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Group I , Phase II

Development Document for Advanced Notice of Proposed or Promulgated Rule Making for Effluent Limitations Guidelines and New Source Performance Standards for the

Bleached Kraft, Groundwood, Sulfite, Soda, Deink, and Non-Integrated Paper Mills

Segment of the

Pulp, Paper, and Paperboard Mills

Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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NOTICE

This document supports the Advanced Notice of Proposed or Promulgated rulemaking for effluent limitations and standards of performance and pretreatment standards for new sources for the bleached kraft, groundwood, sulfite, soda, deink, and non-integrated paper mills segment of the pulp and paper industry. It includes technical information and recommendations regarding the subject industry. It is being distributed for review and comment only.

The report, including the recommendations, will be undergoing extensive review by EPA, Federal and State agencies public interest organizations, and other interested groups and persons during the coming weeks. The report, and in particular, the recommended effluent limitations guidelines and standards of performance are subject to change in any and all respects.

The regulations to be published by EPA under Section 301, 304, 306, and 307 of the Federal Water Pollution Control Act, as Amended, will be based to a large extent on the report and the comments received on it. However, pursuant to Sections 304(b) and 306 of the Act, EPA will also consider additional pertinent technical and economic information which is developed in the course of review of this report by the public and within EPA. EPA is currently performing an economic impact analysis regarding the subject industry, which will be taken into account as part of the review of the final report. Upon completion of the review process, and prior to final promulgation of regulations, an EPA report will be issued setting forth EPA's final conclusions concerning the subject industry, effluent limitations guidelir and standards of performance applicable to such industry. Subject to these limitations, EPA is making this document available in order to encourage the widest possible particip of interested persons in the decision making process at the earliest possible time.

U.S. Environmental Protection Agency
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DEVELOPMENT DOCUMENT FOR ADVANCED NOTICE OF PROPOSED OR PROMULGATED RULEMAKING FOR EFFLUENT LIMITATIONS GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS FOR THE BLEACHED KRAFT, GROUNDWOOD, SULFITE, SODA, DEINK, AND NON-INTEGRATED PAPER MILLS SEGMENT OF THE PULP, PAPER, AND PAPERBOARD MILLS POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of the following segment of the pulp and paper industry: groundwood, sulfite, bleached kraft, soda, deink, and non-integrated paper mills, for the purpose of developing effluent limitations for existing sources and standards for new sources of performance and pretreatment standards in compliance with Sections 301, 304, 306, and 307 of the Federal Water Pollution Control Act Amendments of 1972 (the "Act").

The subcategories of pulp and paper segments established in this study are the following:

1. Bleached Kraft: Dissolving Pulp
2. Bleached Kraft: Market Pulp
3. Bleached Kraft: Fine Papers
4. Bleached Kraft: B.C.T. Papers
5. Sulfite: Papergrade
6. Sulfite: Dissolving
7. Soda
8. Groundwood: Chemi-mechanical (CMP)
9. Groundwood: Thermo-mechanical (TMP)
10. Groundwood: Fine Papers
11. Groundwood: C.M.N. Papers
12. Deink
13. Non-Integrated Fine Papers
14. Non-Integrated Tissue Papers
15. Non-Integrated Tissue Papers (fwp)

This subcategorization does not include two types of operations within the non-integrated paper mill segment. These operations are non-integrated paper mills producing coarse and specialty papers. Effluent limitations will be developed for these types of mills at a later date.

Effluent limitations are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available," and the "Best Available Technology Economically Achievable," which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. "Standards of Performance for New Sources" set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

The identified technology for July 1, 1977, is good in-plant waste water management followed by preliminary screening, primary sedimentation, and biological treatment. The 1977 limitations can be met by mills utilizing only biological treatment, but a combination of in-plant controls and biological treatment may be more cost effective.

The identified technology for July 1, 1983, is in-plant waste water controls and biological treatment. The identified in-plant controls may require some major changes in existing processes and design modifications to existing equipment. In addition, filtration with chemical addition and coagulation is identified for TSS reduction. Physical-chemical treatment for color removal is identified for five subcategories.

The identified technology for new source performance standards is in-plant waste water controls, biological treatment, and chemical addition and coagulation. The identified in-plant controls and external treatment systems are available for implementation as they have all been demonstrated at mills within the subcategories under study.

Supportive data and rationale for development of the effluent limitations and standards of performance are contained in this report.

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SECTION I

CONCLUSIONS

For the purpose of establishing effluent limitations and standards of performance, the segments of the pulp and paper industry which were studied have been subcategorized as follows:

Groundwood: Chemi-mechanical
Groundwood: Thermo-mechanical
Groundwood: CMN Papers
Groundwood: Fine Papers
Bleached Kraft: Dissolving Pulp
Bleached Kraft: Market Pulp
Bleached Kraft: BCT Papers
Bleached Kraft: Fine Papers
Soda
Papergrade Sulfite
Dissolving Sulfite
Deink
Non-Integrated Fine Papers
Non-Integrated Tissue Papers
Non-Integrated Tissue Papers (FWP)

Within each identified subcategory, factors such as age, size of plant, process employed, climate, and waste treatability confirm and substantiate this subcategorization for the purpose of establishing effluent limitations and performance standards to be achieved through the application of identified treatment and control technologies.

The 1977 requirement of best practicable technology currently available (BPCTCA) suggests biological waste treatment as the basic treatment process for all except the non-integrated tissue paper subcategory. Primary treatment is suggested for the latter. Limitations for BOD, total suspended solids, zinc, and pH are set forth.

Best available technology economically achievable (BATEA) is a requirement for 1983, and a few mills in the subcategories studied are currently achieving this for most identified pollutants. This technology level suggests major internal mill improvements, biological waste treatment, and physical-chemical waste treatment as the basic treatment and control technologies, and limitations for BOD, suspended solids, pH, zinc, and color are set forth.

New source performance standards (NSPS) reflect internal improvements which can be achieved through effective design and layout of mill operations. Standards are set forth for BOD, suspended solids, pH, and zinc. The basic treatment and control processes which are suggested as a means of meeting these performance standards are similar to those proposed for existing mills by 1983.

SECTION II

RECOMMENDATIONS

INTRODUCTION

The recommended effluent limitations for existing sources are shown in Table 1 and Table 2 for BPCTCA and BATEA, respectively. Standards of performance for new sources are shown in Table 3.

The average of daily values for any 30 consecutive days should not exceed the maximum 30 day average shown in the tables. The value for any one day should not exceed the daily maximum as shown in the tables. The limitations and standards are in kilograms of pollutant per metric ton of production (pounds of pollutant per short ton of production). Effluents should always be within the pH range of 6.0 to 9.0.

For all of the wood pulping subcategories, the following allowances for BOD5 and TSS can be added to BPCTCA effluent limitations for mills with wet woodyard operations:

	Max 30 day average kg/kkg (lbs/ton)	Max Daily average kg/kkg (lbs/ton)
BOD5	0.5 (1.0)	0.9 (1.8)
TSS	0.75 (1.5)	1.6 (3.2)

Production in kkg (tons) is defined as annual tonnage produced from pulp dryers (in the case of market pulp) and paper machines (for paper/board) divided by the number of production days in the 12 month period. Pulp production is to be corrected, if necessary, to the "air dry" moisture basis. No such correction is necessary for paper/board production.

The limitations for TSS are for TSS as measured by the techniques utilizing glass fiber filter discs as specified in Standard Methods for the Examination of Water and Wastewater (13th Edition).

It is recommended that ammonia nitrogen effluent limitations be developed for ammonia base sulfite and dissolving sulfite mills. Insufficient data exists to determine representative ammonia nitrogen levels discharged by these mills, but sparse data indicate that their effluents contain 1 to 3 kg/kkg (2 to 6 lb/ton). No technology is currently available or anticipated for 1983 for removing ammonia nitrogen at the flows and concentrations found in these effluents and thus, ammonia nitrogen removal is not practicable or economically achievable at this time.

It is also recommended that color effluent limitations be developed for all sulfite and dissolving sulfite mills. Sparse

data indicated that color discharged from these mills contain 200 to 250 kg/ kkg (400 to 500 lb/ton). No technology is foreseen to be available prior to 1983 for removing color from these effluents and thus color removal by sulfite mills is not practicable or economically achievable at this time.

Table 1
BPCTCA
Effluent Limitations in kg/kkg(lbs/ton)

Subcategory	Maximum 30 Day Average		Maximum Day	
	BOD5	TSS	BOD5	TSS
Dissolving Kraft	12.95(25.9)	15.55(31.1)	21.95(43.9)	34.05(68.1)
Market Kraft	7.1 (14.2)	10.3 (20.6)	12.05(24.1)	22.6 (45.2)
BCT Kraft	6.35(12.7)	10.3 (20.6)	10.75(21.5)	22.6 (45.2)
Fine Kraft	4.7 (9.4)	7.35(14.7)	7.9 (15.8)	16.05(32.1)
Papergrade Sulfite	15.2 (30.4)	21.15(42.3)	25.75(51.5)	46.4 (92.8)
Dissolving Sulfite	22.7 (45.4)	26.25(52.5)	38.5 (77.0)	57.55(115.1)
GW-Chemi-Mechanical	3.5 (7.0)	5.9 (11.8)	5.95(11.9)	12.9 (25.8)
GW-Thermo-Mechanical	2.6 (5.2)	4.45(8.9)	4.4 (8.8)	9.7 (19.4)
GW-CMN Papers	4.2 (8.4)	7.0 (14.0)	7.1 (14.2)	15.35(30.7)
GW-Fine Papers	3.75(7.5)	6.45(12.9)	6.35(12.7)	14.1 (28.2)
Soda	5.75(11.5)	8.3 (16.6)	9.75(19.5)	18.2 (36.4)
Deink	7.0 (14.0)	12.65(25.3)	11.9 (23.8)	27.7 (55.4)
NI Fine Papers	4.2 (8.4)	4.25(8.5)	7.1 (14.2)	9.35(18.7)
NI Tissue Papers	4.7 (9.4)	4.65(9.3)	7.9 (15.8)	10.25(20.5)
NI Tissue (FWP)	4.7 (9.4)	4.65(9.3)	7.9 (15.8)	10.25(20.5)

pH for all subcategories shall not exceed 6.0 to 9.0

Subcategory	Zinc	
	Maximum 30 Day Average kg/kkg(lbs/ton)	Maximum Day kg/kkg(lbs/ton)
GW:Chemi-mechanical	0.125 (0.25)	0.25 (0.50)
GW:Thermo-mechanical	0.095 (0.19)	0.19 (0.38)
GW:CMN Papers	0.150 (0.30)	0.30 (0.60)
GW:Fine Papers	0.135 (0.27)	0.27 (0.54)

Table 2
PATEA
Effluent Limitations in kg/kkg(lbs/ton)

Subcategory	Maximum 30 Day Average BOD5	TSS	Maximum Day BOD5	TSS
Dissolving Kraft	5.45(10.9)	3.45(6.9)	11.25(22.5)	7.6 (15.2)
Market Kraft	3.35(6.7)	2.25(4.5)	6.9 (13.8)	4.95(9.9)
BCT Kraft	2.85(5.7)	1.85(3.7)	5.9 (11.8)	4.05(8.1)
Fine Kraft	1.9 (3.8)	1.55(3.1)	4.0 (8.0)	3.35(6.7)
Papergrade Sulfite	6.45(12.9)	3.15(6.3)	13.3 (26.6)	6.9 (13.8)
Dissolving Sulfite	8.35(16.7)	4.05(8.1)	17.3 (34.6)	8.85(17.7)
GW-Chemi-Mechanical	1.25(2.5)	1.2 (2.4)	2.6 (5.2)	2.65(5.3)
GW-Thermo-Mechanical	1.1 (2.2)	0.65(1.3)	2.25(4.5)	1.4 (2.8)
GW-CMN Papers	1.75(3.5)	1.3 (2.6)	3.65(7.3)	2.8 (5.6)
GW-Fine Papers	1.65(3.3)	1.2 (2.4)	3.45(6.9)	1.0 (2.0)
Soda	2.4 (4.8)	1.55(3.1)	5.0 (10.0)	3.35(6.7)
Deink	2.5 (5.0)	2.4 (4.8)	5.2 (10.4)	5.3 (10.6)
NI Fine Papers	1.25(2.5)	0.65(1.3)	2.6 (5.2)	1.4 (2.8)
NI Tissue Papers	2.0 (4.0)	0.95(1.9)	4.15(8.3)	2.1 (4.2)
NI Tissue (FWP)	2.0 (4.0)	0.95(1.9)	4.15(8.3)	2.1 (4.2)

pH for all subcategories shall not exceed 6.0 to 9.0

Color

Subcategory	Maximum 30 Day Average kg/kkg(lbs/ton)	Maximum Day kg/kkg(lbs/ton)
Dissolving Kraft	125 (250)	250 (500)
Market Kraft	95.0 (190)	190 (380)
BCT Kraft	65.0 (130)	130 (260)
Fine Kraft	65.0 (130)	130 (260)
Soda	65.0 (130)	130 (260)

Zinc

Subcategory	Maximum 30 Day Average kg/kkg(lbs/ton)	Maximum Day kg/kkg(lbs/ton)
GW:Chemical-mechanical	0.115 (0.23)	0.23 (0.46)
GW:Thermo-mechanical	0.065 (0.13)	0.13 (0.26)
GW:CMN Papers	0.120 (0.24)	0.24 (0.48)
GW:Fine Papers	0.115 (0.23)	0.23) (0.46)

Table 3
NSPS
Effluent Limitations in kg/kkg(lbs/ton)

Subcategory	Maximum 30 Day Average BOD5	Maximum 30 Day Average TSS	Maximum Day BOD5	Maximum Day TSS
Dissolving Kraft	5.45(10.9)	7.0 (14.0)	11.2 (22.5)	15.35(30.7)
Market Kraft	1.85(3.7)	2.6 (5.2)	3.8 (7.6)	5.65(11.3)
BCT Kraft	2.85(5.7)	3.6 (7.2)	5.9 (11.8)	7.95(15.9)
Fine Kraft	1.9 (3.8)	3.05(6.1)	4.0 (8.0)	6.7 (13.4)
Papergrade Sulfite	4.1 (8.2)	3.95(7.9)	8.5 (17.0)	8.65(17.3)
Dissolving Sulfite	8.35(16.7)	8.05(16.1)	17.3 (34.6)	17.65(35.3)
GW-Chemi-Mechanical	1.25(2.5)	2.4 (4.8)	2.6 (5.2)	5.3 (10.6)
GW-Thermo-Mechanical	2.6 (5.2)	2.0 (4.0)	5.35(10.7)	4.4 (8.8)
GW-CMN Papers	1.75(3.5)	2.6 (5.2)	3.65(7.3)	5.65(11.3)
GW-Fine Papers	1.65(3.3)	2.4 (4.8)	3.45(6.9)	5.3 (10.6)
Soda	2.4 (4.8)	3.05(6.1)	5.0 (10.0)	6.7 (13.4)
Deink	3.75(7.5)	3.6 (7.2)	7.8 (15.6)	7.95(15.9)
NI Fine Papers	1.25(2.5)	1.2 (2.4)	2.6 (5.2)	2.65(5.3)
NI Tissue Papers	2.0 (4.0)	1.85(3.7)	4.15(8.3)	4.25(8.5)
NI Tissue (FWP)	2.0 (4.0)	1.85(3.7)	4.15(8.3)	4.25(8.5)

pH for all subcategories shall not exceed 6.0 to 9.0

Zinc

Subcategory	Maximum 30 Day Average kg/kkg(lbs/ton)	Maximum Day kg/kkg(lbs/ton)
GW:Chemi-mechanical	0.115 (0.23)	0.23 (0.46)
GW:Thermo-mechanical	0.095 (0.19)	0.13 (0.26)
GW:CMN Papers	0.120 (0.24)	0.24 (0.48)
GW:Fine Papers	0.115 (0.23)	0.23 (0.46)

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Federal Water Pollution Control Act, as amended in 1972, requires the achievement, by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available (BPCTCA) as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement, by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable (BATEA) which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. Section 307(b) and (c) of the Act requires the achievement of pretreatment standards by existing and new sources for introduction of pollutants into publicly owned treatment works for those pollutants which are determined not to be susceptable to treatment by such treatment works or which would interfere with the operation of such treatment works.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods, and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for segments of the pulp, paper, and paperboard point source categories. They are the groundwood, sulfite, bleached kraft, soda, and deinked pulping segments and the non-integrated fine, and tissue papermaking segments.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b)(1)(A) of the Act, to propose regulations establishing federal standards of performance for new sources within such categories. The Administrator published in

the Federal Register of January 16, 1973, (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the pulp, paper, and paperboard point source categories, which were included within the list published January 16, 1973. This report proposes such standards for the groundwood, sulfite, bleached kraft, soda, and deinked pulping segments and the non-integrated fine, and tissue, papermaking segments.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS AND STANDARDS OF PERFORMANCE

This study was initiated to gather the necessary information upon which to base effluent limitations and standards of performance for the manufacturing facilities included in the following segments of the pulp and paper industry:

Groundwood
Sulfite
Bleached Kraft
Soda
Deinked
Non-Integrated Paper Mills

These major segments represent significant differences in production processes which, experience demonstrates, bear a direct relationship to the quantity and quality of their waste waters.

A literature search and screening program were undertaken in order to identify all the mills in each of the above segments. Directories which describe the production processes and products manufactured by each mill in the pulp and paper industry were utilized, along with industry journals, direct mill contact, and contractor knowledge. Mills were allocated to the various segments according to criteria explained in detail later in this Section.

Next, information describing the waste water treatment facilities and the quantity and quality of the waste water discharged by each mill was tabulated. In this effort, the contractor was assisted by EPA regional offices which provided NPDES data and other pertinent information from their files. Various state pollution control agencies also cooperated in furnishing waste water discharge and additional data. The National Council for Air and Stream Improvement also provided considerable assistance. It was particularly valuable in verifying data obtained from other sources which appeared to need clarification and/or substantiation. In addition, an in-depth literature search was conducted to strengthen the data base and to provide information on the internal and external control technologies utilized by the various mills.

This program culminated in the tabulation of approximately 358 mills that qualify for inclusion in this study. In this total, each mill site is counted only once, even though it may encompass multiple physical facilities housing more than one pulping and/or papermaking process. While there is considerable variation in reporting numbers of "mills" within the industry, this approach was used because of its relationship to the total raw waste load of an industrial complex.

Selection of Mills for On-Site Survey

Screening sheets were prepared for each segment showing, by mill, all production and waste treatment data available.

Evaluation of this information indicated that it was an adequate basis upon which to select those mills in each segment that would provide the broad-based in-depth information necessary to subcategorize the segments and to identify BPCTCA. It should be noted that information was subsequently updated and corrected as the study progressed.

These mills thus became candidates for on-site surveys to assure the reliability and validity of the performance ascribed to them -- i.e., a tour and evaluation of the production processes and waste treatment facilities to verify the quality of the production and waste water data generated by the mill.

The selection of a mill as a survey candidate was made on a descending order of priorities. First priority was an operating treatment facility that includes biological treatment of the entire process waste water. Second priority was the quality of the final discharge after treatment and the quantity of waste water generated by the mill in terms of l (or kl)/kkg (gallons per ton) of product. Predicated on these criteria, 74 mills appeared to be candidates for mill survey; of these, 44 were in the bleached kraft segment, nine in the groundwood segment, one in the soda segment, and four each in the remaining five segments. All of the mills with biological treatment were selected in each segment except the bleached kraft segment. Twenty-five of the 44 mills in that segment utilizing secondary treatment were selected, and the remaining 19 mills were eliminated for one or more of the following reasons:

1. The available data indicated poor performance of treatment facilities.

2. The mill utilized two or more pulping processes involving substantial unbleached kraft and/or semi-chemical pulp production. The waste generated by such complex mills would therefore not be representative of any single segment included in this study.

3. Abnormally high water-use values suggested minimal utilization of internal controls.

4. Waste water discharge data were not available.

5. Non-standard analytical procedures and/or flow measuring devices were utilized.

The 25 mills selected for the bleached kraft segment adequately represented a cross-section of the segment in terms of raw materials, production processes, geographic locations, internal and external control practices, and age and size of mill. This was not the case, however, with the mills with biological treatment in the other segments. Therefore, it was necessary to select mills for survey in the segments other than bleached kraft on the basis of well-operated primary treatment facilities and/or available raw waste data to broaden the data base for subcategorization and to define waste water characteristics for each subcategory. In addition, considerations of raw material usage, processes, number of production units, geographic location, internal and external control practices, and age and size of mill were balanced among additional selections. As a result, the total number of mills selected for on-site survey reached 104, or over 25 percent of all the mills covered by this study. Records on waste treatment facilities, waste water discharge, and production processes were also obtained on 10 additional mills.

Following these original data collection efforts, the resulting data base was evaluated to determine how representative the available data was of each segment or subcategory. From this analysis, additional efforts were made to collect data from an additional 70 mills and further data from approximately 30 mills previously surveyed. Collection of the additional information and data involved on-site surveys, written correspondence, and telephone surveys. The data collected from mills previously surveyed is identified in this report with the original mill code followed by an "A" (i.e. 101A). The number of mills surveyed and the percent that this represents of the total number of mills in each segment is shown in Table 4.

Mill Survey Program

A comprehensive mill survey format was developed for completion at the mill site by a survey team. The format was designed to make it possible to equate the information obtained at one mill with that of all mills included in the survey and to evaluate the many variables associated with their production processes and waste treatment.

The analytical test procedures utilized by each mill were documented and the deviations from standard methods employed for several waste water parameters were noted. The type of flow measuring and sampling devices used were also recorded and evaluated as to their reliability. Information regarding the nominal production capacity and raw materials used by the mill was obtained, and the dates on which production facilities and/or

TABLE 4

SUMMARY OF SURVEYED MILLS BY SEGMENT

Segment	Total No. of Mills	Mills with Secondary Treatment	Percent of Segment	No. of Mills Surveyed	Percent of Segment
Groundwood	39	8	21	22	56
Sulfite	28	6	21	19	68
Bleached Kraft	74	42	56	40	52
Soda	3	1	33	3	100
Deink	17	6	35	15	88
Fine	46	4	9	21	46
Tissue	74	4	5	25	34
	282	70		144	51

waste treatment facilities were installed, modified, or updated were established.

The survey form was also designed to quantify to the extent possible the internal and external technologies employed at each mill and the extent to which these technologies were utilized. It was accompanied by single-line block diagrams of the production process and waste streams generated by each process. Similar diagrams of the waste treatment facilities were sketched showing the sampling and flow measurement points for which the mill had 12 months of records. Such records of data on all routinely tested streams and parameters were requested.

Data Handling and Computer Program

The production and waste treatment records obtained were subjected to detailed screening and evaluation to 1) eliminate obviously erroneous data and 2) code each waste stream for which mills did have usable records in order to develop a uniform and consistent data format for computer programming. The code numbers and waste streams to which they apply are shown in Table 5. The evaluation and coding program culminated in the completion of Survey Form Number 7. This form provided the computer programmer with the mill code number, the kkg/day (tons/day) of production attributable to each mill, the waste streams described by the data, and the parameters to be utilized for computer input. Parameters tested by one or more mills are identified in Table 6, together with the abbreviations used in computer outputs. It should be noted particularly that non-standard test methods are identified in the computer analysis by the letter "N" following the abbreviation. Such data must be used very cautiously since it is not comparable to data obtained by standard methods. The definition of standard methods for all parameters except color was derived from Standard Methods for the Examination of Water & Waste Water, 13th edition (191). In the case of color, the method outlined in National Council for Air and Stream Improvement Bulletin 253 (192) was used to define the standard method (Appendix 15). For total suspended solids, either the fiberglas method described in current editions of Standard Methods or the asbestos method described in earlier editions was taken as the standard method.

The computer program provided the following data output for each of the "computerized" mills:

1. Annual means for individual waste streams for all parameters for which there were data.

2. Monthly averages for all available parameters on the total raw waste, stream No. 9, and the final discharge, stream No. 79.

3. The 30-maximum-day values for all waste parameters available for stream No. 79.

4. Three types of statistical plots for all available stream No. 79 parameters for 45 surveyed mills. To the extent possible the mills selected for these plots utilized biological treatment facilities; for those segments in which few mills have biological treatment mills with well operated primary treatment facilities were included. The three plots can be described as follows: (a) frequency distribution histogram; (b) a cumulative probability plot; (c) chronological plot.

From the cumulative probability plot the minimum data value, maximum data value, mean value, standard deviation, coefficient of variation, and number of data days are determined for each parameter plotted. The chronological plot is actually three plots of a given parameter. One plot is of the daily data value; the next is the average of four calendar days; and the third plot is the 30-calendar-day moving average. In all cases, missing data are excluded from the averaging calculation and the averages are determined from the actual data available within the calendar time specified -- i.e., four days or 30 days.

Table 5

STREAM SYMBOLS

Stream No.	Description
0	Principally pulp mill waste
1	Principally bleach plant waste
2	Principally paper mill waste
3 to 8	Raw waste stream not otherwise identified
9	TOTAL raw waste streams
10 to 18	Individual streams to primary treatment
19	TOTAL streams to primary treatment
20 to 28	Individual sreams after primary treatment
29	TOTAL effluent from primary treatment
30 to 38	Individual streams to secondary treatment
39	TOTAL influent to secondary treatment
40 to 48	Individual streams after secondary treatment (includes streams from activated sludge secondary clarifier)
49	TOTAL effluent from secondary treatment (includes effluent from activated sludge secondary clarifier)
50 to 58	Individual streams to post storage (holding ponds, storage oxidation basin, and other post secondary devices)
59	TOTAL influent to post storage
60 to 68	Individual streams from post storage
69	TOTAL effluent from post storage
70 to 78	Individual streams from treatment
79	TOTAL effluent from treatment to receiving waters
80 to 88	Individual streams not receiving any treatment
89	SUM of all streams not receiving treatment

Table 6

PARAMETERS MEASURED AND ABBREVIATIONS

Parameter	Abbreviations*
5-Day Biochemical Oxygen Demand	BOD5 or BOD
Temperature	Temp
Total Suspended Solids	TSS
Color	Color
Turbidity	Turbid
Zinc	ZINC
Phosphate	PO4
pH	pH
Nitrogen	N or Nitrogen
Ammonia Nitrogen	NH4 or Ammonia
Settleable Solids	Setslds
Chemical Oxygen Demand	COD
Total Solids	TS
Total Volatile Solids	TVS

*The letter "N" following the abbreviation was used to designate a non-standard method of laboratory analysis.

GENERAL DESCRIPTION OF INDUSTRY SEGMENTS

Paper is made from raw materials which contain adequate amounts of cellulose fiber, its basic component. The cellulose must first be separated from other constituents of the fiber source and fiberized. This is the function of the pulping process. During the 19th century, wood began to supplant cotton and linen rags, straw, and other less plentiful fiber sources. Today, wood accounts for over 98 percent of the virgin fiber used in papermaking.

This report deals exclusively with wood pulp and products made primarily from it and the reclamation of used papers, which, in turn, consist primarily of wood fiber.

There are several methods used for pulping wood. In some, it is cooked with chemicals under controlled conditions of temperature, pressure, time, and liquor composition (1). The various processes utilize different chemicals or combinations of them. In other methods, wood is reduced to a fibrous state by mechanical means alone or by a combination of chemical and mechanical action.

Mechanical pulp is commonly called groundwood. In the basic process, stone groundwood, pulp is made by grinding logs, or short lengths of logs called billets, on a grindstone; pulp produced by passing wood chips through a disc refiner is termed refiner groundwood. In the chemi-groundwood process the billets are first pressure imprenated with a dilute solution of sodium sulfite before grinding; in cold soda (chemi-mechanicall) pulping, chips are steeped in a caustic solution and refined. Such pretreatment softens the wood so that less power is required for grinding. In a new process, thermo-mechanical pulping, chips are first softened with heat and then refined under pressure. These general descriptions are subject to modification in practice.

Although groundwood pulp was initially shunned by the makers of fine paper when the basic process was introduced in this country in the last century, today it is considered a very versatile pulp and is put to many uses. Its initial success in the manufacture of paper was its acceptance for newsprint and that is still its primary market. The major disadvantage of groundwood, impermanence, is offset by the economy of its production, especially for the manufacture of the wide range of "throw-away" products demanded by 20th century Americans -tissues, toweling, paper plates, etc. -- and the millions of "paperbacks" printed every year. The mechanical pulps of more recent vintage -- refiner, cold soda, chemi-groundwood, and thermo-mechanical -- are also components of diversified products.

Both of the major chemical pulping processes in use in the U.S. today, acid sulfite and kraft (or sulfate), also had their origins in the 19th century. Kraft, an alkaline process, was not, however, fully commercially developed until the early 1900's

and it was the soda process, the alkaline forebear of kraft, which was the early competitor of sulfite pulping for some grades of pulp. With the ascendancy of the kraft process, most soda mills converted to kraft, a stronger pulp, and subsequent developments have minimized the differences between the two (2). Currently, there are only three major mills which report the production of soda pulp from wood fiber. All of these mills are engaged in the manufacture of printing and fine papers.

Acid sulfite pulps, too, are primarily associated with fine papers, although either alone or in combination with other pulps, they have many papermaking capabilities. In addition, dissolving pulps, the highly purified chemical cellulose used in the manufacture of rayon, cellophane, and explosives, was produced solely by the sulfite process for many years.

Sulfite pulping developed around the use of calcium as the base of the sulfite liquor (2) because of an ample and cheap supply of limestone (calcium carbonate). Ironically, the use of calcium has, in recent years, led to the demise of many old sulfite mills because 1) the difficulty and expense of recovering or burning spent liquor from this base was not economic to the operation and the absence of non-polluting disposal methods precluded their compliance with water quality standards and/or effluent limitations; and 2) the diminishing quantities of soft woods suitable for calcium-base pulping (3) (4). In addition, attempts to utilize more than about 10 percent of the spent liquor in various byproducts failed. As a result, most acid sulfite mills have changed to a soluble base -- magnesium, ammonia, or sodium -- which permits recovery or incineration of the spent liquor or have switched to the kraft pulping process (4) (5). Today, only nine mills utilize a calcium base; nine employ magnesium, 10 ammonia, and four sodium. Only four sulfite mills have been built since the 1940's -- two of them in Alaska. Three of these produce chemical cellulose or specialty pulps, and the fourth, a small one, manufactures tissue grades.

Kraft is currently the dominant pulping method since over 80 percent of the chemical pulp produced in this country is made with it. Three major developments were primarily responsible for this achievement. First, in contrast to sulfite pulping, chemical recovery, because of the cost of chemicals utilized, is an economic necessity to this process, and, in the 1930's, successful recovery techniques were applied and since have been vastly improved. Second, the process was found to be adaptable to nearly all wood species and its application to southern pines resulted in a rapid expansion of kraft pulping (2). Third, new developments in kraft bleaching techniques spurred another dramatic growth period just after World War II.

Earlier, sulfite, the naturally brightest unbleached pulp and the most easily bleached one, had been preeminent in the light-color grades (3). Kraft bleached by new processes which retained its superior strength began to replace sulfite in many bleached papers. Kraft then made further inroads on traditional sulfite

markets with the production of dissolving pulp and greaseproof and tissue papers (3). Today, a broad spectrum of printing and fine papers, tissue, food and milk containers, and boxes and containers of many other varieties are manufactured from bleached kraft pulp.

However, acid sulfite pulps do possess distinct properties which are superior for some products. These include special grades of dissolving pulps, tissues, and some grades of fine paper.

Although wood supplies the fiber for the great majority of pulp produced in this country, about 21 percent of the paper and paperboard produced annually is reused as a raw material for new products. Of this, large quantities are used in coarser products such as waste paperboard, building papers, etc., without extensive pretreatment. (The manufacture of these products is covered in earlier EPA Development Documents).

However, some reclaimed papers are deinked prior to use in a pulping process somewhat similar to the chemical pulping of wood. Deinked pulp provides an important fiber source which is low in cost, conserves wood resources, and, in some cases, improves product quality (6) when incorporated in the furnish. Deinking of waste paper was in commercial operation during the last century although the large scale operations extant today developed much more recently. In addition to removing ink, fillers, coatings, and other non-cellulosic materials must also be removed in order to reclaim useful pulp. These are added to modern papers to impart special characteristics (such as superior printing qualities, gloss, wet strength, grease resistance, etc.) (6). Deinked pulp is used mainly in business, bank, and printing papers, tissues and toweling, as liner for some paperboards, and in molded products and newsprint.

Pulp in its natural state is brown in color due primarily to the lignin content of wood. It is therefore bleached to modify or remove the color bodies when necessary in order to produce a light colored or white product. Bleaching techniques are also used to manufacture dissolving pulps.

The degree of bleaching pulp for paper manufacture is measured in terms of units of brightness and is determined optically by established TAPPI methods (7). Partially bleached pulps (semi-bleached) are employed in newsprint and similar papers, intermediate for food containers, computer cards, etc., and fully bleached for white paper products. By different gradations in treatment, pulp of the desired brightness can be manufactured up to a level of 92 on the brightness scale of 100. These techniques are described in detail in a TAPPI monograph (8).

Bleaching is frequently performed in several stages in which different chemical compounds are applied and separate functions take place. The symbols commonly used to describe a bleaching sequence are shown and defined in Table 7. The table may be used to interpret bleaching "shorthand," which is used extensively in

Table 7

BLEACHING SYMBOLS

A	-	Acid Treatment or Dechlorination
C	-	Chlorination
D	-	Chlorine Dioxide
E	-	Alkaline Extraction
H	-	Hypochlorite
HS	-	Hydrosulfite
O	-	Oxygen
P	-	Peroxide
PA	-	Peracetic Acid
W	-	Water Soak
( )	-	Simultaneous Addition of the Respective Agents
/	-	Successive Addition of the Respective Agents without Washing in Between

later sections of this report. For example, a common sequence in kraft bleaching, CEDED, is thus interpreted:

Chlorination & Washing
Alkaline Extraction & Washing
Chlorine Dioxide & Washing
Alkaline Extraction & Washing
Chlorine Dioxide & Washing

Almost all sulfite pulps are bleached, but usually a shorter sequence such as CEH is sufficient to obtain bright pulps. This sequence involves chlorination, alkaline extraction, and hypochlorite application, all followed by washing.

Some mills manufacture paper and/or paperboard which do not engage in pulping. These are called non-integrated paper mills and the pulp they utilize is either shipped from another of the company's facilities or is purchased. Pulp mills which do not have attendant papermaking operations are a major source of pulp for these mills, although some integrated mills also sell "market" pulp.

The papermaking process is essentially the same regardless of the type pulp used or the end product produced. A layer of fiber is deposited, from a dilute water suspension of pulp, on a fine screen, called the "wire," which permits the water to drain through but which retains the fiber layer (2). This layer is then removed from the wire, pressed, and dried. Two basic types of paper machines and variations thereof are commonly employed. One is the cylinder machine in which the wire is on cylinders which rotate in the furnish, and the other is the fourdrinier in which the furnish is deposited upon an endless wire belt. Generally, the fourdrinier is associated with the manufacture of paper and the cylinder with paperboard.

Products

Table 8 illustrates the diversity of papers manufactured by integrated pulp and paper mills and non-integrated paper mills. The various grades are delineated according to end use and/or furnish.

Although this list is representative of the production of the mills subject to this report by grade, a complete tally of their products as reported to industry directories would include numerous other terminologies. Since this multiplicity of nomenclature essentially defines specialized uses of products which themselves fall within the generic grade classifications of Table 8, they will not be separately itemized here.

Among the major fundamental differences in the various papers are durability, basis weight, thickness, flexibility, brightness, strength, and color. These characteristics are a function of raw

material selection, pulping methods, and/or papermaking techniques.

As has already been noted, some pulps are naturally more adaptable as furnish for certain paper grades than for others. This is influenced by fiber length, strength, and other factors which can be controlled by the type of woods employed, the selection of a mechanical or chemical pulping process, cooking chemicals, length of cook, etc. With improved techniques and the ability to mix pulps in stock preparation to achieve desired properties, however, few paper grades are uniquely a product of one pulp only.

In addition to variations in stock preparation and sheet control on the paper machine, the papermaking operation may enhance the basic qualities of paper, or achieve other properties -- such as wet strength, greaseproofness, printing excellence, etc. -- through the use of additives. These include a variety of substances such as starch, clay, and resins used as fillers and coatings.

The grades listed in Table 8 are, for the most part, self-explanatory, and definitions according to industry usage may be found in the publication Paper, Paperboard, Wood Pulp Capacity 1971-1974 of the American Paper Institute (API) (9). However, for purposes of this study, the many separate grades have been grouped under four major headings: newsprint, fine papers, tissue, and coarse papers.

Newsprint is, of course, separately identified in Table 8. Tissue, too, is clearly set apart except that, in the context of this report, glassine, greaseproof, and vegetable parchment are included in the tissue segment. These papers are basically a tissue sheet treated with additives to serve specific purposes. For example, glassine is a lightly waxed tissue familiar as candy wrappers and envelope windows.

Table 8

PRODUCTS OF SUBJECT INDUSTRY SEGMENTS (1)

PAPER

I. Newsprint

II. Printing-Writing Papers

A. Uncoated Groundwood

1. Publishing & Printing
2. Converting

B. Coated Papers

C. Uncoated Book

1. M.S.,E.F., Etc. (2) & Super Calendered
2. Offset
3. Envelope
4. Tablet

D. Papers Made from Chemical Wood Pulp

1. Bond & Writing
2. Form Bond
3. Ledger
4. Mimeograph
5. Duplicator
6. Manifold
7. Papeterie & Wadding
8. Body Stock for Commercial & Copying
9. Other Technical & Reproduction Paper
10. Opaque Circular
11. Colored School

E. Cover & Text Papers

(1) Excerpted from Paper and Paperboard Statistics 1973, American Paper Institute, and API's Paper, Paperboard, Wood Pulp Capacity 1971-1974.
(2) Machine Finish, English Finish.

Table 8 - Cont'd.

F. Thin Papers

1. Carbonizing
2. Condenser
3. Cigarette

G. Bleached Bristols

1. Tabulating Index
2. Tag
3. File Folder
4. Index Bristol
5. Postcard
6. Coated Bristol

III. Unbleached Kraft & Bleached Packaging Papers

A. Unbleached Kraft Papers

1. Wrapping
2. Bag & Sack
3. Shipping Sack
4. Other Converting

B. Bleached Packaging Papers

1. Wrapping
2. Bag & Sack
3. Shipping Sack
4. Other Convering

IV. Glassine, Greaseproof, & Vegetable Parchment

V. Special Industrial Papers

VI. Tissue Papers

A. Sanitary Tissue

1. Toilet
2. Facial
3. Napkins
4. Sanitary Napkins
5. Towels
6. Wipers

B. Non-Sanitary Tissue

1. Waxing
2. Wrapping
3. Industrial Cellulose
4. Miscellaneous

Table 8 - Cont'd.

PAPERBOARD

Bleached (3)

Milk Cartons
Folding Cartons
Heavyweight Cup, Rounded Nested Food Containers, & Cup Lids
Plate, Dish, & Tray
Other Packaging
Linerboard
Non-Packaging

Unbleached (4)

Linerboard
Boxboard (Folding Carton)
Chip and Filler Boards

(3) Paperboard made from 85% or more bleached chemical wood pulp.
(4) Solid unbleached wood pulp paperboard.

Fine papers encompass all of the printing-writing papers. Coarse papers are considered to include: unbleached and bleached kraft packaging papers (used for grocery and shopping bags, heavy wrapping paper, and sacks for shipping sugar, flour, cement, and other commodities); bleached and unbleached paperboard (the materials of boxes, cartons, and other containers); and special industrial papers.

While unbleached kraft linerboard (the smooth facing on "corrugated boxes") produced by integrated unbleached kraft pulp and paper mills was the subject of an earlier study, some mills covered by this investigation also produce linerboard and other unbleached kraft paperboards. This is true of several non-integrated mills and a few integrated mills which make other pulps in addition to unbleached kraft, although their tonnage of the latter is very small in comparison with the output of the large unbleached kraft mills.

Special industrial papers include paper and boards of all weights, calipers, and furnishes designed for specialized end uses, such as abrasive and absorbent papers, cable papers, electrical insulation, vulcanized fiber , resin-impregnating stock, and similar grades (9). Thus, in grouping them in toto as "coarse" papers, some inconsistencies occur within the usual meaning of that term. It is felt, however, that their production is more closely related to coarse paper manufacture than to the other segments.

Paperboard is, of course, a type of paper and the terms "paper" and "paperboard" generally imply physical differences only, some of which overlap in gradation. Further, many mills produce, or have the capability to produce, both products interchangeably. Therefore, they will not be treated separately in this report except when necessary for clarification, and the phrase "paper/board" or "paper" will be applied for simplification.

Many of the finished products made from the paper grades enumerated in Table 8 do not arrive directly at the retail market from the paper mill. While some mills have attendant operations in which to convert their own stock into boxes, bags, envelopes, paper plates, wall paper, food and milk containers, etc., much of the raw stock is sold to manufacturers of these items. Whether or not the converting operations are conducted on site at the paper mill, they constitute a separate and dry operation and are not considered in this report.

Daily Production Capacity

The daily production capacity of mills is an especially important consideration in this report for two reasons. First, it provides a useful means of classifying mills, as discussed below. Second, its correlation with waste water data makes it possible to express pollutants discharged in pounds per ton of product, the value used in effluent limitations guidelines and standards.

Traditionally, limits on waste discharges were based on an allowable concentration for each pollutant parameter. This type of value, mg/l (or ppm), is also used in this report to characterize certain waste streams. However, the pounds-per-ton-of-product concept equalizes the limitations among all mills, regardless of size. In this report it is often expressed simply as "pounds per ton" or in the abbreviated metric (English) unit expression "kg/kkg (lb/ton)." All waste parameter values reported in kg/kkg (lb/ton) are based on an annual average of daily production. "Ton" means a 907.20-kilogram or (2000-pound) short ton.

Except as otherwise noted, production includes the total weight of product off the paper machine(s) plus pulp dryer(s) where applicable, as reported by mills. Paper machine production includes the normal moisture content of approximately six percent. Pulp intended for use offsite is expressed as "air dry" weight including 10 percent moisture. Where off-machine coaters were used, the coat weight was included in the production weight wherever sufficient data were available. In the case of on-machine coaters, the coat weight is automatically included in the reported paper machine production weight. Where the data furnished by mills did not meet these criteria, they were converted to provide a uniform data base.

Mill Characterization According to Daily Production

Numbered among the mills discussed in this report are many so-called complex mills -- i.e., mills which produce more than one variety of pulp or multiple paper grades. Since the study was directed to specified segments of the pulp and paper industry, it was desirable, for working purposes, to characterize all mills according to segment.

The basis used for classifying or assigning complex pulp and integrated mills to a segment was the pulping process which accounts for the largest daily production capacity. For example, a mill with a daily capacity to produce 340 kkg (375 tons) of groundwood pulp, 122 kkg (135 tons) of sulfite, 453 kkg (500 tons) of newsprint, and 41 kkg (45 tons) of sulfite specialties was assigned to the groundwood segment.

Strict application of this criterion, however, would result in placing some of these mills in segments covered in EPA's Development Document for the Unbleached Kraft and Semi-Chemical Pulp Segment of the Pulp, Paper, and Paperboard Mills Point Source Category. This is particularly true where the production of unbleached kraft is involved. The earlier study of this subcategory was limited to those mills which produce no pulp other than unbleached kraft. Thus, mills which have attendant kraft bleaching or another pulping capacity fall within the scope of this report although their largest production tonnage may be unbleached kraft pulp. This is also the case with two mills

which produce more substantial quantities of semi-chemical pulp, another subcategory covered by the above Development Document, but which by virtue of their other production were subject to this investigation. In these instances, the mills have been assigned to the segment which is most representative of their other pulping operations.

