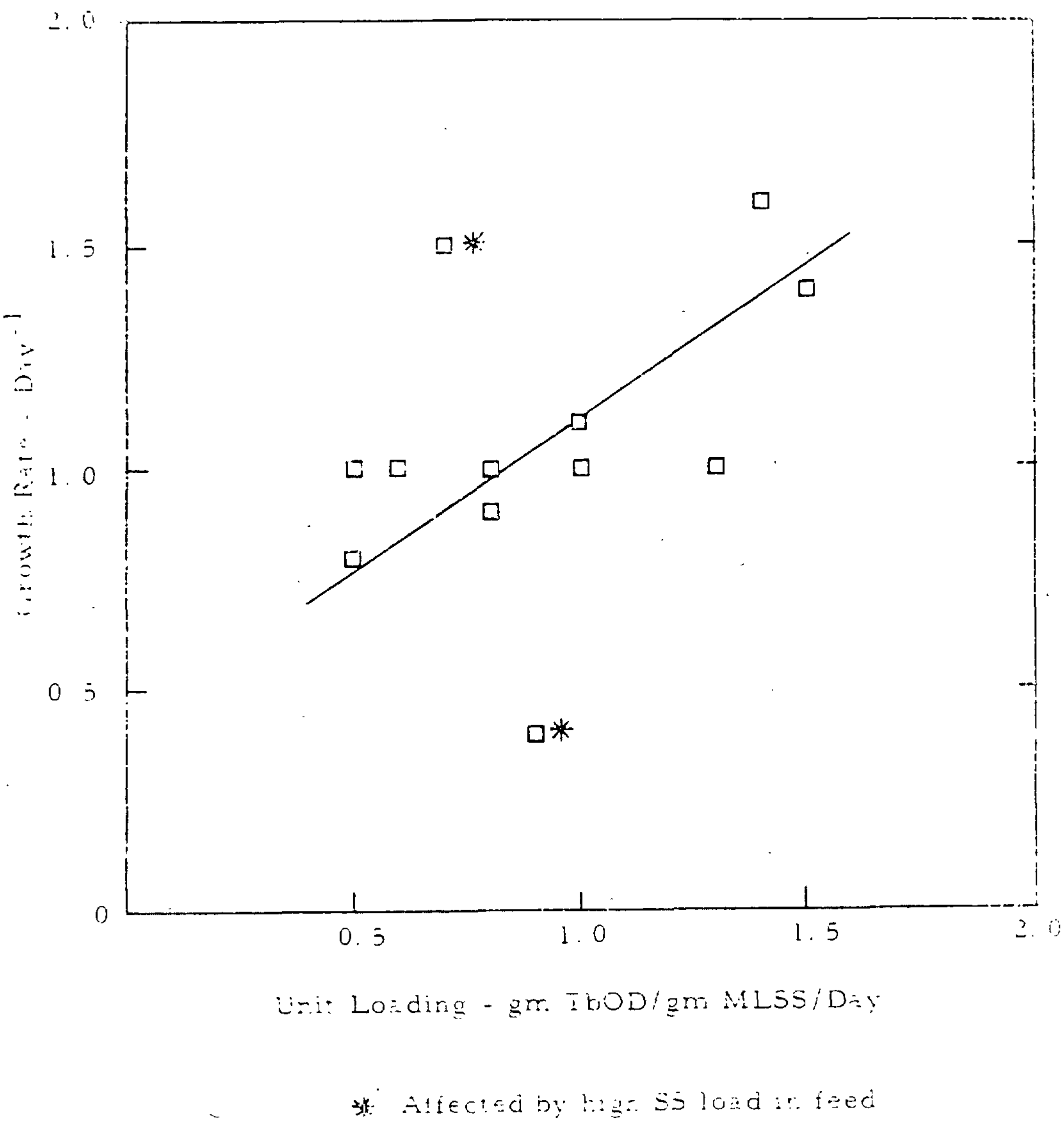


FIGURE 8. TOTAL MILL REACTOR - WITH FIBER
GROWTH RATE VS UNIT LOADING
2/5/65 - 2/16/65

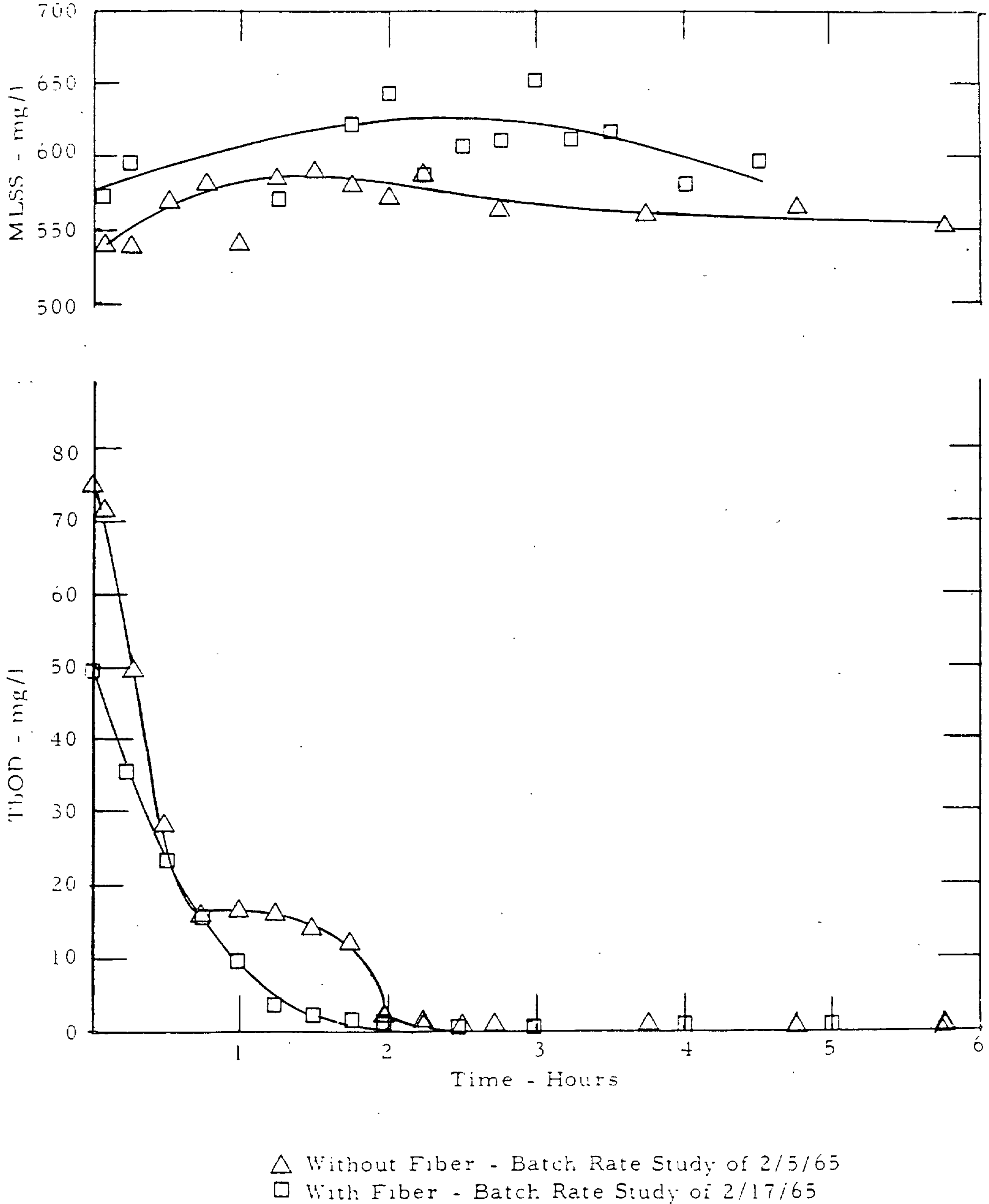
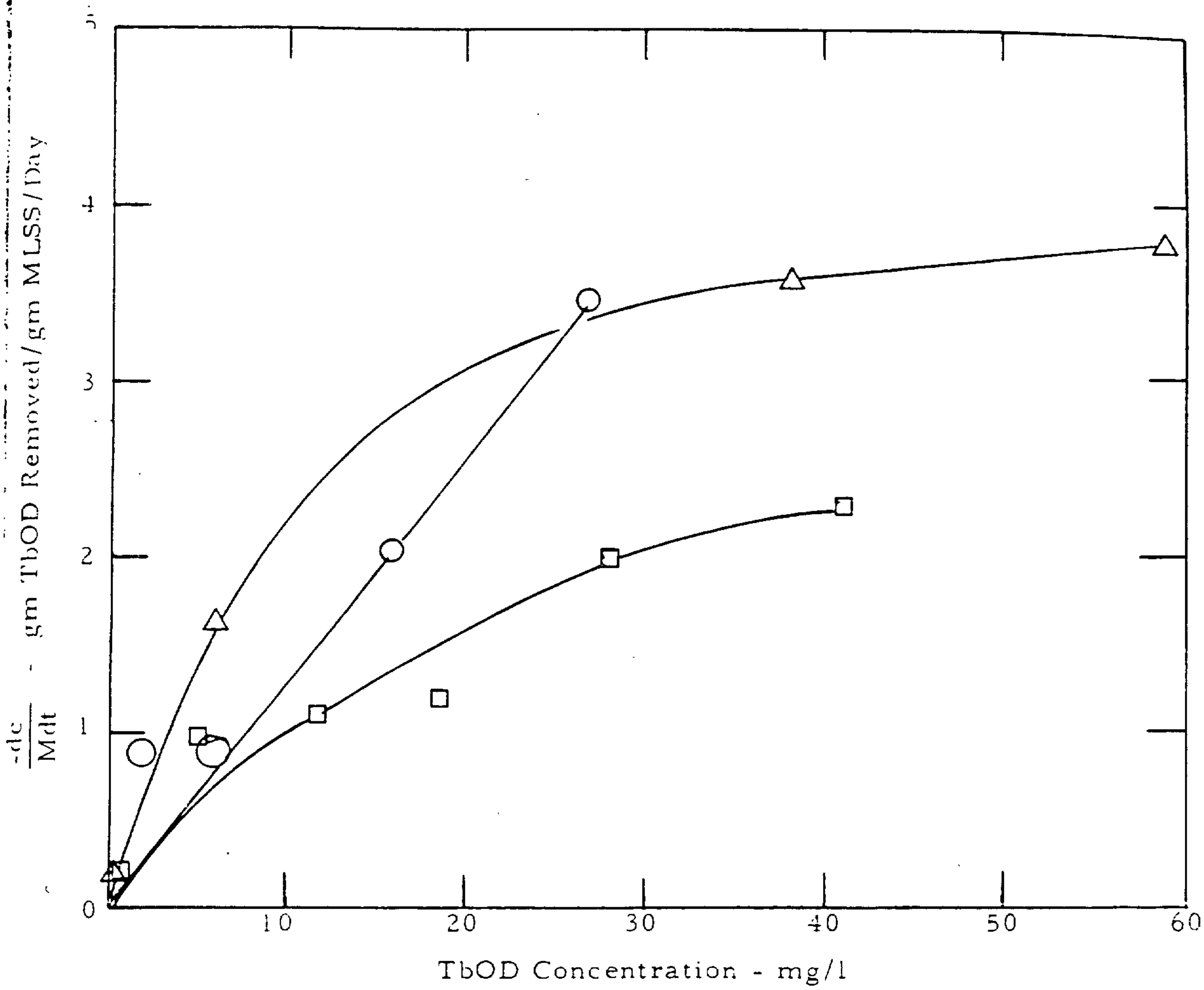


FIGURE 9A. TOTAL MILL WASTE BATCH RATE TbOD AND MLSS PROGRESSION



Symbol	Fiber	Overflow Rate	Batch Run Date
○	No	200 gpd/sq. ft.	1/19/65
△	No	650 gpd/sq. ft.	2/5/65
□	Yes	550 gpd/sq. ft.	2/17/65