It is recognized, too, that application of the product tonnage criterion to some non-integrated paper mills is perhaps somewhat arbitrary due to the fact that many of these mills report the production of many grades encompassing more than one segment without accompanying tonnage breakdowns. However, it is felt that the general accuracy of allocation to segment is sufficient to support the statistical estimates of this section of the report.

The groundwood segment is composed of 38 mills; of these, 28 produce groundwood pulp only. Nine additional groundwood operations appear in the bleached kraft segment and two under sulfite, making a total of 49 U.S. groundwood mills. (Those mills producing a different type of groundwood pulp utilized in building products are not included).

Twenty-eight mills are designated as sulfite mills, 21 of which produce sulfite pulp only. Four mills produce sulfite, but in smaller quantities than groundwood, and three produce bleached kraft and NSSC.

Seventy-four mills are defined as bleached kraft, and five are listed in conjunction with groundwood operations for a total of 79. Thirty-eight produce bleached kraft only. There are three mills in the soda pulp segment and an additional very small soda operation with attendant sulfite and semi-chemical pulping.

The deinked segment encompasses 17 mills, 14 of which reclaim fiber for the manufacture of fine papers and tissue and three which produce newsprint. In addition, there is one groundwood/deinking mill and one sulfite/deinking combination.

A breakdown of the pulping segments is shown in Table 9.

There are 46 non-integrated fine paper mills and 74 tissue mills.

Table 9

DISTRIBUTION OF MILLS BY SEGMENT

Segment	Mills	No. of Pulp Production
Groundwood	28	Groundwood
	2	Groundwood/Bleached Kraft
	1	Groundwood/Unbleached Kraft
	3	Groundwood/Bleached/Unbleached Kraft
	3	Groundwood/Sulfite
	1	Groundwood/Deinked
	38	Total
Sulfite	21	Sulfite
	4	Sulfite/Groundwood
	1	Sulfite/NSSC
	1	Sulfite/NSSC/BK
	1	Sulfite/Bleached Kraft
	28	Total
Bleached Kraft	38	Bleached Kraft
	16	Bleached/Unbleached Kraft
	3	Bleached Kraft/Groundwood
	6	Bleached/Unbleached Kraft/Groundwood
	1	Bleached/Unbleached Kraft/Sulfite
	2	Bleached Kraft/Semi-Chemical
	5	Bleached/Unbleached Kraft/Semi-Chemical
	1	Bleached Kraft/Sulfite/Semi-Chemical
	74	Total
Soda	3	Soda
Deink	17	Deink

Size Distribution

The relative size of mills in each segment which produce only the one designated type of pulp is illustrated as follows:

	Capacity kkg (tons)/day		
	Largest Mill	Median Mill	Smallest Mill
Groundwood	834 (920)	181 (200)	18 (20)
Sulfite	580 (640)	209 (230)	91 (100)
Bleached Kraft	1379 (1520)	454 (500)	27 (30)
Soda	635 (700)	222 (245)	127 (140)
Deinked (Fine Paper & Tissue)	499 (550)	87 (96)	37 (41)
(Newsprint)	408* (450)*	272* (300)*	222* (245)*

*Paper production; pulp tonnage not published.

When complex mills in the groundwood, sulfite, and bleached kraft segments are considered the size range is as follows:

	Capacity kkg (tons)/day		
	Largest Mill	Median Mill	Smallest Mill
Groundwood	1020 (1125)	172 (190)	18 (20)
Sulfite	771 (850)	209 (230)	25 (28)
Bleached Kraft	1379 (1520)	499 (550)	27 (30)

The total daily capacity of the mills listed in Table 9 has been tabulated by pulp type. These figures, presented below, represent the best estimates which can be made utilizing published information and information gathered during the course of the project. It must be emphasized, however, that they are approximate only. This is especially the case of the bleached kraft total because the differential between bleached and unbleached production is not always clearly identified.

Pulp	Total Capacity kkg (tons)/day
Groundwood	11,654 (12,850)
Sulfite	8,344 (9,200)
Bleached Kraft	72,379 (79,800)
Soda	907 (1,000)
Deinked	2,721 (3,000)

A separate breakdown is not presented for bleached and unbleached groundwood and sulfite. There is relatively very little sulfite pulp which is not bleached before use, and groundwood undergoes many varying degrees of brightening or bleaching, a tabulation of which would be imprecise.

Six sulfite mills and three bleached kraft mills produce dissolving grades of pulp. The total capacity of these sulfite mills is 2721 kkg (3000 tons)/day, and the kraft capacity is 2857 kkg (3150) tons; these figures, however, include some bleached papermaking pulps. These mills are included in the sulfite and kraft segment tabulations.

The approximate total daily paper/board capacity for all mills listed in the groundwood segment is 16,417 kkg (18,100 tons)/day; for the sulfite segment, 5442 kkg (6000 tons)/day; bleached kraft, 61,676 (68,000); soda, 1270 (1400); and deinked, 4535 (5000).

Size distribution of the non-integrated papermaking segments of mills appears in Table 10.

Table 10

TABULAR DESCRIPTION OF NON-INTEGRATED PAPERMAKING SEGMENTS

Segment	No. of Mills	Total Capacity kkg(tons)/day*	Largest Mill kkg(tons)/day	Smallest Mill kkg(tons)/day	Median Mill kkg(tons)/day
Fine Papers	56	6651 (7333)	472 (520)	10.8 (12)	81.6 (90)
Tissue	72	5465 (6025)	726 (520)	6.3 (7)	42.6 (47)
Coarse Papers	72	6295** (6940)**	653 (720)	2.7 (3)	54 (60)

*Approximate.

**This figure is low due to number of mills not reporting tonnage.

Geographic Distribution of Mills

The geographic distribution of the groundwood, sulfite, bleached kraft and soda, deinked, nonintegrated fine, and nonintegrated tissue segments are shown in Figures 1-6, respectively. The numbers refer only to the mills allocated to the designated segments according to the criteria discussed earlier.

Annual Production

Total annual production for 1972 of the products associated with the subject industry segments is tabulated in Table 11.

PULP AND PAPERMAKING PROCESSES

Wood Preparation

Wood arrives at pulp mills in various forms and consequently must be handled in a number of different ways. Some mills receive their wood supply as logs, although the trend is toward the use of purchased chips, or, in some cases, sawdust and other residues of sawmill operation. For example, in 1972 reclaimed chips and wood residues accounted for 84 percent of the total wood volume consumed in pulp and paper production in the Pacific Northwest (16).

The use of whole tree chipping (WTC) in the Northeast, Lake States and South has increased considerably over the past few years. This practice is particularly useful in mixed stands of timber and for thin diameter material. It does not require limbing and topping which are the most expensive parts of wood handling. The use of cutter knives and blades to cut up tree bowls, branches and bark greatly increases the yield of material per acre and 10-100% increases have been found. A side benefit is that less roads are necessary which are required for heavy-duty trucks. Thus, there are lower costs per cubic foot of fiber produced.

Some of the most difficult problems are the inclusion of sand, dirt, and abrasive materials as well as too much bark in the WTC chips. This causes problems not only with the cutting blades but also with mill equipment. The upkeep of the mill equipment involves an increased cost of $10-$20 for each dollar of field equipment used for debarking. This equipment upkeep is necessitated by the unbarked chips included with other material for pulping. The major pulps produced from barky chips are semichemical pulp and unbleached kraft. Companies are now using 5 and up to 30% of their WTC chips while unbleached kraft mills can use 2-5% of WTC chips. Several companies are using pulps with 5-15% bark at present.

One company currently has in use over 275 WTC chipping units. It is estimated that up to three times increase in productivity per man hour can be obtained using field chipping. One company

FIGURE 1

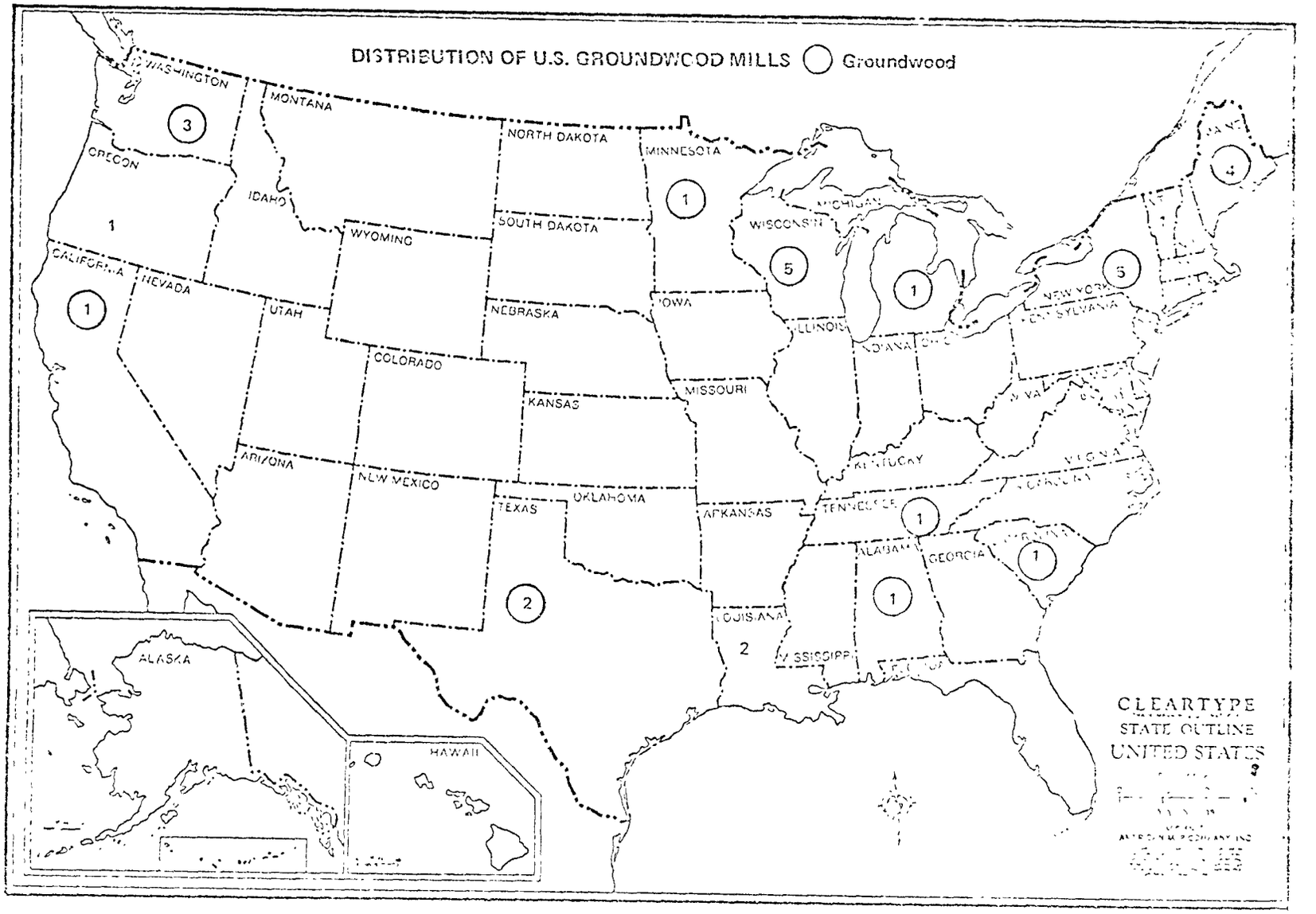

DISTRIBUTION OF U.S. GROUNDWOOD MILLS ◯ Groundwood
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
WYOMING
SOUTH DAKOTA
MICHIGAN
WISCONSIN
CALIFORNIA
NEVADA
UTAH
NEBRASKA
IOWA
ILLINOIS
COLORADO
KANSAS
MISSOURI
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
TENNESSEE
GEORGIA
LOUISIANA
MISSISSIPPI
ALABAMA
ALASKA
HAWAII
CLEARTYPE
STATE OUTLINE
UNITED STATES

FIGURE 2

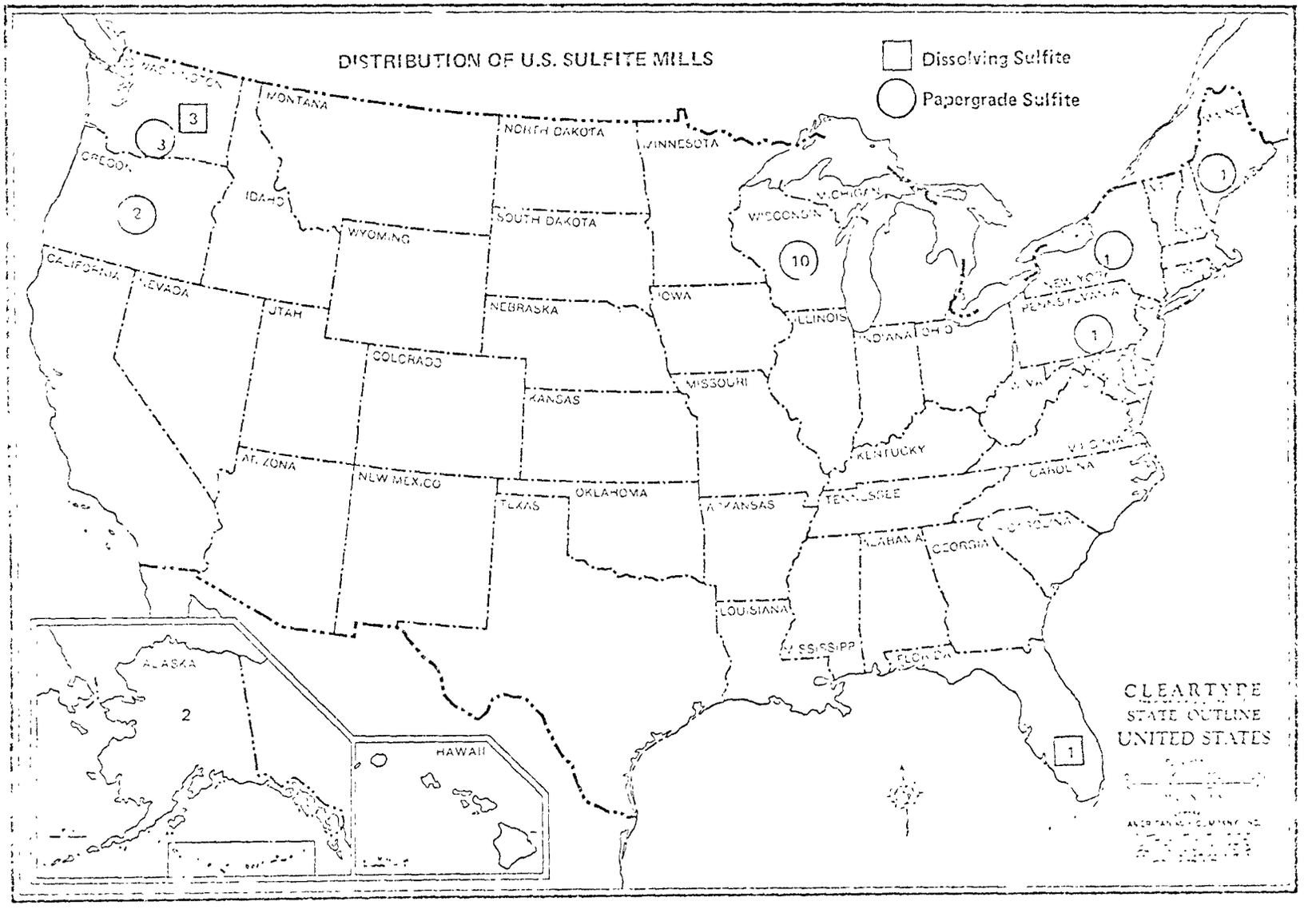

DISTRIBUTION OF U.S. SULFITE MILLS
Dissolving Sulfite
Papergrade Sulfite
MONTANA
NORTH DAKOTA
MINNESOTA
IDAHO
WYOMING
SOUTH DAKOTA
NEBRASKA
COLORADO
KANSAS
MISSOURI
UTAH
NEVADA
CALIFORNIA
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
LOUISIANA
ARKANSAS
KENTUCKY
ILLINOIS
INDIANA
OHIO
WISCONSIN
MICHIGAN
NEW YORK
PENNSYLVANIA
ALABAMA
GEORGIA
FLORIDA
ALASKA
HAWAII
CLEARTYPE
STATE OUTLINE
UNITED STATES

FIGURE 3

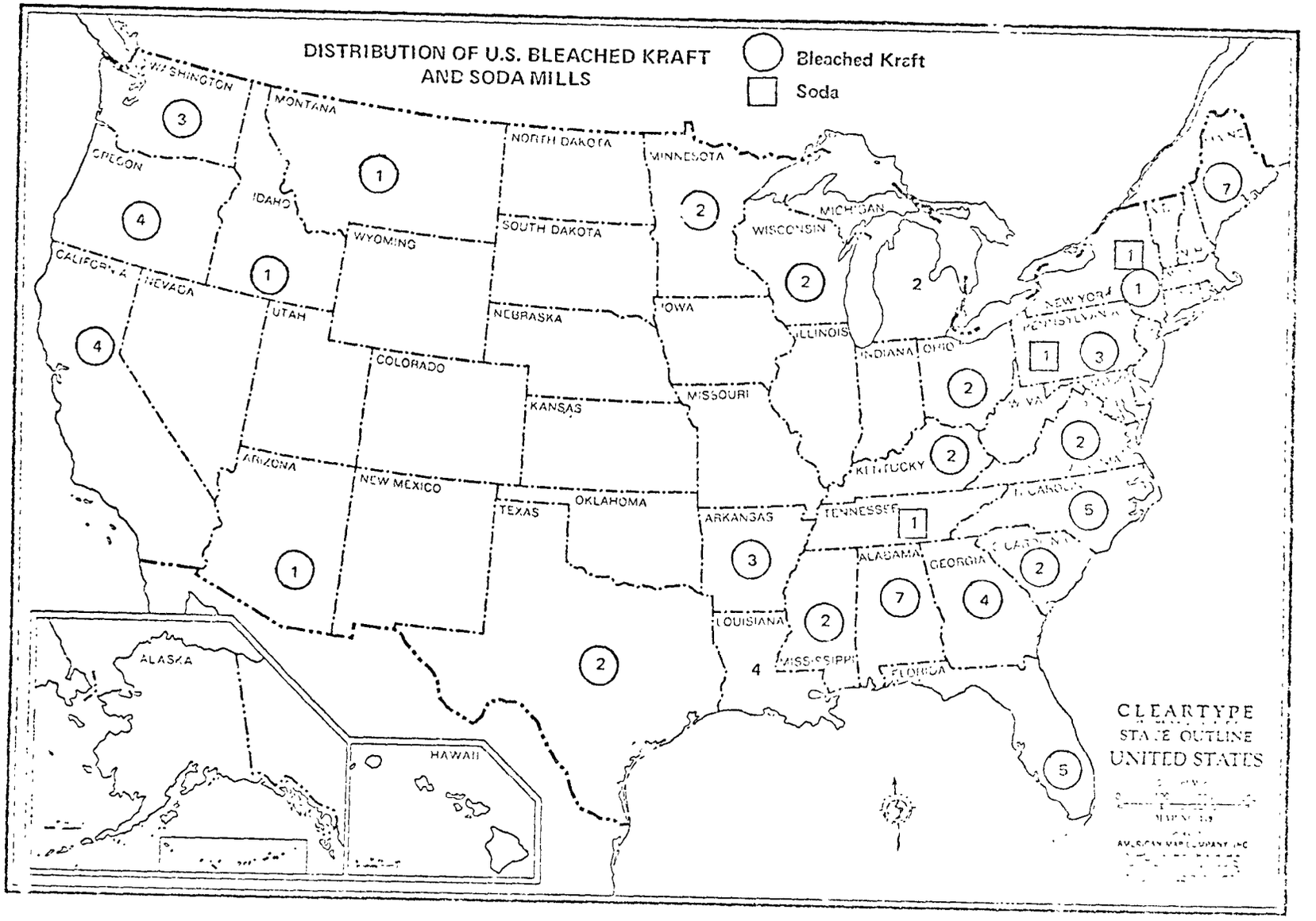

DISTRIBUTION OF U.S. BLEACHED KRAFT AND SODA MILLS
Bleached Kraft
Soda
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
NEW YORK
PENNSYLVANIA
ALASKA
HAWAII
CLEARTYPE
STATE OUTLINE
UNITED STATES

FIGURE 4

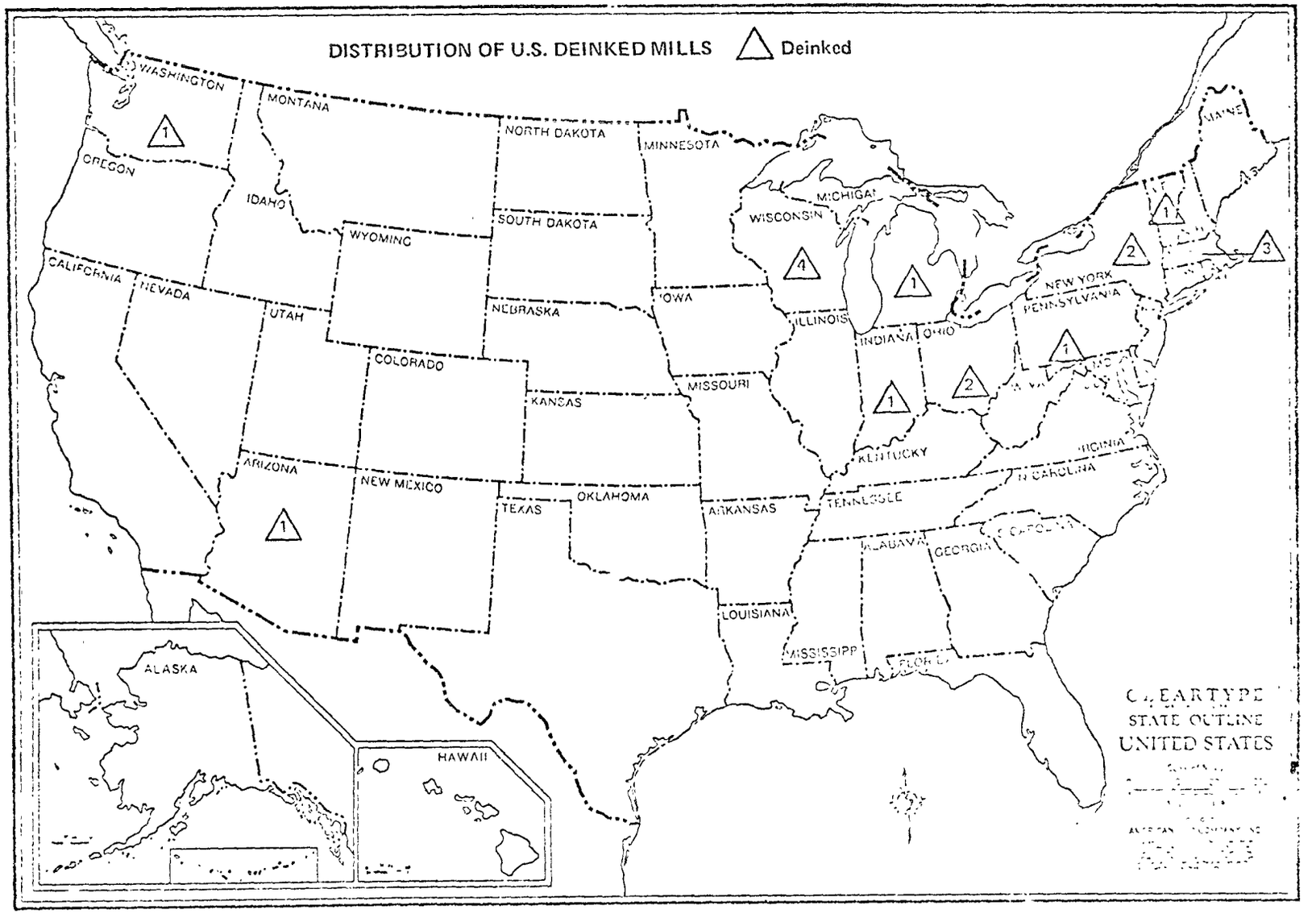

DISTRIBUTION OF U.S. DEINKED MILLS
Deinked
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
WYOMING
SOUTH DAKOTA
WISCONSIN
MICHIGAN
CALIFORNIA
NEVADA
UTAH
COLORADO
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
NEW YORK
PENNSYLVANIA
MAINE
MISSOURI
KANSAS
KENTUCKY
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
TENNESSEE
LOUISIANA
MISSISSIPP
ALABAMA
GEORGIA
ALASKA
HAWAII
EARTYPE
STATE OUTLINE
UNITED STATES

FIGURE 5

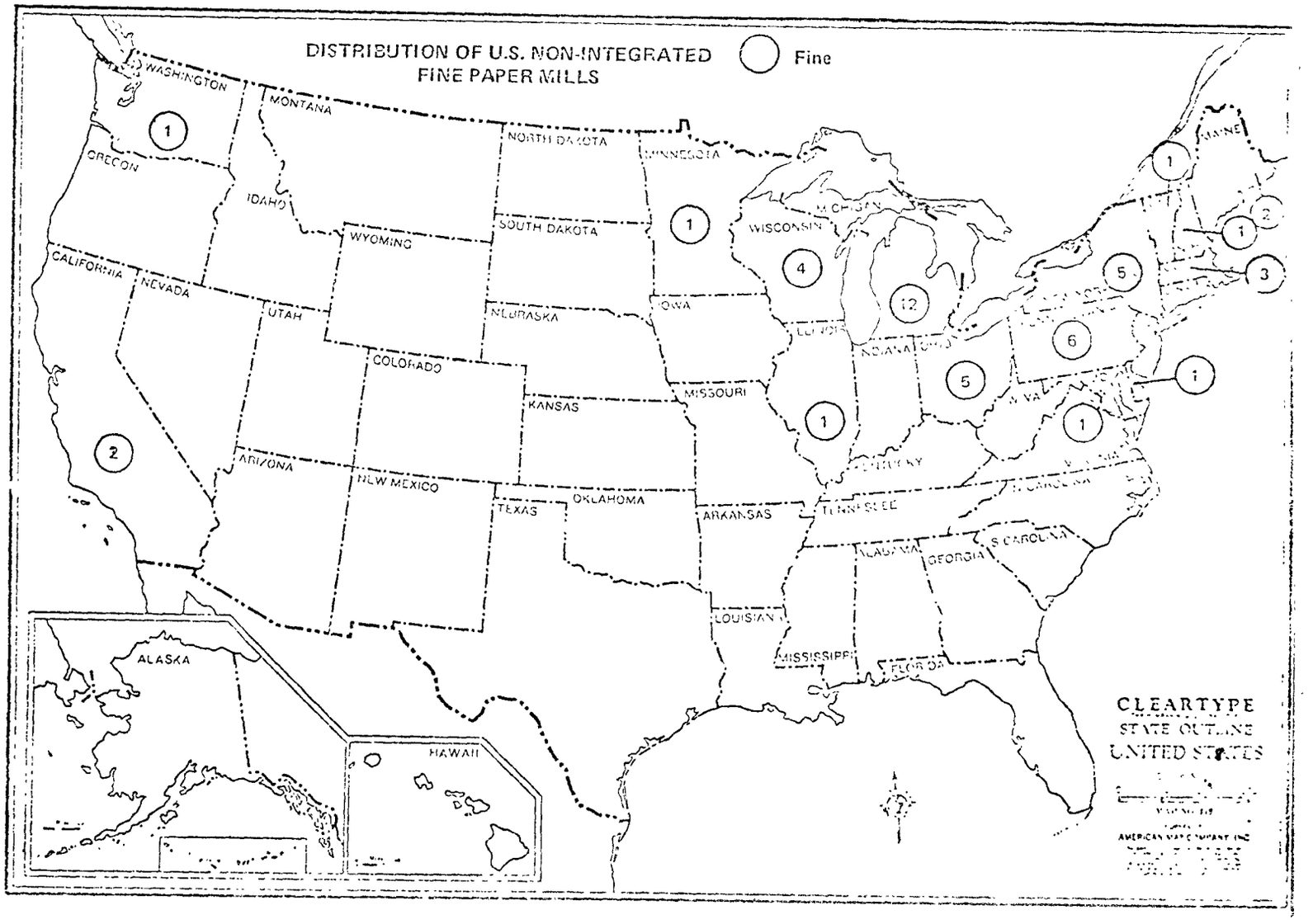

DISTRIBUTION OF U.S. NON-INTEGRATED FINE PAPER MILLS
Fine
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
S CAROLINA
N CAROLINA
W VA
N VA
MAINE
ALASKA
HAWAII
CLEARTYPE
STATE OUTLINE
UNITED STATES

FIGURE 6

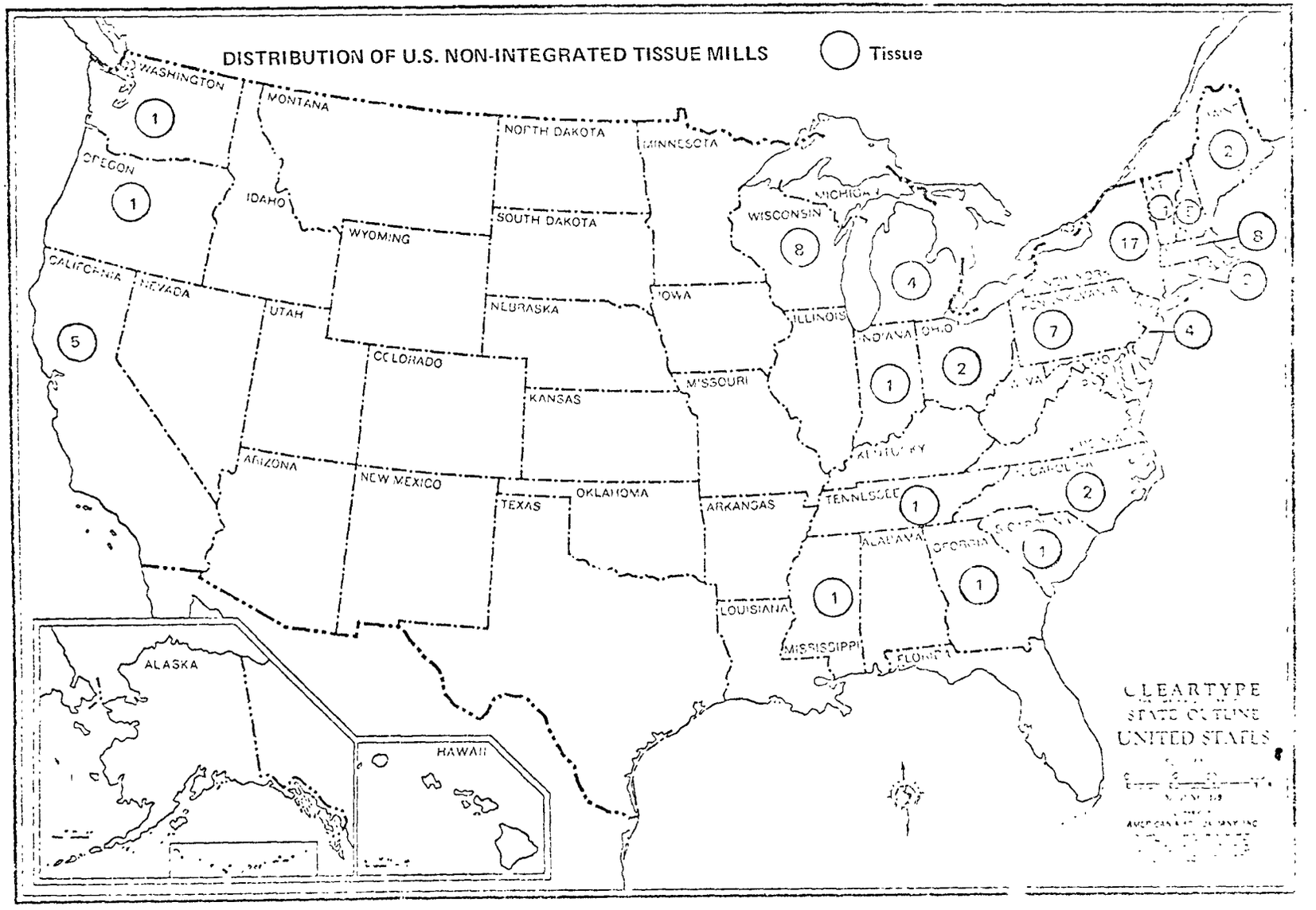

DISTRIBUTION OF U.S. NON-INTEGRATED TISSUE MILLS
Tissue
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
WYOMING
SOUTH DAKOTA
WISCONSIN
MICHIGAN
CALIFORNIA
NEVADA
UTAH
COLORADO
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
MISSOURI
KANSAS
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
TENNESSEE
KENTUCKY
ALABAMA
GEORGIA
LOUISIANA
MISSISSIPPI
FLORIDA
ALASKA
HAWAII
CLEARTYPE
STATE OUTLINE
UNITED STATES

Table 11

1972 PRODUCTION BY PULP TYPE AND PAPER GRADES

	1000 kkg	1000 Tons
Pulp(1)		
Special alpha & dissolving	1,521	1,677
Sulfite	1,931	2,129
Bleached kraft	12,672	13,971
Soda	127	140
Groundwood	4,188	4,617
Paper(2)		
Newsprint	2,360	2,602
Tissue	3,106	3,425
Fine papers	9,087(3)	10,019(3)
Coarse papers	10,310	11,367

(1) U.S. Bureau of the Census data.
(2) Contractor grouping of American Paper Institute data.
(3) Includes papers of textile fibers not subject to this report.

estimates that in five years 80% of their chips will be field chipped WTC wood.

Barked logs received at a mill are chipped directly for use or cut into billets of suitable lengths for the stone and chemi-groundwood processes. Bark is removed from unbarked logs on the premises.

Most of the pulpwood used in the United States is small in diameter and is barked dry in drums. When large diameter or long wood is used, wet barking may be employed although this practice is declining. The two most common mechanisms for wet barking are drum and hydraulic barkers (2)(34) since the wet pocket barker is now largely outmoded. Slabs are generally handled by hydraulic units as is the large and longer roundwood.

The wet drum barker consists of a slotted drum equipped with internal staves which knock the bark from the wood as the drum rotates in a pool of water. The bark falls through the slots and is removed with the overflow of water.

Wet pocket barkers are stationary machines which abrade bark from timber by jostling and gradually rotating a confined wood stack against the wood pile allowing bark to pass between the chains. Water is sprayed through apertures in the side of the pocket.

Hydraulic barkers employ high-pressure water jets to blow the bark from the timber which is either conveyed past them or rotated under a moving jet which traverses the log.

Wood Consumption

Typical wood consumption of median size mills is as follows:

Groundwood	120 cords/day
Sulfite	245 cords/day
Bleached Kraft	850 cords/day
Soda	125 cords/day

(It should be noted that conversions between cords and tons should not be attempted without data on specific situations. The reason for this is that a cord is a measure of volume (4 ft x 4 ft x 8 ft), while a ton is, of course, a measure of weight. Variations in wood species, density, diameter, straightness of log, etc., make conversions between the two units impossible for general situations.)

Mechanical Pulping

The energy used in producing conventional groundwood pulp -- stone or refiner -- is mechanical. Modified groundwood processes such as the cold soda (chemi-mechanical) and chemi-groundwood methods employ a mild chemical treatment ahead of mechanical fiberizing. The latter processes are considered here as mechanical pulping, however, because the chemical pretreatment is much milder and the mechanical action more drastic than is the case in semi-chemical pulping. In thermo-mechanical pulping, an off-shoot of refiner groundwood, the pretreatment is accomplished with heat and pressure. The cold soda and chemi-groundwood pulps are produced and used as a direct substitute for groundwood (10) or as supplements to special furnishes. All mechanical pulps contain practically all of the wood substance and yields are generally 85 to 90 percent of the bone dry weight of the wood processed while semi-chemical pulps fall within the 60 to 80 percent yield range (2).

The type of wood economically available is a factor in selection of the groundwood process applied. Softwood does not necessarily require pretreatment (10) and has thus been the traditional raw material of the stone groundwood process, and more recently of the refiner method. The high energy requirements of grinding untreated hardwood are overcome by the processes which incorporate pretreatment. Thus, their development made possible the use of large stands of hardwood for mechanical pulping. Sawmill wastes are another source of raw material for the mechanical processes which utilize wood chips.

Stone Groundwood

In this process, billets are fed to the grinders by hand or automatically from a belt or chain conveyor (2) and are forced hydraulically against the large rotating grindstone, specifically designed for the purpose. The pocket-type grinder is most common although the magazine, ring, and continuous or chain types are being installed in new mills (10). The grinding occurs in the presence of a large quantity of water which acts as both a coolant and a carrier to sluice the pulp from the body of the grinder. The pulp slurry is diluted to a consistency of from 0.6 to 0.8 percent and is passed through coarse and fine screens and a centri-cleaner to remove dirt and slivers. Over-size rejects maybe passed through a disc refiner and returned to the system ahead of the fine screens. The pulp slurry is then thickened on a Decker to between 10 and 15 percent consistency and discharged to a stock chest for mill use, bleached, or thickened further for transport to other mills (2) either in the form of wet lap at about 25 percent consistency or nodules containing 50 percent fiber. A diagram of the stone groundwood process is presented in Figure 7.

Refiner Groundwood

The availability of saw mill chips as a low-cost wood source led to the development and exploitation of the refiner groundwood process which has the additional advantage of using less power then stone grinding (11)(12). The chips are first washed and two stages of refining are generally employed in the pulp mill, the fiber receiving a third refining in the paper mill. Disc type refiners are used which contain one fixed and one rotary disc between which the wood passes together with a stream of water. A double-disc type unit is used mainly for refining rejects. The pulp is discharged from the refiners at a consistency of about eight percent and moved by a high-density pump to the secondary units. Here it is diluted to low consistency and subsequently fine screened and freed of dirt in centri-cleaners. Screen rejects are refined and returned to process ahead of the screens. After cleaning the pulp is handled in the same manner as stone groundwood as shown in the process flow diagram in Figure 8.

Thermo-Mechanical

A recent development in refiner groundwood is equipment in which the chips are pre-softened with heat and refined under pressure in the range of 110-130°C (230-266°F). This process is called thermo-mechanical pulping. Pulp properties, such as longer fibers, are developed which make this pulp a suitable replacement for a percentage of the more expensive chemical pulp added to newsprint furnish to provide adequate strength (92). This process has not been employed in this country although it is

FIGURE 7
STONE GROUNDWOOD PULP MILL
PROCESS FLOW DIAGRAM

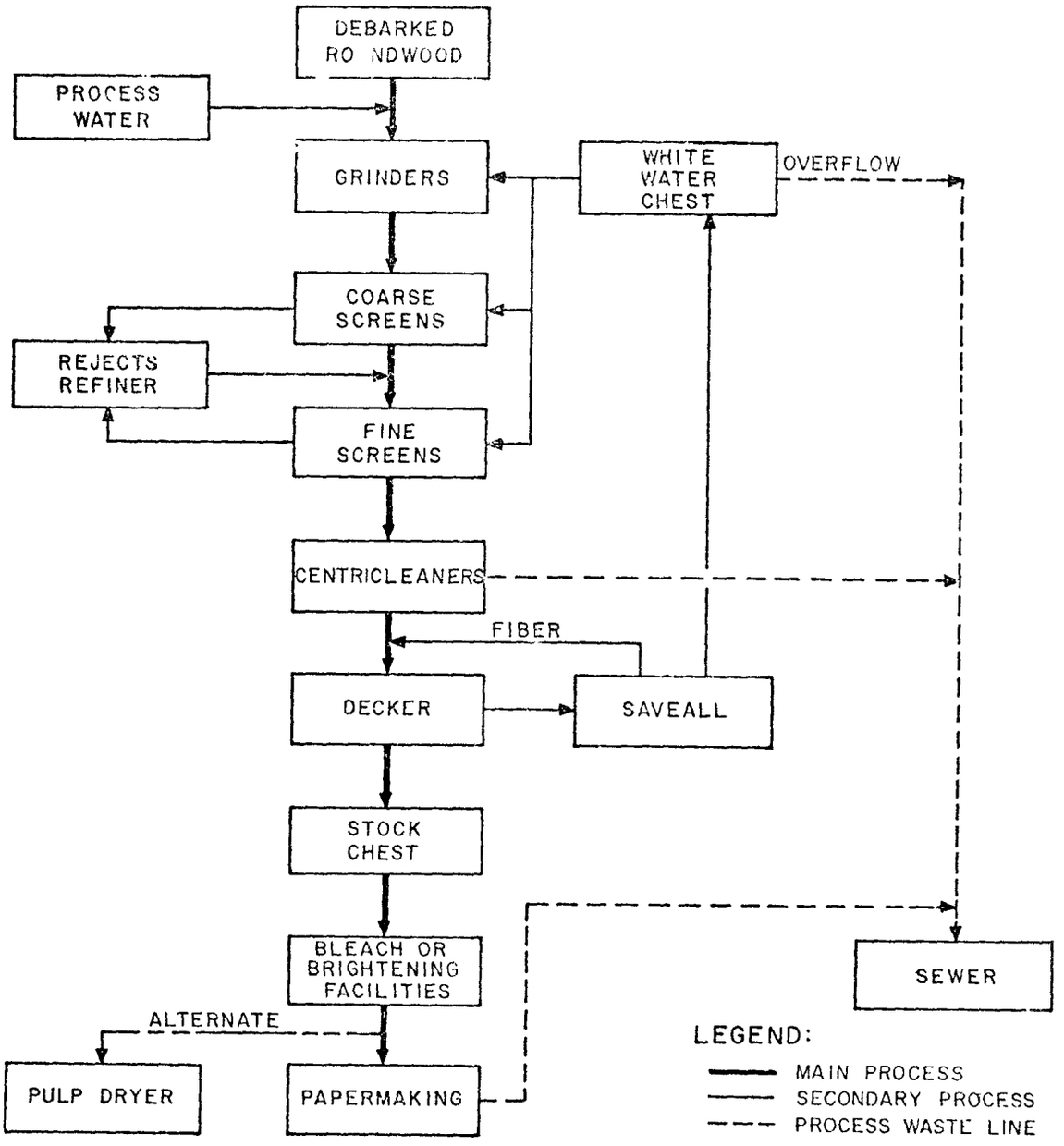
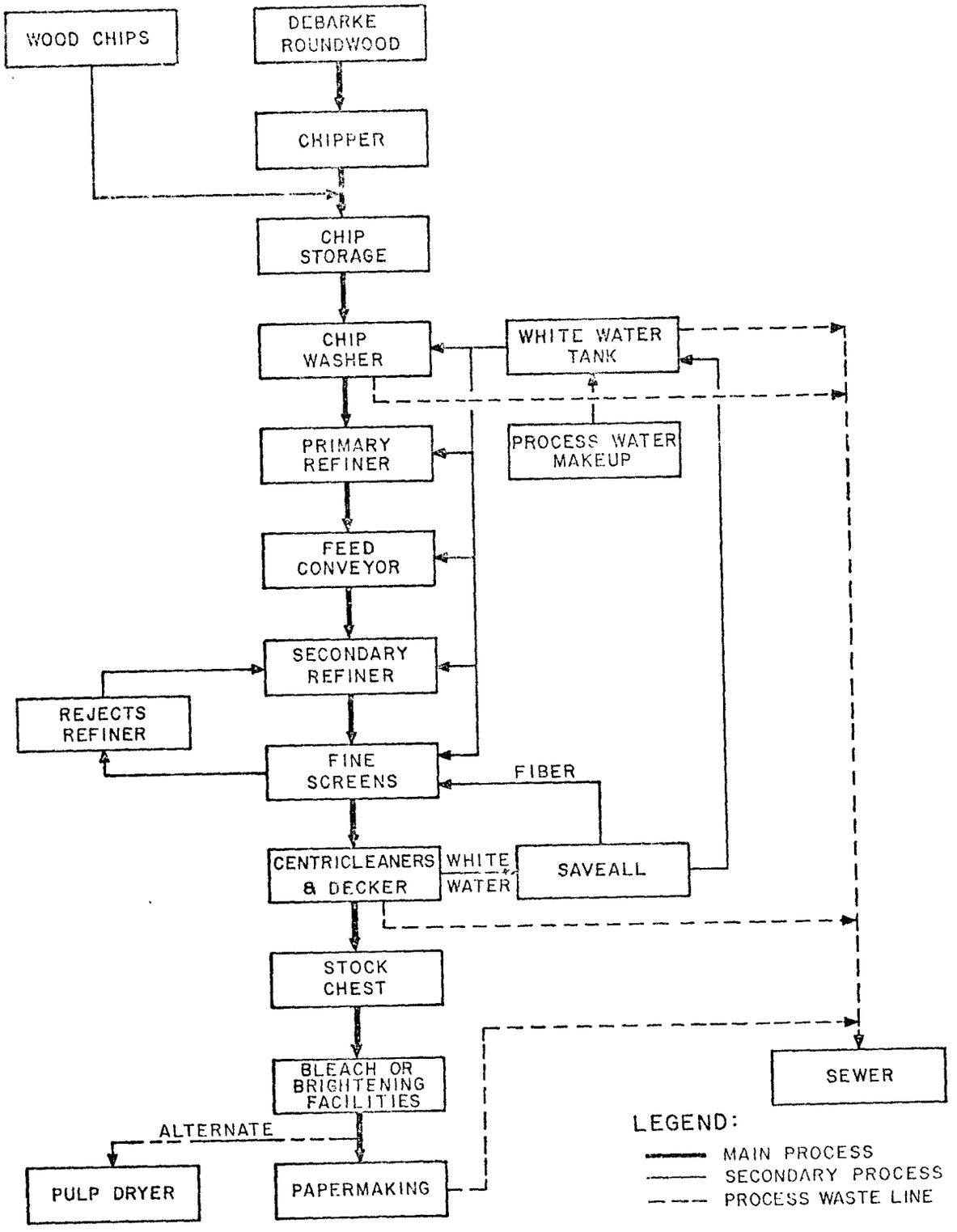


FIGURE 8

REFINER GROUNDWOOD PULP MILL PROCESS FLOW DIAGRAM



understood that a newsprint mill in the Pacific Northwest has ordered a 272-kkg (300-ton) per day thermo-mechanical system (93) and a 91-kkg (100-ton) per day unit will be installed in a southern groundwood/kraft installation (161). Possibly as many as 10 mills will be utilizing the process in the near future.