Culture Selected from Continuous Reactors

FIGURE 9B. TOTAL MILL EFFLUENT - BATCH RATE STUDIES
UNIT REMOVAL RATE VS TbOD CONCENTRATION

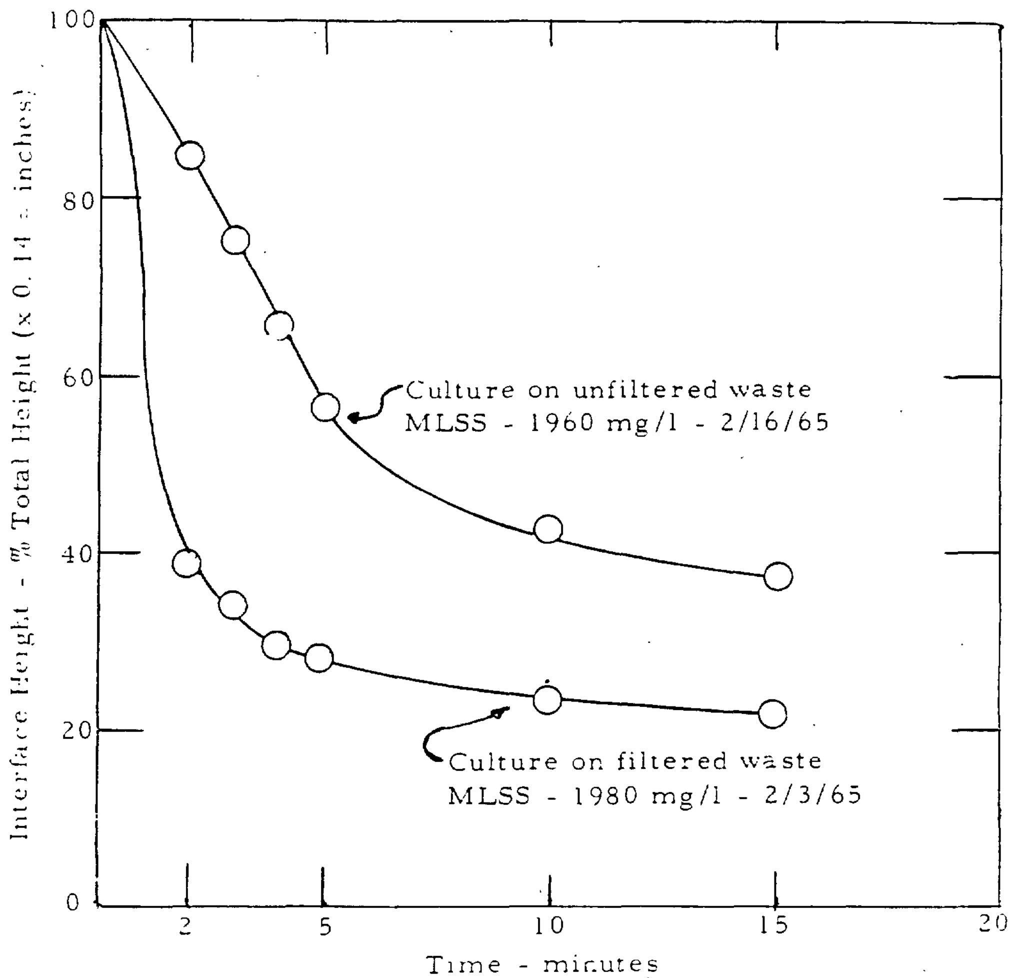
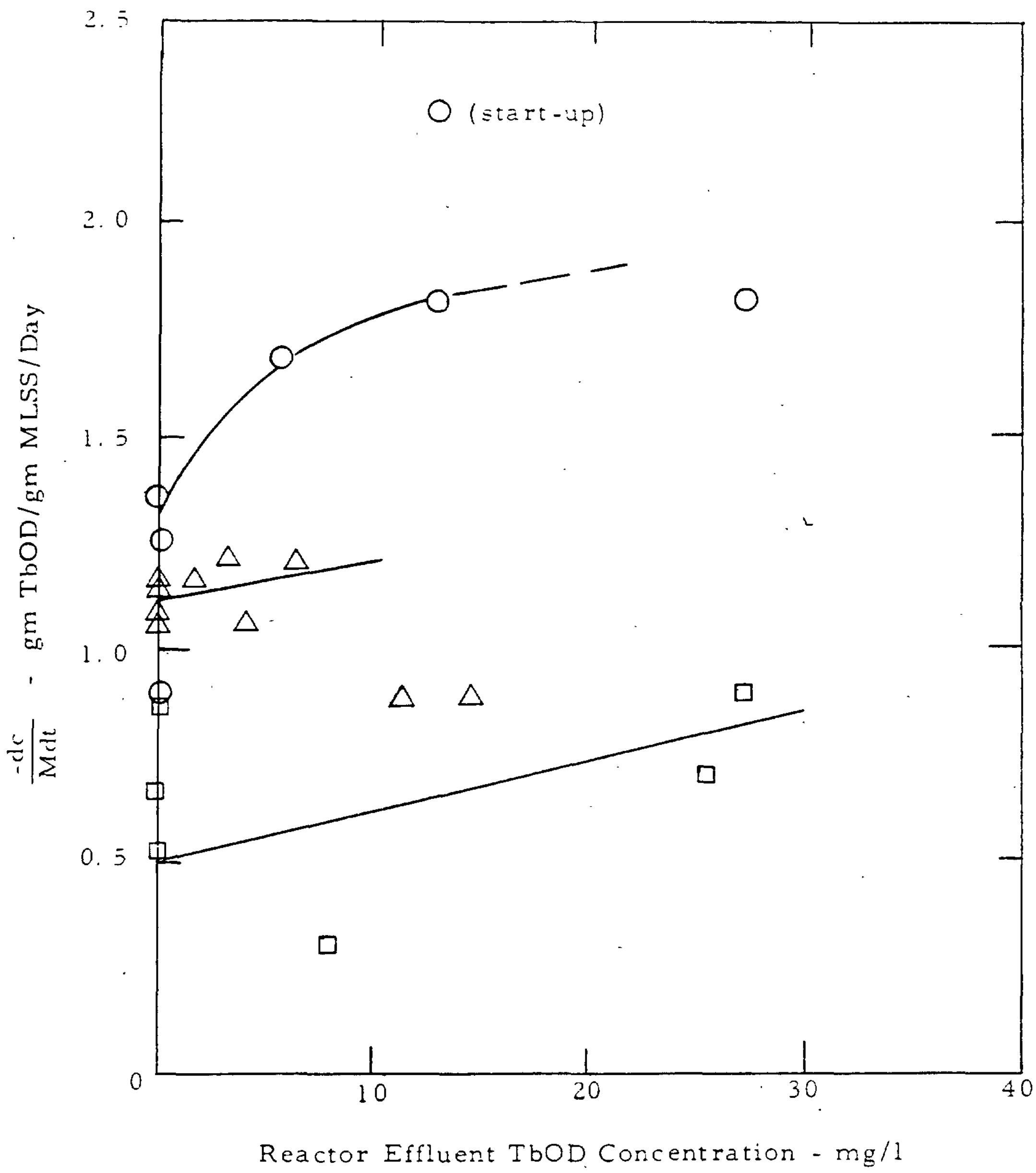