Cold Soda

In the production of cold soda pulp, chips are soaked either at atmospheric pressure for two hours or under forced pressure for shorter periods of time in liquor containing 20 to 40 mg/l of caustic soda (2). The caustic expended varies from two to 10 percent of the weight of the wood depending on the wood species used and the pulp quality desired. The liquor is recycled after fortification. Subsequent separation of chips and liquor may be accomplished by gravity or screw or roll presses may be employed. The treated chips are then handled in a manner similar to that used in manufacturing refiner groundwood (2)(3).

Chemi-Groundwood

The liquor used in chemi-groundwood pulping contains from 60 to 180 mg/l of sodium sulfite buffered with one-sixth to a third that amount of soda ash. Hardwood billets are first impregnated with the liquor and then cooked for periods ranging from a half hour to six hours at a maximum temperature of 135 to 150°C (278-302°F) (2). This is followed by grinding on stones under operating conditions very similar to those of stone groundwood. This pulp is stronger than conventional groundwood (11).

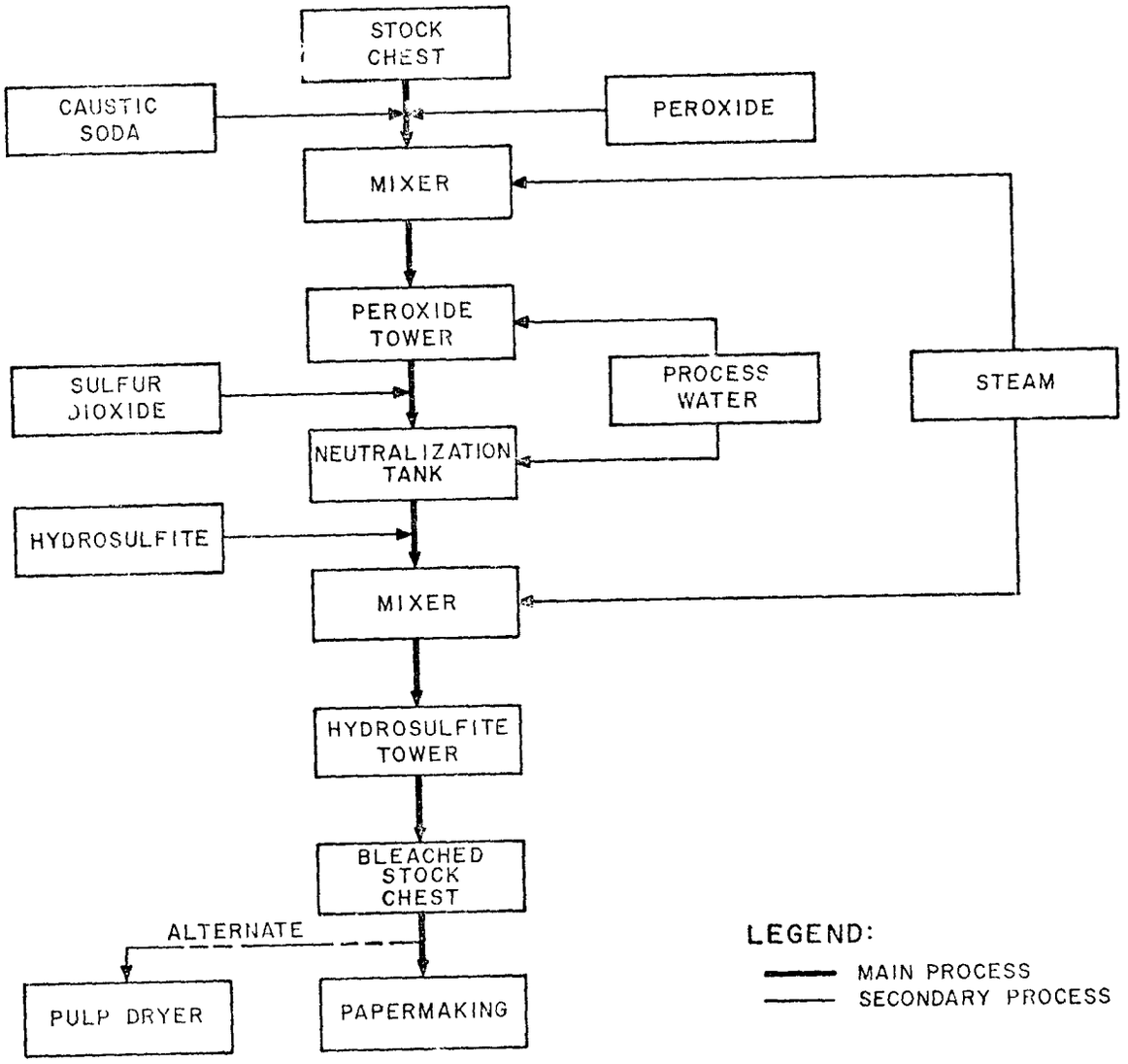
Bleaching of Mechanical Pulp

Stone and Refiner Groundwood

While these purely mechanical pulps have many desirable qualities for the manufacture of low-cost papers, they are not naturally sufficiently bright for the better grades (2). Too, the brightness varies with the characteristics of the wood raw material. For example, northeastern spruce and balsam will generally produce a groundwood pulp in the brightness range of 57 to 65 units while the pulps from west coast species such as western hemlock range in the low 50's. Thus, bleaching is undertaken when necessary to satisfy the demands of various end products.

The most common bleaching agents used for stone and refiner groundwood are hydrosulfites and peroxides, and, in some cases, both are used sequentially as shown in Figure 9. Hydrosulfite systems can improve brightness by as much as eight to 12 standard brightness units in a single stage operation and up to 15 to 20 units in a two stage operation with peroxide (2). Peroxide alone has capabilities in the range of eight to 12 or more units.

FIGURE 9
BRIGHTENING AND BLEACHING GROUNDWOOD AND COLD SODA PULPS PROCESS FLOW DIAGRAM



In peroxide bleaching, hydrogen peroxide is generally used although sodium peroxide is sometimes employed (2)(10). A solution of from 0.5 to 1.5 percent hydrogen peroxide or its oxygen equivalent of sodium peroxide is applied to the pulp. Frequently a small amount of magnesium sulfate -- 0.24 to 0.48 gm/l (1 to 2 lb/500 gal) of bleach solution -is used for stabilization purposes. The pH of the pulp is first adjusted to 10.5 with caustic soda which requires from 1.0 to 3.0 percent NaOH. Sodium silicate or sulfamic acid sometimes replaces the caustic soda since they are capable of sequestering metallic ions which catalyze peroxide decomposition or discolor the product. Groundwood pulp is generally bleached with peroxide at between 38 and 49°C (100 and 120°F). Consistencies of bleaching range from four to 35 percent. The pulp is usually subsequently neutralized with sulfur dioxide to prevent reversion.

In some instances, refiner groundwood is subjected to refiner bleaching -- i.e., a solution of peroxide is added to the disc refiner employed for fiberizing. The bleaching reaction thus begins while the pulp is refined and is subsequently completed after discharge by maintaining the pulp at discharge temperature, 77 to 93°C (170 to 200°F), for about 15 minutes (2).

Some mills mix nodulated (pressed and shredded) pulp with sodium silicate and hydrogen peroxide in tank cars or truck tankers utilizing the tankage in transit as a reaction vessel for the bleaching operation.

Peroxide solutions are prepared at the mill by batch or continuous methods, and may contain either hydrogen or sodium peroxide or both. Epsom salts, sodium silicate, sodium and/or hydrogen peroxide is replaced by caustic soda (2). In the case of a sodium peroxide solution, sulfuric acid is used to replace the hydrogen peroxide.

When sodium or zinc hydrosulfite is used to bleach or brighten groundwood pulp, the chemical is frequently added directly to the secondary refiner or grinder sinks, canals, or stock chests since heat is important to the reaction (13)(14). From 0.2 to 2.0 percent of the chemical is used depending upon the species of wood from which the pulp was derived and desired brightness; a temperature of 49 to 50°C (120 to 130°F) is most desirable at a consistency of 15 percent or greater. Sodium hydrosulfite is now preferred because of zinc discharge limitations.

Hydrosulfite solutions are prepared from purchased hydrosulfite or from chemicals manufactured at the mill. In one method, zinc hydrosulfite is made by reacting zinc dust with aqueous sulfur dioxide. In another, the zinc dust is mixed with pulp and the sulfur dioxide is introduced in aqueous solution or as a gas. Hydrosulfite can also be added dry at lower consistencies. Sodium and potassium borohydride, which also inhibit reversion following bleaching are sometimes used for brightening groundwood pulps (14), but, because of the chemical costs involved, the use of these chemicals has not become established practice in this

country (10). The cost of peracetic acid has similarly precluded its use for groundwood bleaching (15).

There has been no experience in this country as yet with bleaching thermo-mechanical pulp.

Cold Soda

Due to the alkaline pretreatment they receive, cold soda pulps are darker than stone and refiner groundwood (2). However, the chemicals used to bleach these pulps are the same, except that calcium and sodium hypochlorites may also be utilized because of their amenability to hardwood. Single stage treatment can produce a brightness of from 67 to 72. Seventy-five to 80 brightness can be obtained from multi-stage bleaching.

Bleaching chemicals are generally applied in retention chests or towers, although peroxide can be added at the refining stage and hypochlorites during the steeping process. The latter applications require more chemical, however, to achieve a brightness equal to that attained by the use of towers (2), which can yield a brightness increase of 20 units with one stage bleaching. When peroxide is used in the refiner it may be necessary to control the alkalinity of the pulp by adding sulfuric acid.

Chemi-Groundwood

Chemi-groundwood pulp is also characterized by low initial brightness (1). It responds well to peroxide or hypochlorite bleaching, however, and the processes utilized are very similar to those for the other types of groundwood pulp.

One exception is that peroxide refiner bleaching is not appropriate for this pulp unless the residual sodium sulfite liquor is removed before peroxide is added. It may even then be ineffective (2).

Chemical Pulping of Wood

As the term implies, the energy utilized in chemical pulping to separate cellulose fibers from other wood components derives from chemical application. Wood is cooked in batch or continuous digesters, large pressure vessels, with solutions of various chemicals to the point at which non-cellulosic constitutents are dissolved and the fibers can be liberated by blowing the digester, or by jets of dilution water in the blow pit (3). Other than a simple "opener" device used in conjunction with the blowing of some high lignin content sulfite pulps (2), no subsequent mechanical devices are necessary.

Thus, chemical pulping methods are described as "full cook" processes. This differentiates them from the mechanical operations described above and semi-chemical pulping, which employ both chemical pretreatment and mechanical energy in varying relative degrees of strength.

In some cases in chemical pulping, screenings (incompletely pulped wood fragments) may be refined and returned to the process to increase yield. However, as long as the entire stock is not subject to refining, the process is considered chemical (3).

The range of pulp yields obtained from chemical processes are lower than those of mechanical and semi-chemical pulping. In general, the sulfite papermaking pulp range is from 45-60 percent, and kraft and soda, 40-55 percent. The yield range for dissolving pulps is from 30-40 percent.

Softwoods are the primary fiber raw material of the sulfite process, and both soft and hardwood are used in kraft and soda pulping.

Acid Sulfite

The acid sulfite process is used to make two distinctly different types of pulp -- papermaking grades and dissolving grades. The basic process is the same for both, although there are significant differences in cooking temperatures, strength of chemical application, and bleaching practices. The following discussion of sulfite pulping is generally applicable to both. The major differences in its application to dissolving pulp are noted at the end of this discussion, and the variations in bleaching are covered under "Bleaching of Chemical Pulp."

In the acid sulfite process, wood chips are cooked with solutions of the bisulfite of calcium, magnesium, ammonia, or sodium containing an excess of free sulfur dioxide. The cooking liquor is manufactured at the mill from purchased and recovered chemicals (4).

Sulfurous acid is prepared by absorbing sulfur dioxide in water. Sulfur dioxide is made at the mill by burning sulfur or is purchased in liquid form either of which is supplemented by that returned to process from the sulfur dioxide recovery system.

In calcium base mills, calcium is supplied either in the form of calcium carbonate or calcium oxide; the base is reacted with sulfurous acid and is not usually recovered from the spent liquor. In ammonia base mills, aqua ammonia is reacted with sulfurous acid. If the chemical is purchased in the anhydrous form, it is first put into solution. Ammonia, too, is not recovered. Magnesium oxide and caustic soda are purchased as make-up base for the magnesium and sodium base recovery systems which retain about 90 percent of the base in the system (17) through recovery.

When ammonia, magnesium, or sodium base cooking is completed, the pulp is blown into a blow tank. It is then delivered to multi-stage vacuum washers on which countercurrent washing separates the spent liquor from the pulp. In the case of calcium base pulp and some ammonia base pulps, blow pits rather than tanks are generally employed where the pulp is washed by diffusion of wash water through the pulp mass. It is possible to recover 95 percent of the liquor solids by vacuum washing, but the limit is about 85 percent from displacement washing in blow pits. A 15 percent liquor concentration is obtainable by vacuum washing while the highest solids concentration attainable by blow-pit washing is about 10 percent (5). Off-gases are passed to an absorption system for recovery of their sulfur dioxide content (17). After washing, the pulp is diluted, screened, centrifugally cleaned, and deckered to the desired stock chest consistency for bleaching. A process diagram is presented in Figure 10.

The weak red liquor separated from the pulp is evaporated in multiple effect long tube evaporators and recovery furnace contact units to a consistency of about 60 percent solids which is suitable for burning (18). Because of scaling problems, special evaporation units of the switching type are required for calcium base liquor. Also, forced feed evaporators must be used for ammonia base liquor because of its high viscosity.

In the magnesium base process, the ash produced on burning the liquor is magnesium oxide which is recovered in cyclones and returned to the liquor manufacturing section of the mill (1). The smelt obtained on burning sodium base liquor is solidified and redissolved under controlled conditions so that the soda ash and sodium sulfide present can be separated by differential solubility. The sodium sulfide is reacted with carbonic acid to form hydrogen sulfide which is burned to produce sulfur dioxide. The latter is reacted with the soda ash obtained from the smelt to form sodium bisulfite cooking liquor, and the carbon dioxide produced is employed in the sodium sulfide reaction (1) (19). Ammonia base liquor is burned either in a typical recovery furnace or a fluidized bed unit and sulfur dioxide is stripped from the off-gases for use in the liquor preparation unit. A process flow diagram of a magnesium base sulfite recovery system is presented in Figure 11.

In the preparation of sulfite dissolving pulps, the wood is cooked at a higher than standard temperature (159). Cooking is continued until most of the lignin and part of the cellulose are dissolved whereas in papermaking pulps only a portion of the lignin is dissolved (187). The resulting spent liquor thus has a higher solids content and a much higher heat content when burned. In addition to screening to remove bark and wood particles after the pulp is washed, it is sent through special "side-hill" screens for thickening and to separate resinous materials (159) (180).

FIGURE 10
SULFITE PULP MILL
PROCESS FLOW DIAGRAM

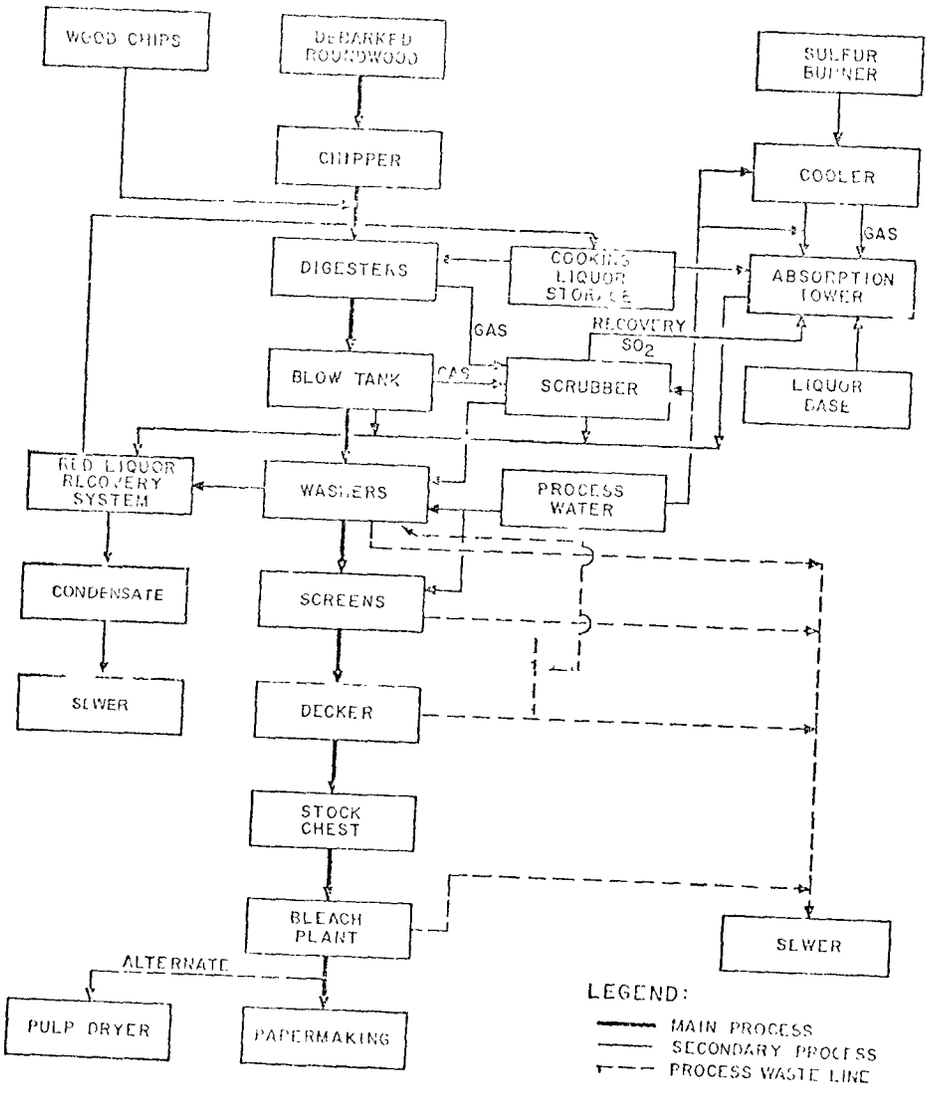
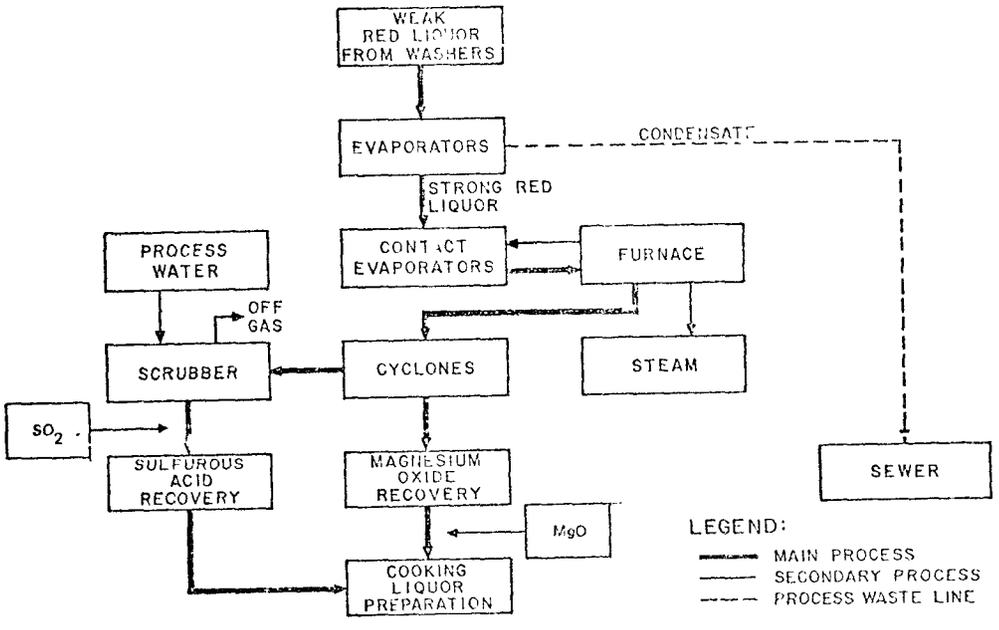


FIGURE 11
MAGNESIUM BASE SULFITE RECOVERY SYSTEM
PROCESS FLOW DIAGRAM



Bleached Kraft

Both paper grades and dissolving pulp are also made by the kraft process. Here, too, the fundamentals of the process are the same for both but there are variations in details as noted below.

Wood chips are cooked in a solution consisting primarily of a mixture of caustic soda and sodium sulfide which is known as white liquor. The pulp characteristics desired determine the percentage of sulfide used in the liquor. Both batch and continuous digesters are employed although the latter are more common in operations in which only one grade of pulp is cooked (2).

In order to make kraft pulps more amenable to bleaching, the chips are sometimes steamed in the digester for a short period prior to the addition of the cooking liquor (2) (3). This is called pre-hydrolysis and is a necessary adjunct to the production of dissolving pulps by the kraft process.

In this step, the chips are loaded into the digester which is then partially or totally filled with water and the whole mass is heated, usually by means of direct steam injection. As the temperature rises, wood acids are released and the pH drops rapidly from approximately 7.0 to 3.5 (189). The acidic conditions degrade and solubilize hemicellulose molecules in the wood thus removing materials detrimental to the cooking process. After about two hours the acidic sugar-rich liquors are drained from the digester and the kraft liquor is introduced to start the cooking stage (189). Kraft dissolving pulp is discussed further under "Bleaching of Chemical Pulp."

Because the chemical cost is high, chemical recovery has always been accessory to the kraft process. This is accomplished by burning the spent liquor and in so doing sufficient heat is generated to sustain the pulping process. The recovery system and its role in the preparation of cooking liquor are described in ensuing paragraphs.

When cooking is completed the chips are "blown" from the digester to a tank where they separate into fibers. Steam from the tank goes to an accumulator for heating process water. Drainings are frequently returned to the white liquor used in succeeding cooks.

The pulp is transferred, along with the "spent cooking liquor" (called "black liquor"), to a "brown-stock" chest, or tank, and from there to vacuum drum washers or continuous diffusers where the spent liquor is separated by countercurrent washing. In older mills, the pulp is "blown" directly to the diffusers from the digester.

Chemical recovery necessitates a high degree of liquor separation with as little dilution as is possible to minimize heat requirements of evaporation (2) (20) -- i.e., a high percentage of solids must be retained in the liquor in high concentration.

Thus, three stages of washing are common and, in some cases, four are used. In some newer installations a combination of vacuum washers and diffusers is employed (21). When continuous digesters are equipped for internal diffusion washing the pulp requires only one or two stages of external washing.

After washing, the pulp is diluted and screened to remove knots, incompletely cooked chips, resin particles, etc. It is then deckered to a consistency suitable for bleaching. In modern bleached kraft mills, a decker is used which has been adapted to provide a final wash shower which enhances bleaching performance.

The kraft pulping process is illustrated in Figure 12.

The liquor separated from the pulp in the washing operation is called "weak black liquor" and contains about 10 to 14 percent solids. In addition to the inorganic cooking chemicals, it contains organic wood constituents separated in the pulping process. The weak black liquor is concentrated to about 40 to 45 percent solids in long tube multiple effect evaporators and the resulting viscous mass is called "strong black liquor." This is then concentrated further to a consistency of 60 to 65 percent solids in the recovery furnace contact evaporator or in a concentrator.

Cooking chemicals lost in pulping and washing are replaced with make-up chemical, usually sodium sulfate, or a residue with a high content of this salt (5). Acid sludge from tall oil treatment, neutral sulfite semichemical (NSSC) waste liquor, and ash from incineration of NSSC liquor are examples of such residues. Salts captured from the recovery furnace stack gases are also reintroduced into the system. Sulfur and caustic soda are sometimes used to adjust the sulfidity.

The strong black liquor is then burned and the heat recovered in an especially designed boiler. During burning, the organic sodium compounds are converted to soda ash and sulfates to sulfides on the floor or reducing section of the furnace. The molten smelt of salts is dissolved in water to form "green liquor." This is clarified by sedimentation and then causticized with lime to convert the soda ash to caustic soda. After causticizing, the combined sodium sulfide-caustic soda solution is known as "white liquor." This is settled and sometimes filtered through pressure filters, adjusted to the desired strength or concentration for cooking with weak black liquor, and the white liquor is stored for use in the pulping process.

The lime mud (calcium carbonate) obtained from settling this white liquor is washed and dewatered on rotary vacuum filters or centrifuges and burned in rotary or fluidized bed kilns to form quick lime. This is hydrated with green liquor in slakers for reintroduction to the recovery cycle.

FIGURE 12
BLEACHED KRAFT PULPING
PROCESS FLOW DIAGRAM

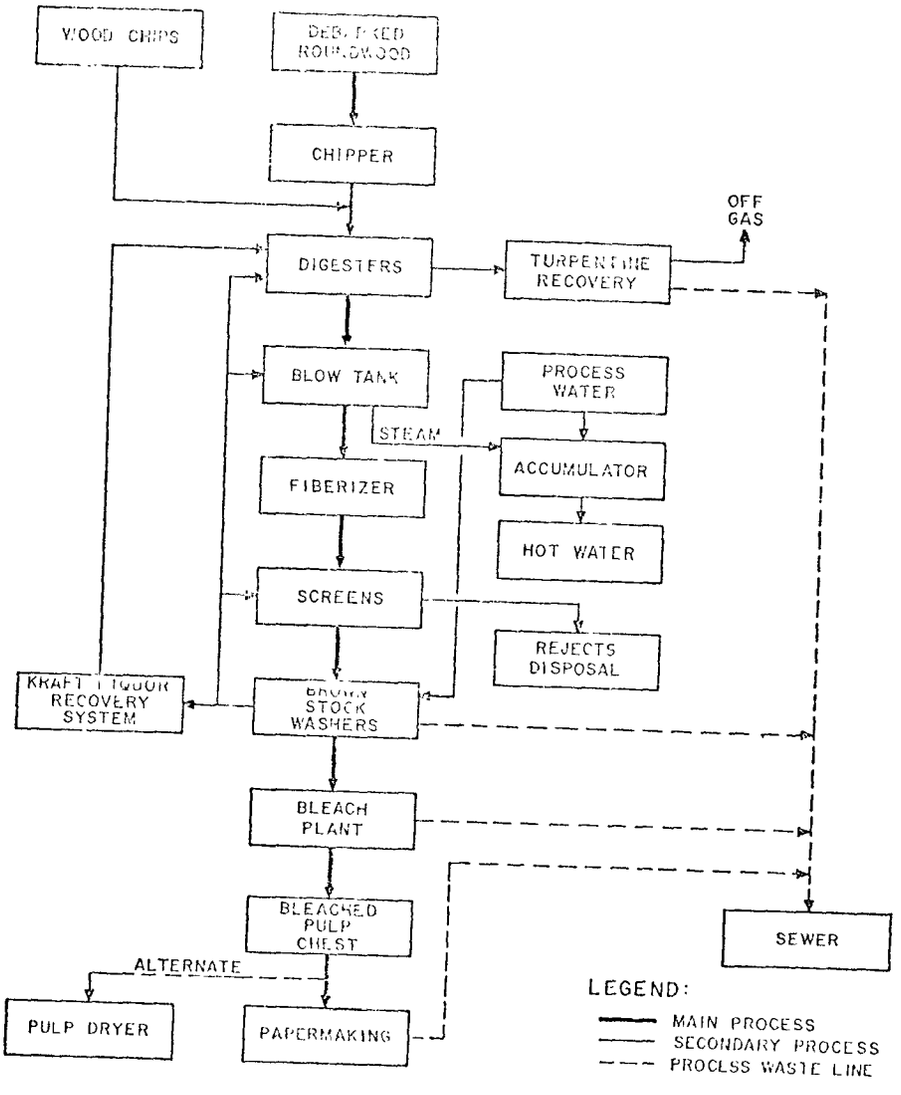


FIGURE 13

KRAFT CHEMICAL RECOVERY PROCESS

Burning:

$$Na_2SO_4 + 2\ C \longrightarrow Na_2S + 2CO_2$$

$$Na_2 + CO_2 \longrightarrow Na_2CO_3$$

Causticizing:

$$Na_2CO_3 + Ca\ (OH)_2 \quad 2NaOH + CaCO_3 \downarrow$$

Reburning: (of mud)

$$CaCO_3 \longrightarrow CaO + CO_2$$

Slaking:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

FIGURE 14

KRAFT RECOVERY SYSTEM PROCESS FLOW DIAGRAM

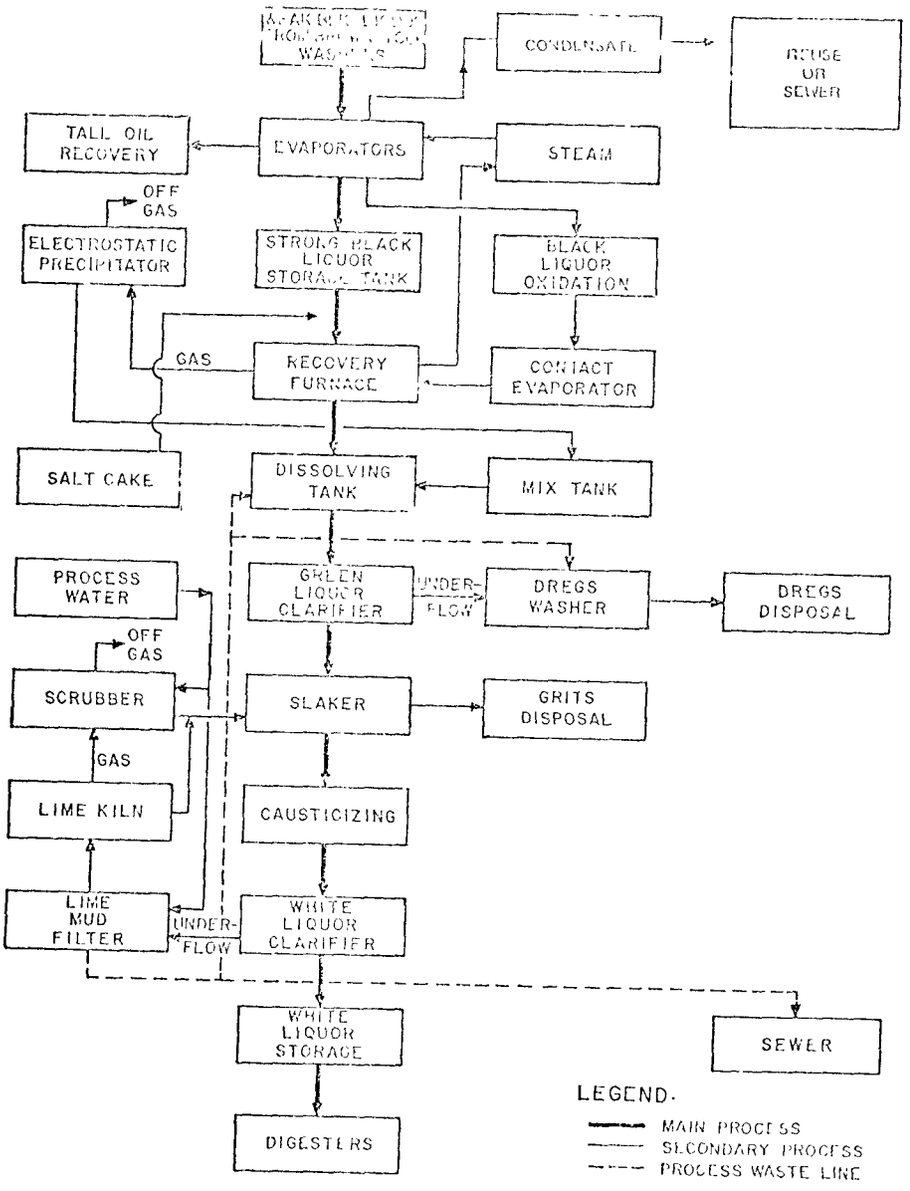


FIGURE 15

CHEMICAL REACTION INVOLVED IN THE
SODA PULP MILL RECOVERY SYSTEM

Liquor Combustion	$R \quad Na + \Delta \longrightarrow C + Na_2O$ $C + O_2 \longrightarrow CO_2$ $CO_2 + Na_2O \longrightarrow Na_2CO_3$
Causticizing	$Na_2CO_3 + Ca(OH)_2 \longrightarrow 2NaOH + CaCO_3 \downarrow$
Calcining	$CaCO_3 + \Delta \longrightarrow CaO$
Slaking	$CaO + H_2O \longrightarrow Ca(OH)_2$

Equations describing the chemical recovery process are shown in Figure 13. (5) The kraft recovery system is illustrated in Figure 14.

Soda

The only major difference today between the soda and kraft processes and their recovery systems is that sulfur is present in kraft liquor and because of this black liquor oxidation is practiced at a number of kraft mills (3). All the recovery systems of both are designed to burn all the organic matter present in the black liquor rather than producing black ash as in the old soda process (30).

In the soda process wood chips are cooked in a solution of caustic soda containing 6.1 to 6.6 pounds of active alkali per cubic foot of liquor. When pulping is complete the contents of the digester are blown into a tank. Exhaust steam passes through a cyclone to remove entrained black liquor which is sent to the recovery plant. This steam and that contained in the relief gases is condensed in a heat exchanger used for heating process water before entering the atmosphere. Knots are removed from the pulp which is then washed on countercurrent drum washers generally in three stages. The pulp is then diluted, screened, and deckered to stock chest consistency.

The weak black liquor from the washers is concentrated to 40 percent solids content in long tube multiple effect evaporators and then to about 65 percent in a recovery furnace stack evaporator. The liquor is then burned in the recovery boiler. The molten ash, which consists almost entirely of sodium carbonate, is dissolved in weak wash water and the make-up chemical -- purchased and recovered soda ash -- is added to form green liquor. Also, the make-up chemical can be sodium hydroxide to the white liquor rather than sodium carbonate to the green liquor. The green liquor is clarified and causticized with lime to convert the sodium carbonate to sodium hydroxide. The lime mud is settled and filtered from the solution which is now designated a white liquor. This is filtered through a pressure filter and stored for use in the digesters. Lime mud is dried and burned to calcium oxide which is slaked and used again for causticizing. The kiln is equipped with a venturi scrubber for dust collection which generally utilizes weak wash from the causticizing system. This is returned to the process carrying recovered lime and some soda (21).

The soda pulping process is identical to that of kraft pulping illustrated in Figure 12. The reactions involved are shown in Figure 15.

Bleaching of Chemical Pulp

The chemicals most commonly employed for bleaching chemical pulps are chlorine, calcium or sodium hypochlorite, and chlorine

dioxide. Alkalies such as caustic soda and calcium hydroxide are used for extracting chlorinated reaction products from treated pulp. In some instances, hydrogen peroxide or sodium peroxide or peroxyacetic acid are used in the finishing stages of bleaching (22). Sulfur dioxide or sodium sulfite (1) (8) can be used as neutralizing and anti-chlor reagents and in some instances to stabilize pulp brightness. However, the chlorine compounds and alkalis are the most commonly applied chemicals.

Chlorine and caustic soda are either purchased in liquid form or, in rare cases, manufactured at the mill by electrolysis of sodium chloride. Hypochlorites are generally manufactured on site by treatment of milk of lime or caustic soda with chlorine. Strengths produced vary with intended use since this chemical is used not only for bleaching, but, in the case of dissolving pulps, to control rate of extraction of materials from the pulp and the ultimate viscosity of it.

Chlorine dioxide, because of its instability, is manufactured at mills which use it by one of four methods. These are the Mathieson process, a modification thereof, the R-2 process, and the Solvay process. They all employ sodium chlorate and sulfuric acid. Sulfur dioxide is also used in both the Mathieson processes, and sodium chloride is added in the modified Mathieson method and R-2 technique. Methanol is substituted for sulfur dioxide in the Solvay process (8) (24).

Other bleaching chemicals are purchased in their common form and treating solutions are prepared according to process needs. These are employed in relatively small quantities as compared to the major bleaching agents.

Bleaching is ordinarily performed in a number of stages. This is done to preserve the strength of the pulp by avoiding excessively rigorous chemical treatment and to control consistency and temperature in accordance with the demands of the particular treatment applied. Each stage consists of a reaction tower in which the pulp is retained in contact with a particular chemical agent for the optimum period of time. It is then washed on vacuum washers or diffusers and discharged to the next stage. Consistency in the reactors generally ranges from 3.5 to 12 percent and temperatures range from ambient in the chlorination stage, to 60°C (140°F) in extraction stages, 35°C (95°F) in hypochlorite stages, and 82.2°C (180°F) in chlorine dioxide treatment.

The chemical concentrations employed depend upon the consistency, the temperature, the number of stages, the specific chemicals used, the species of wood from which the pulp was produced, and the degree to which it was cooked, as well as the quality of product desired. Three stages are generally used in semibleached kraft operations and for bleaching of sulfite paper grade pulps. Since kraft pulps are dark in color, particularly when made from softwoods, high-bright kraft pulps usually require more stages. Normally five are used although some mills employ six or more

(25) (26). Three stages may be used for low-brightness soda pulp and four stages for high brightness.

Table 12 shows the most common sequences used to bleach kraft pulp to various degrees of brightness.

For high bleach kraft pulp, the CEDED sequence appears to be favored. Ten mills report using it against 14 employing other sequences, most different from the other. CHHD is used by a few mills as a means of reducing color in the bleaching effluent. Mills which partially bleach kraft most commonly employ a CED sequence while a few either modify this procedure or add another hypochlorite stage. The CEH sequence is frequently used for bleaching paper grade sulfite pulps, although additional or other stages may be utilized by mills producing several different grades. CEH is also used by one mill for semi-bleached soda pulp; one soda mill employs CEHP for fully bleached pulp and another utilizes CEHD.

A typical four stage kraft bleach plant is shown in Figure 16, and Figure 17 illustrates a three stage sulfite bleachery.

Oxygen Bleaching

Oxygen bleaching is a very recent development and is presently used in only six mills throughout the world. Three of these are in Sweden, where the process was initiated, and there is one each in France (122), South Africa (40), and the U.S.

The U.S. mill bleaches kraft pulp with a three stage bleaching sequence, D/C OD, which is illustrated in Figure 18 (187) (188). It achieves a brightness equivalent to that obtained by the more costly five and six stage sequences such as CEDED and CEHDED. The pulp is being used in nearly every paper grade and provides quality equal to that of conventionally bleached pulp. It is also reported to be less susceptible to brightness reversion.

Subsequent to the ClO_2/Cl_2 treatment, SO_2 is added to the stock flow and the pulp is then pressed to a consistency of 27 to 52 percent. It next receives a five percent caustic solution. When it enters the oxygen reactor the high consistency pulp is fluffed to increase fiber exposure to the oxygen atmosphere (177). It is reacted at 121°C (260°F) for 20-30 minutes with oxygen produced on-site from the atmosphere (23). A final ClO_2 stage completes the sequence.

Another oxygen bleaching stage has been in use in a Swedish kraft mill since November, 1973. In contrast to the sequence of the U.S. mill, the process there employs the oxygen stage first in an OC/DEDED sequence (140) (Figure 19). The pulp is of high quality with brightness in excess of 92, and has the same physical strength as pulp previously bleached by a C/DEDED sequence.

Table 12

COMMON SEQUENCES USED TO BLEACH KRAFT PULP
TO VARIOUS DEGREES OF BRIGHTNESS

Range of G.E. Brightness	Bleaching Sequence
70 to 80	CEH
	CEHH
80 to 85	CHEH
	CEHEH
	CC/HEHH
	CED
85 to 92	CEHD
	CHED
	CEHDD
	CC/H ED/H
	CEDED
	CEDHED

Steam and alkali (caustic soda, at present) are added to pressed stock of approximately 35 percent consistency which is reacted with oxygen, after fluffing, for 30 minutes at 95-100°C (203-212°F). In order to meet a requirement of sulfur emission standards the caustic soda used in the "O" stage can be reclaimed and used in the cooking liquor preparation to reduce its sulfidity at a considerable cost saving (140). This stage is followed by the remaining stages of the sequence in conventional equipment.

Some experimental work has been done with ozone as a bleaching agent. Since it is more a delignifying agent than a bleaching agent (11), it could be used most effectively as a first stage in bleaching. However, when large amounts of ozone are charged in one stage, a dramatic drop in the viscosity of the pulp occurs (11). This can be overcome with the use of several stages although at considerable cost. Also, the production capacity of existing ozone generators is too small for bulk use of this chemical.

Displacement Bleaching

Two U.S. companies are installing a new displacement bleaching process which has been in pilot operation in Finland. Bleaching

FIGURE 16

FOUR STAGE KRAFT PULP BLEACH PLANT PROCESS FLOW DIAGRAM

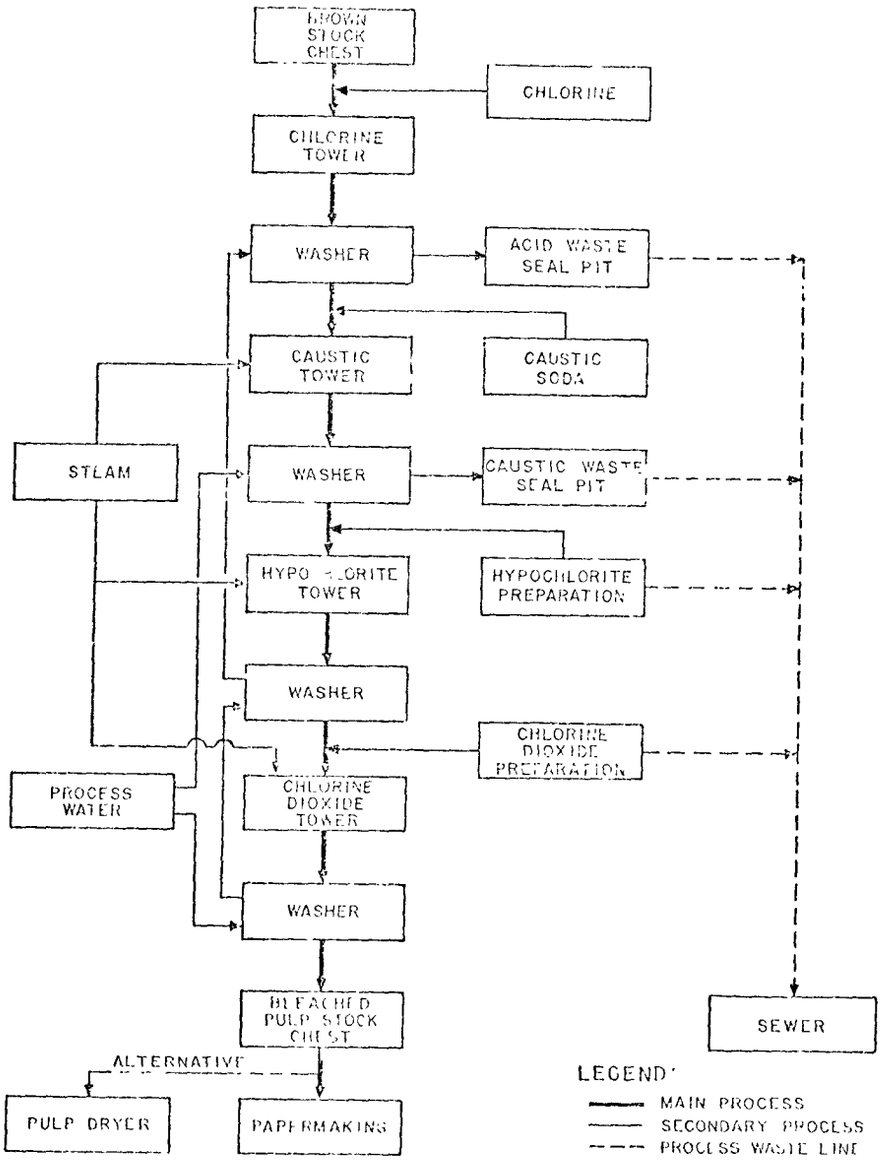


FIGURE 17
THREE STAGE SULFITE PULP BLEACH PLANT
PROCESS FLOW DIAGRAM

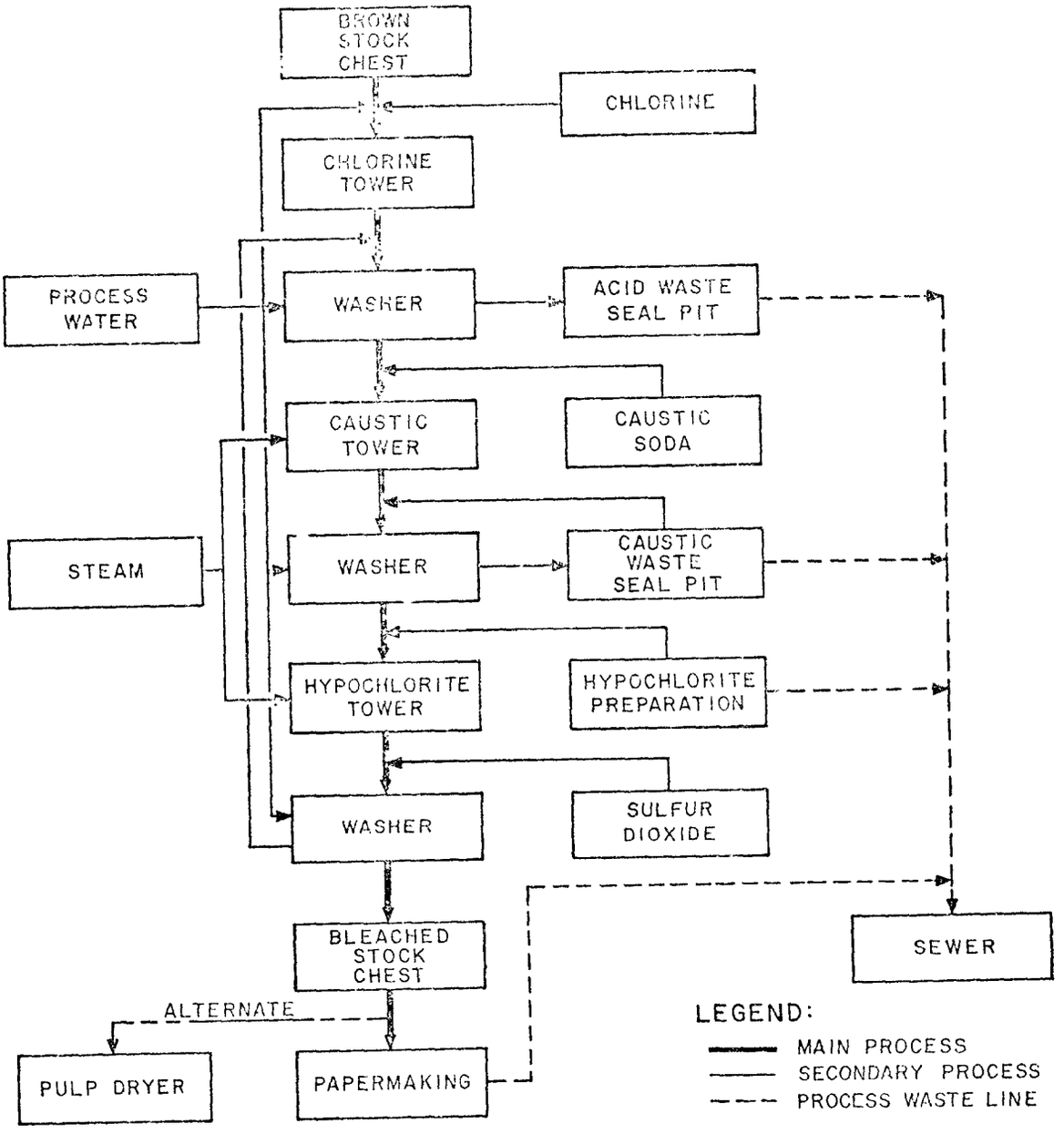


FIGURE 18

OXYGEN BLEACH PLANT AT SURVEYED MILL 124

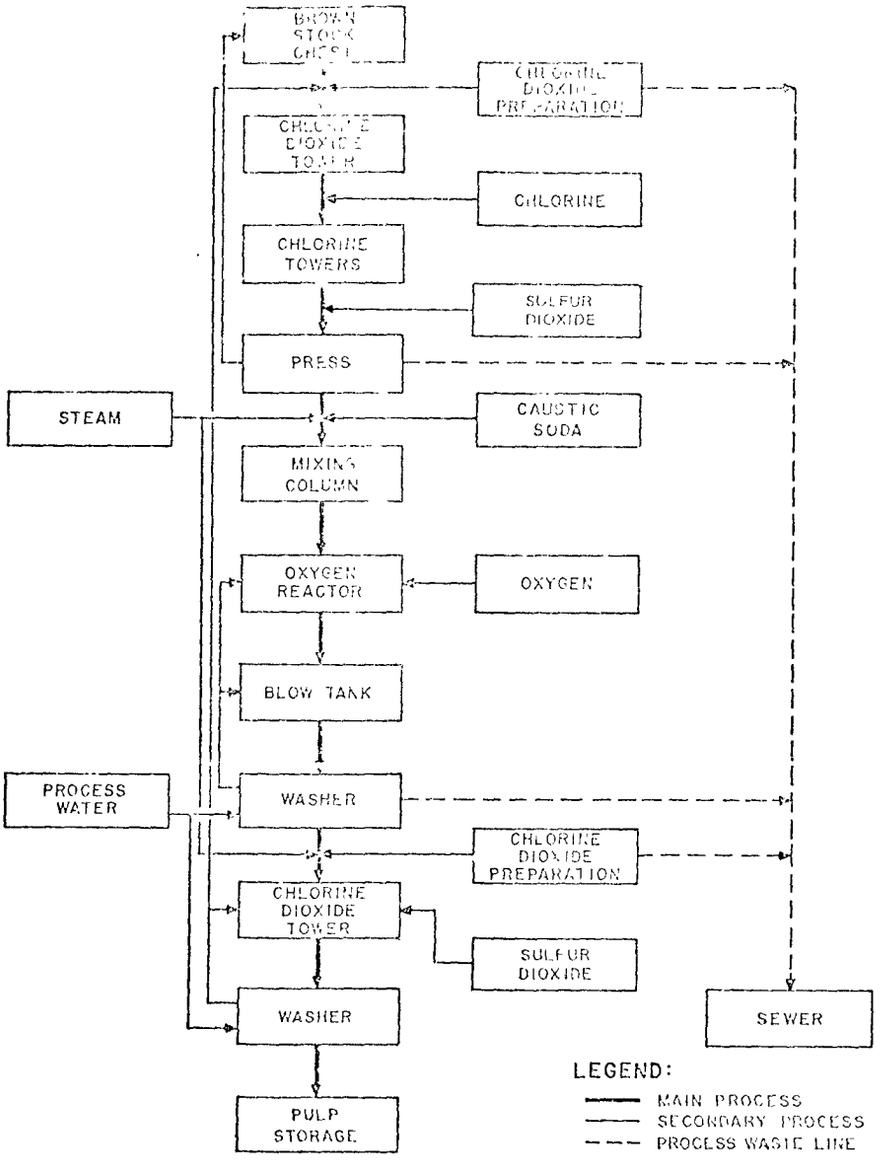
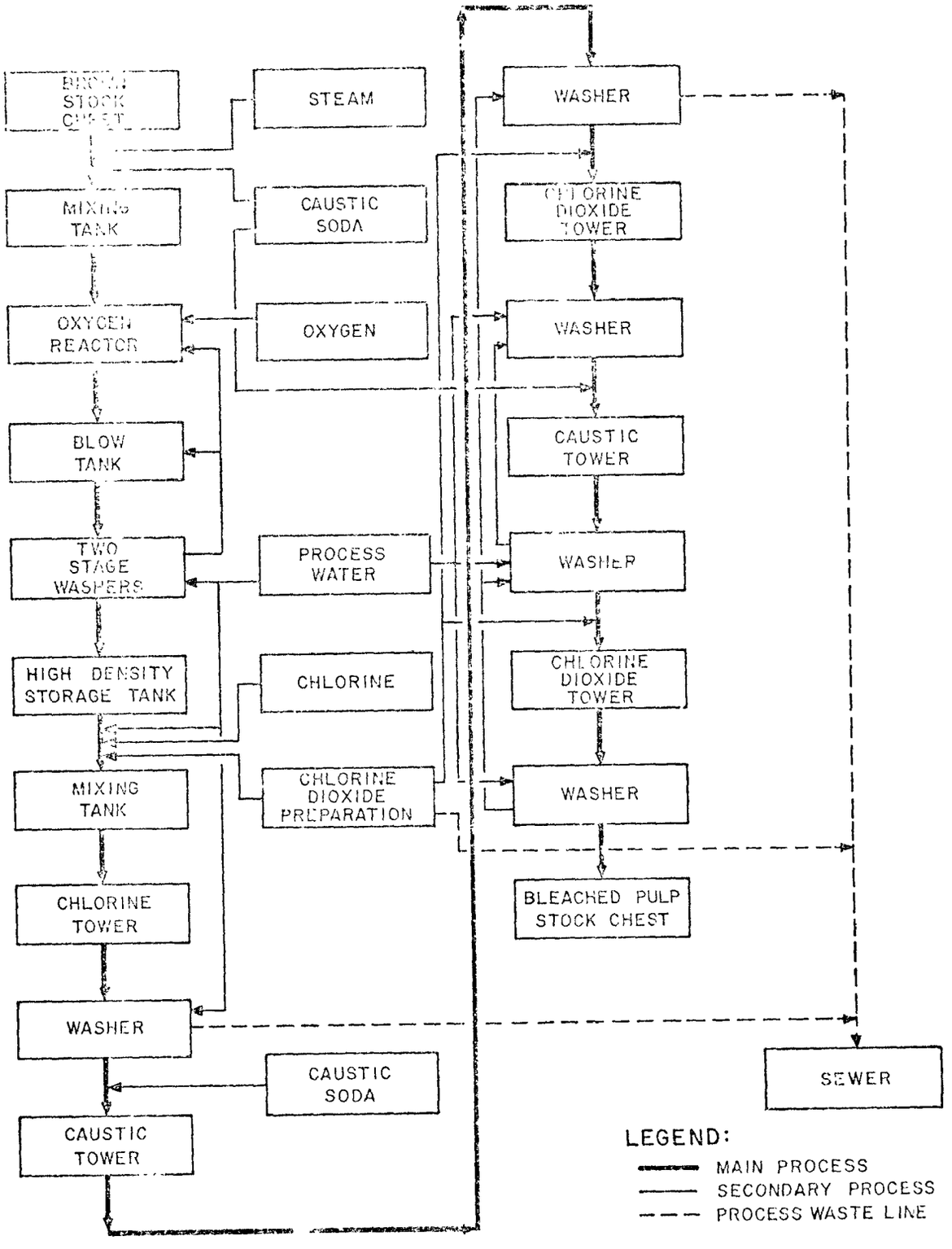


FIGURE 19

OXYGEN BLEACH PLANT AT SWEDISH MILL



chemicals are displaced through a pulp mat rather than being conventionally mixed into the pulp (185). Very rapid bleaching can be accomplished due to high reaction rates. Filtrate withdrawal at one stage is fortified with make-up chemical and reused (186). In the first such system in this country, the bleaching tower will be 15 feet in diameter and 80 feet in height (186). It will accommodate four stages of bleaching, stacked in the tower so that the unbleached pulp moves sequentially from bottom to top as shown in Figure 20.

Bleaching of Dissolving Pulps

Dissolving pulps are always bleached, and, in addition, usually must undergo one or more additional reactions such as chemical purification, deresination, ash removal, etc. Most of these steps are combined in a complex bleaching and purification process (2).

The actual bleaching for both sulfite and prehydrolysis-kraft is accomplished by standard procedures as described above. CEHD is used by some sulfite dissolving mills, although others employ a five-stage process which may or may not include a chlorine dioxide stage. The use of this chemical, however, is indispensable for the production of dissolving grades from kraft pulp.

The purpose of the caustic extraction stage in bleaching dissolving sulfite pulps is somewhat different from its function in bleaching sulfite paper grade pulps. In the latter, this stage is utilized to remove partially bleached material solubilized in the chlorination stage. In the manufacture of dissolving pulp, the extraction stage is much more drastic in terms of caustic concentrations and degree of heat in order to dissolve a specific fraction of the cellulose itself which is not suited to the manufacture of rayon (159). Over 45 kg (100 lb) of caustic may be added per kkg (ton) of pulp and reaction temperatures exceed the boiling point while only about 14 kg (30 lb) of caustic under warm conditions are required for paper grade pulp (180). In dissolving pulp bleaching, this step dissolves approximately 10-16 percent of the pulp, depending on the grade of cellulose desired.

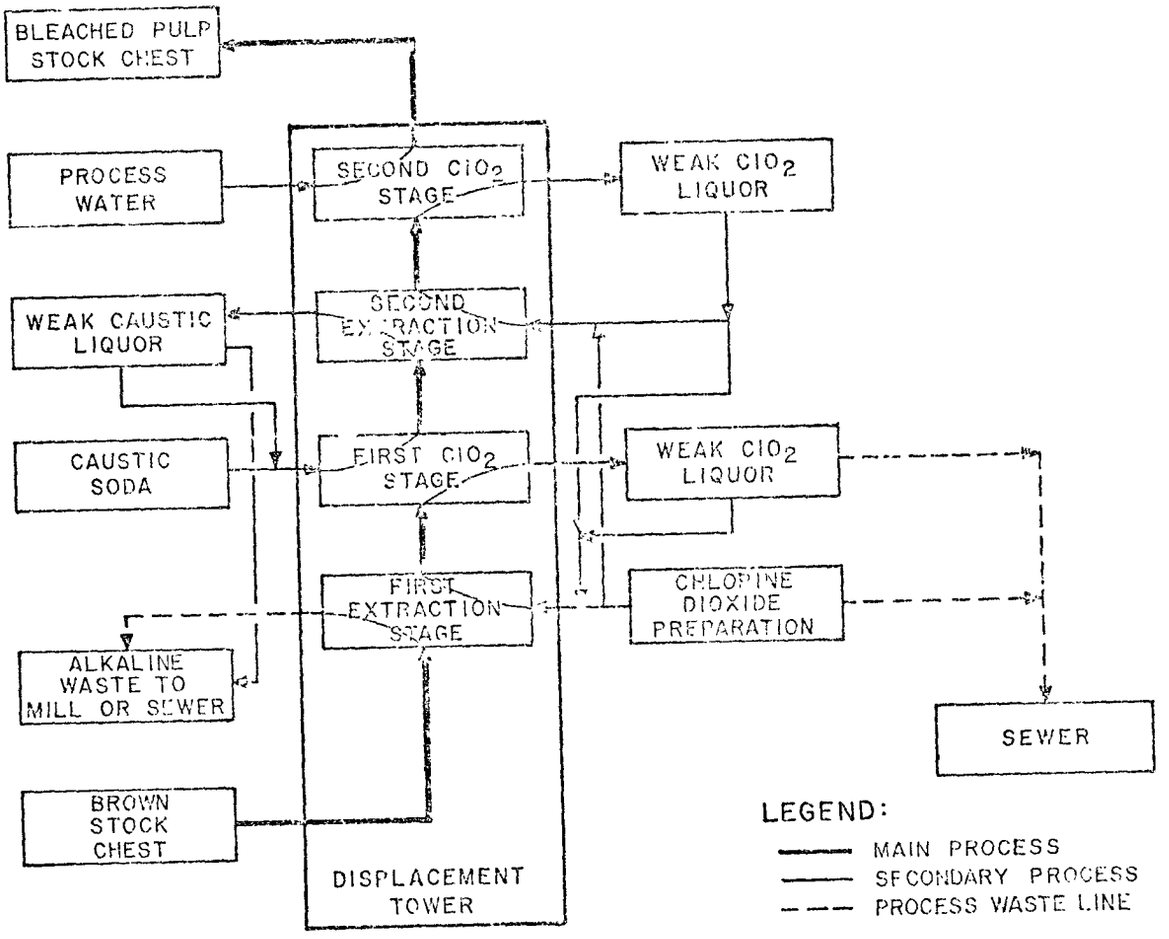
The final bleaching steps in sulfite dissolving also serve a different purpose from the last stage in bleaching paper pulp. In the latter case, the bleaching agent is usually used to achieve high brightness with minimum effect on the cellulose itself. In bleaching dissolving pulp, high brightness is only an incidental requirement and actual modification of the cellulose molecule itself is desired. Thus, the dissolving sequence usually ends with a relatively harsh bleaching agent such as sodium hypochlorite (159).

For kraft dissolving grades, the unbleached pulp is purified in the bleach plant to remove all traces of lignin and

FIGURE 20

PLANNED DISPLACEMENT BLEACH PLANT

AT SURVEYED MILL 121 (179)



hemicellulose. This is done by means of a five to eight stage process, typically consisting of chlorination, caustic extraction, hypochlorite bleaching, chlorine dioxide bleaching, further caustic extraction followed by more chlorine dioxide and hypochlorite. Lignin is removed by chlorine and chlorine dioxide and hemicellulose by caustic extraction (189). The extreme hot alkaline extraction conditions designed for sulfite dissolving, described above, are not useful for the kraft dissolving process in which the alpha cellulose level is determined largely by cooking procedures (8).

Deinked Pulp

A variety of waste papers are deinked to make several grades of pulp. Most waste paper used in this manner must be sorted and carefully classified since 1) not all papers are suitable for deinking; 2) certain types are desirable for some types of reclaimed pulps and are not suitable for others; and 3) papers which can be processed successfully by one process could be troublesome if mixed with papers requiring different treatment (2).

Waste paper is preferably sorted at its source (homes, offices, stores, factories, printers, or manufacturers of paper products such as boxes, envelopes, etc.); otherwise it must be sorted by the dealer, or at the mills. Sorting at the source is becoming more common today for two reasons. One, sorted waste papers bring higher prices both to the generator and the dealer than mixed bales. Second, sorting at the mill is an expensive hand operation.

Some mills are able to buy overruns of specific publications which are uniform in character. This makes for a successful operation since sorting is not required and the deinked product is more uniform.

High groundwood content papers are deinked for use in tissue or molded products, and for liner in board mills. These papers are not as suitable for fine or printing paper operations. Papers which contain plastics, latex, exotic inks, and other non-dispersible materials cause difficulties in deinking, degrade the product, or generate troubles on the paper machine. Wet strength papers are given separate treatment because of their resin content.

Details of the deinking process used to produce pulp for fine papers depend upon the characteristics of the waste paper, but the process consists primarily of an alkaline cook to which dispersants, detergents, and solvents are added. The process is essentially a laundering operation in which the sizes, any coating binder, and the pigment vehicle in the ink are dissolved or dispersed and the ink pigment released, along with filler and coating agents such as clay, calcium carbonate, and titanium dioxide. Adhesives such as starch and glue are also dissolved

and dispersed. The process is essentially the same in all mills except that somewhat different process units may be used from a variety of specific pieces of equipment. The equipment and process are described in detail in a TAPPI monograph (27).

The waste paper is generally cooked in a pulper at a consistency of between five and eight percent and a temperature ranging from 82° to 99°C (180° to 210°F). Cooking time is determined generally by examination of a sample from the pulper. During this step a trash boot and a ragger may be used to remove trash, rags, rope, wire, etc. The stock is then usually screened at about one to two percent consistency, after which it is ready for cleaning. This is accomplished by passing the stock at about 0.5 percent consistency through centri-cleaners and fine screens. Generally countercurrent washing is employed on washers of various types. Some mills employ flotation for separating the fiber from the undesirable materials and others use various kinds of deckering or thickening equipment. Fiber leaves the washers and is delivered to a stock chest at six to 15 percent.

Deinking practices in a tissue or molded pulp mill do not vary appreciably from the above. However, cooking temperatures for papers high in groundwood content are generally lower -- 38° to 71°C (100° to 160°F) with a pH below 10. In addition, sodium peroxide is frequently added to the cooking liquor since its bleaching action tends to prevent browning of the pulp.

A considerable shrinkage of the raw stock occurs in deinking because of the filler and coating materials washed from it along with large quantities of fiber fines when appreciable groundwood is present. The shrinkage for common grades of waste paper is shown in Table 13 (27).

Newsprint is deinked by a proprietary process employing a special detergent. The pulp produced is suitable for conversion on high-speed newsprint paper machines with the addition of little, if any, long fiber stock and may not require bleaching. Shrinkage is reported to run around 15 percent.

In some non-deinking operations considerable quantities of books, envelope cuttings, and flyleaf shavings, and similar unprinted scrap is repulped and washed free of fillers, adhesives, and sizing materials. Although ink removal is not involved, shrinkage and attendant sewer losses from such operations are similar to those from deinking.

At some paper mills relatively small amounts of selected kinds of waste paper are deinked from time to time for use in furnishes employed in the production of particular specialties. In such cases, almost the entire operation, including bleaching, is carried out in Hollander beaters (28). This may be the case also with the reclamation of fiber for use as liner in board mills.

Bleaching of Deinked Pulp

Deinked fibers consisting primarily of bleached chemical pulp are bleached in one stage with chlorine or calcium or sodium hypochlorite. From two to five percent of available chlorine is commonly used. Consistencies of the pulp bleached range from three to as high as 12 percent; tower type bleaching is used for the higher consistencies. When pulps containing considerable lignin are bleached after deinking, the threestage CED process commonly applied to kraft and sulfite pulps is employed (6). In this process, three percent of chlorine is applied to a dilute slurry of the pulp at ambient temperature. The pulp is then thickened and treated with caustic soda at 38°C (100°F) which is followed by washing and treatment with hypochlorite. A variety of equipment and variations of this process are in use. Pulps high in groundwood are bleached by the methods employed for groundwood alone and variations thereof employing caustic soda, peroxides, and hydrosulfites. Bleaching decreases the yield in the range of from 2.9 to five percent (28) (8).

A process flow diagram of a deinking operation with single stage bleaching is presented in Figure 21 and a similar diagram of a three stage bleaching system for deinked pulp is shown in Figure 22.

Papermaking

In stock preparation, pulp, either purchased or produced on site, is resuspended in water to a consistency of four to six percent. The stock is mechanically treated in beaters or continuous refiners to "brush" or fray the individual fibers to obtain the necessary matting which produces the desired strength in the paper. This process also cuts the fibers to some degree. In cases where good formation is desired, such as fine papers, the stock is also pumped through a jordan which further cuts the fibers, with a minimum of brushing, to the necessary length. The amount of brushing and cutting varies with the type of pulp and the end product requirements. In a few cases, no mechanical treatment is needed.

Table 13

SAMPLES OF SHRINKAGE
OF VARIOUS TYPES OF PAPER
ON DEINKING

	%Ash	%Shrinkage
Bond	2	10
Ledger	5	15
Offset	12	19
Book	20	34
Gummed	10	40
Coated	25	42
Coated	30	50

Chemical additives may be added either before or after stock preparation. The most common additives are alum and rosin used for sizing, which prevents blotting of ink. Fillers such as clay, calcium carbonate, and titanium dioxide are added where opacity and brightness of the paper are important. A wide variety of other additives such as wet strength resins, dyestuffs, and starches may be used, depending on end-use requirements.

Either a fourdrinier or cylinder forming machine may be used to make paper/board. The primary operational difference between the two types is the flat sheet-forming surface of the fourdrinier and the cylindrical-shaped mold of the cylinder machine. The type of machine used has little bearing on the raw waste load.

In the fourdrinier operation, dilute pulp, about 0.5 percent consistency, flows from the headbox onto the endless wire screen where the sheet is formed and through which the water drains. A suction pick-up roll transfers the sheet from the wire to two or more presses which enhance density and smoothness and remove additional water. It then leaves the "wet end" of the machine at about 35 to 40 percent consistency and goes through dryers, heated hollow iron or steel cylinders, in the "dry end."

In the cylinder operation, a revolving wire-mesh cylinder rotates in a vat of dilute pulp picking up fibers and depositing them on a moving felt. The pressing and drying operations are the same as described above. The cylinder machine has the capacity to

FIGURE 21

DEINKING PLANT PROCESS FLOW DIAGRAM

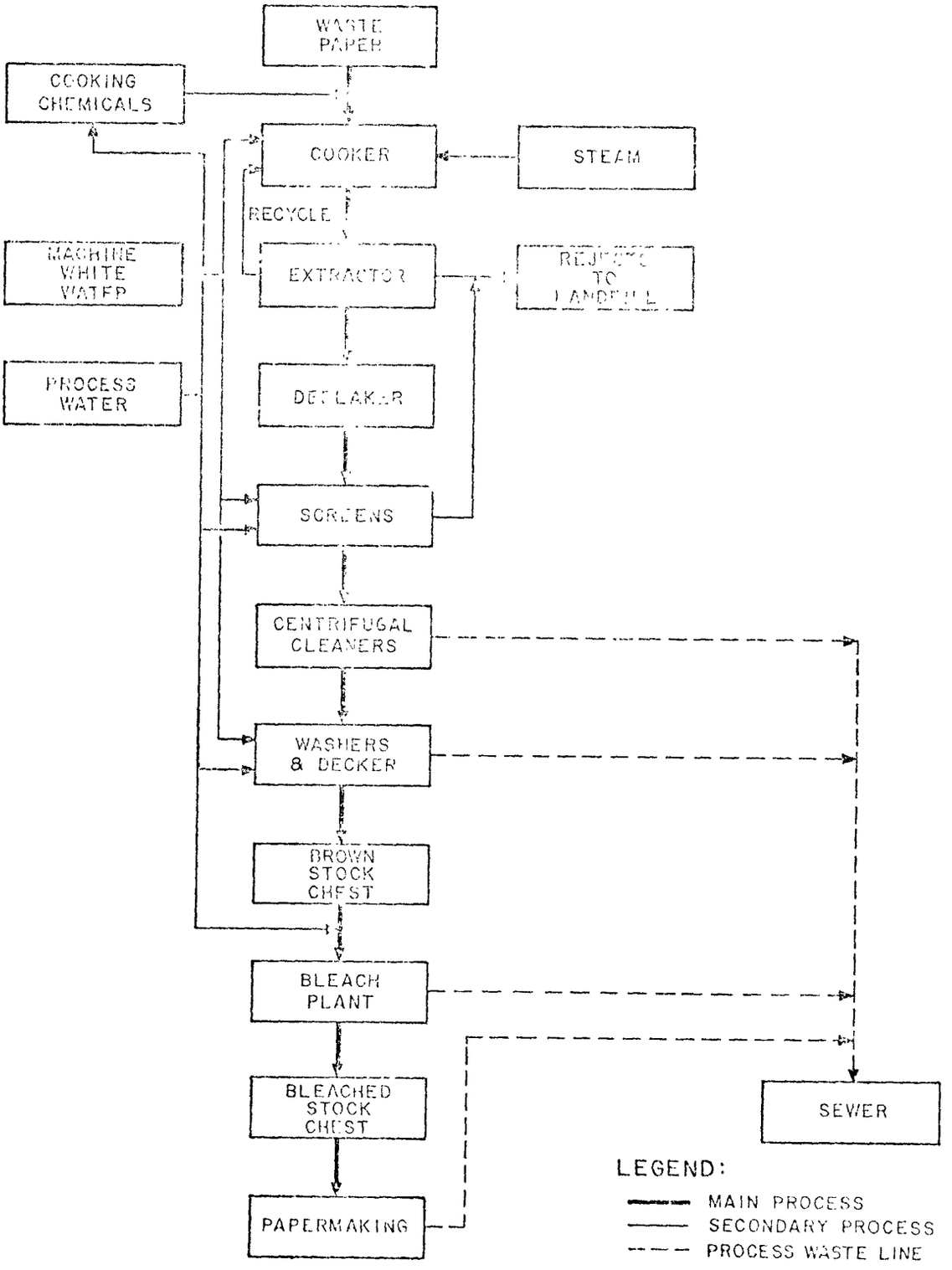
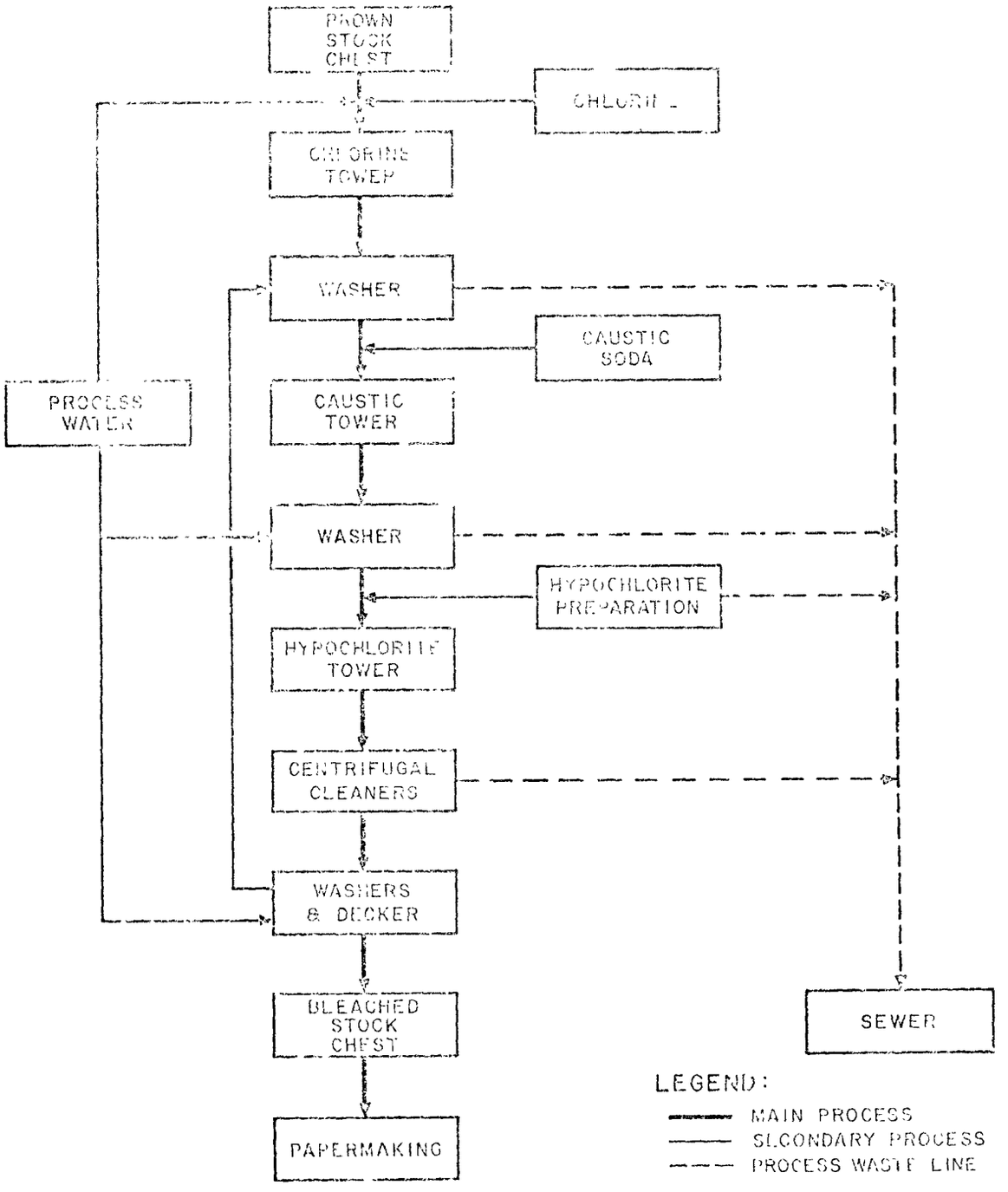


FIGURE 22

THREE STAGE DENNED PULP BLEACH PLANT

PROCESS FLOW DIAGRAM



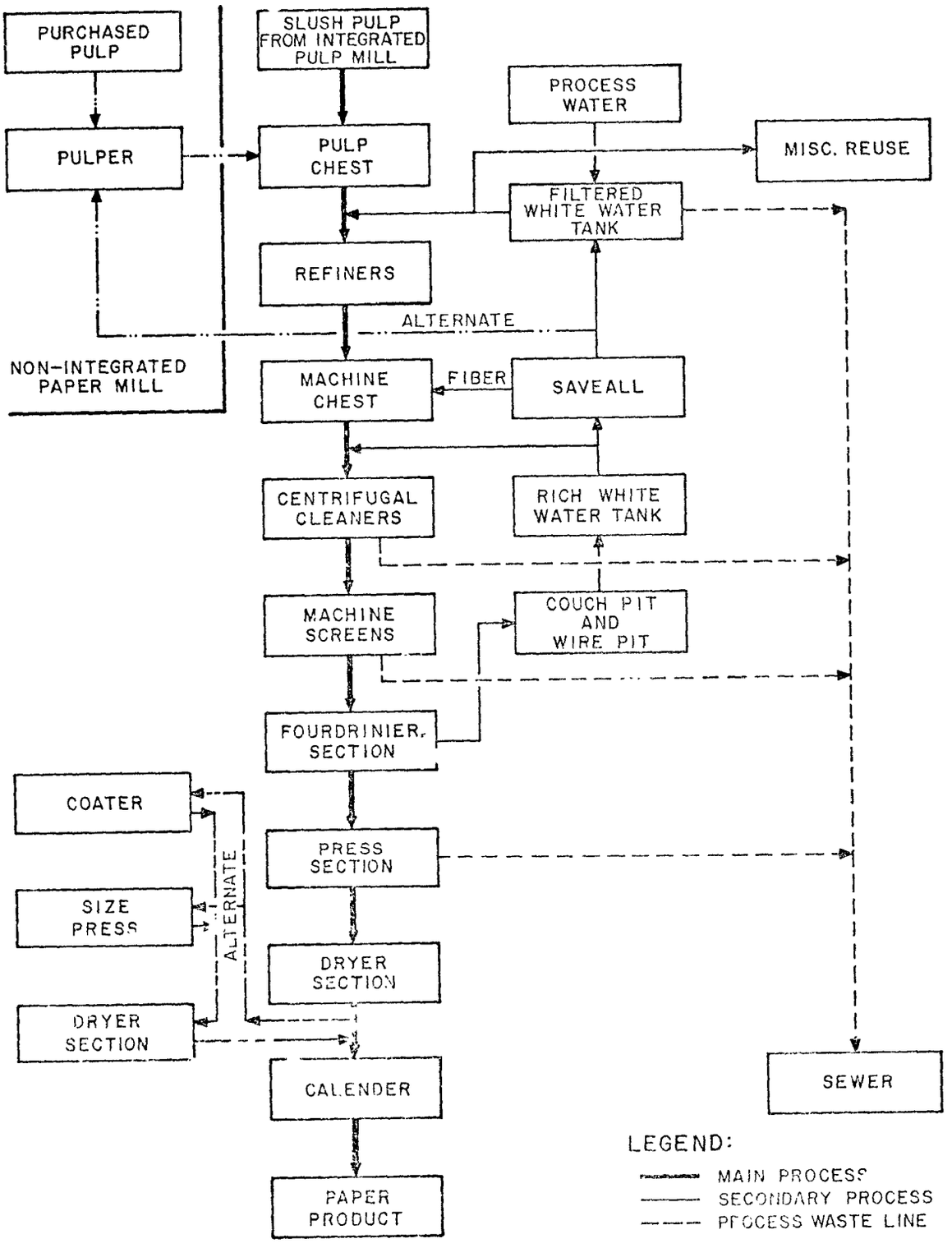
make multi-layered sheets which accounts for its principal use in the manufacture of paperboard.

Because of its higher speed and greater versatility, the fourdrinier is in more common use than the cylinder machine. In either case, coatings may be applied in the dry end or on separate coating machines. After initial drying on the paper machine, the sheet may be treated in a size press, and then further dried on the machine. Calender stacks and breaker stacks may be employed to provide a smoother finish, either after drying or while the sheet is still partially wet.

A flow sheet of the fourdrinier operation is presented in Figure 23.

FIGURE 23

PAPER MANUFACTURING PROCESS FLOW DIAGRAM



SECTION IV

SUBCATEGORIZATION OF THE INDUSTRY

FACTORS OF CONSIDERATION

This study is concerned with the groundwood, acid sulfite, bleached kraft, soda, deink, and non-integrated paper mill segments of the pulp and paper industry, and applies to the manufacture of pulp and paper from wood cellulose fibers. In order to identify any relevant, discrete subcategories of these segments of the industry, the following factors were considered:

1. Raw materials
2. Production processes
3. Products produced
4. Size and age of mills
5. Waste water characteristics and treatability
6. Geographical location

After analyzing these factors, it is concluded that the segments should be divided into the following 15 subcategories:

1. Bleached Kraft: Dissolving Pulp
2. Bleached Kraft: Market Pulp
3. Bleached Kraft: Fine Papers
4. Bleached Kraft: B.C.T. Papers
5. Sulfite; Papergrade
6. Sulfite: Dissolving
7. Soda
8. Groundwood: Chemi-mechanical (CMP)
9. Groundwood: Thermo-mechanical (TMP)
10. Groundwood: Fine Papers
11. Groundwood; C.M.N. Papers
12. Deink
13. Non-Integrated (NI) Fine Papers
14. Non-Integrated Tissue Papers
15. Non-Integrated Tissue Papers (from Waste Paper)

Analysis of the above factors resulted in excluding two types of operations within the non-integrated paper mill segment from the effluent limitations. These operations included those non-integrated paper mills producing coarse and specialty papers. Effluent limitations will be developed for these types of mills at a later date.

The subcategories are defined as follows:

1. BLEACHED KRAFT: DISSOLVING PULP means the production of a highly bleached pulp by a "full cook" process utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. Included in the manufacturing process is a "pre-cook" operation termed prehydrolysis. The highly bleached and purified dissolving pulp is used principally for the manufacture of rayon and other products requiring the virtual absence of lignin and a very high alpha cellulose content.

2. BLEACHED KRAFT: MARKET PULP means the production of bleached pulp by a "full cook" process utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. Included in this subcategory are mills producing papergrade market pulp as the only product.

3. BLEACHED KRAFT: FINE PAPERS means the production of bleached pulp by a "full-cook" process utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. This pulp is used to manufacture fine papers which are defined as those papers containing eight per cent clays and fillers or above.

4. BLEACHED KRAFT: B.C.T. PAPERS means the production of bleached pulp by a "full cook" process utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. This pulp is used to manufacture a variety of papers with clays and fillers contents less than eight per cent. Included in this subcategory are mills producing paperboard (B), coarse (C) papers, and tissue (T) papers.

5. PAPERGRADE SULFITE means the production of pulp, usually bleached, by a "full cook" process using an acidic cooking liquor of bisulfites of calcium, magnesium, ammonia, or sodium containing an excess of free sulphur dioxide. This pulp is used to manufacture a variety of paper products such as tissue and fine papers.

6. DISSOLVING SULFITE means the production of highly bleached and purified pulp by a "full cook" process using very strong solutions of bisulfites of calcium, magnesium, ammonia, or sodium containing an excess of free sulphur dioxide. This pulp is used principally for the manufacture of rayon and other products requiring the virtual absence of lignin and a very high alpha cellulose content.

7. SODA means the production of bleached pulp by a "full cook" process utilizing a highly alkaline sodium hydroxide cooking liquor. This pulp is used principally to manufacture a wide variety of papers such as printing and writing papers.

8. GROUNDWOOD: CHEMI-MECHANICAL means the production of pulp, with or without brightening, utilizing a chemical cooking liquor to partially cook the wood followed by mechanical defibration by refining at atmospheric pressure. This pulp is used to produce a variety of products including fine papers, newsprint, and molded fiber products.

9. GROUNDWOOD: THERMO-MECHANICAL means the production of pulp, with or without brightening, by a brief cook utilizing steam, with or without the addition of cooking chemicals such as sodium sulfite, followed by mechanical defibration by refiners which are under pressure. This pulp is used to produce a variety of products such as fine papers, newsprint, and tissue products.

10. GROUNDWOOD: FINE PAPERS means the production of pulp, with or without brightening, utilizing only mechanical defibration by either stone grinders or refiners. This pulp is used to manufacture fine papers which are defined as those papers containing eight per cent or more clays and fillers.