FIGURE 10. TOTAL MILL REACTOR
TYPICAL MIXED LIQUOR SETTLING CURVES



○ Without Fiber - high flow 2/18/65 - 2/23/65
△ Without Fiber - low flow 1/6/65 - 1/16/65
□ With Fiber - high flow 2/18/65 - 2/23/65

FIGURE 11. GROUNDWOOD REACTOR
UNIT REMOVAL RATE VS TbOD CONCENTRATION

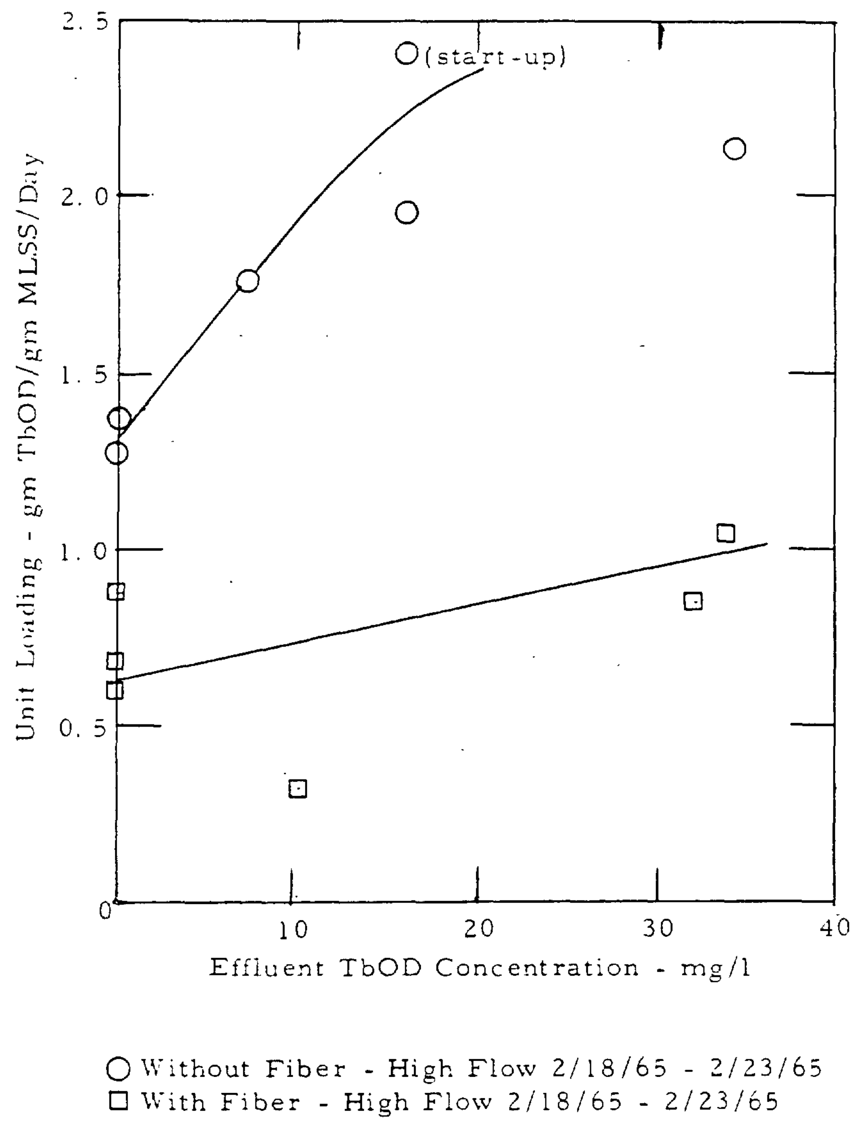
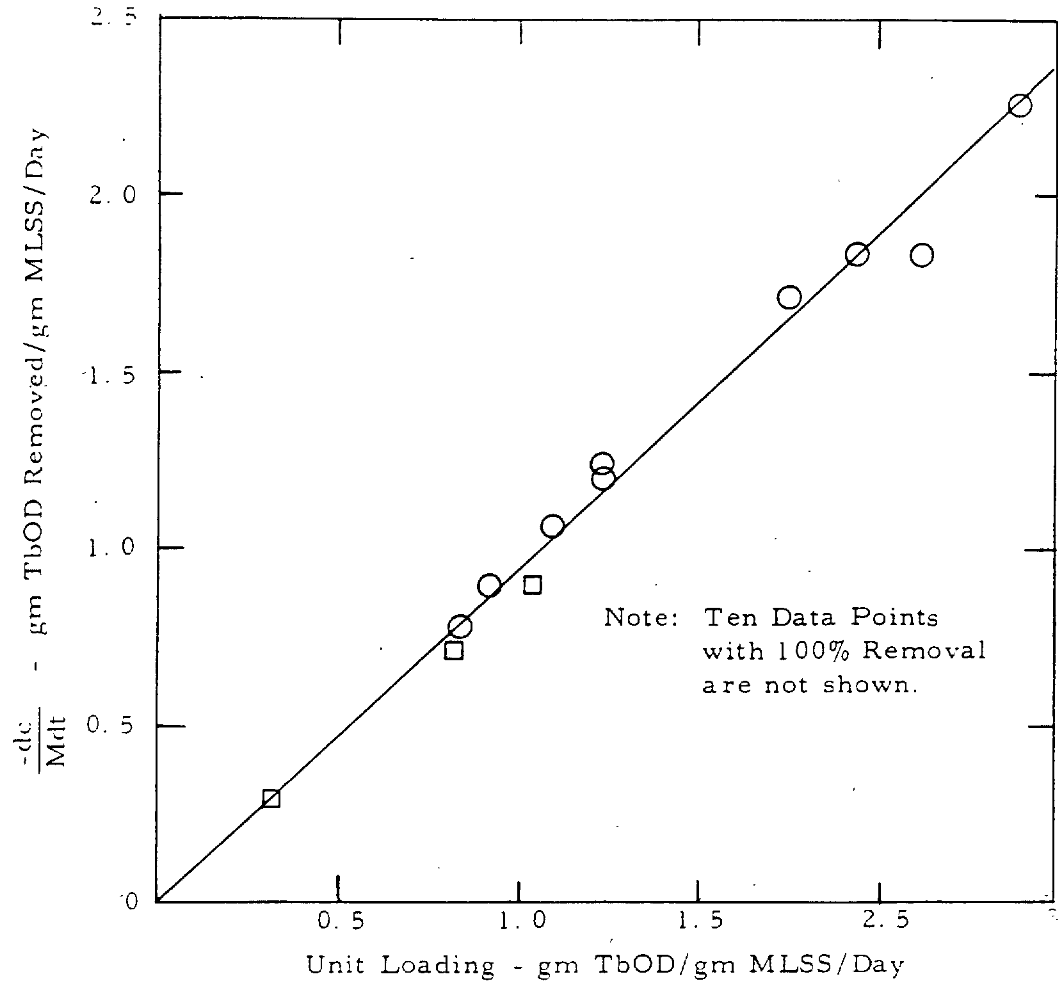
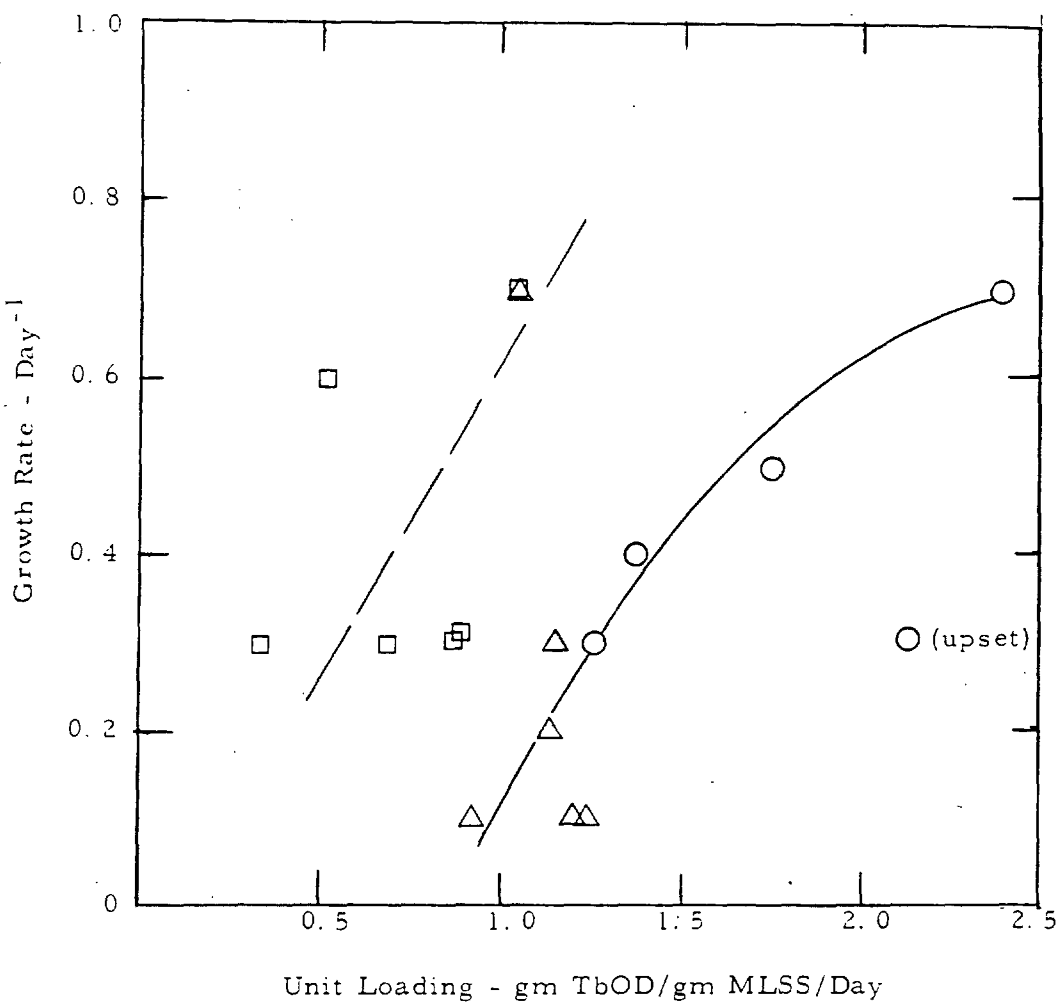


FIGURE 12. GROUNDWOOD REACTOR
UNIT LOADING VS EFFLUENT TbOD CONCENTRATION



○ Without Fiber - 1/6/65 - 1/16/65
& 2/18/65 - 2/23/65
□ With Fiber - 2/18/65 - 2/23/65

FIGURE 13. GROUNDWOOD REACTOR
UNIT REMOVAL RATE VS UNIT LOADING



○ Without Fiber - high flow 2/18/65 - 2/23/65
△ Without Fiber - low flow 1/6/65 - 1/16/65
□ With Fiber - high flow 2/18/65 - 2/23/65

FIGURE 14. GROUNDWOOD REACTOR
GROWTH RATE VS UNIT LOADING

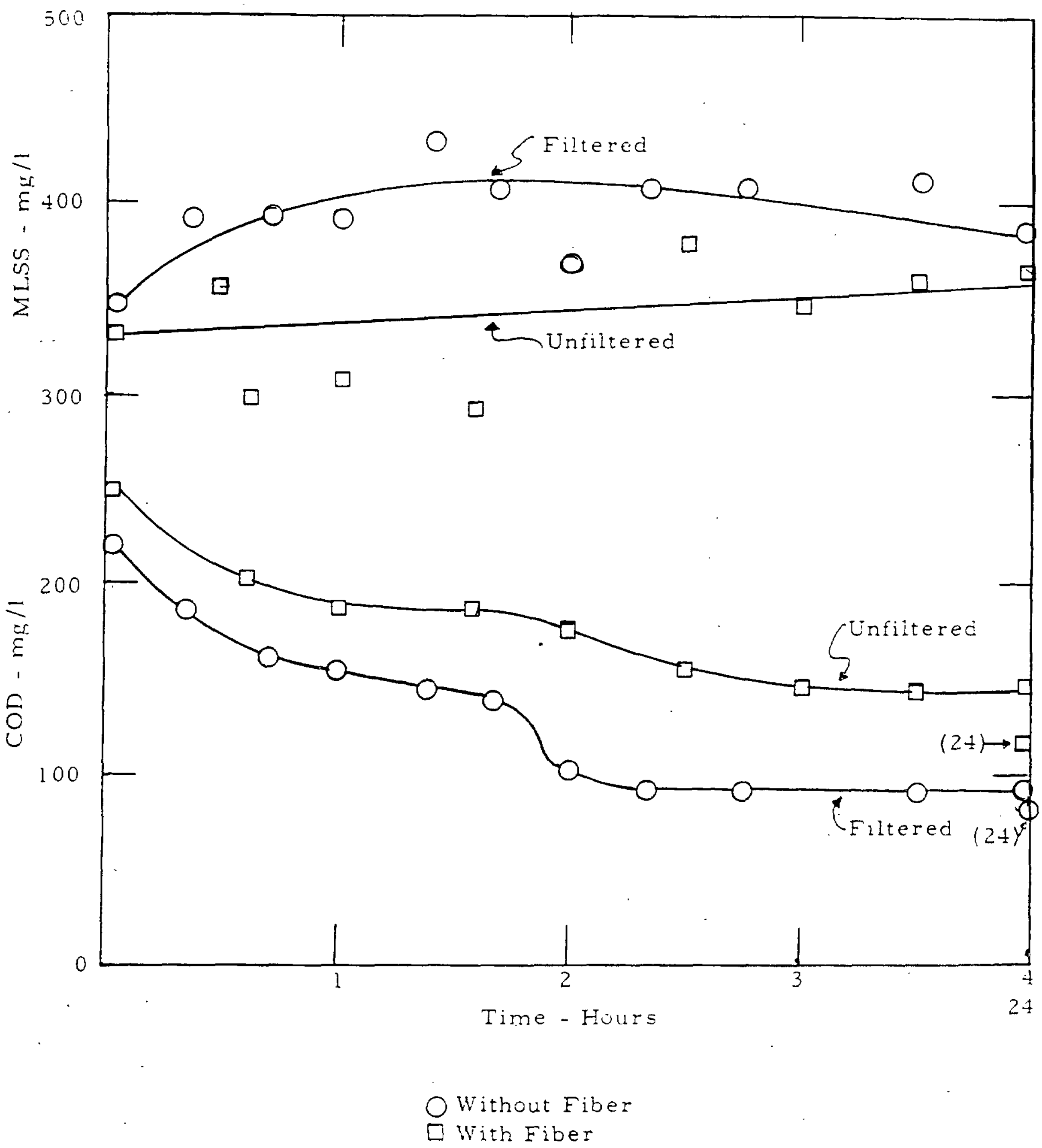
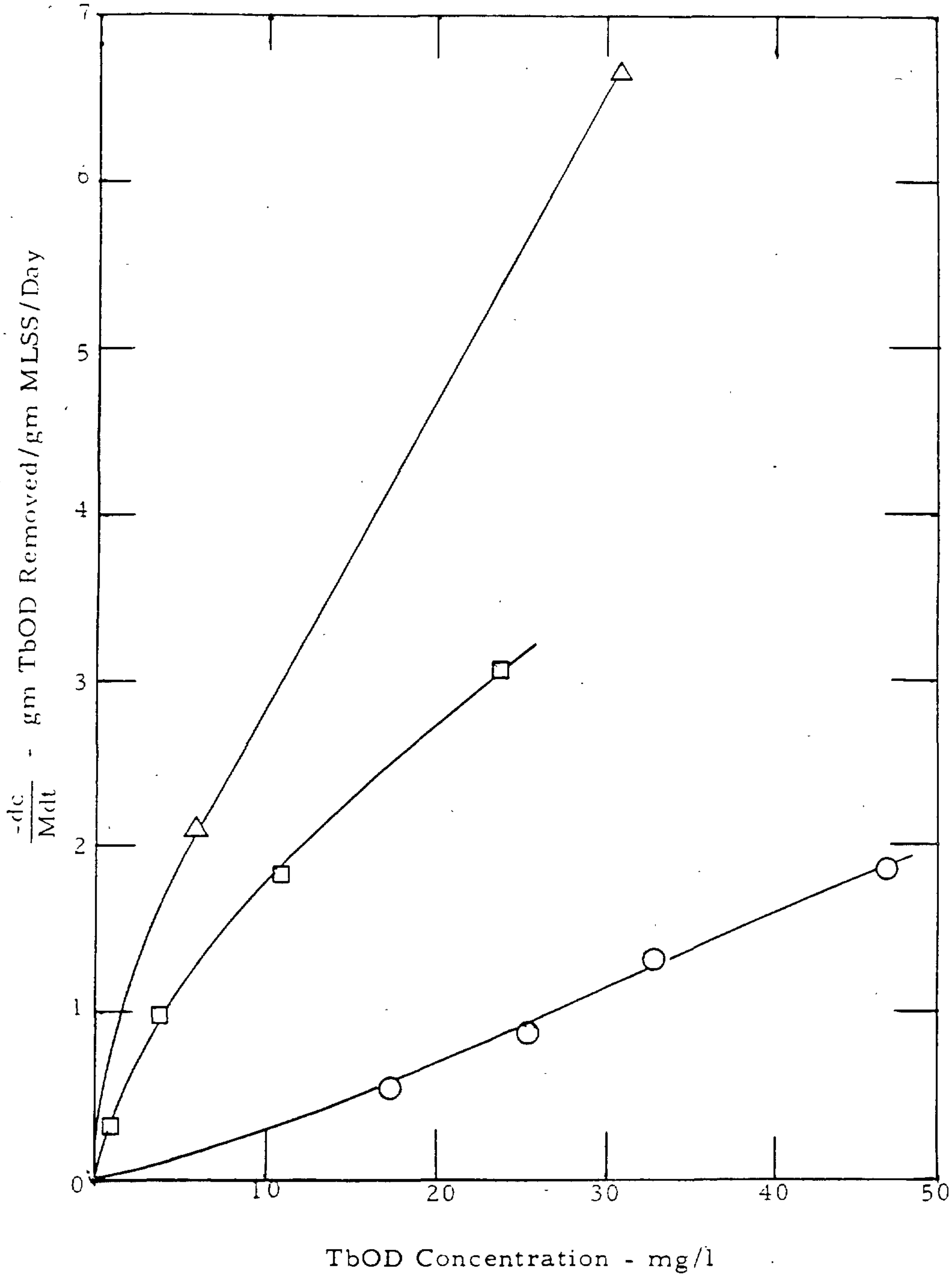