11. GROUNDWOOD: C.M.N. PAPERS means the production of pulp, with or without brighterning, utilizing only mechanical defibration by either stone grinders or refiners. This pulp is used to manufacture coarse (C) papers, molded (M) fiber products, and newsprint (N) which include papers with clays and fillers contents less than eight per cent.

12. DEINK means the production of pulp usually brightened or bleached from recycled waste papers in which an alkaline treatment is utilized to remove contaminants such as ink and coating pigments. The pulp is used, frequently in combination with chemical pulp, to manufacture a wide variety of papers such as printing, tissue, and newsprint.

13. NON-INTEGRATED FINE PAPER means the manufacture of fine papers from wood pulp or deinked pulp prepared at another site. Fine papers are relatively high in price, and include grades such as printing, writing, and technical.

14. NON-INTEGRATED TISSUE PAPER means the manufacture of tissue papers from wood pulp or deinked pulp prepared at another site. Tissue papers include grades such as facial and toilet papers, glassine, paper diapers, and paper towels.

15. NON-INTEGRATED TISSUE PAPERS (FROM WASTE PAPER) means the manufacture of tissue papers from recycled waste papers. Tissue papers include grades such as facial and toilet papers, glassine, paper diapers, and paper towels.

RATIONALE FOR SELECTION OF SUBCATEGORIES

The subcategorization shown above was developed through extensive efforts in evaluating the factors listed above. Each of these factors is discussed below as to how the factors relate to the resultant subcategories.

The basic approach utilized to technically develop the subcategories was to first segment the industry by manufacturing process. The resultant broad segments were the following:

A. Chemical Pulping
B. Mechanical Pulping
C. Non-Integrated Paper Mills

These broad segments were further broken into more specific process segments including the following:

A. Bleached Kraft Pulping
B. Sulfite Pulping
C. Soda Pulping
D. Groundwood Pulping
E. Deink Paper Mills
F. Non-Integrated Paper Mills

Inherent in dividing the pulp and paper industry into the above specific process segments is the basic assumption that raw waste loads are related to the specific manufacturing process involved (Factor No. 2 above).

These specific process segments were then thoroughly evaluated as to the relationships between factors listed above and the waste water characteristics of the process effluents within the segments. These analyses resulted in dividing the above segments into the 15 subcategories. In addition, two groups of mills (coarse paper mills and specialty paper mills) within the non-integrated paper mills segment were eliminated from these effluent limitations because adequate data was not available to support (1) subcategorization of these groups of mills and (2) effluent limitations and standards.

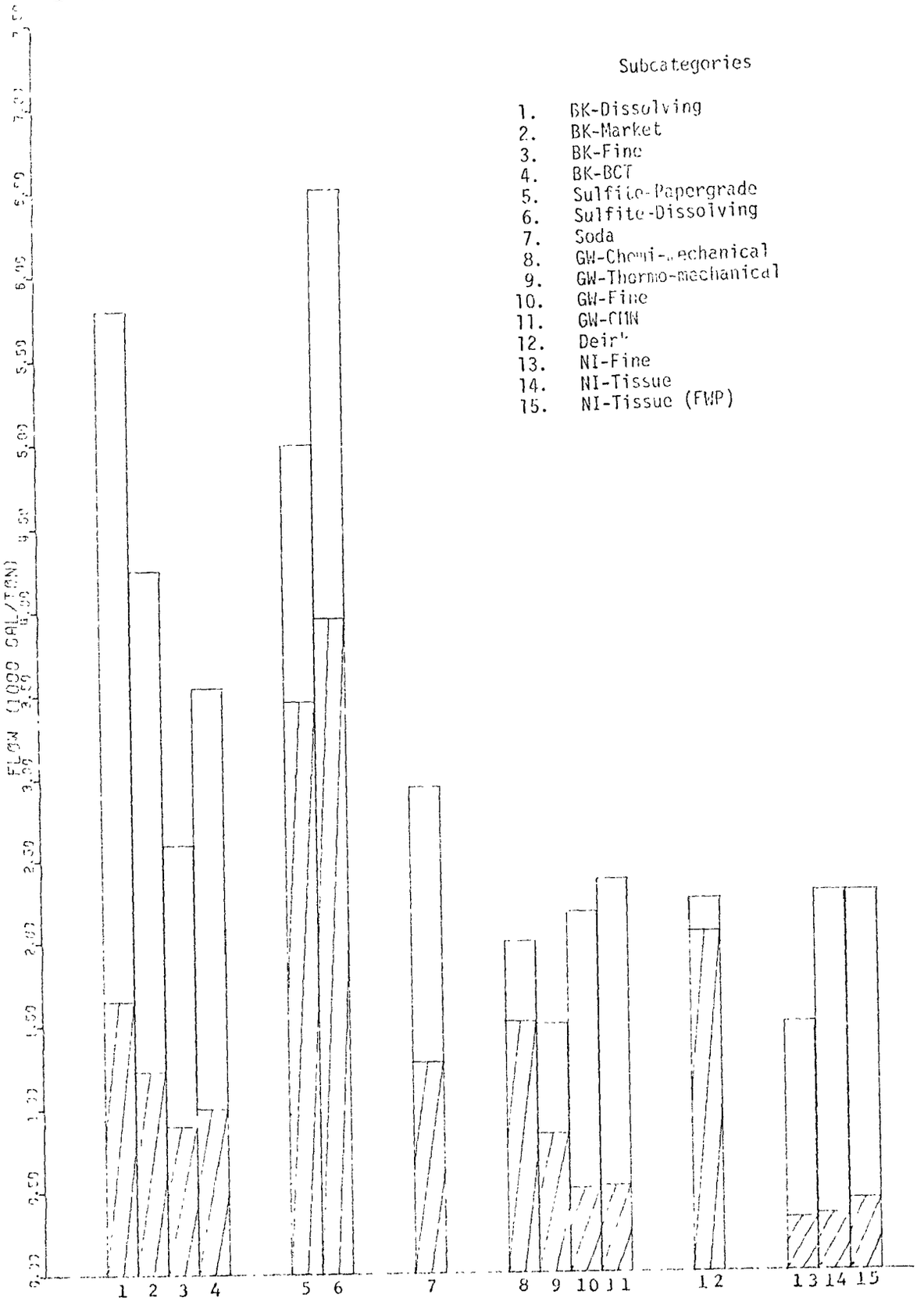
In examination of the relationships between the above factors and the process segments, the raw waste flow and BOD_5 loads were of primary concern. These two parameters were used as the basis for subcategorization as the pollution control technologies applicable to the segments under study are primarily designed as a function of flow and BOD_5. The average raw waste loads for each of the subcategories are shown in Table 14 and displayed graphically in Figure 24. The development of the specific subcategories as to the relationships between the factors and raw waste loads are discussed below, whereas the development of the specific raw waste loads per subcategory is discussed in Section V.

TABLE 14

RAW WASTE LOAD PER SUBCATEGORY

Subcategory	FLOW kl/kg (kgal/ton)	BOD5 kg/kg (lbs/ton)	TSS kg/kg (lbs/ton)
BK-Dissolving	241.9 (58.0)	55.0 (110)	150.0 (300)
BK-Market	177.2 (42.5)	41.0 (82.0)	70.0 (140)
BK-Fine	108.4 (26.0)	30.0 (60.0)	84.0 (168)
BK-BCT	152.2 (36.5)	33.5 (67.0)	51.5 (103)
Sulfite Papergrade	208.5 (50.0)	115.5 (231)	82.0 (164)
Sulfite-Dissolving	271.9 (65.2)	132.0 (264)	92.5 (185)
Soda	123.0 (29.5)	42.5 (85.0)	105.0 (210)
GW-Chemi-Mechanical	83.4 (20.0)	50.5 (101)	28.0 (56.0)
GW-Thermo-Mechanical	62.5 (15.0)	28.0 (56.0)	25.0 (50.0)
GW-Fine	90.9 (21.8)	17.0 (34.0)	52.0 (104)
GW-CMN	99.2 (23.8)	17.5 (35.0)	70.0 (140)
Deink	94.2 (22.6)	68.5 (137)	204.0 (408)
NI Fine	62.5 (15.0)	10.7 (21.5)	31.0 (62.0)
NI Tissue	95.9 (23.0)	11.5 (23.0)	34.0 (68.0)
NI Tissue (fwp)	95.9 (23.0)	14.5 (29.0)	40.0 (80.0)

Figure 24


Subcategories
1. BK-Dissolving
2. BK-Market
3. BK-Fine
4. BK-BCT
5. Sulfite-Papergrade
6. Sulfite-Dissolving
7. Soda
8. GW-Chemi-mechanical
9. GW-Thermo-mechanical
10. GW-Fine
11. GW-CMN
12. Deink
13. NI-Fine
14. NI-Tissue
15. NI-Tissue (FWP)
FLOW (1000 GAL/TON)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Raw Material

Raw materials were used as a basis for subcategorization. The primary raw materials used in pulp and paper making can be generally be classified as follows: (1) wood fiber, (2) chemicals for cooking and bleaching liquors, and (3) papermaking additives. These three basic raw materials result in distinctly different raw waste loads depending upon the closely related factors of process and products.

Wood is the primary raw material of all virgin fiber pulping processes. Consideration was given to subcategorization on the basis of wood type, but this could not be documented from raw waste data obtained from surveyed mills. For example, bleached kraft Mill 113 utilizes about equal amounts of southern hardwood and softwood and has a raw waste load of 30 kg/kkg (60 lb/ton). On the other hand, Mill 117 uses western softwood and has similar BOD waste load of 27.5 kg/kkg (55 lb/ton). Table 15 shows Flow and BOD_5 vs. type wood for surveyed mills in the bleached kraft and groundwood subcategories. It is apparent from these analyses that no definite relationship can be documented as to the specific effects of the type of wood on raw waste loads. Inherent in examining the relationships (or lack of) between wood types and raw waste loads is the geographical location factor, as the type of wood used by a mill is certainly a function of the location of that mill.

In addition to the type of wood, consideration was given to the condition of the wood as it arrived at the mill meaning either chips or logs. This difference in raw materials relates to the process factor as depending upon the form of the wood, additional waste loads are generated by some mills using wet log debarking processes whereas mills receiving wood as chips do not have this source of waste. Consideration was given to developing subcategories within each of the segments based upon chips vs. logs as this operation does result in an effluent waste load not present in mills using only chips. However, the wet barking operation is similar for all pulping segments and thus is not unique to one segment. Instead of subcategorization, an additional allowance is included in the BPCTCA effluent limitations for mills practicing wet barking without regard to the subcatetgory (See Section IX).

The source of wood fiber used as the raw material was used as a basis for subcategorization. The sources of fiber are (1) wood (as described above), (2) pulp, and (3) waste paper. Again, subcategorization by these fiber sources relates closely with the process. Non-integrated paper mills do not have wood pulping facilities and thereby depend upon either pulp or waste paper as their fiber source. Distinctly differernt BOD_5 loads result from the use of pulp or waste paper as the fiber source. This is apparent in Table 14 which shows the NI tissue subcategory BOD_5 waste load of 12.5 kg/kkg (23 lbs/ton) which by definition uses purchased pulp as the fiber source. In comparison, the NI tissue (FWP) subcategory is 14.5 kg/kkg (29 lbs/ton) which uses waste

TABLE 15

BLEACHED KRAFT SEGMENT
WOOD TYPE vs RAW WASTE LOAD

Mill Code	Wood Type % Hardwood	Flow kl/kkg(kgal/ton)	BOD5 kg/kkg(lbs/ton)
Market Pulp			
126	45	194.3 (46.6)	45.5 (91.0)
140	50	78.4 (18.8)	- (-)
114A	31	173.1 (41.5)	46.6 (93.2)
139	55	76.7 (18.4)	- (-)
BCT Papers			
105	43	162.2 (38.9)	36.2 (72.5)
109A	22	163.0 (39.1)	33.3 (66.7)
111A	57	134.7 (32.3)	30.8 (61.6)
121A	30	149.3 (35.8)	- (-)
BCT & MKT			
100	55	150.5 (36.1)	44.8 (89.7)
113A	50	140.9 (33.8)	38.4 (76.9)
131	20	158.9 (38.1)	60.5 (121)
Fine Papers			
104A	43	218.1 (52.3)	34.2 (68.5)
112	100	110.1 (26.4)	24.5 (49.0)
136	33	119.7 (28.7)	29.0 (58.0)
118	67	107.2 (25.7)	19.5 (39.0)
119	63	97.2 (23.3)	23.3 (46.7)
132	22	81.3 (19.5)	23.5 (47.0)
Fine & Mkt			
103	48	181.0 (43.4)	37.4 (74.9)
135	84	167.6 (40.2)	- (-)
Dissolving Pulp			
127A	0	230.0 (55.1)	- (-)
108	9	227.3 (54.5)	55.0 (110)

paper as the fiber source. Both of these subcategories produce the same product but were subcategorized on the basis of raw materials.

The chemicals used in preparation of the cooking liquors and in the bleaching process can have significant effects upon raw waste load, but again this is primarily a function of the process and product factors. The segmentation and subcategorization of the industry used chemical cooking liquors as a basis and is shown by the two distinct segments of kraft and sulfite. Bleached kraft mills use a highly alkaline cooking liquor resulting in raw waste loads ranging from 20 to 60 kg/kkg (40 to 120 lbs/ton) depending upon final product qualities. Sulfite mills, on the other hand, use highly acidic cooking liquors resulting in raw waste loads ranging from 70 to 140 kg/kkg (140 to 280 lbs/ton). The differences between kraft and sulfite relate to the recovery of the spent cooking chemicals and to the reuse of the condensates.

Papermaking additives were used as a basis for subcategorization primarily as they related to the final products. The additives have a discernible effect upon raw waste loads with the most significant effects shown by the non-integrated paper mills. These mills do not engage in wood pulping, but the wastes reflect the use of a wide variety of fiber types, fillers, wet strength agents, starches, rosins, and other additives. The effects upon raw waste load are shown in Table 14 for NI fine papers and NI tissue papers subcategories.

The deink subcategory can be used as an example of how the three basic classifications of raw materials (fiber, chemicals, additives) were used in the development of the subcategories. Deink mills are similar to non-integrated paper mills in that deink mills have no chemical or mechanical wood pulping on site. In addition, both deink and non-integrated paper mills purchase their fiber and manufacture similar products by similar process. The most significant differences are in the raw materials and in the manufacturing process which must be used to produce the final product qualities. Because waste paper is the fiber source rather than the relatively much cleaner purchased pulp used by non-integrated paper mills, chemicals must be used in the deink manufacturing process to clean the waste paper to specifications as demanded by product qualities. (3) Similar products are manufactured by deink mills and non-integrated paper mills using various papermaking additives, but this has lesser effects upon the raw waste load than the above two factors. Deink mills were subcategorized separate from the non-integrated mills primarily because of the raw materials used, which in turn has a direct relationship in determining the manufacturing process. Because of the raw materials, the primary purpose in the repulping of the waste paper is to remove the non-fibrous materials, such as pigments, starches, and inks (paper making additives), and it is actually a cleaning process. On the other hand, the primary purpose of non-integrated paper mills in repulping purchased pulp is merely to separate the fibers previous to forming the sheet of paper. These differences can have significant effects upon the

raw waste load as can be seen in Table 14 which shows the effluent flow to be similar for deink mills and non-integrated paper mills but the BOD_5 and TSS are significantly higher for deink mills (BOD_5: 68.5 kg/kkg (137 lbs/ton) vs. 12.5 kg/kkg (23 lbs/ton): TSS: 204 kg/kkg (408 lbs/ton) vs. 34 kg/kkg (68 lbs/ton)).

Production Processes

Production processes were used as the primary basis for subcategorization as differences in waste water characteristics and treatability are most significantly affected by the manufacturing process. Of course, the manufacturing process is closely related to raw materials and final products, and these two factors are inherently included in any evaluations involving the manufacturing process.

All chemical pulping processes are similar in that each utilizes digestion of wood chips with a chemical cooking liquor and the removal of spent liquor from the cellulose pulp. Process differences among the various pulp types relate primarily to the preparation, use, and recovery of cooking liquor. Such liquors are generally not used to make groundwood pulps, although small quantities are applied in some grades. The deinking process does not employ cooking liquors, although chemical treatment is utilized in the separation of cellulose fibers in waste papers. Non-integrated mills employ no cooking chemicals.

All segments of the industry use similiar paper making and/or forming equipment to manufacture paper or pulp products, as described in Sections III and V. Process differences in the paper making process relate primarily to the additives used to produce specific product qualities, i.e. book paper vs paperboard

The effects of the process differences on waste characteristics are shown in Table 14. It should be noted that treatability of waste water is accounted for in the subcategorization process by subcategorizing on the basis of similar processes and raw materials which contribute similar types of waste waters.

Products Produced

The wide variety of products produced by these segments of the industry is discussed in Section III. Differences in waste water characteristics generated by their manufacture are substantial but actually these differences are more attributed to the process and raw materials rather than to products produced. For example, tissue papers are manufactured by both bleached kraft and sulfite mills yet the waste water characteristics of the effluents generated by the manufacturing processes are significantly different.

As shown previously, the bleached kraft segment was subcategorized into four subcategories: (1) dissolving pulp, (2)

market pulp, (3) board, coarse, and tissue papers, and (4) fine papers. Within the bleached kraft segment, the variations of the process used to produce the above products is the most significant factor in characterizing the waste water characteristics rather than the products themselves. Another example is the subcategorization of the non-integrated paper mills into NI fine papers and NI tissue papers. The primary differences in waste water characteristics from these mills relates to the additives used in the paper making process rather than to the products. These differences in waste water characteristics are shown in Table 14.

Newsprint manufacture can also be used as an example of difference processes producing similar products. Consideration was given to subcategorization on the basis of newsprint manufacture as newsprint uses two specific types of pulp: 65-80% groundwood and 20-35% chemical pulp. Approximately 13 integrated mills manufacture newsprint; however, these integrated mills that produce newsprint do not have similar processes and thereby significant differences in waste water characteristics exist. Table 16 shows process information for the integrated mills producing newsprint. The dissimiliarities between the mills relates primarily to process and products as several mills produce 100% newsprint using groundwood pulp along with either bleached kraft, unbleached kraft, or sulfite pulps. In addition, nine of the 13 mills produce other products besides newsprint. Also, mills that produce newsprint from on-site groundwood pulping and purchased chemical pulp are not included in the table.

Thus, the products themselves were considered and were used as a basis for subcategorization but only as they related to the process and raw materials.

Age and Size of Mills

There is a substantial difference in age as well as size among mills in the industry. Mills built over 90 years ago are still in operation along with new ones built within the last two years. Most of the older mills have been substantially upgraded, modernized, and expanded, so that they are not "old" in the production sense. Because of this, differences in waste water characteristics related to age of mill are not discernible in the data from surveyed mills. The following examples from the bleached kraft segment illustrate this point. Mill 111, built in 1912 and modernized as recently as 1973, produced 656 kkg/day (723 tons/day) with a raw waste BOD load of 22.5 kg/kkg (45 lb/ton). Mill 112, built in 1969, produces about the same tonnage, i.e., 544 kkg/day (600 tons/day), with a nearly identical BOD load of 24.5 kg/kkg (49 lb/ ton). Mill 118 is much smaller, producing 174 kkg/day (192 tons/day) and was built in 1867 and rebuilt in 1951, and modernized in 1964, but has approximately the same BOD load, i.e., about 20 kg/kkg (40

Table 16
Newsprint Segment

Mill	Production kkg/day (tons/day)		Pulping (%) GW	BK	UK	S	Products (%)
033	1088	(1200)	80	-	20	-	100N
036	408	(510)	60	-	-	40	100N
037	517	(570)	70	-	-	30	100N
508	1288	(1420)	65	35	-	-	100N
514	1088	(1200)	65	35	-	-	80N
072	1120	(1235)	65	-	-	35	70N,30S
509	590	(650)	50	50	-	-	50N
166	1179	(1300)	20	55	25	-	40N,60C
165	635	(700)	30	40	30	-	70N,30B
167	1451	(1600)	20	80	-	-	80N,20F
034	1292	(1425)	30	-	70	-	30N,70F
141	1008	(1200)	20	60	20	-	80N,20T
164	943	(1040)	20	60	20	-	80N,20F

N: Newsprint
B: Board
C: Coarse
F: Fine
S: Sulfite
T: Tissue

GW: Groundwood
BK: Bleached Kraft
UK: Unbleached Kraft

TABLE 17

BLEACHED KRAFT SUBCATEGORY
AGE vs BOD WASTE LOAD

Mill Code	Year Built *	FLOW kl/kkg (gal/ton)		BOD5 kg/kkg (lbs/ton)	
Market Pulp					
126	1936	194.3	(46.6)	45.5	(91.0)
140	1939	78.4	(18.8)	-	(-)
114A	1957	173.1	(41.5)	46.6	(93.2)
139	1965	76.7	(18.4)	-	(-)
BCT Papers					
109A	1941	163.0	(39.1)	33.3	(66.7)
111A	1912	134.7	(32.3)	30.8	(61.6)
121A	1954	149.3	(35.8)	-	(-)
BCT & MKT					
100	1958	150.5	(36.1)	44.8	(89.7)
113A	1951	140.9	(33.8)	38.4	(76.9)
117A	1959	203.9	(48.9)	-	(-)
131	1928	158.3	(38.1)	60.5	(121)
Fine Papers					
104A	1971	218.1	(52.3)	34.2	(68.6)
134	1888	92.6	(22.2)	30.8	(61.7)
112	1969	110.1	(26.4)	24.5	(49.0)
130	1903	119.7	(28.7)	29.0	(58.0)
116	1847	130.9	(31.4)	56.0	(112)
118	1867	107.2	(25.7)	19.5	(39.0)
119	1864	97.2	(23.3)	23.3	(46.7)
132	1890	81.3	(19.5)	23.5	(47.0)
Fine & MKT					
101A	1971	150.9	(36.2)	30.3	(60.6)
103	1964	181.0	(43.4)	37.4	(74.9)
106A	1968	158.9	(38.1)	-	(-)
107A	1964	126.4	(30.3)	-	(-)
110A	1912	102.6	(24.6)	30.3	(60.7)
120	1937	129.7	(31.1)	48.0	(96.0)
135	1970	167.6	(40.2)	-	(-)
Dissolving Pulp					
127A	1954	229.8	(55.1)	-	(-)
108	1954	227.3	(54.5)	55.0	(110)

* Note - This date reflects the year that the original facility was built and does not show the major upgrades or expansion of the facilities.

lb/ton). Table 17 compares the age of the original facility for bleached kraft mills with the mills' raw waste loads.

The above data are selected from Figures 25 and 26 which graphically displays the size and effluent characteristics of bleached kraft mills. This figure demonstrates the apparent lack of correlation between size of mill and raw waste flow and BOD load. To further illustrate the point, Figures 27, 28, 29, and 30 show size verses flow and BOD_5 for non-integrated fine and tissue subcategories. Table 18 compares the number of paper/pulp machines in a mill with the corresponding raw waste load, and shows that no significant differences due to this factor may be detected within the segments. As further substantiation of this point, it may be seen in Figure 31 that no significant correlation is apparent between number of machines and raw waste BOD load within the bleached kraft segment which is used as an example. To the extent that such a correlation may exist, however, it is taken into consideration in Section IX through the selection of mills having various numbers of machines, as used to determine guidelines.

Any such correlation which may exist, however, is taken into consideration in Section IX through the selection of various ages and sizes of mills used to determine effluent limitations.

Thus, age and size of mills were considered but not used as a basis for subcategorization.

Table 18

RAW WASTE BOD VS. NUMBER OF MACHINES

Mill Code	Segment	No. of Machines	Raw Waste BOD kg/kkg (lb/ton)
2	Groundwood	1	20.5 (41)
3	Groundwood	4	16.5 (33)
5	Groundwood	8	18 (36)
112	Bleached Kraft	2	24.5 (49)
119	Bleached Kraft	8	23.5 (47)
150	Soda	2	57 (114)
151	Soda	7	49.5 (99) est.
262	Fine	1	9 (18)
265	Fine	6	11 (22)

Geographical Location

Mills are widely dispersed throughout the United States, from Maine to Alaska, and from Minnesota to Louisiana. Despite this dispersion, the data from surveyed mills in the same segments do

FIGURE 25

FIGURE 25

FIGURE 27

NIL FINE
PRODUCTION VS BOOS
FIGURE 23

NI TISSUE
PRODUCTION VS FLOW

FIGURE 29

FIGURE 30

PRODUCTION VS BOSS
NI TASSCE

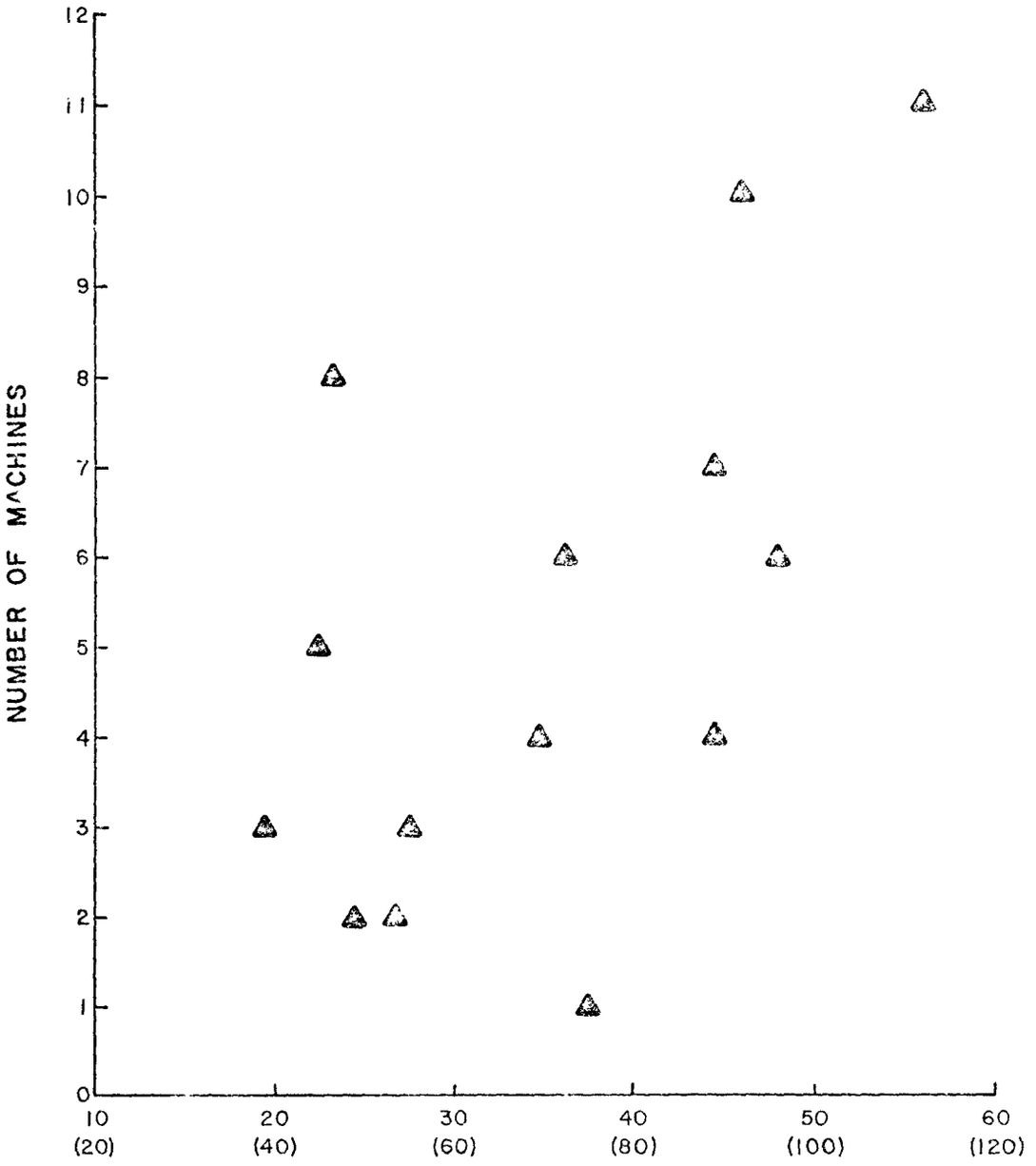


FIGURE 31
BOD VS NUMBER OF MACHINES
BLEACHED KRAFT SEGMENT

not reveal significant differences in annual BOD loads as affected by geographical location and is illustrated in Table 19.

Geographical location can have an effect upon BOD_5 removal efficiencies of biological treatment systems as a result of temperature extremes caused by climatic conditions. The effects of temperature variations can be minimized through effective design and operation of the biological treatment facilities (See Section VII). Any temperature effects upon adequately designed and operated facilities are taken into account in the determination of effluent limitations as discussed in Sections VII, IX, X, and XI.

Geographical location was, therefore, considered but not used as a basis for subcategorization.

Table 19

RAW WASTE BOD VS. GEOGRAPHICAL LOCATION

Mill Code	Segment	Location	Raw Waste BOD kg/kkg	(lb/ton)	
3	Groundwood	Northeast	16.5	(33)	
5	Groundwood	Northwest	18.0	(36)	
51	Sulfite	Northwest	91.5	(183)	
56	Sulfite	North Central	109.0	(218)	
101	Bleached Kraft	South	27.0	(54)	
117	Bleached Kraft	Northwest	27.5	(55)	
151	Soda	Northeast	45.5	(99)	est.
152	Soda	South	48.0	(96)	est.
204	Deinked	Central	27.5	(55)	
205	Deinked	East	26.5	(53)	est.
265	Fine	Northeast	11.0	(22)	
270	Fine	North Central	11.5	(23)	

SUBCATEGORY RATIONALE

The rationale for subcategorization of the segments under study is discussed below:

Bleached Kraft Segment

The effluent waste water characteristics generated during pulp and paper manufacturing can generally be considered to be related to two basic groupings: (A) process variables and (B) waste water variables. The "process variables" relates to the specific manufacturing operations used to produce a specific final product and affects effluent characteristics as a function of the process necessary to produce the final end product. The "waste water variables" relates to the internal measures used to recover chemicals and fibrous materials and to reuse process waters and affects effluent characteristics as a direct function of the extent of recovery and reuse procedures. The difference between the "process variables" and the "waste water variables" is that the former are inherent effects upon effluent characteristics as a function of the raw materials and the product required and the latter are controllable effects upon effluent characteristics as a function of recovery and reuse measures. The two are related in that the "waste water variables" are a function of the "process variables".

The "process variables" actually relate to the specific manufacturing operations utilized for using fibrous raw materials to produce pulp and paper. The major component parts of the "process variables" include: (1) digestion, (2) bleaching, and (3) product making. The variations in these three operations is a direct response to the raw materials utilized but more so is primarily a function of the final product qualities. These variations produce distinct differences in waste water characteristics. The primary "process variable" for digestion is simply termed as "the degree of cooking" which can essentially be characterized by such measurements as yield loss or KAPPA numbers. The factors affecting digestion include (a) the cook characteristics, such as the length, and temperature and pressure, and (b) the strength and chemical makeup of the cooking liquor. Also included are variations in the kraft digestion process such as the prehydrolysis step in producing dissolving kraft pulp. The primary "process variable" for bleaching is simply termed "the degree of bleaching" which is can be described by the yield loss or brightness levels. The factors affecting bleaching include (a) bleaching sequence (number and type of bleaching steps) and (b) the individual bleach stage characteristics, such as the strength and chemical makeup of the bleach liquor and the length (time, temperature, and pressure) of the bleach. The primary process variable for product making is if paper or pulp is the final product. For mills producing paper, an additional process variable includes the types and quantities of additives utilized in producing the qualities of the final paper product.

The "waste water variables" relate to the recovery of chemicals and fibers and to the reuse of process waters. The "waste water variables" are somewhat a function of the "process variables" since some recovery and reuse practices are limited by the specifics of the raw materials, manufacturing process, and final end product qualities. The extent of the recovery and reuse procedures affects the effluent characteristics. These recovery and reuse procedures are discussed in Section VII and VIII and include such items as the following: capacity of the brownstock washers for recovery of the black liquor; spill control and reuse systems for recovery and reuse of such items as liquor spills, evaporator boilout, and evaporator carryover; screen room water reuse and knots recovery; white liquor preparation; landfill of grits and dregs; recovery of lime mud; bleach plant jump stage countercurrent washing; and save-alls and the reuse of white water.

The above discussion of "process and waste water variables" was given as a basis for subcategorization of the bleached kraft segment. As is apparent from the discussion, the "process variables" are used as the primary basis for subcategorization since inherent in the process variables are raw materials, manufacturing operations, and final products. The "waste water variables" are considered primarily in the establishment of raw waste loads for each subcategory and in developing effluent limitations and standards of performance. These are discussed in Sections V, IX, X, and XI. It should be pointed out that in the examination of the "process variables" for the purpose of subcategorization, any relationship between the recovery and reuse procedures utilized specifically by one type of manufacturing operation were taken into account (i.e. reuse of prehydrolysate from dissolving kraft mills).

The bleached kraft segment was subcategorized into four separate subcategories each described by the final product manufactured: (1) dissolving pulp, (2) market pulp, (3) fine papers, and (4) BCT papers. The final end product qualities determines the specifics of the manufacturing process utilized (the "process variables"), and thus, the bleached kraft segment was subcategorized as a result of the process and product factors effects upon effluent characteristics. In evaluation of the factors discussed earlier, it was concluded that the most significant effects upon effluent characteristics were related to process and product factors rather than to several other factors such as age, size, location, or raw materials.

As shown previously in Figures 25 and 26, the age or size of mills do not have any signficant effects upon the waste water characteristics. In addition, Table 15 shows the type of wood used in comparison to the effluent characteristics and again no signficant effect upon effluent characteristics is shown. The geographical location has no significant effect upon effluent characteristics. An evaluation of the effect of bleaching upon effluent characteristics was made and again no signficant effects were determined. Figures 32 and 33 show effluent characteristics

compared to brightness levels for bleached kraft mills. Extensive analysis showed that the most signficant effects upon effluent characteristics related to the manufacturing process used to produce a specific end product. By subcategorizing based upon the final product as it relates to the manufacturing segment, the "process variables" are essentially the same and variations in effluent characteristics are a function of the "waste water variables."

The effluent characteristics for the bleached kraft subcategories are displayed in Figure 24. The dissolving kraft subcategory has the highest effluent flows and BOD5 loads due to the final product qualities. An additional step in the digestion process is required and extensive pulp washing and bleaching are necessary to produce a highly purified pulp. These process factors result in a relatively higher effluent waste load than for mills producing market pulp. The effluent waste loads of mills producing market pulp are relatively higher than mills producing paper, as market pulp mills generally produce a higher grade pulp (i.e. higher brightness).

Mills that produce bleached kraft papers can generally be divided into mills that use relatively large amounts of additives (i.e. fillers, wet strength agents, starches, and rosins) and mills that use very few additives. Additional effluent waste load generally results from the use of additives, as for example, use of starches is a source of BOD5. Also, use of additives can add as much as 33% additional weight to the sheet of paper. Mills using large amounts of additives produce fine papers and generally use upwards of 8 to 10 % by weight of additives. Mills using less amounts of additives produce such products as paperboard, coarse papers, and tissue papers. Effluent characteristics generated by the production of these two groupings of papers are significantly different and are shown in Figure 24. The use of additives by mills producing fine papers is an added source of BOD5 but apparently is more than compensated for by the additional weight of the additives when examined on a kilograms per 1000 kilograms (lbs/ton) basis. The process factors must also be considered when attempting to determine the reasons for the differences in effluent characteristics between mills producing fine papers and those producing paperboard, tissue, or coarse papers.

Sulfite Segment

The sulfite segment was subcategorized into two separate subcategories, dissolving sulfite and papergrade sulfite, based upon process factors. The discussion of "process variables" and "waste water variables" in the bleached kraft section can generally be applied to the sulfite segment. The "process variables" distinctly separate two grouping of mills: (1) mills producing dissolving sulfite pulp and (2) mills producing papergrade pulp and/or paper.

FIGURE 32

FIGURE 33

Effluent characteristics of dissolving sulfite mills are considerably higher than mills producing papergrade pulp as shown in Figure 24. In the dissolving sulfite process, the digestion and bleaching operations are relatively much more extensive than papergrade pulping. Because of the more extensive digestion and bleaching, the pulp yield is considerably lower than papergrade and thereby corresponding higher effluent loads are generated.

The subcategorization of sulfite mills producing papergrade pulp or paper into one subcategory was based upon both "process variables" and "waste water variables". The final products produced by mills in the papergrade sulfite subcategory include fine papers, tissue papers, newsprint, coarse paper, paperboard, and market pulp. In producing these products, seven of the 22 papergrade sulfite mills utilize other pulping processes on-site, such as groundwood, bleached kraft, or neutral sulfite semi-chemical. Determination of effluent characteristics specifically resulting from the sulfite production process at these seven mills is generally impossible from the available data as waste waters are not segregated between the processes.

The "waste water variables" unique to sulfite mills include such internal control measures as spent liquor recovery (evaporation and incineration and/or production of by-products), the types of pulp washing (blow pit or vacuum drum), and the type of condensor (barometric or surface). In this case, these "waste water variables" have a more significant impact upon the effluent characteristics than the "process variables." Table 29 shows some of the internal recovery and reuse procedures used at sulfite mills. Thorough examination of the technology information presented in the table and the flow and BOD_5 data (29) could lead to the conclusion that several subcategories should be created to account for such "waste water variable" as (1) wet woodyard operations, (2) blow pit pulp washing, (3) vacuum drum pulp washing, (4) barometric condensors, (5) surface condensors, and (6) bleaching sequence variation (actually a "process variable"). However, the identification of the technology in Section VII, VIII, and IX for BPCTCA and the establishment of the effluent limitations actually eliminates the need for any further subcategories. The wet woodyard operations mentioned above are accounted for in an additional allowance for all mills, exclusive of the subcategory, practicing wet woodyard operations and is discussed in Sections V and IX. The identified in plant control technology for BPCTCA for papergrade for sulfite mills includes (1) spent liquor recovery, (2) blow pit pulp washing, and (3) barometric condensors. As thoroughly discussed in Section V, these inplant control technologies result in the highest effluent characteristics and thereby all of the other mills should have lesser effluent loads. In addition, the bleaching sequence has an effect upon effluent characteristics, and this is accounted for in the selection of mills as representative of the higher effluent loads for the subcategory by using mills which practice extensive bleaching. Because the "waste water variables" have more significant effects upon effluent characteristics than the

"process variables", subcategorization according to the final product was considered unnecessary and any effects of the process variables were accounted for in the selection of representative mills for the subcategory.

Groundwood Segment

The groundwood segment was subcategorized into four separate subcategories based upon "process variables." These subcategories include the following: groundwood: chemical-mechanical, groundwood: thermo-mechanical, groundwood: fine papers, groundwood; CMN papers. Distinct differences in the manufacturing process between these subcategories result in significant differences in effluent characteristics and are shown in Figure 24.

The "process variables" that exist in the groundwood segment primarily involve differences in pulping and papermaking. The most significant "process variable" for mills using chemi-mechanical and the thermo-mechanical process is the pulping process. Mills producing paper by the chemi-mechanical (or cold soda) use a pulping process involving a short digestion of the wood chips with a cooking liquor followed by mechanical refining at atmospheric pressure. Mills using the thermo-mechanical process also use a "digestion" process prior to mechanical refining but the differences are that the thermo-mechanical cook is much shorter, no cooking liquor is used (generally a steaming process), and the first stage of mechanical refining is done under pressure. The difference in effluent characteristic are signficant between the two processes as the flow and BOD_5 characteristics for the chemi-mechanical and thermo-mechanical processes are 83.4 kl/kkg (20 kgal/ton) and 50.5 kg/kkg (101 lbs/ton) and 62.5 kl/kkg (15 kgal/ton) and 28.0 kg/kkg (56.0 lbs/ton), respectively.

The most significant "process variable" for mills using the groundwood process (without any digestion or cooking stage) is the type of paper produced. No significant effects upon effluent characteristics of the type of groundwood process used, stone or refiner, are shown by the available data. In addition, the effects of brightening were considered as a basis for subcategorization but were eliminated by developing the subcategorization based upon representative mills that do use brightening as part of their process. Thus, the few mills that do not brighten their pulps would have lesser effluent characteristics than the subcategory averages. Mills using the stone or refiner groundwood process produce a wide array of products including fine papers, newspapers, coarse papers, and molded pulp produtcts. The distinction between these products is primarily in the quantity of additives used to produce the desired product qualities. Coarse papers, molded pulp products, and newspapers use very few, if any, additives whereas mills producing fine papers use additives which make up 10 to 35% by weight of the final product. The use of additives and the processes used to produce the final product qualities generates

differences in effluent characteristics as shown in Figure 24. Thus, two subcategories described by the final product were established.

Soda Segment

Because of similarities of the "process variables" between the three mills in the soda segment, one subcategory was developed. Each mill produces fine papers by the soda pulping process. In addition, the mills purchase market pulp to supplement their own manufactured pulp in making fine papers. Each of the mills is relatively old with the newest mill (mill 150) being built in 1923. The bleaching operation at these mills is similiar except that mill 150 has a shorter sequence and thereby does not bleach to as high a brightness as mills 151 and 152. Higher bleaching generally results in higher effluent loads; mill 150 is the "newest" soda mill with the lowest amount of bleaching yet the effluent loads from mill 150 are higher than mills 151 and 152 (see Table 44). Thus, one subcategory was developed as "process variables" were similiar and any differences in effluent characteristics are taken into account by using data from all mills in the subcategory to determine the average effluent characteristics.

Deink Segment

One subcategory which includes all deink mills was established for the deink segment. The deink manufacturing process uses waste paper as its primary source of raw materials and as such the purpose of the pulping process is to separate the fibers and to remove the unfibrous materials (i.e. papermaking additives, inks). As such, the deink process has been termed a cleaning operation. A wide array of products are manufactured including fine, tissue, and news papers.

The principle effects upon effluent characteristics are related to (1) the type of waste paper used as raw materials and (2) the end product qualities. The data shown in Table 47 is broken into two products, fine papers and tissue papers, and shows differences in effluent characteristics between mills producing the two product types. Consideration was given to subcategorization based upon the type of product produced, but raw material generally has a more significant impact upon effluent characteristics. Because of possibly changing market conditions for purchase of waste paper, one subcategory was developed and differences in effluent characteristics are accounted for through selection of mills which have high effluent characteristics in relation to the raw waste loads of other mills in the subcategory (see Section V).

Non-Integrated Paper Mills Segment

The non-integrated paper mills segment was subcategorized into three subcategories based upon "process variables." The three subcategories include mills using purchased pulp to produce (1)

fine papers and (2) tissue papers and mills using waste paper to produce (3) tissue papers. Consideration was given to subcategorization based upon percent C & F but as shown in Figures 34 and 35 no significant relationship exist between C & F and effluent characteristics for NI fine paper mills. In addition, a large number of non-integrated paper mills were excluded from this study because of a lack of adequate data base upon which subcategories and effluent limitations could be establishd. Effluent limitations and standards of performance will be developed for these mills at a later date. Included in this group are non-integrated paper mills producing coarse and specialty papers. The use of additives in the papermaking process to produce the desired end products of either fine papers or tissue papers is the most significant factor upon effluent characteristics, and the subcategories of fine papers and tissue papers were developed accordingly. The subcategorization of non-integrated tissue mills into two subcategories was based upon the type of raw materials used as a source of fiber, purchased pulp or waste paper. The use of waste paper has significant impact upon effluent treatability as well as upon effluent characteristics. The differences in effluent characteristics are shown in Figure 24 and the differences in treatability are shown in Section IX.

NI FINE
%C+F vs BOD5
FIGURE 34
% C+F
5.00
7.50
10.00
15.00
17.50
20.00

% C+F vs FLOW
FIGURE 35

SECTION V

WATER USE AND WASTE CHARACTERIZATION

Water is an important raw material in the manufacture of pulp and paper, and all subject subcategories use large quantities of it throughout most of their subprocesses. The major uses are similar industry-wide although the amounts typically used may vary from subcategory to subcategory. Data on total use of mills in each subcategory are available both from the mill surveys conducted during this project and from the literature. However, there is relatively less verifiable data on the amount used by each subprocess for specific purposes within subcategories since quantities for separate uses are seldom metered. Interpretation of this information must also consider, in some cases, the reuse of process water in other areas of the mill, as discussed in Section VII.

Through its contact with and transport of other raw materials, the water absorbs other substances and is characterized at the end of its use in a mill as waste water. The material it ultimately contains, and the amount, varies to some degree among subcategories as discussed in Section IV, and from one waste stream to another in the same mill.

Waste variations among subcategories have likewise been documented by representative mill surveys, as described previously, and are set forth in text and tabular form in this section. Similarly to the lack of data on subprocess water use, there is also considerably less survey documentation on the loadings of the separate waste streams in integrated mills. This is due to the fact that the available raw waste data is for the most part based on measurements of the combined waste stream as it leaves the mill and is directed toward waste treatment. Segregated data on major process streams -- pulping, recovery, bleaching, and papermaking -- are not as common. Thus, survey data will be presented where it is available to describe the characteristics of the separate streams of integrated mills and these descriptions will be supplemented by data from the literature, including previous EPA studies as referenced.

In order to address the total water use and raw waste load characteristics of integrated mills, as represented in the bulk of the survey data, all of the applicable subprocesses of each pulping subcategory will be discussed as one entity. This is in contrast to the separate process descriptions of pulping, bleaching, and papermaking of Section III.

Two subprocesses, however, are common to most subcategories and are therefore discussed separately. These are wood preparation and papermaking.

In the case of wood preparation, variations in waste waters produced result from very localized conditions, as discussed below, and are not a function of the pulping or other processes. Thus, the description of its contribution, which usually accounts for a very small portion of the total waste, applies to all pulping subcategories.

Paper and paperboard are made on similar equipment within all subcategories with similar water uses and sources of waste water. Therefore, the papermaking operation is also discussed in detail. In addition, the survey data presented by subcategory will, where applicable, include the papermaking waste stream unless otherwise indicated.

In order to obtain an overview of levels of mercury and zinc in waste waters, grab samples of raw waste and final discharge streams were collected at surveyed mills and analyzed for these parameters. The concentration of both metals are generally very low.

Water usage per kkg (ton) of production has generally declined dramatically in recent years due to increased emphasis on water reuse and reduction of fresh water uses. This is demonstrated in Table 20 which compares 1965 data (87) with data from surveyed mills. While the subcategorization of mills used in the 1965 data does not agree precisely with that used in this report it may be seen that water use declined substantially in the eight years after 1965. For example, the average flow of individual median flow values for bleached kraft and sulfite segments decreased by some 20-30 percent over this period. Data for non-integrated mills are not included in Table 20 because the 1965 subcategorization of these mills is not comparable with that employed in this report. Of course, these comparisons can only be considered as generalizations since mill data included in the 1965 figures are probably not all the same as the surveyed mills. However, the point that effluent volume per kkg (ton) of production has been significantly reduced between 1965 and 1973 through inplant reuse measures is valid.

The major process applications of fresh and reused water in pulp and/or paper mills may include where applicable:

Wood Preparation

This is a major factor only where wet barking is employed.

Pulping

Fiberizing of wood and waste paper occurs in the presence of water in all pulping processes whether this is accomplished in mechanical grinders, chemical cooking, or pulpers. In mechanical processes utilizing a grindstone, its surface is cooled, cleaned, and lubricated with a stream of water which also carries away the

TABLE 20

WATER USE
1965 vs. 1973

Segment	Flow kl/kkg(kgal/ton)	
	1965(1)	1973(2)
Groundwood	200(48)	91.5(22)
Sulfite	288(69)	208(50)
Bleached Kraft	180(43)	146(35)
Soda	290(70)	108(26)
Deink	138(33)	87.5(21)

(1) Reference 783

(2) Data from Surveyed Mills

Note - Groundwood Segment includes only GW-Fine and CP-CMN mills
- Sulfite Segment includes Sulfite papergrade
- Bleached Kraft includes BCT and Fine mills

pulp; the chips are conveyed through the refiners on a stream of water in other mechanical processes. Water is added to the digester along with the chips in chemical pulping, and to the pulper in deinking. Water is also used to prepare cooking liquors. Subsequently, water serves to convey the pulp in a slurry to and through the remaining operations.

Pulp Washing

The degree of washing required and the method used, and thus quantities of water, vary with type of pulp, end products produced, recovery system design, and other factors.

Dilution

Water is used to dilute the pulp slurry to facilitate screening, cleaning, and other processes.

Deckering

Although this is primarily a thickening operation, one of the common practices is to use the equipment to provides a final wash shower.

Chemical Recovery

In kraft and soda pulp mills water is used in the recovery system for several purposes such as dissolving the molten smelt from the furnace, lime mud washing, and lime kiln scrubbing (see Section III). In sulfite recovery systems, water is used to dissolve smelt, to absorb recovered sulfur dioxide, and for scrubbing off-gases. This is not a comparatively large use in either case.

Bleaching

Water is used in preparing bleach solutions and in washing between stages and at the end of the process. The amount of water use ranges the spectrum from a simple one stage brightening of groundwood pulp with no washing to a complex five and six stages of chemical pulp bleaching.

Papermaking

Water is used in stock preparation which may involve several steps such as beating and refining to develop desired pulp characteristics for specific grades of paper. It is also employed to dilute the furnish to appropriate consistency for application on the paper machine, and for solution and conveyance of additives.

The non-process water uses may include lubrication and sealing of moving parts such as shafts and vacuum pumps, steam for the process and space heating, cooling equipment and process fluids, and for washing equipment and floor areas.

WOOD PREPARATION

Little, if any, water is employed in the preparation of delivered chips or the chipping of barked logs and no effluent is produced. Unbarked logs are frequently washed before dry or wet barking in order to remove silt (32). In most installations a water shower is activated by the log itself while on the conveyer so that a minimum of water is used. The limited data available indicate that this flow amounts to about 378 to 1135 l (100 to 300 gal) per cord of wood washed and the range of losses is as follows (33).

BOD_5	0.5-4.0 kg/kkg (1-8 lb/ton)
TSS	2.5-27.5 kg/kkg (5-55 lb/ton)
Color	Less than 50 Units

Spent process water is frequently used in wet drum barkers and recycling within the barking unit itself is often practiced. Barkers of this type contribute from 7.5 to 10 kg of BOD (15 to 20 lb) and from 15 to 50 kg (30 to 100 lb) of suspended solids per kkg (ton) of wood barked.

The volume of water employed by the high-pressure jets of hydraulic barkers is generally from 19,000 to 45,400 l (5000 to 12,000 gal) per cord of wood barked depending upon log diameter. In wet pocket barkers, water is sprayed through apertures in the side of the pocket at rates of between 1.25 and 2.27 cu m/min (330 and 600 gpm) for pockets of 2.8 and 5.7 cords per hour, respectively.

Water discharged from all three types of wet barking is usually combined with log wash water, and coarse screens are used to remove the large pieces of bark and wood slivers. The flow then passes to fine screens. Screenings are removed and mixed with the coarse materials from the initial screenings and the mixture is dewatered in a press prior to burning in the bark boiler. Press water, which is combined with the fine screen effluent, is very minor in volume. The total waste flow, which amounts to about 19,000 to 26,500 l (5000 to 7000 gal) a cord, generally carries from 0.5 to 5.0 kg/kkg (1 to 10 lb/ton) of BOD_5 and 3.0 to 27.5 kg/kkg (6 to 55 lb/ton) of suspended solids.

The combined discharge contains bark fines and silt. The quantity of the latter varies greatly from wet to dry weather since its presence is due mainly to soil adhering to the logs.

The fine screen effluents following hydraulic barkers (32) (33) (35) of eight wood handling operations are analyzed in Table 21 which indicates a total suspended solids content ranging from 520 to 2350 mg/l with the ash content running from 11 to 27 percent. The latter is generally below 15 percent for clean logs. BOD_5 values range between 56 and 250 mg/l. These low values are due to the fact that the contact of the water with the bark is short and no grinding action on the wood takes place. Also, the water employed is all fresh process water. Also included in Table 21 are effluent characteristics of clarifier effluents treating hydraulic barker waste waters for seven mills.

Such low BOD values are not the case with drum and pocket grinding which involve attrition in contact with water over an appreciable period of time and frequently utilize spent pulping process waters already high in BOD and color (35) (36). The suspended solids content is not appreciably different. The wet drum barking effluents of three operations are analyzed in Table 22.

BOD values of barking effluents are also greatly affected by the species of wood barked and the season in which the wood was cut due to variables in wood juices and water extractables. That contributed by the suspended matter present is a minor fraction of the total BOD.

It is estimated that approximately 27 pulp mills in the subject subcategories presently practice wet barking.

PULPING PROCESSES

GROUNDWOOD SEGMENT

As discussed in Section III, the types of groundwood and chemical-mechanical pulps produced by grinding wood billets or chips are as follows:

1. Stone groundwood
2. Refiner groundwood
3. Chemi-groundwood
4. Cold soda
5. Thermo-mechanical

Mechanical power is the essential force in the production of all five although the latter three processes involve a pre-softening step which, in the case of chemi-groundwood and cold soda, includes the use of chemicals. This reduces the power requirement and produces pulps with somewhat different characteristics (2) (5).

Effluents produced by all of these pulping methods contain suspended solids and dissolved organic matter, both of which contribute to the BOD (5) (37). In addition, chemi-groundwood and cold soda process waters contribute electrolytes which contain

Table 21

ANALYSIS OF HYDRAULIC BARKING EFFLUENTS*

Mill Code	TSS mg/l	NON-SET. SOLIDS mg/l	% ASH OF SS	BOD_5 mg/l	COLOR UNITS
AB	2362	141	27	85	<50
CD	889	101	14	101	<50
EF	1391	180	17	64	<50
GH	550	66	11	99	<50
IJ	521	53	13	111	<50
KL	2017	69	21	6	<50
MN	2000	<200	19	97	
OP	600	41	10	250	35

*Flow data not available

TABLE 21 cont'd

HYDRAULIC BARKER EFFLUENTS

Mill	Flow (l/day/(ton/day))	BOD5 mg/l	TSS mg/l	Production cords/day
AA	816(3[illegible])	118	1[illegible]0	940
BB	816(3[illegible])	71	128	385
CC	1179(1[illegible])	58	116	910
DD	1633(1[illegible])	72	135	1130
EE	363(4[illegible])	114	183	330
FF	1270(1400)	34**	234**	NA
FF	1270(1400)	29	64	NA

* Data represents clarifier effluents treating hydraulic barker waste waters.
** Clarifier influent.

Table 22

ANALYSIS OF WET DRUM BARKING EFFLUENTS

TSS mg/1	NON-SET. SOLIDS mg/1	% ASH OF SS	BOD_5 mg/1	COLOR UNITS
2017	69		480	20
317	57	21	605	50
2875	80	18	987	50

some ions in the form of residual and spent chemicals. Most of these are combined with organic matter.

Raw waste characteristics of a groundwood mills are summarized in Figure 36 which is presented as an example of a groundwood mill with the effluent characteristics shown as to how the pulping and papermaking operations contribute to the total raw waste load. Effluent volume from the pulp mill can be expected to range between 8346 and 16,692 l/kkg (2000 and 4000 gal/ton) of product. For example, Mill 13 had an effluent volume from the pulp mill of 13,600 l/kkg (3.26 kgal/ton). Differences in discharge volume are generally due to equipment variations and the species of wood pulped, with more fresh water usually required for resinous wood. Clarified white water from papermaking operations is frequently a partial source of process water and contains additional electrolytes in the form of papermaking additives (2).

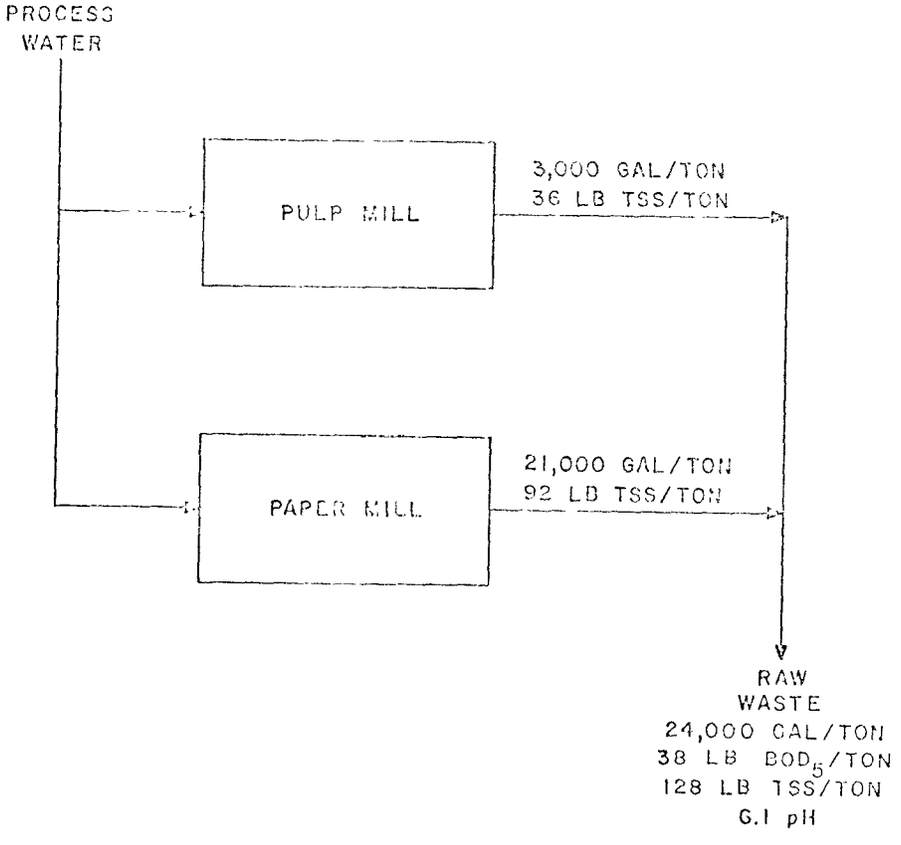
The suspended solids present in groundwood effluents consist primarily of fiber fines, ray cells, and hydrated wood dust. They are over 90 percent combustible, and while they are generally over 80 percent settleable, they will not thicken to a substantial degree and seldom produce a sludge of over two percent solids (5). This is due to hydration produced by grinding and the small particle size of these solids. Data gathered during an earlier study (5) shows a range of total suspended solids in groundwood pulping effluents alone as follows:

Type of Pulp	Total Suspended Solids Range kg/kkg (lb/ton)
Stone	5.5 - 10.5 (11-21)
Refiner	15 - 29.5 (30-59)
Chemi-groundwood	7.5 - 16 (15-32)
Cold Soda	12 - 18.5 (24-37)

There are no data from surveyed mills to verify the above TSS ranges, since very few mills measure pulp mill wastes alone. Surveyed mill data on total raw waste TSS, however, show no discernible relationship between TSS and types of groundwood pulping processes. These Stream 9 data for TSS show a range of 21 kg/kkg (42 lb/ton) to 80.5 kg/kkg (161 lb/ton), with chemi-mechanical Mills 1 and 12 at the low and high ends of this range, i.e., 23.3 kg/kkg (46.6 lb/ton) and 80.5 kg/kkg (161 lb/ton) respectively. Mills 4 and 2 on the other hand, fall in the middle of this range with TSS values of 37.8 kg/kkg (75.6 lb/ton) and 62.4 kg/kkg (124.9 lb/ton), respectively. These mills are refiner and stone groundwood mills, respectively.

Dissolved organic materials present in groundwood waste waters consist of wood sugars and cellulose degradation products as well

FIGURE 36
EFFLUENT CHARACTERISTICS: GROUNDWOOD MILL



as resinous substances. In effluents free of appreciable fiber the dissolved organics account for about three-quarters of the BOD_5. The BOD_5 discharge of the various groundwood pulping processes range, according to the above study (5), as follows:

Type of Pulp	BOD_5 kg/kkg (lb/ton)	
Stone	4 - 9.5	(18-32)
Refiner	9 - 16	(18-32)
Chemi-groundwood	34.5 - 40.5	(69-81)
Cold Soda	36.5 - 50.5	(73-101)

The higher values observed for pulps whose manufacture involves the use of conditioning chemicals are due to the solubilizing and peptizing effects on the organics present in the wood. Data from surveyed mills tend to support this conclusion through comparison of Stream 9 values. Mills 1 and 12, which add chemicals and are in the chemi-mechanical subcategory, have raw waste BOD's of 48.4 kg/kkg (96.9 lb/ton) and 53 kg/kkg (106 lb/ton), respectively. Mills not employing chemicals or a "pre-softening" step, on the other hand, generally have a much lower BOD, with a typical value of about 17.5 kg/kkg (35 lb/ton).

In cold soda pulping 18 to 45 kg (40 to 80 lb) of sodium ion are added per kkg (ton) of product. Some of this ion remains adsorbed on or chemically bound to the pulp; another portion appears in the effluent chemically bonded to organics such as resins and lignins; and a third is a residual of unreacted chemical also present in the effluent. The chemi-groundwood process which employs sodium sulfite and caustic soda contributes sulfur as well, in the range of 2.5 to 5 kg (5 to 10 lb) per kkg (ton) of product.

The pH of all groundwood effluents, except cold soda, is in the neutral range, somewhat on the alkaline side.

The color of groundwood effluents from most of the woods pulped is low, under 100 mg/l.

As discussed in Section III, groundwood pulp is generally bleached or brightened with hydrogen or sodium peroxide, sodium or zinc hydrosulfite, or sodium sulfite. In practice, the pH is usually adjusted to between 4.5 and 7.0 depending upon the bleaching agent and sometimes complexing chemicals are added to overcome the effect of heavy metals that may be present, such as iron and manganese. Buffers and catalytic agents in trace quantities are also sometimes used. Since groundwood can be bleached at high consistency, it is frequently accomplished in stock chests. Bleaching agents are not washed from the pulp and thus, the residues of bleaching appear in the white water of the

paper machine system. Data from surveyed mills do not demonstrate a clear relationship between degree of bleaching, as measured by pulp brightness, and resulting raw waste BOD. Table 23 shows that mills with nearly identical brightness, in the 73-74 range, vary in BOD load from 12.5 to 20.4 kg/kkg (25 to 40.0 lb/ton).

The somewhat higher concentration of zinc in groundwood effluents is undoubtedly attributable to the use of zinc hydrosulfite. Most mills are now abandoning the use of this chemical.

Table 23

RAW WASTE BOD VS. GROUNDWOOD PULP BRIGHTNESS

Mill	Raw Waste BOD kg/kkg	(lb/ton)	Pulp Brightness
2	20.4	40.9	74
15	19.5	39.0	60
5	18.1	36.3	67
3	16.2	32.5	73
13	12.5	25	73

Development of Subcategory Raw Waste Loads

The development of the raw waste loads (RWL) for each of the groundwood subcategories is discussed below. The resultant raw waste loads were used in developing the effluent limitations for each subcategory and in determining the costs presented in Section VIII.

GW: Chemi-Mechanical Subcategory

Two mills are included in the chemi-mechanical subcategory. These mills utilize similar pulping processes to manufacture distinctly different products, fine papers and molded pulp products. Both mills purchase in varying amounts market pulp and waste paper as additional sources of fiber. The effluent raw waste BOD_5 characteristics and effluent flow volume for the mills is very similar; as discussed in Section IV, this indicates that the most significant effect upon the RWL is the pulping process. Mill 01 has a BOD_5 RWL of 48.5 kg/kkg (97.0 lbs/ton) whereas mill 12 has a BOD_5 RWL of 53.0 kg/kkg (106 lbs/ton). Similarly, effluent flow values are 84.6 kl/kkg (20.3 kgal/ton) and 81.3 kl/kkg (19.5 kgal/ton), respectively. As discussed previously, TSS values do not correlate between mills. The RWL for these mills are summarized in Table 24 with the resulting subcategory RWL shown.

GW: Thermo-Mechanical Subcategory

The thermo-mechanical process is relatively new in this country, and thus data from foreign mills was used as the principle source of data on which the subcategory RWL was based. It has been reported that at least seven mills were using the thermo-mechanical process in early 1975 and at least six more mills were to begin thermo-mechanical systems by the end of 1975 in this country. (38). The mills presently operating thermo-mechanical systems are operating in conjunction with some pulping process such as bleached kraft, sulfite, or stone groundwood. Because of the mixture of pulping operations at these mills, waste water data representing exclusively that discharged by the thermo-mechanical process is non-existant. However, a 100% thermo-mechanical mill in the Pacific Northwest is scheduled for start up in the Fall of 1975 and data should be available at a later date.

Thermo-mechanical pulping has been practiced in the Swedish pulp and paper industry since 1967. Data received from IVL (Swedish Pollution Control Company), Stockholm, Sweden, showed that BOD7 RWL for thermo-mechanical pulping was 16-18 kg/kkg (32-36 lb/ton) and an additional 15 kg/kkg (30 lbs/ton) if peroxide bleaching were practiced. IVL reports a conversion factor for BOD7 to BOD5 of 0.85. The above data were based upon sampling of effluents from two thermo-mechanical mills in Sweden. Thus, the maximum BOD5 that would be expected from mills practicing thermo-mechanical pulping and peroxide bleaching is 28.0 kg/kkg (56.0 lbs/ton).

During an on-site plant survey by the EPA to a thermo-mechanical mill in Sweden, the RWL BOD5 was reported to be 21.25 kg/kkg (42.5 lbs/ton) with an effluent flow of 17.1 to 27.5 kl/kkg (4.1 to 6.6 kgal/ton). However, extensive data was not available to support these effluent characteristics.

The thermo-mechanical mill which will begin operations in the Fall of 1975 has reported that the effluent treatment facilities have been designed for a flow of approximately 41.7 kl/kkg (10.0 kgal/ton) with hopes of actually operating at 20.8 kl/kkg (5.0 kgal/ton) (39).

Based upon consideration and evaluation of the above data, the RWL for the thermo-mechanical which were used in the development of the effluent limitations and costs of technology are shown below:

Flow	62.5 kl/kkg	(15.0 kgal/ton)
BOD5	28.0 kg/kkg	(56.0 lbs/ton)
TSS	48.5 kg/kkg	(97.0 lbs/ton)

Because of the stage of development of the thermo-mechanical process in this country, the above flow values were selected as a very conservative estimate. The flow values for the surveyed mill in Sweden and the mill which will soon begin operations are well below this estimate. The TSS value is from the chemi-mechanical subcategory as no data was available from any source

TABLE 24

RAW WASTE LOAD - GW-CHEMI-MECHANICAL SUBCATEGORY

Mill	Manufacture(%)* GW	PP	WP	Size kkg/day(tons/day)	FLOW kl/kkg(kgal/ton)	BOD5 kg/kkg(lbs/ton)	TSS kg/kkg(lbs/ton)
01	65	5	30	97 (107)	84.0 (20.3)	48.5 (97.0)	23.3 (46.6)
12	45	45	10	326 (359)	81.3 (19.5)	53.0 (106)	80.5 (161)
	Average				83.0 (19.9)	50.3 (101)	52.0 (104)

* GW: Groundwood Pulp
PP: Purchased Pulp
WP: Waste Paper

and the two processes are somewhat similar. The BOD5 value was based upon the IVL data since was it is felt to be more reliable than the conservative estimate of the mill to soon begin operations. Support for the IVL data in apparent by evaluating the operational characteristics between chemi-mechanical process, thermo-mechanical processes, and groundwood processes.

In mechanical pulping, the yield gives a excellent indication of the effluent BOD5 characteristics. Generally, the higher the yield, the less the BOD5 RWL will be. Table 25 shows the yields and BOD5 RWL for chemi-mechanical, thermo-mechanical, and groundwood processes, and as shown the yield is related to the inclusion of the pre-softening step.

Table 25

BOD5 vs Groundwood Yield

Pulping Process	Pre-Softening Step	Chemical Addition	Yield %	BOD5 kg/kkg (lbs/ton)
Chemi-Mechanical	20 mins.	Yes	80	50.5 (101)
Thermo-Mechanical	2-5 mins.	No	90-95	28 (56)
Groundwood	None	No	90-98	17.5 (35)

GW: Fine Papers Subcategory

Table 26 is a summary of the data from which the groundwood fine papers subcategory RWL were developed. As shown in Table 26 many of these mills purchase market pulp and/or waste paper as a supplementary source of fiber. Also, the papermaking additives content of the final products ranges from 10 to 35% by weight. Since groundwood mills producing fine papers generally purchase supplementary fiber (market pulp or waste paper) and since no significant relationships exist for the mills in Table 26 between RWL and the amount of fiber purchased, the subcategory RWL was developed by averaging the flow, BOD5, and TSS data shown in the table. Mill 21, as noted in the table, uses the thermo-mechanical process for 10% of their total production and since the flow value of 51.7 kl/kkg (12.4 kgal/ton) is significantly lower than the other mills flows, the RWL for mill 21 was not included in the calculation of the subcategory averages. The subcategory RWL would, however, be lower if mill 21 were included.

GW: CMN Papers Subcategory

Table 27 shows manufacturing information and effluent characteristics for groundwood mills producing coarse (C) papers, molded pulp products (M), and/or news (N) papers. Also, shown is mill 17 which is a small mill producing 29 kkg (32 tons) per day of market (mkt) groundwood pulp.

TABLE 26

RAW WASTE LOAD - GW-FINE PAPERS SUBCATEGORY

Mill	Manufacture (%) GW	PP	WP	C+F	Size kkg/day(tons/day)		FLOW kl/kkg(kgal/ton)	BOD5 kg/kkg(lbs/ton)		TSS kg/kkg(lbs/ton)
03	30	40	10	20	492	(542)	106.3 (25.5)	16.2	(32.5)	66.0 (132)
19	30	25	10	35	453	(499)	78.8 (18.9)	20.9	(41.8)	42.9 (85.0)
05	30	55	5	10	498	(549)	98.0 (23.5)	17.9	(35.9)	51.5 (103)N
20	33	33	0	33	537	(592)	83.0 (19.9)	12.8	(25.6)	41.4 (82.8)
02	55	30	0	15	193	(213)	97.2 (23.3)	20.2	(40.4)	57.5 (115)
13	55	30	0	15	457	(504)	83.0 (19.9)	13.5	(27.0)	49.0 (98)N
21	40*	25	15	20	517	(570)	51.7 (12.4)	15.2	(30.4)	32.7 (65.5)
Average							90.9 (21.8)	16.9	(33.8)	52.0 (104)

* 10% of total production is reported as thermo-mechanical.

As shown in Table 27, mills in the GW: CMN subcategory purchase additional fiber to supplement the groundwood pulp produced on-site which is similar to groundwood mills producing fine papers. However, the amount of purchased additional fiber is significantly different between mills producing CMN papers and mills producing fine papers. As shown in Tables 26 and 27, respectively, mills in the GW: fine papers subcategory manufacture 30-55% of their total product by on-site groundwood pulping whereas mills in the GW: CMN papers subcategory generally manufacture 55-90% on-site. The amount of market pulp purchased to supplement the groundwood pulp produced on-site is generally a function of the type of paper produced; i.e. manufacture of newspapers requires a blend of 65-80% groundwood pulp (short fibers) and 20-35% chemical pulp (long-fibers).

The GW: CMN papers subcategory RWL was determined by averaging the RWL data presented in Table 27. Data for mill 17 were not included as the mill produces market pulp and the data showed effluent flows of 12.5 kl/kkg (3.0 kgal/ton) which were significantly below all other mills in the subcategory.

SULFITE SEGMENTS

The Sulfite segment of the pulp and paper industry was subcategorized into papergrade sulfite and dissolving sulfite subcategories and the effluent characteristics are discussed below.

Papergrade Sulfite Subcategory

Modernized sulfite pulp mills which employ chemical recovery and/or spent liquor burning discharge between 63,000 and 125,000 l (15,000 and 30,000 gal) of effluent per kkg (ton) of pulp. This volume approaches 208,655 l (50,000 gal) for older mills (2) (5). (It should be noted that the survey data discussed below represents the total waste stream.) The major pollutional characteristics of this effluent are BOD, suspended solids, color, and acidity.

Typical data given in the literature on the individual waste streams emanating from the pulping process are shown in Table 28 (41) (42) (44). Overall losses amount to about 600 pounds of total solids, 45 pounds of suspended solids, and close to 300 pounds of BOD_5 per ton of pulp produced. The pH value is in the range of 2.5 to 3.2. Solubles present consist of lignosulfonates, lower fatty acids, alcohols, ketones, and pentose and hexose sugars (43) as well as a number of miscellaneous complex compounds such as cymene (30). The lignin fraction is largely responsible for the color of the effluent, the degree of which depends upon the efficiency of the liquor separation and recovery system as well as the base employed and the wood species pulped (44). Effluent color values on the chloroplatinate scale generally range from 100 to 750 mg/l (45); the lower value is typical of magnesium base pulping and the higher, the ammonia base.

TABLE 27

RAW WASTE LOAD - GW-CMN PAPERS SUBCATEGORY

Mill	Manufacture (%) GW	PP	WP	Product	Size kkg/day(tons/day)		FLOW kl/kkg(kgl/ton)	BOD5 kg/kkg(lbs/ton)	TSS kg/kkg(lbs/ton)
09	80	20	0	N	342	(377)	52.9 (12.7)	19.6 (39.2)	21.0 (42.0)
10	80	20	0	N	904	(997)	112.6 (27.0)	21.4 (42.9)	- (-)
08	70	30	0	N	374	(412)	115.1 (27.6)	20.3 (40.7)	68.0 (136)N
14	75	25	0	N, C	96	(106)	107.6 (25.8)	12.0 (24.0)	63.0 (126)N
04	55	20	25	C	72	(79)	113.0 (27.1)	9.9 (19.9)	33.0 (66.0)
16	65	30	5	M	69	(76)	86.3 (20.7)	19.1 (38.2)	62.0 (124)
15	90	0	10	M	113	(125)	107.6 (25.8)	19.5 (39.0)	78.0 (156)
17	100	0	0	Mkt	29	(32)	12.51 (3.0)*	9.7 (19.5)*	12.5 (25.0)*
Average							99.2 (23.8)	17.4 (34.8)	48.5 (97.0)

* Not included in subcategory average

Table 28

TYPICAL EFFLUENT LOADINGS FROM INDIVIDUAL PROCESSES IN A SULFITE PULP MILL

Process Source	Volume l/kkg (gal/ton)	Total Solids kg/kkg (lb/ton)	Suspended Solids kg/kkg (lb/ton)	BOD_5 kg/kkg (lb/ton)	pH Range
Blow Tank	7,928 (1,900)	123.5 (247)	0.5 (1.0)	[illegible] (11[illegible])	2.2-2.9
Condensates	4,590 (1,100)	23.5 (47)	0.05 (0.1)	33 (66)	2.3-3.1
Liquor Losses	31,298 (7,500)	52.5 (105)	10.5 (21.0)	26.5 (53)	2.2-2.6
Screening	25,038 (6,000)	13.5 (27)	4.0 (8.0)	4 (8)	5.4-5.7
Washing & Thickening	31,298 (7,500)	65.5 (131)	4.0 (8.0)	9 (18)	2.4-3.9
Acid Plant Wastes	1,251 (300)	5 (10)	2.5 (5.0)	Neg.	1.2
Boiler Blow Down	417 (100)	11 (22)	1.0 (2.0)	Neg.	
Total	101,823 (24,400)	294.5 (589)	22.5 (45.1)	130.5 (261)	2.5-3.2
Bleaching	50,077 (12,000)	100 (200)	7.5 (15.0)	15 (30)	5.0-5.8

Various aquatic and marine biology problems have been ascribed to the discharge of sulfite pulping wastes into surface waters (50) (51). These include deoxygenation, toxicity to fish, thin eggs, and interference with shell fish spawning.

Such difficulties appear to have been caused to a large degree by the discharge of spent liquor. It has been demonstrated (49) that recovery systems alone have remarkably reduced effluent toxicity to sensitive species of fish.

Biological imbalance in streams has also occurred due to slime growths engendered by wood sugars and fatty acids present in the wastes (53) (54) (55). Such growths clog fishing nets and thus shorten fishing time and pose a difficult net cleaning problem. In many cases, unsightly accumulations develop upon or become attached to objects in contact with the water. Field and laboratory studies have demonstrated that slime growth can be inhibited by any process capable of reducing the amount of sugar and related compounds discharged and that waste receiving effective biological treatment will not normally cause infestations of these organisms (56).

A further stream problem is the presence of ammonia in effluents from ammonia base sulfite pulping. The effluent from one such mill was found to contain from 96 to 189 mg/l of NH_3-N (57). This must be considered both in terms of the ultimate maximum concentration which will result in a body of fresh water from its utilization of oxygen in oxidizing to nitrates and the public health significance of the latter in relation to downstream use of the water for potable purposes.

As discussed in Section III, the most common method for bleaching paper grades of sulfite pulp is the three stage chlorine-alkaline extraction-hypochlorite (CEH) sequence (8), although in recent years, some sulfite mills have used a stage of chlorine dioxide. Generally, the chemical requirements of the CEH sequence range from two to six percent of chlorine, 1.0 percent of caustic soda, and from 0.5 to 0.9 percent calcium hypochlorite for bleaching most paper grade sulfite pulps (2). Some mills produce a partially bleached pulp with a single chlorine or hypochlorite treatment. Others produce a variety of specialty grades by adjusting the number of sequences and degrees of chemical treatment in accordance with the type of pulp desired (91). As many as six stages are employed for high grade pulps. The bleached pulp is sometimes treated with sulfur dioxide to remove heavy metals and retard reversion.

A three stage bleaching operation which does not recycle discharges about 50,072 l (12,000 gal) of waste water per kkg (ton) of production. Recycling the hypochlorite stage effluent as wash water in the caustic extraction step can reduce this quantity to below 41,676 l (10,000 gal). Single stage bleaching produces about 16,692 l (4,000 gal) of effluent per kkg (ton) of product while 125,193 to 250,386 l (30,000 to 60,000 gal) per kkg (ton) is discharged from bleach plants producing specialty pulps.

The total solids content of the combined effluent of a three stage bleaching operation ranges from 100 to 125 kg/kkg (200 to 250 lb/ton) of product and the total suspended solids from 7.5 to 15 kg (15 to 30 lb). The latter are largely fiber fines which have passed through washer wires. The BOD_5 runs from 5 to 30 kg/kkg (10 to 60 lb/ton) of product (4) and color from 10 to 20 kg (20 to 40 lb) (77). The pH is on the acid side generally ranging from 2.5 to 3.5. The major electrolytes present in these waste waters are the chlorides of sodium and calcium which amount to about 20 to 25 kg (40 to 50 lb) per kkg (ton) of product.

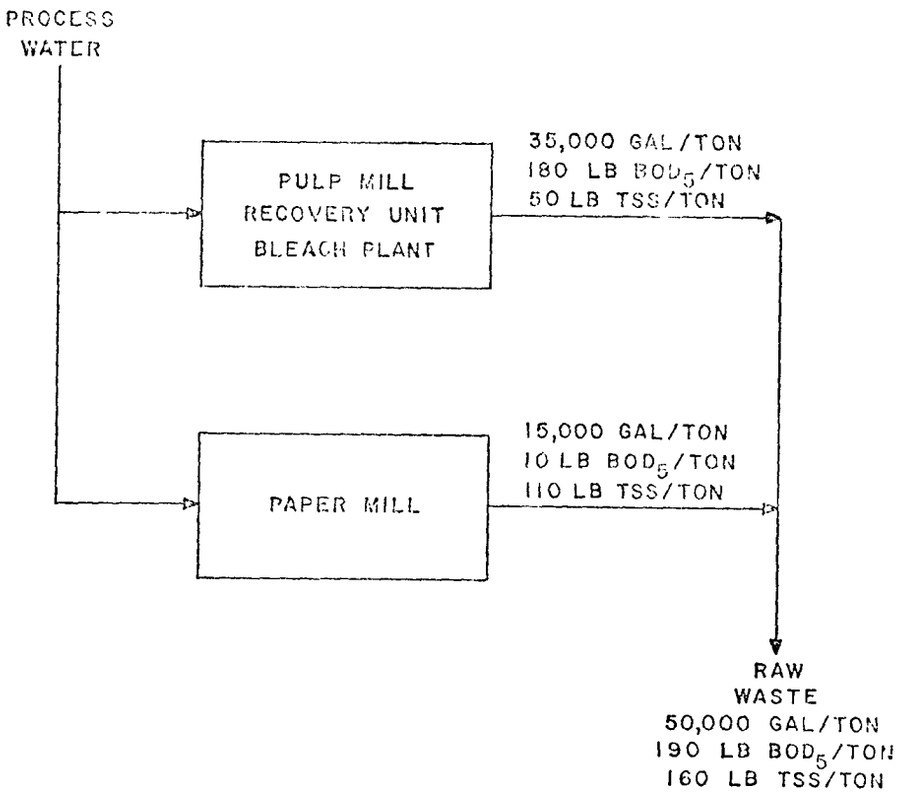
Effluents from one stage bleacheries contain from 50 to 87.5 kg (100 to 175 lb) of total solids per kkg (ton) of product and 2.5 to 5 kg (5 to 10 lb) of total suspended solids. The BOD_5 ranges between 3.5 and 5 kg (7 and 10 lb) per ton and color from 7.5 to 10 kg (15 to 20 lb) (90).

Wastes from the on-site manufacture of bleaching chemicals, such as calcium hypochlorite, are described in the ensuing section on kraft bleaching.

Figure 37 is presented to show the basic contributing waste streams for a sulfite mill with the effluent characteristics shown. Total raw waste (Stream 9) varies in flow from 169.4 to 234.5 kl/kkg (40.6 to 56.2 kgal/ton) and BOD varies from 91 to 109 kg/kkg (182 to 218 lb/ton). TSS data are available from only two of these mills, and reveal a wide variation from 29.9 kg/kkg (59.9 lb/ton) for Mill 56 to 83.1 kg/kkg (166.2 lb/ton) for Mill 51. All the surveyed sulfite mills practice recovery of spent cooking liquor. This procedure reduces raw waste BOD significantly although sulfite liquor recovery is not as affective as that for kraft due to the presence of a considerable quantity of acetic acid in the condensates (46).

Mills 51 and 52 are ammonia base, while Mill 56 is calcium base. The flow and raw waste BOD loads from all three mills are similar, indicating that there are no significant variations in pollution load ascribable to the type of base used. A possible exception is nitrogen in the raw waste from ammonia base mills. No nitrogen data are available on effluents from the surveyed mills in the sulfite subcategory. Nitrogen data are available from Mill 6, however, which is in the groundwood subcategory, but has an ammonia base sulfite process which manufactures about 40 percent of its total pulp. Data from this mill shows an ammonia nitrogen level of 2.8 kg/kkg (5.6 lb/ton) in the influent to its ASB, dropping to 1.24 kg/kkg (2.48 lb/ton) in the final effluent.

FIGURE 37
EFFLUENT CHARACTERISTICS: SULFITE MILL



Dissolving Sulfite Subcategory

Dissolving sulfite mills require large quantities of water. The stringent requirements of product purity inhibit reuse, recycling, or reclamation of water (180).

Over 50 percent -- possibly up to 65 percent -- of the wood used to produce sulfite dissolving pulp becomes waste. This largely biodegradable organic material is carried away in the effluent streams (159). The major areas of its concentration are the spent cooking liquor ("red liquor") evaporator condensates, side-hill screen rejects, and bleach plant effluent (159).

In this pulping process, the spent liquor carries a very heavy solids load since cooking is continued until most of the lignin and part of the cellulose are dissolved (180). As a result, four stages of washing, usually countercurrent, are generally required. This removes about 95 percent of the lignin from the pulp (180) which in turn generates a considerably larger solids load in the evaporator condensate of dissolving sulfite mills than is the case with sulfite mills producing papermaking grades.

The side-hill screens -- equipment unique to dissolving pulp manufacture which is used in addition to conventional screens -- thicken the pulp and can account for approximately 18,925 l/min (5000 gpm) of waste water which contains about three percent of the pulp, ray cells, sand, and residual red liquor (180) (159).

A great deal of material, including beta and gamma cellulose, is extracted from dissolving pulp in bleaching (5) (52). The caustic extraction stage alone dissolves about 10-16 percent of the pulp, depending on the grade of cellulose desired (180). The wash water from this stage is much higher in BOD than the comparable stream in the bleaching of sulfite papermaking pulps.

The hypochlorite stages create further losses but little BOD load since the cellulose modification they perform is an oxidizing process (180).

Sulfite dissolving bleachery effluents contain from 50 to 100 kg (100 to 200 lb) of total suspended solids per kkg (ton) of product. The BOD ranges from 100 to 225 kg (200 to 450 lb) per kkg (ton) and the color unit content approaches 500 kg (1000 lb) per kkg (ton) (91) (5). The pH value ranges between 2.0 and 3.0 and the electrolyte content is usually about double that of sulfite papermaking bleachery effluents.

Mills 401 and 511 practice recovery and obtain raw waste BOD loadings of 143.5 kg/ kkg (287 lb/ton) and 133.5 kg/kkg (267 lb/ton), respectively. This is in contrast to Mill 50 which does not practice recovery of spent liquor. This mill has a much higher BOD loading of 740 kg/kkg (1480 lb/ton), although the mill projects that this value will drop to 137.5 kg/kkg (265 lb/ton) upon completion of its recovery system.

Flow from dissolving sulfite mills varies from 235.6 to 331.6 kl/kkg (56.5 to 79.5 kgal/ton). TSS varies widely between the two mills having data, with Mill 511 at 100 kg/kkg (200 lb/ton) and Mill 512 at 11 kg/kkg (22 lb/ton). A portion of this apparent variation may be explained by the fact that Mill 512 measures TSS(N) rather than TSS.

Figure 38 is presented to show the relative contributions of the basic unit processes to the total waste load for a dissolving sulfite mill with the effluent characteristics shown.

Development of Subcategory Raw Waste Loads

The development of the raw waste loads (RWL) for each of the sulfite subcategories is discussed below. The resultant raw waste loads were used in developing the effluent limitations for each subcategory and in determining the costs presented in Section VIII.

Papergrade Sulfite Subcategory

As discussed in Section III, mill visits were made to 13 of the 22 mills in this subcategory with regard to gathering information and data concerning manufacturing operations and effluent characteristics. In addition, information and data on every papergrade sulfite mill was available from Reference 29. Beyond that contained within the published report, the raw data sheets were available to support the information and data summarized in the report. Thus, the subcategory RWL was based upon the information and data accumulated from the plant surveys and upon the supporting information and data from Reference 29.