FIGURE 15A. GROUNDWOOD WASTE BATCH STUDY
COD & MLSS PROGRESSION
BATCH RATE STUDY OF 2/24/65



Symbol	Fiber	Overflow Rate	Batch Run Date
○	No	380 gpd/sq. ft.	1/19/65
△	No	700 gpd/sq. ft.	2/24/65
□	Yes	400 gpd/sq. ft.	2/24/65

Cultures Selected from Continuous Reactors

FIGURE 15B. GROUNDWOOD WASTE - BATCH RATE STUDIES
UNIT REMOVAL RATE VS TbOD CONCENTRATION

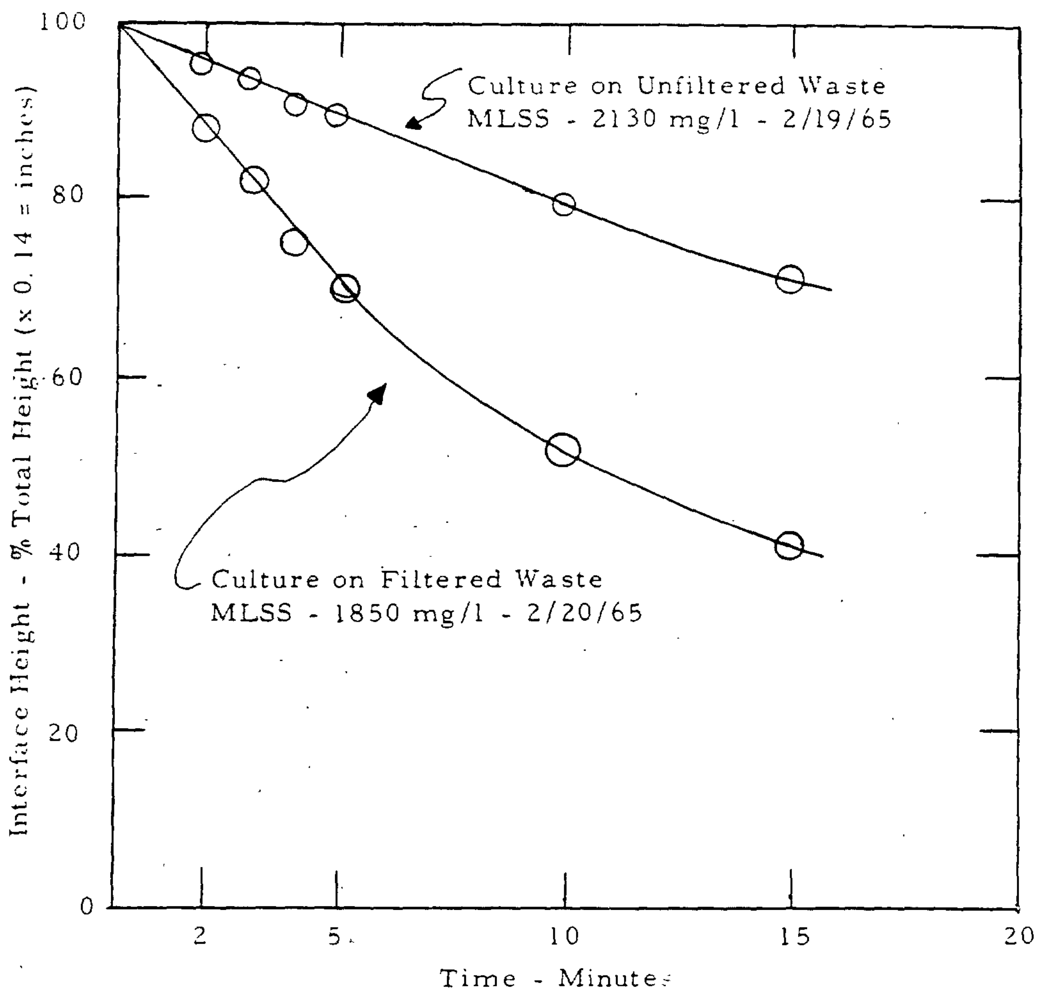


FIGURE 16. GROUNDWOOD REACTOR
TYPICAL MIXED LIQUOR SETTLING CURVES

APPENDIX

APPENDIX

BENCH SCALE BIOLOGICAL REACTOR - DAILY PROCEDURE

It is important that the reactor unit be down for a minimum of time during daily sampling. To expedite this, Sections II and III can be done concurrently with Section I of the following procedure.

It is important that the unit be fed continuously and daily. It is permissible to defer sampling on holidays, etc. but the unit must be fed and samples composited for the holiday period.