Table 29 shows information and data for each mill in the papergrade sulfite subcategory (also the dissolving sulfite subcategory which will be discussed later) and was derived from Reference 29 as well as from the supporting raw data sheets. The effluent flow and BOD_5 values presented are from the published report. The symbols used in the columns entitled "Products" and "Other Pulping Processes" can be interpreted as follows: F: fine papers, N: Newspapers, T: Tissue papers, P: Market pulp, C: Coarse papers, B: paperboard GW: groundwood, NSSC: Neutral Sulfite Semi-chemical, BK: bleached kraft, and WP: waste paperboard. In addition, the column entitled "Woodyard-Water Use" indicates the use of wet barking procedures at the mills. Also, the column entitled "Type Condenser" shows if mills are using barometric (B) or Surface (S) type condensers in their waste liquor recovery systems. The column entitled "Liquor Recovery" shows information on what mill personnel reported as the percentage of their spent sulfite liquor (SSL) which is collected (C), converted to by products (B), and incinerated (I). Mills with partial or no SSL recovery systems can be interpreted from the amount of liquor collected, such as mills L-4 and L-11 which show 25% and 0%, respectively. It should be noted, however, that the percentages are based on information received

FIGURE 38
EFFLUENT CHARACTERISTICS, SULFITE DISSOLVING MILL

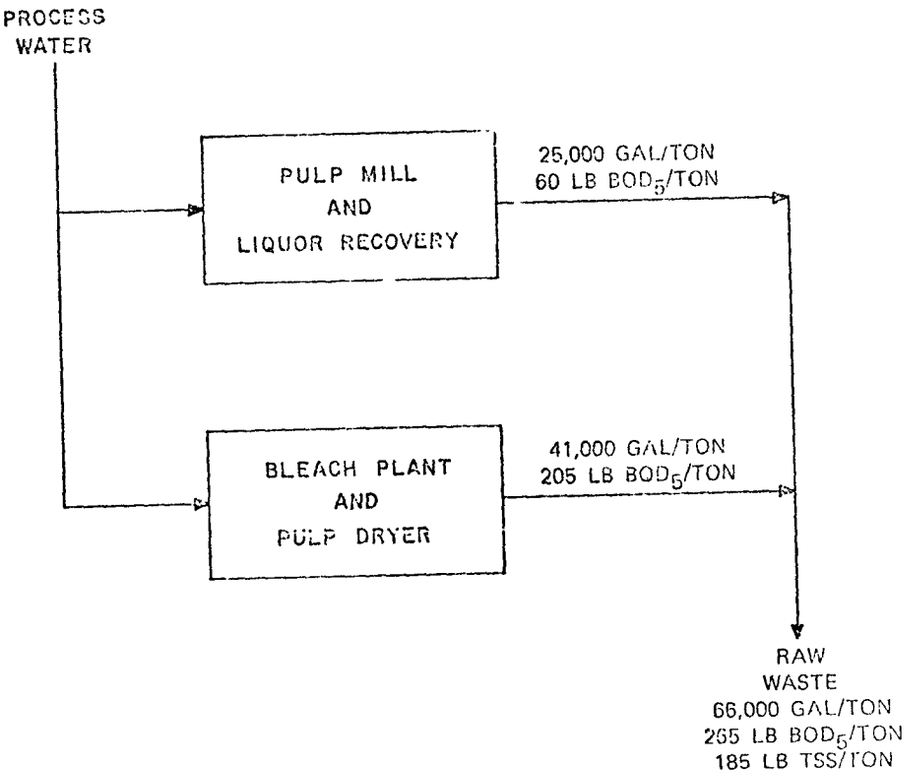


Table 29
Mill Characteristics and Raw Waste Loads
Sulfite Segment

Mill	Sulfite Production kkg(tons/day)	Total Production kkg(tons/day)	Products	Other Pulping Processes	%Chips	Woodyard Water Use	Pulping Blow Pit	Washing Vacuum Drum	Bleaching Sequence	Type Condenser	Liquor Recovery (%) C : B : I*	Flow kl/kkg(kgal/ton)	BOD5 kg/kkg(lb/ton)
Dissolving Sulfite													
L-15	571(630)	571(630)	Pulp	-	0	Wet	-	4-stage	CEHH	V	97 : 0 : 100		
L-17	544(600)	544(600)	Pulp	-	0	Wet	-	4-stage	CEHH	S	- : 0 : 97	279.4(67.0)	129(258)
L-20	435(480)	435(480)	Pulp	-	0	Dry	yes	-	CEHD	S	0 : 0 : 0	221.0(53.0)***	-(-)
L-16	417(460)	417(460)	Pulp	-	0	Wet	-	4-stage	CEH, CEDP, CEHP	S	98 : 0 : 100	-(-)	-(-)
L-14	449(495)	449(495)	Pulp	-	0	Wet	yes	-	CECHD, CHED	B	98 :5-10: 70	304.4(73.0)	150(300)
L-10	440(485)	440(485)	Pulp	-	0	Wet	-	4-stage	-	S	90 : 0 : 100	291.9(70.0)	226(451)
												216.8(52.0)****	423(845)*
Papergrade Sulfite													
L-13	500(550)	1180(1300)	F,N	GW	60	Dry	-	3-stage	NONE	S	99 : 0 : 100	229.4(55.0)	75.0(150)
L-11	435(480)	544(600)	F,T	-	06	Dry	yes	1-stage	CEH, H	NONE	0 : 0 : 0	208.5(50.0)	150(900)
L-22	171(152)	335(370)	F	NSSC	10	Wet	-	continuous	CEH	B	80 : - : 100	-(-)	-(-)
L-18	209(230)	381(420)	P,N	GW	60	Wet	-	3-stage	NONE	S	99 : 0 : 100	112.6(27.0)	62.5(125)
L-19	149(164)	512(564)	N	GW	100	-	-	3-stage	CEH**	B	99 : 0 : 100	133.4(32.0)	63.5(127)
L-1	100(110)	100(110)	C,B	-	100	-	yes	-	NONE	B	85 :40 : 60	157.6(37.8)	81.0(162)
L-9	209(230)	268(295)	F	-	100	-	yes	-	CEH	B	81 : 5 : 100	291.9(70.0)	110(220)
L-28	-(-)	-(-)	T	-	10	-	-	2-stage	H	S	98 : 0 : 95-100	-(-)	99(198)
L-5	127(140)	127(140)	P	-	10	Dry	yes	-	C-H	NONE	0 : 0 : 0	229.4(55.0)	450(900)
L-8	489(535)	662(730)	T,B,P	GW,WP	50	Wet	yes	-	CEHDP	B, S	85 :78 : 0	329.4(79.0)	106(211)
L-4	771(850)	907(1000)	T, P	-	100	-	yes	3-stage	CEH	S	25 : 0 : 94	395.3(94.8)	420(840)
L-2	330(430,	1052(1160)	T	BK	33	Wet	yes	-	CH, CEH, CEHD	B	- - -	-(-)	-(-)
L-21	236(260)	272(300)	B,C,F,P	BK,NSSC	43	Wet	-	4-stage	CEH, CNH, CEHD	B	81 : 0 : 100	-(-)	-(-)
L-24	135(150)	136(150)	P	-	25	Dry	yes	-	CEH	B	70 :70 : 0	241.7(58.0)	115(230)
L-29	161(177)	335(369)	F	-	77	Dry	-	3-stage	CEH	S	96 : 0 : 100	221.0(53.0)	70.0(140)
L-26	135(150)	409(450)	T	-	67	Dry	-	2-stage	H	S	92 :92 : 0	329.4(79.0)	123(245)
L-23	-(-)	-(-)	T	-	0	Dry	-	2-stage	H	B	90 : 5 : 100	-(-)	-(-)
L-3	100(115)	136(150)	T	-	0	Wet	yes	-	H	B	45 :100: 0	383.6(92.0)	120(240)
L-6	103(114)	221(244)	F	-	0	Wet	yes	-	CEH	B	86 :86 : 0	-(-)	140(280)
L-12	92(102)	131(145)	F	-	20	Dry	yes	-	CEH	S	60 :60 : 0	184.3(44.2)	139(278)
L-27	218(240)	399(440)	F	-	100	-	-	2-stage	CEH	S	95 : 0 : 100	208.5(50.0)	380(760)
L-25	118(130)	195(215)	T,F	-	0	Dry	yes	-	CEH	B	95 :100: 0	700.6(168)	93.0(185)

*Collected: By products: Incinerated
** 0-20% of Time
***Estimate
****Before SSL Recovery

in questionaires and as such do not necessarily represent precise figures of the extent of the SSL recovery systems presently in use.

The most significant effects upon effluent characteristics involve the following operations: (1) woodyard, (2) pulp washing, (3) spent sulfite liquor recovery, (4) type of condensor (5) bleaching, and (6) papermaking. As discussed in Section IV, the effluent waste loads from woodyard operations are considered in developing effluent limitations by the establishment in Section IX of separate allowances for all woodyard operations. The efficiency of SSL removal from the pulp has significant impacts on RWL and the two types of systems primarily in use are (a) blow pit and (b) vacuum drum. Blow pit washing systems do not separate the SSL from the pulp as efficiently as vacuum drum washers and thereby higher effluent characteristics generally result from mills using blow pit washing systems. Certainly, the most significant effect upon RWL is the SSL recovery system as to (a) the use of and (b) the capacity of. There are still several mills continuing to operate without SSL recovery or with only partial recovery systems. The use of barometric type condensers in the SSL recovery system results in higher flows than the use of surface type condensers. In addition, the extent of bleaching ranging from one to five stages can have significant impacts on effluent characteristics. As discussed previously in the bleached kraft discussion, papermaking can have significant impacts on RWL but for sulfite mills is relatively less significant than the other factors discussed above.

Table 29 presents information on the above process factors for each papergrade sulfite mill. Mentioned above, most mills utilize SSL recovery systems or are presently installing these systems. As shown in the Table, 18 of the 22 mills presently have SSL recovery systems and thereby, as discussed in Section VII and VIII, is considered as part of BPCTCA which includes internal controls commonly practiced by the industry. For mills with SSL recovery systems, the highest effluent characteristics would result from mills using a combination of blow pit washing, barometric condensers, and three or more stages of bleaching. Consideration was given to subcategorization to account for the effects of mills using SSL recovery systems and various combinations of (a) blow pit vs vacuum drum, (b) barometric vs surface condensors, and (3) the extent of bleaching. However, one subcategory was established for papergrade sulfite mills (See Section IV) and the selection of mills from which the subcategory RWL was developed encompassed mills with combinations of the above process factors resulting in the highest RWL.

Table 30 shows the raw waste loads used for determination of the subcategory RWL. The mills were selected as representative of mills with SSL recovery and varying combinations of process factors which resulted in the higher waste loads. Mill 51 (L-9) is probably the most representative mill in the papergrade sulfite industry of a mill with a combination of process factors which theoretically should result in a relatively high RWL. For

TABLE 30
RAW WASTE LOAD
PAPERGRADE SULFITE SUBCATEGORY

Mill	Production (1) kkg/day (tons/day)		FLOW kl/kkg (gal/ton)		BOD5 kg/kkg (lbs/ton)	TSS kg/kkg (lbs/ton)
066 (L-26)(1)	136	(150)	206.4	(49.5)	125.5 (247)	74.5 (149)
071 (L-12)(2)	93	(103)	191.4	(45.9)	111.5 (223)	80.5 (161)
051 (L-9)(3)	227	(250)	210.2	(50.4)	115.0 (230)	91.5 (183)
056 (L-24)(4)	155	(171)	224.3	(53.8)	113.0 (226)	30.0 (60.0)*
Average			208.1	(49.9)	116.0 (231.5)	82.0 (164)

*Not included in average

(1) In Table 29, mill L-26
(2) In Table 29, mill L-12
(3) In Table 29, mill L-9
(4) In Table 29, mill L-24
(5) Unbleached Sulfite Pulp Production

Note: Calculations of RWL for each mill subtracted the RWL attributable to purchased pulp.

example and as shown in Table 29, mill 51 (L-9) employs SSL recovery, blow pit washing, barometric condensors, a bleaching sequence of CEH, and produces fine papers. As shown in Table 30, mill 51's BOD_5 RWL was 115 kg/kkg (230 lbs/ton) and flow was 210.2 kl/kkg (50.4 kgal/ton) which are essentially equal to the subcategory RWL of 115.75 kg/kkg (231.5 lbs/ton) and 208.1 kl/kkg (49.9 kgal/ton), respectively. The other mills in the table produce either tissue papers, fine papers, or market pulp and employ SSL recovery systems with blow pit washing except for mill (L-26) which uses vacuum drum washing. The mills included in Table 29 that were not selected as representative were excluded for a variety of reasons, some of which include the following: (1) seven mills were excluded because other types of pulping operations, such as bleached kraft or groundwood, were conducted on-site and waste waters were not necessarily separate between the processes resulting in effluent data that does not represent the effluent characteristics of the sulfite process; (2) one mill was unique in that it was constructed in the late 1960's and the in plant control measures were beyond those commonly practiced and thereby was not considered as representative of BPCTCA; (3) four mills did not have full SSL recovery systems; (4) mills using various combinations of vacuum drum washing and surface condensors were excluded (with the exception of mill (L-26) which had RWL nearly equal to mill 51); (5) one mill was excluded for the primary reason that no bleaching was practiced at the mill; and (6) extensive data was unavailable for a number of mills. Thus, four mills were selected following extensive evaluations of the available information and data for each mill. These mills represent sulfite mills producing a wide variety of products using a SSL recovery system (with or without by product recovery) and generally unit process operations (i.e. blow pit washing, barometric condensors, extensive bleaching) that result in the higher RWL.

Dissolving Sulfite Subcategory

The dissolving sulfite subcategory includes six mills, five of which are located in the Pacific Northest (and Alaska) and one is located in Florida. Information and data on manufacturing operations and effluent characteristics were collected for effluent limitations development by on-site surveys at all six mills. In addition to the information and data collected during the mill surveys, Reference 29 provided supplementary information and data. As for the papergrade sulfite mills, the raw data sheets were available from the dissolving sulfite mills which supported the information and data summarized in the report.

Table 29 presents the information and data contained in the report and in the supporting data files. At the time when the information and data in Table 29 were being collected, mills L-15, L-16, and L-14 were the only mills with full SSL recovery systems in use. Mill L-10 has recently installed full SSL recovery as indicated in the table but the RWL data represents mill operations without SSL recovery. In addition, mill L-17 has partial SSL recovery and mill L-20 is presently installing full

recovery. As shown in the Table 29, the only mill, following completion of mill L-20's SSL recovery system, that uses blow pit pulp washing and barometric condensors is mill L-14 and thus, BPCTCA for the dissolving sulfite subcategory includes full SSL recovery with four stage vacuum drum pulp washing using surface condensors (See Sections VII and VIII). The selection of the internal controls portion of BPCTCA as above represents a somewhat different situation for dissolving sulfite mills than, as previously discussed, for papergrade sulfite mills. Five of the six dissolving sulfite mills are using (or installing) four stage vacuum drum pulp washing and surface condensors whereas approximately half of the papergrade sulfite mills are still using blow pit pulp washing and barometic condensors. Thus, the internal controls portion of BPCTCA for dissolving sulfite mills represents a higher degree of control than does the papergrade sulfite technology.

Table 31 presents effluent characteristics for the mills used in developing the dissolving sulfite subcategory RWL. Effluent data for the other dissolving sulfite mills presented in Table 29 was not used primarily because the available data did represent full SSL recovery and/or SSL recovery with vacuum drum pulp washing and barometric condensors. For example, mill L-17 has partial SSL recovery presently installed; mill L-20 is presently installing SSL recovery; mill L-10 presently has full SSL recovery but is still in the startup stage and available data represented mill operations prior to SSL recovery startup; and mill L-14 uses SSL recovery with blow pit washing and barometric condensors. The differences in data presented in Tables 29 and 31 for mills L-15 and L-16 are apparently due to differences in the calculation methodologies (i.e. Table 29 gives effuent values in terms of unbleached kkg (tons) of production whereas Table 31 represents final bleached kkg (tons) and differences in the actual data used (different periods of mill operations)). As shown, the flow, BOD_5 and TSS RWL for the dissolving sulfite subcategory are 271.9 kl/kkg (65.2 kgal/ton), 132 kg/kkg (264 lbs/ton), and 92.5 kg/kkg (185 lbs/ton), respectively.

BLEACHED KRAFT SEGMENT

Effluent volume from the modern kraft pulping operation alone ranges from 41,731 to 104,327 l (10,000 to 25,000 gal) per kkg (ton) of product. This volume depends upon the grade of pulp manufactured, further processing which may be involved, and cooling water requirements. The latter vary with the type of condensing devices employed in the mill as well as local ambient water and air temperatures. Except where salt or brackish water is used for cooling, the water is frequently reused as process water. Also, mills which produce unfilled paper return a considerable amount of white water to the pulp mill which replaces a substantial portion of fresh water (87) (58). Water use in all kraft mills is integrated to some degree among the various subprocesses which results in considerable dilution of the pulping waste. The major waste streams are digester and evaporator condensates, decker seal pit water, and the recovery

TABLE 31
RAW WASTE LOAD
DISSOLVING SULFITE SUBCATEGORY

Mill	Production kkg/day(tons/day)	FLOW kl/kkg(kgal/ton)	BOD5 kg/kkg(lbs/ton)	TSS kg/kkg(lbs/ton)
511(L-15)	579 (638)	268.5 (64.4)	128.5 (257)	92.5 (135)
401(L-16)	376 (415)	275.2 (66.0)	135.5 (271)	26.5 (53)N
	Average	271.9 (65.2)	132 (264)	92.5 (185)

plant effluent although in some of the older mills these individual streams are seldom separated (59) (60) (54). The recovery stream generally contains miscellaneous waste waters such as floor and tank apron drainings and storage tank overflows. In addition, boiler plant and water treatment plant wastes are sometimes sewered with the recovery unit. In other mills they are discharged to lagoons with the water-borne solid wastes such as fly ash, grits, and dregs.

Figure 39 summarizes the unit process waste characteristics of a bleached kraft mill with the effluent characteristics that are shown. The figure is presented to show the relative contributions of the unit processes to the total raw waste load, but should not be interpreted as representing the typical bleached kraft mill.

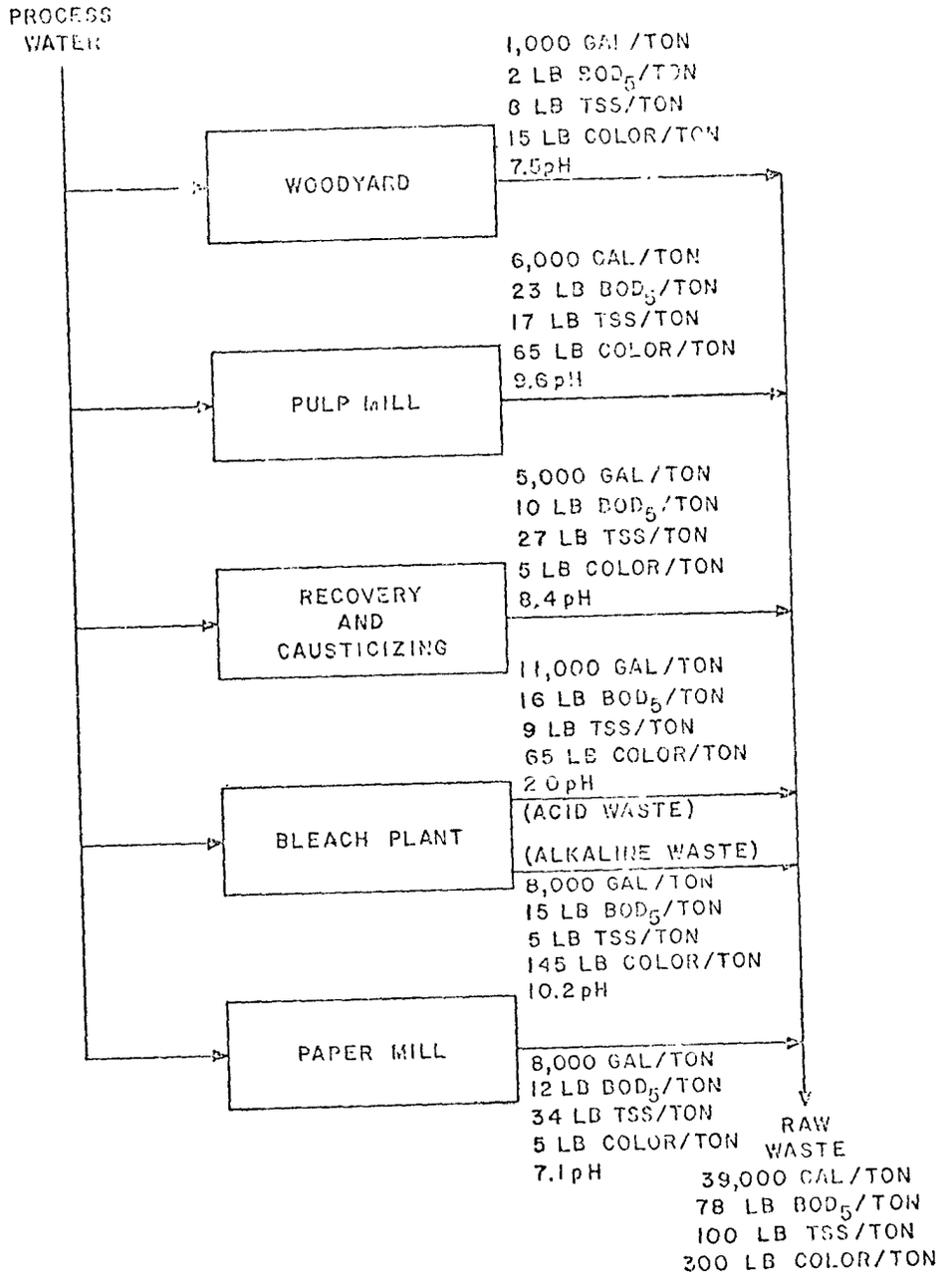
The quantity of the various materials in the effluent stream depends to a considerable degree on the efficiency of the recovery and associated operations as well as the effectiveness of provisions for handling cleaning operations, process upsets, and equipment failures. The very high efficiency of modern recovery installations results, as a general rule, in lower losses than those of older units. Many older mills have completely rebuilt or replaced the original equipment and reach efficiency levels similar to those of new mills (58). Examples from surveyed mill data support this conclusion and have been presented in Section IV. High sewer losses will invariably occur, however, when these systems are overloaded irrespective of their age. Variations in raw waste quality will also occur throughout periods of normal operation (62) due to irregularities in equipment operation as well as periodic wash-up procedures which contribute to the sewer losses.

Pollutional components of kraft pulping effluents include suspended solids, dissolved organics, and electrolytes. Also, inorganic ions are attached to organic compounds such as lignins, resins, and fatty acids.

The quantity of total suspended solids can vary widely but on the average runs between 20 and 30 kg (40 and 60 lb) per kkg (ton) of pulp for well operated mills. They are largely fiber fines and wood debris plus about five to 10 percent dispersed inorganic material. They account for from 10 to 20 percent of the five-day BOD and contribute substantially to the COD. Over 80 percent of the total suspended solids are settleable (63), and the resulting sludge thickens well and dewaters readily by established means. The sludge cakes are low in ash and can be incinerated (64) (65).

The dissolved organics fall into two classes: those which are amenable to biological decomposition and those which are not. The former include methanol, ethanol, turpenes, and acetone from the condensates, (66) (67) and fatty acids, and other cellulose decomposition products of spent cooking liquor origin (68) (60). This fraction accounts for over 80 percent of the BOD_5 of kraft mill effluent. The average BOD_5 load amounts from 12.5 to 25 kg

FIGURE 39
EFFLUENT CHARACTERISTICS: BLEACHED KRAFT MILL



(25 to 50 lb) per kkg (ton) of product and the concentration of the final effluent generally ranges from 150 to 300 mg/l (59) (54). Data from three surveyed mills tends to support these figures. Mill 103, for example, has a pulp mill effluent BOD load (Stream 0) of 18.45 kg/kkg (36.9 lb/ton). The comparable figure for Mill 108 which is a dissolving pulp mill is 23.5 kg/kkg (46.99 lb/ton) and for Mill 122 is 17.5 kg/kkg (35.05 lb/ton).

The non-degradable organic fraction is largely responsible for the color of kraft effluents. It is generally caused by lignins and tannins and is commonly measured by comparison with the platinum-cobalt standards. Based on this standard, kraft pulping effluents normally contain from 500 to 2000 mg/l of color units during periods of normal operation. This amounts to 50 to 400 kg (100 to 800 lb) of color units per kkg (ton) of product (69) (70). These values can rise considerably if carry-over in the black liquor evaporators or pulp washing problems occur.

Both degradable and refractory organics contribute to the COD of kraft pulping effluents which is a measure of the total oxidizable content of the waste. Together with some inorganic sulfides they produce COD values of 500 to 950 mg/l in normal mill effluents (71). From roughly 37.5 to 75 kg (75 to 150 lb) of COD per kkg (ton) of product are ususally discharged from these mills. No fixed ratio between the BOD_5 and COD has been established.

A number of other oxidation methods have been employed for analyzing kraft pulp mill waste waters (72). The most noteworthy of these is a technique using combustion and infrared detection of the carbon dioxide formed (73). This technique measures total carbon (TC), but it has been modified to measure total organic carbon (TOC) and total organic matter (TOM) from which the total oxygen demand (TOD) can be computed. TOD values developed by this method correlate well with COD test data (72). However, since the BOD_5 values measure only readily biologically oxidized materials and the ratio of these substances to the total organic content of kraft effluents fluctuates continually, no correlation between BOD_5 and total chemical oxygen consumption can be anticipated. Because of the complexity of operation and instrument cost, the infrared methods have been largely limited in application to research and as a measure of the effectiveness of advanced waste treatment systems. However, when fully developed they may be adapted to effluent monitoring (74).

Substances harmful in very low concentrations to aquatic life have been found in kraft pulping effluents. These consist mainly of sulfides, mercaptans, resin acid, fatty acid soaps, and turpenes (75) (76), but some less common and more complex compounds demonstrating toxic properties have been identified (77). Generally these substances are present in concentrations of less than five mg/l. Some of them, such as sulfides and mercaptans, are rapidly destroyed by natural oxidation but others, such as resin acid soaps, are more stable. They are,

however, removed by biological treatment and it has been demonstrated that treated kraft effluents do not affect fish propagation or growth at the concentrations at which they exist in surface waters (78).

The electrolyte content of kraft mill effluent normally ranges from 1500 to 3000 mg/l. The salts comprising this fraction of the waste derive from the mill's water supply, paper machine white water used in the pulp mill, the pulping process, and boiler blow-down. Those contributed by process are mainly sulfates and carbonates of sodium and calcium together with some more complex sodium compounds containing sulfur. Most effluents are almost devoid of nitrogen and phosphorus compounds although in some instances, phosphates are present due to their use in boilers and as detergents.

The pH of the pulping effluent is on the alkaline side ranging normally from 9.0 to 10.0 due to the presence of sodium carbonate. From time to time a small amount of sodium hydroxide drives this value somewhat higher. Ordinarily, however, the total alkalinity is low particularly when paper machine white water which contains some acidity is used in the pulp mill.

The condensates and drainings from prehydrolysis of the chips in kraft dissolving pulp mills contain wood solubles with a BOD_5 value of 30 to 60 kg (60 to 120 lb) per kkg (ton) for softwoods and 90 to 100 kg (180 to 200 lb) for hardwoods and amount to approximately 127 l (300 gal) per kkg (ton) in volume (79). They contain little in the way of suspended solids.

The manufacture of chlorine or caustic soda for pulp bleaching produces a small amount of inorganic waste containing impurities from the purchased salt (mainly salts of the alkaline earth metals) together with some unreacted sodium chloride. Pulp mills no longer employ mercury cells in producing chlorine (94). Therefore, generally only very low levels of mercury are found in the effluent. There are two operations located adjacent to pulp mills in which chlorine and caustic are produced by this method but these are classified as chemical plants and are subject to separate EPA effluent limitations (45).

The only waste produced by hypochlorite manufacture is washout from the absorption towers employed. The solids contained in the waste are inorganic in nature, containing insoluble impurities present in the chemicals, such as silica and sulfates of alkaline earth metals.

The wastes from the manufacture of chlorine dioxide are concentrated solutions which amount to 4.17 to 8.3 l (0.5 to 1.0 gal) per kg (lb) of ClO_2 produced, or about 25 to 42 l (6 to 10 gal) per kkg (ton) of pulp bleached. They consist primarily of sodium sulfate and sulfuric acid, together with a small quantity of residual chemicals which vary with the process employed. Because of their sulfuric acid content, they are sometimes employed in converting soap skimmings to tall oil before they are

introduced into the kraft recovery system as chemical make-up (24). In this step the acid present is converted to sodium sulfate, the primary make-up compound, and, on the average, such wastes can supply up to 25 percent of the total salt cake make-up of the kraft mill.

By 1969, all but five of 67 mills producing chlorine dioxide disposed of the waste in the recovery system, although there is wide variation as to the point where it is introduced. Through this procedure most of the inorganic chemical is converted to white liquor constituents (NaOH and Na2S), and when unreacted methanol is present, it is burned in the recovery furnace.

Other chemicals are used in the bleaching process in relatively small quantities and contribute to the mill effluent only to a very minor degree.

Effluent from modern bleach plants is normally discharged only from the chlorination and extraction stages since effluents from other stages are reused utilizing countercurrent washing techniques.

The combined effluent contains the impurities from the process water supply, substances extracted from the pulp, and chemicals added in the process in modified form. For example, caustic soda appears as the cation of the extracted organics. Because of the dilute nature of the effluents and their chloride content, their introduction into the kraft recovery system is not presently feasible.

The major polluting factors contributed by bleaching effluents to surface waters are BOD and color, although chlorides, COD, and suspended solids must also be considered. Figures for BOD, suspended solids, and color which are representative of kraft bleaching are presented in Table 32 (5). These data may be compared to that obtained from surveyed mills as shown in Table 33. Flow, for example, is much lower than reported in Table 32 ranging from 6.0 to 90.4 kl/kkg (1.44 to 21.67 kgal/ton). Likewise, BOD is significantly lower in surveyed mills, ranging from 1.25 to 16.0 kg/kkg (2.5 to 32 lb/ton), whereas that reported in Table 32 suggests a minimum value of 15 kg/kkg (30 lb/ton). Similarly, both TSS and color, as obtained from surveyed mills, are significantly lower than reported in Table 32. No clear cut explanation can be made of these differences, but it is logical to assume that the surveyed mill results, which represent 1972-3 operation, reflect the beneficial effects of recent efforts directed toward water conservation and reuse (particularly by countercurrent washing), whereas the data reported in Table 32 represent operations in 1970 and earlier. A breakdown of the contribution of the various stages of the CEDED bleach plant is shown in Table 34 (81). Data in substantial agreement with these and other data for BOD_5 and color may be found in Reference 11. Flow from a five stage bleachery is now about 47,731 l (10,000 gal) per kkg (ton) of product. The solids

Table 32

VOLUME AND CHARACTERISTICS OF KRAFT BLEACHERY WASTES (5)

	Effluent Volume 1000 l/kkg (100 gal.ton)	BOD kg/kkg (lb/ton)	Total Susp. Solids Kg/kkg	Color mg/l	pH Range
Semi-Bleaching	75-104 (18-25)	15-17.5 (30-35)	7.5-10 (15-20)	2500-3000	4-5
High-Bleaching	104-146 (25-35)	20-30 (40-60)	10-15 (20-30)	4000-6000	3-4
Dissolving Pulp (Soft Wood)	209-250 (50-60)	60-75 (120-150)	65-75 (130-150)	>5000	2-3
Dissolving Pulp (Hard Wood)	230-289 (55-70)	250-350 (500-700)	95-100 (190-200)	>5000	2-3

Table 33

KRAFT BLEACHING RAW WASTE CHARACTERISTICS (STREAM 1)

MILL CODE	FLOW		BOD		TSS		COLOR		
	kl/kkg	(kgal/ton)	kg/kkg	(lb/ton)	kg/kkg	(lb/ton)	gr/l	kg/kkg	(lb/ton)
100	23.7	(5.69)	4.55	(9.09)	2.88	(5.76)			
101	30.2	(7.24)	10.9	(21.83)	2.24	(4.48)*	525	15.9	(31.74)
103	70.3	(16.86)	12.9	(25.77)	3.21	(6.41)*			
104	40.0	(9.59)	1.25	(2.50)	0.86	(1.72)			
108	90.4	(21.67)	12.11	(24.23)	1.45	(2.89)			
117	39.1	(9.37)	16.0	(32.0)	4.58	(9.17)*	1396	51.9	(103.8)
122	23.9	(5.73)	4.78	(9.55)	2.94	(5.88)			
124	6.0	(1.44)	2.52	(5.04)	9.51	(19.02)*	1397	8.4	(16.8)
125	42.2	(10.12)	7.52	(15.03)	1.95	(3.90)*			
							Average	25.4	(50.8)

* TSS(N)

Table 34

RAW WASTE CHARACTERISTICS OF
VARIOUS STAGES OF BLEACHING

Bleaching Stage	kg/kkg (lb/ton) BOD5	Color (pt)
Chlorination	5.0 (10.0)	43.8
Extraction	7.1 (14.2)	142.2
Finishing Stages (DED)	5.5 (11.0)	21.9
Total	17.6 (35.2)	

and chloride losses for this type bleaching are shown in Table 35.

Effluent concentrations at a water usage of 41,731 l (10,000 gal) per kkg (ton) will amount to around 400 mg/l of BOD_5, 1600 mg/l COD, and 2400 mg/l of color for the combined waste of a five-stage bleachery. Since water usage has little effect upon the total amount of material removed from the pulp, the concentration of these constituents will be directly proportional to water consumption.

The pH value of the combined waste is on the acid side due to mineral acidity from hydrochloric acid formed by reaction of the chlorine compounds employed. The degree of acidity depends upon the amount of active alkali remaining in the caustic extract and the neutralizing chemical used after the final chlorine dioxide stage. These effluents generally range from pH 3.0 to 4.0.

The overall shrinkage in kraft pulp weight during bleaching ranges from four to ten percent and is due mainly to the removal of dissolved substances since fiber losses are generally less than 0.5 percent. This accounts for the normally lower suspended solids content of kraft bleaching effluents and explains why these wastes are frequently by-passed around clarification devices at pulp mills.

The simple dissolved organics present in bleachery effluents are low molecular weight substances (83). They primarily include methanol, methy-ethyl ketone, and formic acid although small quantities of oxalic, malonic, fumaric, and succinic acids, and acetaldehyde are also present as well as some chlorinated compounds.

The complex dissolved organics have been found to represent only two percent of the total non-volatile organics. These are color bodies present in chlorination and caustic extraction wastes. They are described in NCASI bulletins (84) (85) reporting on studies conducted at the New York State University College of Forestry. The color bodies produced by chlorination were chlorine-containing lignin, i.e., unsaturated acidic lignin fragments having few of the aromatic properties of the lignins themselves although lignin derived. Those color bodies found in caustic extract were comparatively low molecular weight, chlorine-substituted acidic materials displaying no aromatic characteristics. It appears then that the chlorination stage forms color bodies by lignin oxidation and the extraction stage produces them by chlorine substitution.

Raw waste color data of bleach plant effluents from surveyed mills have been presented in Table 33. Total raw waste color data (Stream 9) from these mills are shown in Table 36. Total raw waste color data (Stream 9) and final treated effluent data (Stream 79) for surveyed mills are presented in Table 37. Included in the table are mills in each of the four bleached kraft subcategories, and as such considerable ranges of color

Table 35

CONSTITUENTS OF FIVE STAGE BLEACHING EFFLUENT

	#/ton @ 7% Shrinkage
Total Dissolved Solids	340
Dissolved Inorganics	205
Dissolved Organics	135
Cl - from Chlorine	123
Cl - from Dioxide	36
NaOH	59
Na2SO4	14

Table 36

STREAM 9 COLOR DATA FROM SURVEYED MILLS

MILL CODE	COLOR		
	mg/l	kg/kkg	(lb/ton)
101	843	135.5	(271)
117	634	122	(244)
119	616	60	(120)
	Average	106	(212)

TABLE 37

COLOR WASTE LOADS - BLEACHED KRAFT SEGMENT

Mill	Subcategory	FLOW kl/day(kgal/day)	Stream 09 CU	Stream 09 kg/kkg (lbs/ton)	Stream 79 CU	Stream 79 kg/kkg (lbs/ton)	Treatment	Test Method
107	F, Mkt	158.5 (38.0)	855	135.5 (271)	805	127.5 (255)	ASB-PS	Fisher Colorimeter
108	BCT	162.2 (38.9)	1500	243 (486)	1110	180 (360)	ASB-PS	Taylor Color Comparator
105	F,Mkt	157.2 (37.7)	-	- (-)	1760	277 (554)*	ASB-PS	Hellige disk, pH=7.6
110	F, Mkt, GW	97.6 (23.4)	1980	193 (386)	917	89.5 (179)	ASB-C	APHA apparent color
112	F	110.1 (26.4)	-	- (-)	572	63 (126)	ASB-C	NCASI
114	Mkt	178.9 (42.9)	-	- (-)	1730	310 (620)	ASB	Std. Meth. pH=7.6
116	F	130.9 (31.4)	-	- (-)	560	76 (152)	ASB	NCASI
117	BCT-Mkt	205.6 (49.3)	593	122 (244)	1070	220 (440)	ASB	Oregon DEQ Procedure
119	F	97.2 (23.3)	617	60 (120)	468	45.5 (91)	AS	NCASI (except pH=7 C)
125	BCT-GW	103.8 (24.9)	-	- (-)	2032	211 (422)*	ASB-PS	Hellige Comparator pH=7.0
127	Diss.	229.8 (55.1)	-	- (-)	1800	413.5 (827)	ASB	Hach Color Comparator

* Stream 59

values are shown. Differences between raw waste data and final effluent data indicate a reduction in color across biological treatment from 10 to 50% which is higher than previously reported reductions of around 10% (86). The color for the final effluent values varies from a low of 45.5 kg/kkg (91.0 lbs/ton) to a high of 413 kg/kkg (827 lbs/ton) with a range of color units from 468 to 2032. The relatively wide range of values reported can be partially explained by (1) the extent of pulping and bleaching at a particular mill as indicated by the subcategory and by (2) the type of analytical procedures used in measuring the color. The test methods used by the surveyed mills are shown in Table 37 and the effects, if any, on the color values reported have not been reconciled at this time. The highest color values of 413.5 kg/kkg (827 lbs/ton) in Table 37 is for surveyed mill 127 which a dissolving kraft mill and should be at the high end of the range due to the characteristics of the dissolving kraft process; i.e. low yield, high bleaching. In comparing Tables 33 and 36, it may be seen that Stream 1 color as measured in kg/kkg (lb/ton) is only about 25 percent of Stream 9 color. This percentage is substantially lower than the 70 to 80 percent rule-of-thumb figure. The explanation may be in the difficulty of separating bleach plant flows in order to obtain representative samples, or in the fact that only three surveyed mills reported bleach plant effluent color data.

One undesirable characteristic of bleachery waste water is foaming. The caustic extraction effluent is primarily responsible for this propensity which increases if the caustic and chlorination stage effluents are directly mixed. The effect is avoided to a considerable degree if the two streams are mixed with the pulp and paper mill effluents at different points in the effluent collection system to allow dilution of the extraction stream before mixing occurs. However, some foaming cannot be entirely avoided and measures may need to be taken for its control.

The only kraft bleach plant in the country using oxygen as one stage is designed so that except during startup it uses fresh water only for equipment seals, washer and press wire cleaning showers, and chemical supply (chlorine and chlorine dioxide water and caustic dilution) (190). This amounts to about 6258.3 l (1500 gal) of fresh water per kkg (ton). Approximately 11,355 l (3000 gal) of white water per kkg (ton) are used in addition for wash water and seal tank make-up (177).

Currently, approximately 378.5-757 l (100-200 gpm) of the "O2" stage effluent which contains highly concentrated BOD losses and color is sent to treatment (177). The remainder is used internally to dilute the stock from 28 percent consistency as it enters the "O2" stage to 12 percent as it leaves (177).

While there has been no operating experience yet with displacement bleaching two such systems are being installed, as discussed in Section III. Pilot plant operations indicate that bleached pulps of market quality can be produced by this process

without washing between stages and that effluent flow can be reduced to the amount of water introduced with fresh chemicals (185).

Development of Subcategory Raw Waste Loads

The development of the raw waste loads (RWL) for the four bleached kraft subcategories is discussed below. The resultant raw waste loads were used in developing the effluent limitations for each subcategory and in determining the costs presented in Section VIII.

BK-Dissolving Pulp Subcategory

Each of the three mills in the bleached kraft-dissolving pulp subcategory were surveyed and extensive data were available for two of the three mills. Table 38 summarizes the raw waste effluent characteristics for mill 108 and 127. As shown, the effluent volume for the two mills is relatively close with an average of 241 kl/kkg (57.7 kgal/ton). The differences in BOD5 RWL may possibly be attributable to the differences in in-plant control measures utilized for disposal of prehydrolysate.

BK-Market Pulp Subcategory

The data from surveyed mills in the bleached kraft market pulp subcategory are summarized in Table 39. The mills in Table 39 represent market pulp mills in all sectors of the country. The mills are relatively new (1960s) with no significant correlation between age of the mill and the RWL. The size of the mills ranged from around 272 kkg (300 tons) to nearly 907 (1000 tons) of pulp per day with no significant correlation between size and RWL. Each of the mills produces exclusively highly bleached market pulp by similar manufacturing operations. The differences in BOD_5 RWL and effluent volumes is attributed to the extent of internal pollution control measures as discussed in Section VII.

Mill 140 was not included in calculating the subcategory effluent flows or BOD_5 as both values were significantly less than the other mills in Table 39. The TSS data for mill 140, however, was used in calculating the average TSS RWL because data was unavailable for mills 126 and 114, and mill 130 RWL TSS data was determined by non-standard methods. It should be pointed out that data from mill 139 was included in the subcategory average since even though the flow was close to that for mill 140, the BOD5 value was very comparable to mills 126 and 114. Inclusion of data in the subcategory average of four of the five mills resulted in an average effluent flow of 176.8 kl/kkg (42.4 kgal/ton). If the low and high flow values were eliminated, the average would than be 183.5 kl/kkg (44.0 kgal/ton) which is very comparable to the average for the four mills. Being representative of four mills, the value of 176.8 kl/kkg (42.5 kgal/ton) was used as the subcategory RWL in developing costs and effluent limitations; the average RWL flow for all five mills was 157.6 kl/kkg (37.8 kgal/ton). The average BOD_5 RWL shown in the

TABLE 38

RAW WASTE LOAD
BK: DISSOLVING PULP SUBCATEGORY

Mill	Size kkg/day(ton./day)	FLOW k*/kkg(kgal/ton)	BOD5 kg/kkg(lbs/ton)	TSS kg/kkg(lbs/ton)
108	824 (908)	251 (60.2)	69.5 (139)	139 (277)
127	*	230 (55.1)	40.0 (80.0)	87.0(174)
	Average	241 (57.7)	55.0 (110)	113 (226)

*Trade Secret

Table 39
Raw Waste Load
Bleached Kraft - Market Pulp Subcategory

Mill	Size kkg/day(tons/day)		Flow kl/kkg(kgal/ton)		BOD_5 kg/kkg(lbs/ton)		TSS kg/kkg(lbs/ton)	
126	480	(529)	194.3	(46.6)	45.5	(91.0)	-	(-)
114	669	(737)	172.6	(41.4)	46.6	(93.2)	-	(-)
139	883	(973)	85.1	(20.4)	40.7	(81.4)*	70	(140)
140	288	(318)	79.2	(19.0)**	27.7	(55.4)**	72.5	(145)
130	366	(404)	256.4	(61.5)	31.6	(63.2)	17.9	(35.8)N
Average			175.8	(42.4)	41.1	(82.2)	7[illegible]	(142)

*Calculated using 15% primary treatment removal.
**Not included in subcategory average (see text).

table is 41.1 kg/kkg (82.2 lbs/ton) and is essentially the median value for the five mills.