Basic data will include:

Raw waste - COD, SS, pH and Volume
Reactor - MLSS, pH and Settling Test
Effluent - COD, SS, pH and Volume
Feed Pump rate setting and stop-start times

I. REACTOR PROCEDURE

A. Turn off feed pump.
B. Remove lid and effluent tube. DO NOT TURN OFF AIR.
C. Wash innards in reactor contents (be sure all solids are returned to reactor--including those on lid). Remove cleaned innards.
D. Allow reactor to mix for 1 minute. Remove 1 liter through side connection for settling test.
Record interface height @5-minute intervals for 30-minute period.
Record total height.
E. While running settling test, sample mixed liquor for MLSS (2 - 25 ml aliquots). See Section IV. A and B for sampling procedure.
F. Replace reactor innards and level up.
G. Replace 1 liter used for settling test.
H. Refer to Section I for new feed preparation.
I. Refer to Section III for effluent handling.
J. On completion of H and I, turn on feed pump.

II. SAMPLE PREPARATION

A. Filter 20 liters of sample through Buchner Funnel with coarse filter paper.
B. Add 20 ml of 100 g/l $(NH_4)_2HPO_4$ solution to 20 liters of filtered waste. (1 ml/liter).
C. Pour in clean and empty feed jar -- record pH, start mixer.
D. Sample for SS and COD. See Section IV. A and B for sampling procedure. Use two 25 ml replicate samples.

III. EFFLUENT ANALYSES

A. Remove effluent tubing from bottle, invert bottle and mix well.
B. Pour approximately one liter into beaker.
C. Empty bottle and rinse well with tap water.
D. Replace effluent tubing.

NOTE: Before proceeding, return reactor to service.

E. Mix beaker sample well and sample for SS and COD (2 - 25 ml replicate samples) and record pH.

SEE SECTION IV. A AND B FOR SAMPLING TECHNIQUE.

IV. SAMPLING PROCEDURE

A. MLSS AND SS

1. Dessicate membrane filters overnight in aluminum dishes.
2. Tare filter and dish together.
3. Assemble filter apparatus on Test Tube. Draw 25 ml sample with open tip pipette and place in filter holder.
4. Rinse pipette with tap water into filter.
5. Rinse down filter holder sides with tap water as sample is drawn through.
6. Remove holder clamp and top--carefully scrape solids from top assembly and place on membrane filter and place in aluminum pan.

NOTE: Care must be taken to replace filter in same pan with which it was tared.

7. Dry pan and filter in oven @ 103° C for 1 hour--move to dessicator for stabilization.
8. Weigh dried and dessicated pan and filter. Carry significant figure to 0.0001 g.
9. Calculation: Example -

final wt.	-	1.7943
tare wt.	-	1.7620
Δ g	-	0.0323
	X	4×10^4
MLSS		1292 mg/l
or SS		1292 mg/l

B. COD SAMPLING PROCEDURE

1. Following Section IV. A-6 above, rinse down fritted glass filter with tap water to 40 ml/mark on test tube.

2. Transfer contents of test tube to COD flask and rinse tube with 10 ml tap water and add to COD flask.

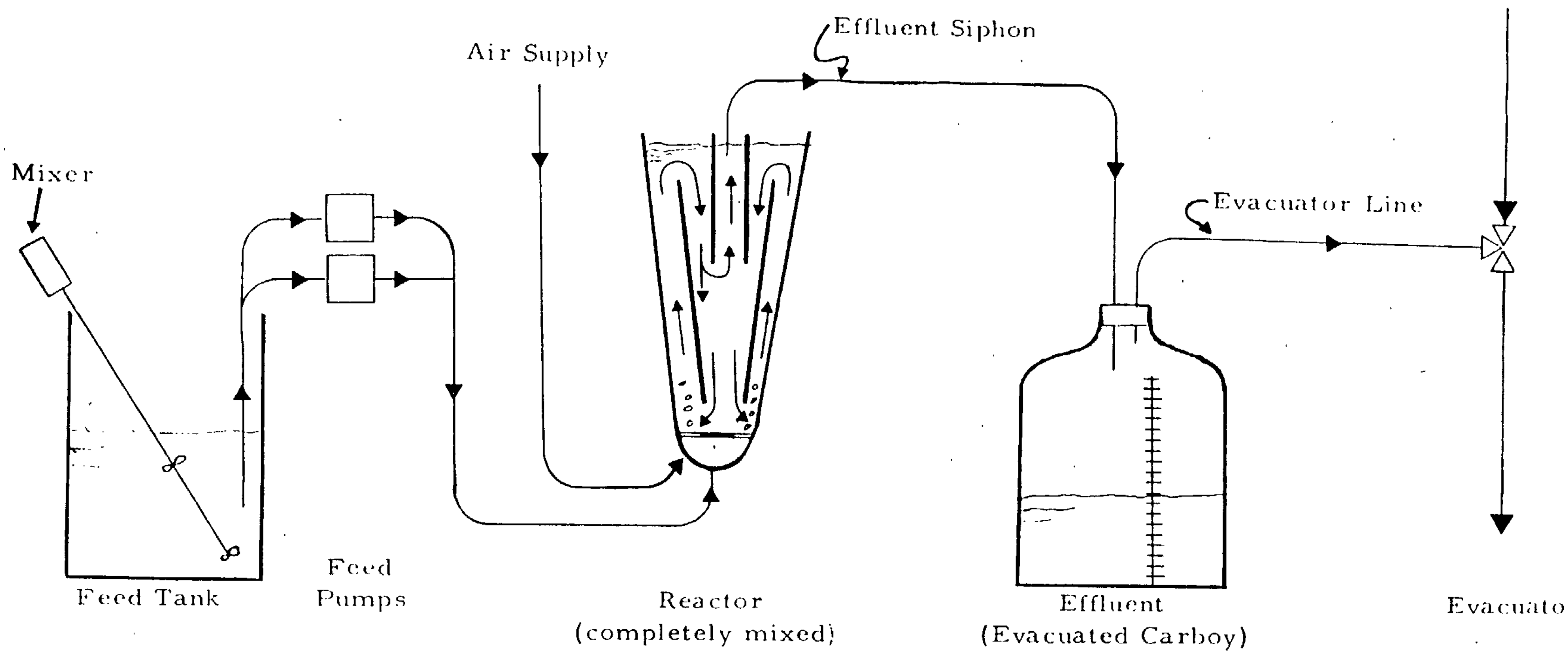


DIAGRAM 1. SCHEMATIC DIAGRAM OF BENCH-SCALE CONTINUOUS FLOW BIOLOGICAL REACTOR