BK-BCT Papers Subcategory

Raw waste effluent characteristics are summarized in Table 40 for surveyed mills in the BK-BCT Papers subcategory. The four mills in Table 40 produce a wide variety of products including coarse papers, paperboard, and tissue papers. Mills 105, 109, and 111 also produce some unbleached kraft products while mill 121 produces a small amount of market pulp. The age of the mills ranges from being built in 1912 to 1954 while the size ranges from 698 kkg (770 tons) per day to over 1179 kkg (1300 tons) per day. This apparent wide range of products, ages, and sizes, however, is not shown to have significant impacts of raw waste characteristics as shown in Table 40. The average effluent flow is 152 kl/kkg (36.5 kgal/ton) with a relatively narrow range between 134 kl/kkg (32.3 kgal/ton) and 163 kl/kkg (39.1 kgal/ton). The BOD_5 RWL is 33.4 kg/kkg (66.9 lbs/ton) with a similarly narrow range. TSS RWL data was only available from mill 111, but appears to be representative as discussed below.

Table 41 shows effluent characteristics of bleached kraft mills producing both market pulp and BCT papers. The column entitled "Subcategory (%)" shows the various percentages of total production of either market pulp or BCT papers that are made at the mills. Comparison of RWL for BK-BCT papers subcategory and BK-Market Pulp subcategory with the averages presented in Table 41 confirms the representativeness of the effluent flow averages for the subcategories. Using a ratio of the subcategory averages for BK-market pulp and BK-BCT papers of 177 kl/kkg (42.5 kgal/ton) and 152 kl/kkg (36.5 kgal/ton), respectively, with the average percentages of product in Table 41 (30% Mkt, 70% BCT), the predicted effluent flow for the mills in Table 41 is 159.7 kl/kkg (38.3 kgal/ton) which compares very closely to the actual average of 159.3 kl/kkg (38.2 kgal/ton). By this same methodology, the predicted BOD_5 value is not as close and possible is a result of having BOD_5 data for only five of the seven mills. The average TSS RWL for mills represented in Table 41 is 47.2 kg/kkg (94.4 lbs/ton) which is less than would be predicted with the methodology used above and is an indication that the TSS RWL for the BK-BCT subcategory of 51.5 kg/kkg (103 lbs/ton) is conservative. However, as discussed previously, significant correlations between TSS RWL and production processes do not exist as a general rule because of the internal practices on fiber control in use by pulp and paper mills.

TABLE 40

RAW WASTE LOAD
BLEACHED KRAFT - BCT SUBCATEGORY

Mill	Size kkg/day (tons/day)		FLOW kl/kkg (gal/ton)		BOD5 kg/kkg (lbs/ton)		TSS kg/kkg (lbs/ton)	
105	1017	(1121)	162	(38.9)	36.2	(72.5)	-	(-)
109	1015	(1119)	163	(39.1)	33.3	(66.7)	127	(254)N
111	700	(772)	134	(32.3)	30.8	(61.6)	51.5	(103)
121	1225	(1351)	149	(35.8)	-	(-)	-	(-)
Average			152	(36.5)	33.4	(66.9)	51.5	(103)

Table 41
Raw Waste Load
BK - BCT & Market Mills

Mill	Subcategory %	Size kkg/day (tons/day)		Flow kl/kkg (kgal/ton)		BOD_5 kg/kkg (lbs/ton)		TSS kg/kkg (lbs/ton)	
501	60MKT, 40BCT	1256	(1385)	198.9	(47.7)	-	(-)	-	(-)
117	30MKT, 70BCT	297	(327)	203.9	(48.9)	27.5	(55.0)*	65	(130)
113	30MKT, 70BCT	1068	(1177)	140.9	(33.8)	38.4	(76.9)	-	(-)
122	30MKT, 70BCT	542	(598)	120.9	(29.0)	45.7	(91.4)	52	(104)
100	20MKT, 80BCT	931	(1027)	150.5	(36.1)	44.8	(89.7)	31.8	(63.7)
138	20MKT, 80BCT	894	(986)	139.7	(33.5)	49.0	(98.0)	40	(80)
131	20MKT 80BCT	717	(791)	158.9	(38.1)	-	(-)	-	(-)
Average				159.3	(38.2)	41.1	(82.2)	47.2	(94.4)

*Calculated

BK-Fine Papers Subcategory

Table 42 presents summarized data for mills in the BK-Fine Papers subcategory. The mills included in Table 42 produce fine papers with the size of mills ranging from about 363 kkg (400 tons) per day to over 1450 kkg (1600 tons) per day. Mills 136 and 104 also manufacture some paperboard and tissue products, respectively. The age of the mills in the table varies from 1864 to 1970; mill 119, built in 1864, has a lower RWL than mill 112, built in 1969 which serves to demonstrate that old mills have generally been upgraded and relationships between age and RWL are generally non-existent. Many of the mills in the BK-fine papers subcategory purchase pulp as an additional fiber source. The flow and BOD_5 data presented in Table 42 represents the RWL without any purchased pulp. Using conservative RWL flow and BOD_5 values from non-integrated fine paper mills, the actual effluent data for mills purchasing pulp as a supplementary source of fiber were adjusted to represent the manufacture of fine papers from bleached kraft pulp manufactured on-site. In every case, the mill effluent flow and BOD_5 values were increased by the adjustment.

The average subcategory RWL as shown in Table 42 do not include mills 116, 132, or 104. Mill 116 flow, BOD_5, and TSS values are significantly higher than all of the other mills in the subcategory except for mill 132 which was also eliminated from the calculations because the flow value was significantly less than the other mills. Mill 104 produces both fine papers and tissue papers and thus does not fit precisely within the fine papers subcategory. Table 43 shows RWL data for mills which manufacture both market pulp and fine papers. Comparison by the methodology described in the above discussion of BK-BCT papers using ratios of the percentages of product manufactured in Table 43 with RWL averages for BK-market pulp and BK-fine papers subcategories shows a predicted flow and BOD_5 of 135 kl/kkg (32.4 kgal/ton) and 34.3 kg/kkg (68.6 lbs/ton), respectively. These values are relatively close to the actual values of 145.5 kl/kkg (34.9 kgal/ton) and 36.1 kg/kkg (72.3 lbs/ton), respectively, which indicates that the BK-fine papers subcategory RWL averages are representative.

SODA SEGMENT

Approximatley 83,461 to 125,193 l (20,000 to 30,000 gal) of effluent are produced per kkg (ton) of soda pulp, the specific volume depending largely on cooling requirements. Reuse of paper machine water in the pulp mill is limited by the fillers used in the manufacture of printing papers from soda pulp which render this water unsuitable unless it is clarified to a high degree.

There are four major effluent streams from the pulp production process: the decker seal pit water, the digester relief condensates, the bleach plant effluent, and the recovery plant discharge which includes miscellaneous waste waters such as boiler plant and water treatment plant effluents. In Figure 40,

TABLE 42

RAW WASTE LOAD
BLEACHED KRAFT-FINE PAPER SUBCATEGORY

Mill	Size kkg/day (tons/day)	FLOW kl/kkg (gal/ton)	BOD5 kg/kkg (lbs/ton)	TSS kg/kkg (lbs/ton)
116**	1043 (1150)	149.7 (35.9)*	77.0 (154)*	197.5 (395)
113	174 (192)	107.2 (25.7)	- (-)	- (-)
134	857 (945)	94.2 (22.6)*	36.3 (72.6)*	82.0 (164)
119	522 (575)	97.2 (23.3)	23.3 (46.7)	46.4 (92.9)
132**	378 (417)	75.1 (18.0)*	38.4 (76.9)*	128.0 (256)
112	581 (640)	117.5 (28.2)*	29.8 (59.7)*	- (-)
136	1497 (1650)	124.3 (29.8)*	30.6 (61.2)*	78.5 (157)
104**	1217 (1342)	218.1 (52.3)	34.3 (68.6)	48.5 (97.1)N
	Average	108.0 (25.9)	30.0 (60.0)	69.0 (138)

*Adjusted

**Not included in subcategory average (see text)

TABLE 43

RAW WASTE LOAD - BK-FINE & MKT MILLS

Mill	Subcategory(%)	Size kkg/day(tons/day)		FLOW kl/kkg(kgal/ton)	BOD5 kg/kkg(lbs/ton)	TSS kg/kkg(lbs/ton)
103	45 MKT, 55 F	385	(425)	181.0 (43.4)	37.4 (74.9)	- (-)
135	40 MKT, 60 F	580	(640)	167.6 (40.2)	37.7 (75.4)*	73.0 (146)
106	55 MKT, 45 F	473	(522)	161.4 (38.7)	33.2 (66.4)*	40.3 (80.6)
101	45 MKT, 55 F	517	(570)	150.9 (36.2)	30.3 (60.6)	53.0 (106)N
107	25 MKT, 75 F	281	(310)	126.3 (30.3)	- (-)	- (-)
110	30 MKT, 70 F	1027	(1132)	102.6 (24.6)	30.3 (60.6)	63.0 (127)
120	35 MKT, 65 F	1052	(1160)	129.7 (31.1)	48.0 (96.0)	- (-)
	Average			145.5 (34.9)	36.2 (72.3)	59.0 (118)

*Calculated

the first two flows are combined into the "pulp mill" flow, since waste data are not available for the individual streams. The major pollutional characteristics of the combined effluents are suspended solids, BOD, and color. The suspended solids --fiber fines and debris -- are mostly settleable and are more than 90 percent combustible (5). Normal concentration ranges from 200 to 300 mg/l or about 20 to 30 kg (40 to 60 lb) per kkg (ton) of AD pulp produced. BOD_5 values are in the same range. Color ranges from 800 to 1500 mg/l during periods of normal operation.

Soda pulping effluents contain some components inimical to aquatic life (50). These are resin acid soaps and turpene derivatives. Since sulfur is not used in the process, the effluent appears to have a lower toxicity level than kraft. However, like kraft effluents it can give rise to foaming.

Soda pulp bleaching effluents are similar to those of kraft and contain 10 to 20 kg (20 to 40 lb) of BOD_5 per kkg (ton) of air dry pulp bleached. See Figure 40. The volume ranges between 50,077 to 75,116 l (12,000 and 18,000 gal) per kkg (ton). Color of these effluents will vary widely with the species of wood from which the pulp was produced, as is the case with kraft.

The above data cited from literature sources for soda pulping operations tends to be somewhat higher than more recent data obtained from the three surveyed mills which reflects the efforts in recent years to reduce pollution loads. Figure 40 is presented as an example of a soda pulp and paper mill with the effluent characteristics shown to show the relative contributions of the unit process operations to the total raw waste load.

Development of Soda Subcategory Raw Waste Loads

The development of the raw waste loads (RWL) for the soda subcategory is discussed below. The resultant raw waste loads were used in developing the effluent limitations for the soda subcategory and in determining the costs presented in Section VIII.

All the surveyed soda mills are old, but have been modernized since 1965. All make fine papers from various percentages of purchased pulp and of soda pulp manufactured on-site.

Table 44 presents the raw waste effluent characteristics for the three mills in the soda subcategory. As mentioned above all three mills purchase pulp as a supplementary fiber source and has some effects on the effluent characteristics when evaluating RWL on a (kg/kkg (lbs/ton) basis. However, since all three mills purchase pulp in varying quantities, this factor was not excluded in developing the subcategory RWL. As shown in Table 44, the subcategory flow, BOD_5, and TSS RWL are 123 kl/kkg (29.5 kgal/ton), 42.7 kg/kkg (85.4 lbs/ton), and 105.5 kg/kkg (211 lbs/ton), respectively. It should be pointed out that mill 151

FIGURE 40
EFFLUENT CHARACTERISTICS, SODA MILL

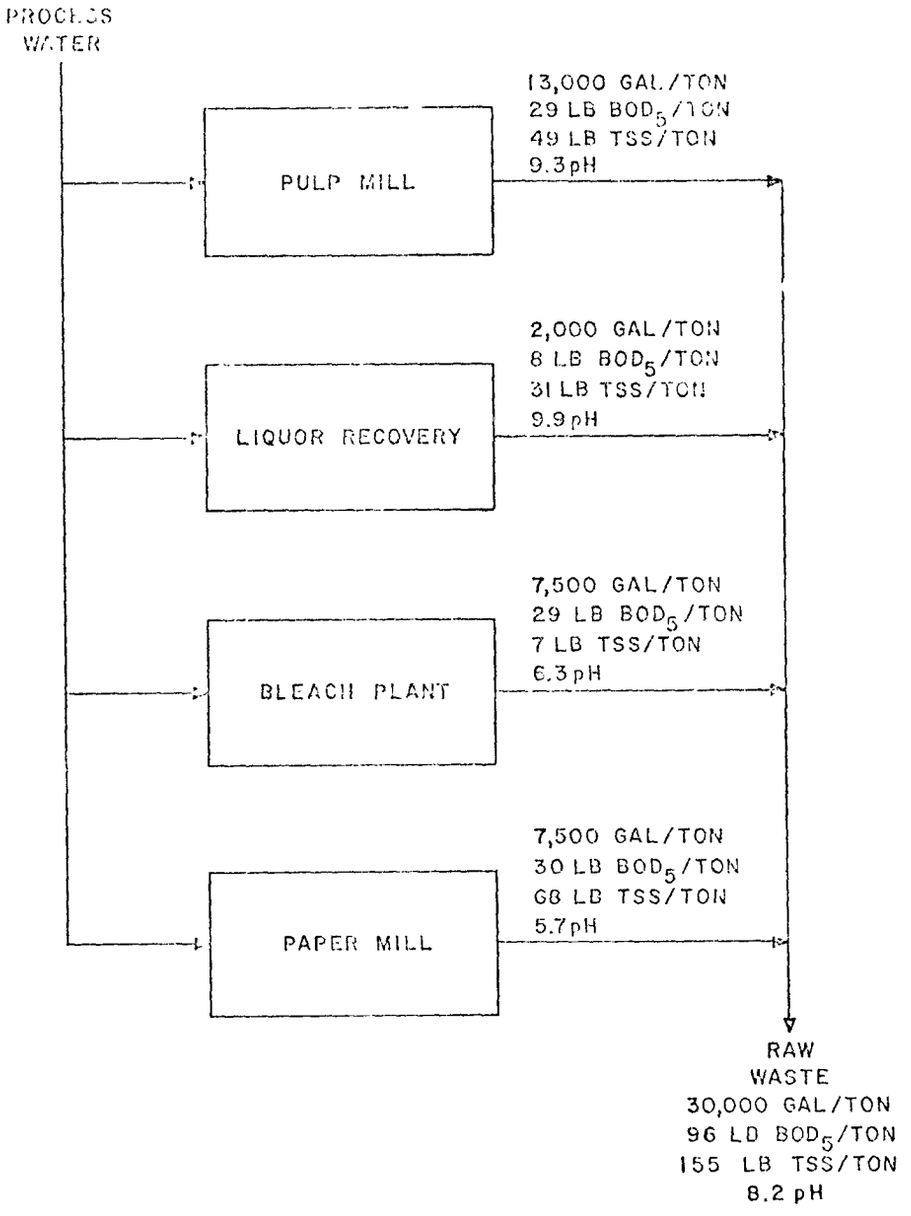


TABLE 44

RAW WASTE LOAD
SODA SUBCATEGORY

Mill	Size kkg/day (tons/day)		FLOW kl/kkg (kgal/ton)		BOD5 kg/kkg (lbs/ton)		TSS kg/kkg (lbs/ton)	
150	262	(289)	158.0	(37.9)	56.7	(113.5)	63.5	(127)
151	620	(684)	101.7	(24.4)	47.6	(95.3)	-	(-)
152	548	(604)	104.7	(26.3)	23.7	(47.4)	147.5	(295)
Average			123.0	(29.5)	42.7	(85.4)	105.5	(211)

which only uses about 12% purchased pulp is well below the subcategory flow and relatively close to the BOD_5 RWL.

DEINK SEGMENT

The major sources of effluent from the deinking process are the washers and centri-cleaners; the remaining streams consist mainly of miscellaneous white water overflows, floor drainage, washup, and cooling waters. In older operations deinking fine papers, the total effluent ranged between 62,596 and 104,327 l (15,000 and 25,000 gal) per kkg (ton) of waste paper processed depending upon the quality of the product produced and equipment used. More recent data from surveyed mills indicates that several mills have substantially reduced their flows in recent years. Mills 217 and 204 which manufacture fine papers and mills 213 and 215 which manufacture tissue papers all have flows of about 50.0 to 54.2 kl/kkg (12.0 to 13.0 kgal/ton). Approximately 41,730 l (10,000 gal) of water are required per kkg (ton) of newsprint deinked (6). In decoating operations producing a crude pulp for use in board products, the wash water is sometimes settled and reused cutting the total discharge to under 20,865 l (5000 gal) per kkg (ton) of waste paper processed.

Clarified white water from papermaking operations may supply a considerable portion of the water used for washing and cleaning. The entire waste water flow from a single-stage bleaching operation can also be used in deinking for dilution and preliminary wash water. However, effluent discharged from three stage bleacheries, 50,077 to 83,463 l (12,000 to 20,000 gal) per kkg (ton) of pulp bleached, is not generally suitable for reuse because of its color.

The major polluting characteristics of deinking effluents are BOD and suspended solids, both settleable and dispersed (88) (89). Organics present include adhesives, products of hydrolysis and fiber lost in the process. Inorganics derive from mineral fillers, ink pigments, and other materials separated from the fiber in waste paper as well as chemicals utilized in the process. Included in the latter are dissolved electrolytes and detergents which add to the total solids and foaming propensities of receiving waters.

The electrolytes are primarily sodium salts. Up to 60 pounds of these salts as Na^+ are added to the cooking liquor per ton of waste paper processed and most appear in the effluent. Cooking also contributes other inorganics present in the waste paper such as aluminum hydrate.

Sodium silicate used as a cooking liquor component will account for the presence of silica in the effluent and calcium can be present as a product of calcium hypochlorite bleaching. Bleaching may also contribute some chloride ion. Color can be a factor in deinking and attendant bleaching operations although it is a minor one in comparison to the color values which result from the manufacture and bleaching of chemical pulps. Data for

color of deinking wastes are not available. However, it is normally not a problem after the waste is diluted with white water and is obscured by the extremely finely dispersed particles present even in highly treated effluents.

Table 45 gives a range of values for the solids and BOD_5 content of total deinking waste, including bleaching. This data is not directly comparable to the surveyed mill data, since the former is based upon kkg (tons) of waste paper handled, while the latter is based upon kkg (tons) of paper produced. Table 45 indicates that BOD and TSS appear to be in the neighborhood of 50 kg/kkg (100 lb/ton) and 150 kg/kkg (300 lb/ton), respectively, on the basis of weight of waste paper handled. These high losses can be expected when considering the shrinkage data obtained from surveyed mills. Shrinkage is the percent loss of weight of waste paper in the deinking process. This loss appears in the waste water primarily as BOD and TSS. As shown in Table 46, shrinkage values range from 18 to 25 percent.

Figure 41 is presented as an example of a deink mill with the final effluent characteristics shown in order to show the relative contributions of the deink mill and the paper mill to the total raw waste load.

Development of Deink Subcategory Raw Waste Load

The development of the raw waste loads (RWL) for the deink subcategory is discussed below. The resultant raw waste loads were used in developing effluent limitations and in determining the costs presented in Section VIII.

The raw waste load data for mills in the deink subcategory are summarized in Table 47. As shown, data was available for 14 of the approximately 17 mills in the subcategory. As discussed in Section IV, consideration was given to establishing two subcategories for the deink segment and as such, Table 47 is divided into two groups of mills. The mills manufacturing fine (F) papers are shown in the top group and those manufacturing tissues (T) papers are shown in the lower group. Also, shown in the table is manufacturing information including the percentage of the total product as made up by purchased pulp, waste paper (not deink), deinked waste papers, and clays and fillers. As shown in the table, the average RWLs for deink mills producing fine papers are less than for mills producing tissue papers. The subcategory RWL was thereby based upon mills producing tissue papers as this represents the higher RWL of the two groups. The methodology used for developing the deink subcategory RWL differed slightly from that used in developing the other subcategory RWL in that the deink subcategory waste load was an average of the RWL of mills 205, 206, and 216 which employ external treatment and generally have the higher RWL shown in the data. Averaging their RWL resulted in the following flow, BOD_5, and TSS values: 94.0 kl/kkg (22.6 kgal/ton), 68.5 kg/kkg (137 lbs/ton), and 204 kg/kkg (408 lbs/ton), respectively. These values are all higher than the average for all mills shown in

Table 45

SOLIDS AND BOD5 LOADING FROM
DEINKING MILL OPERATIONS

(Based on Waste Paper Handled)

Effluent Volume 1000 l/kkg (1000 gal/ton)	TSS #/ton	BOD_5 #/ton
117 (28)	100 (200)	39 (78)
104 (25)	250 (500)	47.5 (95)
125 (30)	225 (450)	50 (100)
71 (17)	195 (390)	37.5 (75)
50 (12)	300 (600)	40 (80)
88 (21)	380 (760)	57.5 (115)

Table 46

Deink Mill Shrinkage

MILL	PERCENT SHRINKAGE
203	25
204	21
207	18
208	20

FIGURE 41
EFFLUENT CHARACTERISTICS: DEINK MILL

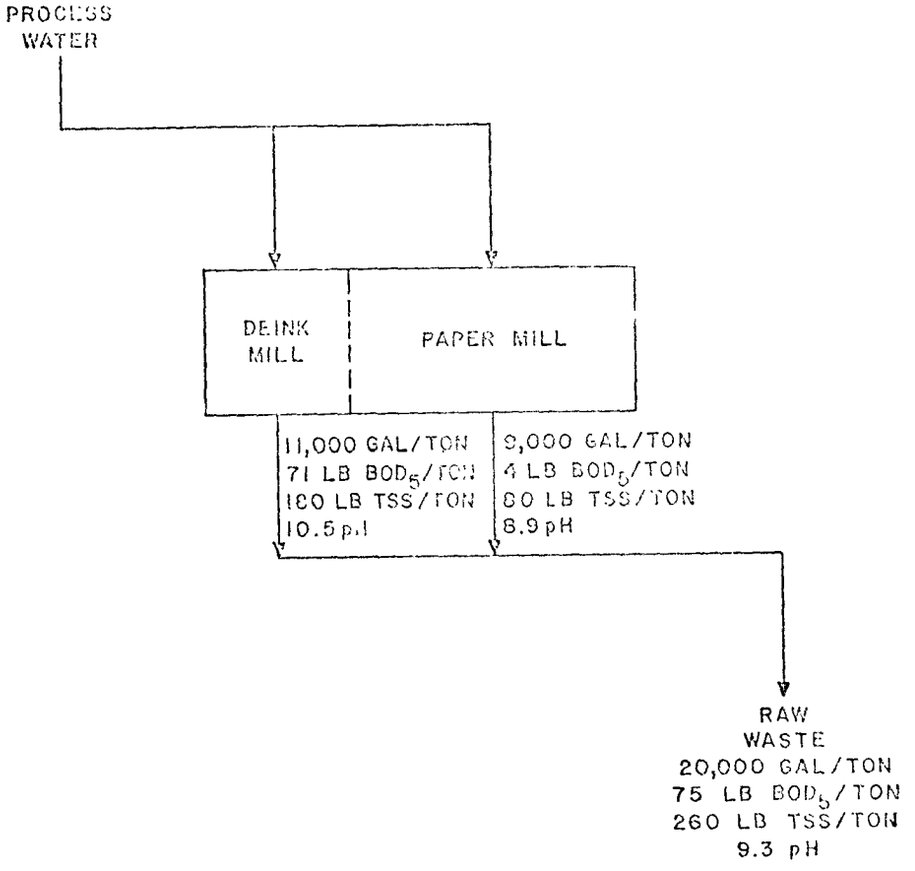


Table 47

RAW WASTE LOAD
DEINK SUBCATEGORY

Mill	Manufactured (%) D	PP	WP	C&F	Products	Size kkg/day (tons/day)		Flow kl/kkg (kgal/ton)		BOD_5 kg/kkg (lbs/ton)		TSS kkg/kkg (lbs/ton)	
203	35	33	12	20	F	349	(385)	75.1	(18.0)	53.5	(107)	155	(310)
217	75	0	0	25	F	293	(323)	55.0	(13.2)	91.5	(183)	194.5	(389)
204	25	50	5	20	F	181	(200)	55.5	(13.3)	27.5	(55)	99.5	(199)
210	25	50	5	20	F	291	(321)	80.1	(19.2)	34.7	(69.4)	92	(184)
207	15	70	0	15	F	245	(270)	162.6	(39.0)	-	(-)	89	(178)
Average								85.5	(20.5)	52	(104)	147	(294)
212	100	0	0	0	T	82	(90)	100.5	(24.1)	92.5	(185)	293.5	(587)
214	100	0	0	0	T	44	(48)	149.7	(35.9)	-	(-)	-	(-)
206	100	0	0	0	T	717	(790)	98.4	(23.6)	61.1	(122)	155	(310)
205	70	20	10	0	T	89	(98)	80.9	(19.4)	-	(-)	-	(-)
216	60	20	20	0	T	72	(79)	106.3	(25.5)	72.5	(145)	253	(505)
213	50	0	50	0	T	30	(33)	50.4	(12.1)	-	(-)	-	(-)
215	25	10	65	0	T	120	(132)	52.9	(12.7)	16.8	(33.6)	55.5	(111)
211	33	0	67	0	T	70	(77)	127.2	(30.5)	62	(124)	101	(202)
Average								95.5	(22.9)	46.5	(93)	204	(408)
Average (all mills)								91.7	(22.0)	57	(114)	46.5	(93)

Table 47 and were used because of the nature of the deinking process (i.e. the type of waste paper used as the fiber source has significant effects upon the effluent characteristics, and changes in market conditions have direct effects upon the availability and use of the type of waste paper). It should be pointed out that since nearly all mills purchase pulp in varying quantities the effects of purchased pulp are included in the subcategory RWL.

PAPERMAKING

As used in this discussion, the term "papermaking" includes stock preparation as well as the forming, drying, and ancillary processes which occur on the paper machine itself. Paper/board is made on similar equipment within all subcategories, with similar water uses and similar sources of waste water. Therefore, papermaking for all subcategories is discussed together, but attention will be drawn to significant differences among the subcategories.

WATER USE AND REUSE

Water is used for a wide variety of purposes in papermaking. Definitive data on quantities used are lacking for two principal reasons. First, there has been an increasing trend toward reuse within the industry involving the transport of waste water from one subprocess for use in one or more different subprocesses. For example, machine white water is used for consistency regulator dilution in both the stock preparation and papermaking areas. Reuse quantities are rarely metered separately. Second, the complexity of the subprocesses and their interconnections, together with the many individual use points of fresh water, makes it almost impossible to meter each usage of fresh water. The overall effect of reuse, however, is to reduce the quantity of fresh water, and hence the quantity of waste water leaving the entire process. This effect is discussed later in this section.

Because of the paucity of published data, estimates have been made of individual usages of water based upon general engineering design values and upon information obtained at surveyed mills. The use points and their estimated flows are shown in Table 48. It must be emphasized that these are gross values, including, in most cases, substantial reuse. Therefore, as discussed below, the sum of individual uses will exceed the total fresh water usage by a substantial amount.

The extent of reuse depends on many factors including product requirements, manufacturing demands, length of production run, and engineering considerations. Every surveyed mill engaged in papermaking reuses water in the process to some extent, and most of them reported continuing programs to reuse more. All of them reuse furnish dilution water which is the largest use shown in Table 48. Because considerable effort has been made by some mills to minimize fresh water use for cleaning of fourdrinier

Table 48

ESTIMATED WATER USAGE FOR PAPERMAKING

Use	Flow, gal/ton
1. To fiberize stock and convey it from one subprocess to another	6000
2. To clean equipment such as wires, cylinder molds, and felts during production, and to knock down foam	See Table 20
3. To "hydrate" and/or cut the fibers to provide proper strength and fiber length	Included in 1
4. To dilute the furnish for cleaning, forming, and for consistency regulation	30,000
5. To dissolve, disperse, dilute, and/or convey additives alum, starch, and fillers	0-2000
6. To lubricate and seal moving parts such as shafts and vacuum pumps	2000-6000
7. To provide steam for processing and space heating (net)	500
8. To cool equipment and process fluids	2000-10,000
9. To wash up equipment and adjacent floor areas after production runs	500-2000

wires, estimates of this use and reuse were obtained from some surveyed mills and are shown separately in Table 49. Further discussion of these results is deferred to Section VII.

WASTE WATER CHARACTERISTICS

In a papermaking area, the principal waste water discharges are as follows:

1. Excess white water from seal pits or other tank overflows
2. Rejects from stock cleaning devices (centrifugal cleaners, screens, and junk traps)
3. Felt and wire cleaning waters
4. Spills, washups, discharge of tank dregs, and other non-equilibrium losses
5. Cooling water discharges
6. Boiler blowdown and other miscellaneous discharges.

In addition, sanitary wastes are almost always collected separately, and either directed to a municipal system or treated separately. Because of this, and the fact that such flows are small compared to process losses, sanitary wastes will not be discussed further in this report.

Sources of BOD in waste waters are the organic raw materials used as the constituents of paper. Cellulose is foremost, comprising 80 percent or more of the weight of most papers. Rosin sizings and starch or protein adhesives also contribute to BOD loadings, as do many special organic chemicals such as wet strength resins. Some or all of these constituents, including cellulose fibers, are in the solid or precipitated state, and therefore also contribute to TSS loadings. Fillers and coating pigments such as clay and titanium dioxide are responsible for virtually no BOD, but add to TSS loadings.

Most losses from papermaking are undesirable from the economic as well as the pollution viewpoint, since they are valuable materials which could otherwise be incorporated in the sheet and sold. Data breakdowns on principal losses as listed above are not available because of sewer interconnections and reuse complications. Each item is discussed below, with estimates of such losses where available.

Excess white water results from necessary additions of fresh water to the process system. While measures are available to reduce these losses by means of savealls, as discussed in Section VII, some material inevitably escapes to sewer. The saveall effluent contains some remaining TSS, and may have significant BOD since the saveall cannot remove dissolved BOD. Centrifugal

Table 49

ESTIMATED WATER USAGE FOR FOURDRINIER MACHINES

SUBCATEGORY	MILL CODE	THOUSAND GALLONS PER TON		
		WHITE WATER	FRESH WATER	TOTAL
Groundwood	007		3.2	3.2
	012	2.0	0.8	2.8
	013	(some)	1.3	1.3+
	014		2.7	2.7
Sulfite	050		2.2	2.2
	053		32	32
	056		10	10
Bleached Kraft	105	3.9	2.6	6.5
	124		2.2	2.2
	125	1.8	1.8	3.6
	126	0.5		0.5
Soda	151	1.0	0.4	1.4
Deink	205	6.8	7.2	14
	207			5.5
Non-Integrated Fine Papers	250		1.2	1.2
	252	5.8	0.2	6.0
	257	4.3	4.3	8.6
	261			2.7
	262		1.0	1.0
	265	3.0	6.8	9.8
	267		12	12
Non-Integrated Tissue Papers	300			10
	305		90	90
	309			18
	310		6.3	6.3
	312	5.0	(some)	5.0+
Non-Integrated Coarse Papers	351	5.4		5.4
	353		14	14

cleaner rejects are reduced to approximately 0.1-1.0 percent of production, but nevertheless represent a significant source of TSS loss. Rejects also contain significant BOD. Felt and wire cleaning waters are frequently diverted to sewer, and usually contain only minor loadings of TSS and BOD.

Non-equilibrium losses can be very significant. Generally, one-quarter to one-half of total paper mill BOD and TSS loadings are due to these losses which are related to production upsets due to machine startups, shutdowns, and washups, dumping of tank remnants at end of runs, electrical and steam outages, and equipment failure. Because of interconnected sewers, data breakdowns within the above list are not available.

A special effort was made at surveyed mills to obtain estimates of nonequilibrium losses, since these may have a significant surge impact upon treatment facilities. Few data were available, however. Those obtained are shown in Table 50.

Water is used to cool condensate from paper machine steam-heated dryers. This use may account for 8.3 to 16.6 cu. m per kkg (2000 to 4000 gal/ton). In addition, water is used to cool gear boxes, brake drums, lubricating oil systems, bearings, and other miscellaneous equipment. Mills which generate electricity from steam may use large volumes of water for condenser cooling. These are normally discharged separately and not admitted to process sewers or treatment facilities. Normally fresh water is used for cooling to minimize fouling problems on heat exchangers and because it is the lowest temperature water available. Several mills collect the major cooling water effluents to supplement fresh water process needs. Cooling waters rarely contain significant loadings of BOD or TSS.

Boiler blowdowns and other miscellaneous discharges also rarely contain significant amounts of BOD and TSS. Phosphates used in boiler water treatment and discharged in the blowdowns are beneficial to biological treatment systems as a partial source of phosphorus nutrient. Data for papermaking operations of mills surveyed in integrated -- i.e., pulping subcategories -- have been presented above. It is probably that these losses are not completely representative, however, since some pulp mill losses may be included. On the other hand, some papermaking white waters may be returned to the pulp mill and therefore not b represented as papermaking losses.

Table 50

ESTIMATED NON-EQUILIBRIUM PAPERMAKING LOSSES

SUBCATEGORY	MILL CODE	START UP BOD_5	START UP TSS	SHUTDOWN BOD_5	SHUTDOWN TSS
Groundwood	010		0.25(0.5)-2		0.25(0.5)-8
	012			(5.5)11	11(22)
	014				4.5(9)
Sulfite	052				
Bleached Kraft	101				1.5(3)-36
	102				2.25(4.5)-2
	107			1(2)	4(8)
	113		4.5(9)-208		4.5(9)-208
	116	0.35(0.7)-1248	0.65(1.3)-1248	0.65(1.3)-1248	1.3(2.6)-1248
	119				12(24)
	121		0.3(0.6)		0.65(1.3)
	126	1.5(3)	1.5(3)	1.5(3)	1.5(3)
Soda	151			1.05(2.1)	0.65(1.3)
	152	0.6(1.2)-12	1.2(2.4)-12	1.6(3.2)-6	3.5(7.1)-6
Deink	204				20(40)-26
	205				2.5(5)-24
Fine Paper	261				
	266			2.15(4.3)-104	4.3(8.6)-104
	267				9(18)-52
Tissue	306				
	308				1.45(2.9)-26
	315	2.45(4.9)-1	4.9(9.8)-1	2.45(4.9)-1	4.9(9.8)-1
Coarse Paper	353		15.5(31)-365		8(16)-365
	360			0.8(1.6)	0.1(0.2)

NOTE: Numbers following hyphen indicate estimated number of occurrences per year.

Table 50 Cont'd.

SUBCATEGORY	MILL CODE	GRADE CHANGE BOD_5	GRADE CHANGE TSS	WIRE CHANGE BOD_5	WIRE CHANGE TSS
Groundwood	010				0.15(0.3)-45
	012	.5.5(11)-224	11(22)-224	5.5(11)-33	11(22)-33
	014				
Sulfite	052		15(30)-120		
Bleached Kraft	101				1.5(3)-6
	102				0.9(1.8)
	107				
	113				4.5(9)-5
	116	0.85(1.7)-288	1.75(3.5)-288	0.65(1.3)-36	1.3(2.6)-36
	119				
	121				0.65(1.3)
	126			1.5(3)	1.5(3)
Soda	151	0.4(0.8)	0.55(1.1)		
	152	1.2(2.4)-52	2.4(4.8)-52	1.2(2.4)-12	24(48)-12
Deink	204				
	205				
Fine Paper	261		9(18)		2.25(4.5)-2
	266	4.3(8.6)-1095	8.5(17)-1095		
	267		9(18)-104		
Tissue	306				
	308		4.15(8.3)-52		1.45(2.9)-6
	315				
Coarse Paper	353		8(16)-365		5.5(11)-9
	360			0.8(1.6)	0.1(0.2)

NOTE: Numbers following hyphen indicate estimated number of occurrences per year.

Table 50 Cont'd.

SUBCATEGORY	MILL CODE	WASHUP BOD_5	WASHUP TSS
Groundwood	010		0.05(0.1)-310
	012	5.5(11)-248	11(22)-248
	014		2.5(5)-100
Sulfite	052		
Bleached Kraft	101		1.5(3)-36
	102		
	107		
	113		
	116		
	119		
	121		3.75(7.5)
	126	1.5(3)	1.5(3)
Soda	151		
	152	0.6(1.2)-52	2.0(4.0)-52
Deink	204		
	205		
Fine Paper	261		
	266		
	267		
Tissue	306	0.05(0.1)-52	0.3(0.6)-52
	308		1.45(2.9)-26
	315		
Coarse Paper	353		5.5(11)-35
	360	0.35(0.7)	0.05(0.1)

NOTE: Numbers following hyphen indicate estimated number of occurrences per year.

DEVELOPMENT OF SUBCATEGORY RAW WASTE LOADS

The development of the raw waste loads (RWL) for the non-integrated paper mill subcategories is discussed below. The resultant raw waste loads were used in developing effluent limitations for each subcategory and in determining the costs presented in Section VIII.

Non-Integrated Fine Papers Subcategory

The raw waste loads on the surveyed non-integrated fine paper mills are shown in Table 51. The mills included in Table 51 produce fine papers with the percentage of clays and fillers shown. As shown the flow ranges from 25.8 to 137.6 kl/kkg (6.2 to 33.0 kgal/ton) with an average of 63.4 kl/kkg (15.2 kgal/ton). The BOD_5 RWL has a range from 7.15 to 19.15 kg/kkg (14.3 to 38.3 lbs/ton) with an average of 10.75 kg/kkg (21.5 lbs/ton). The TSS RWL has an average of 30.8 kg/kkg (61.6 lbs/ton).

Non-Integrated Tissue Papers Subcategory

Information and data on the surveyed non-integrated tissue mills are shown in Appendix 8 and summarized in Table 52. Table 52 is divided into two groups of mills, one using 100% purchased pulp and the other using varying percentages of purchased pulp and waste paper. The averages for each group show no difference in effluent flow volumes with a slightly higher BOD_5 RWL for mills using some waste paper. the flow, BOD_5, and TSS RWL for the NI tissue subcategory are, as shown in Table 52, 95.9 kl/kkg (22.9 kgal/ton), 11.55 kg/kkg (23.1 lbs/ton), and 34.05 kg/kkg (68.1 lbs/ton), respectively. Consideration was given to subcategorizing on the basis of waste paper usage because of the slightly higher RWL attributed to mills using waste paper. Evaluation of final effluent data following external treatment showed that similar final effluent characteristics could be achieved by similar treatment systems for mills using varying percentages of purchased pulp and waste paper and thereby further subcategorization was not warrented. However, mills using 100% waste paper showed significantly higher external treatment effluent characteristics due to increased proportions of soluble BOD_5 in the waste water. Thus, a separate subcategory was established for mills using 100% waste paper to produce tissue papers.

Non-Integrated Tissue Papers (fwp) Subcategory

Information and data were available from only four mills using 100% waste paper to produce tissue papers. Table 53 summarizes the RWL data for these four mills. As shown, the data is based upon very few data points except for mill 320. The average for all mills irregardless of the number of data points was 105 kl/kkg (25.2 kgal/ton) with an extremely large range of values from 27.9 to 205 kl/kkg (6.7 to 49.1 kgal/ton). Because of the large range in flow and the minimal number of data points, the flow value from NI tissue mills was used as the NI tissue (fwp)

subcategory RWL. Mills 330 and 313 both have flow values less than the NI tissue flow of 95.9 kl/kkg (23.0 kgal/ton). The BOD_5 data shown in Table 53 is also quite limited as the mills 330 and 313 only have primary treatment effluent data. A BOD_5 removal rate of 20% through primary treatment was used to calculate the BOD_5 RWL of 14.5 kg/kkg (29.0 lbs/ton). The TSS RWL was based upon NI tissue mills TSS RWL (See Table 52).

Table 51
Raw Waste Load
NI Fine Subcategory

Mill	C+F(%)	Size kkg/day(tons/day)		Flow kl/kkg(kgal/ton)		BOD_5 kg/kkg(lbs/ton)		TSS kg/kkg(lbs/ton)	
272	-	73	(80)	37.9	(9.1)	10.9	(21.8)	23.6	(47.2)N
253	5	218	(240)	77.1	(18.5)	7.3	(14.7)	31.1	(62.3)
266	9	217	(239)	49.2	(11.8)	12.8	(25.6)	22.8	(45.7)
261	9	100	(110)	26.3	(6.3)	8.6	(17.3)	22.1	(44.3)N
257	10	180	(199)	40.0	(9.6)	9.1	(18.3)	38.4	(76.8)N
255	10	57	(63)	37.9	(9.1)	-	(-)	-	(-)
250	10	84	(93)	53.8	(12.9)	-	(-)	-	(-)
276	10	48	(53)	39.2	(9.4)	19.1	(38.3)	38.4	(76.9)
281	10	330	(364)	73.0	(17.5)	-	(-)	-	(-)
275	10	373	(411)	90.5	(21.7)	-	(-)	-	(-)
27[illegible]	10	18	(20)	108.0	(25.9)	11.3	(22.7)	31.0	(62.0)
265	12	415	(458)	69.2	(16.6)	11.2	(22.4)	29.2	(58.4)N
284	15	339	(374)	25.8	(6.2)	7.6	(15.2)	30.3	(60.7)
402	15	269	(297)	57.5	(13.8)	7.5	(15.0)	43.5	(87.1)
269	20	101	(111)	99.7	(23.9)	-	(-)	18.2	(36.4)
277	20	573	(632)	80.5	(19.3)	16.1	(32.3)	123.5	(247)N
279	25	561	(618)	37.5	(9.0)	-	(-)	-	(-)
274	25	18	(20)	137.6	(33.0)	7.1	(14.3)	-	(-)
Average				63.4	(15.2)	10.7	(21.5)	30.8	(61.6)

Table 52

RAW WASTE LOAD
NI TISSUE SUBCATEGORY

Mill	Manufacture (%) CP	NP	Size kkg/day (tons/day)		Flow kl/kkg (kgal/ton)		BOD_5 kg/kkg (lbs/ton)		TSS kkg/kkg (lbs/ton)	
301	100	0	141	(156)	115.5	(27.7)	16.7	(33.4)	30.1	(60.3)
326	100	0	111	(122)	130.9	(31.4)	-	(-)	-	(-)
314	100	0	113	(125)	140.5	(33.7)	-	(-)	-	(-)
315	100	0	926	(1021)	66.3	(15.9)	8.7	(17.4)	25.7	(51.5)N
303	100	0		(*)	43.4	(10.4)	-	(-)	-	(-)
282	100	0		(*)	47.9	(11.5)	-	(-)	-	(-)
319	100	0	20	(22)	120.1	(28.8)	7.3	(14.7)	35.8	(71.7)N
Average					95.1	(22.8)	10.9	(21.8)	30.1	(60.3)
308	60	40	94	(104)	61.3	(14.7)	22.8	(45.7)**	72	(145)**
329	62	38	67	(74)	153.9	(36.9)	-	(-)	-	(-)
302	65	35	235	(226)	50.9	(12.2)	11.7	(23.5)	36.6	(73.3)N
310	70	30	42	(46)	96.7	(23.2)	7.4	(14.8)	22.4	(44.8)
324	70	30	258	(285)	97.2	(23.3)	15.9	(31.8)	35.6	(71.2)N
313	70	30	71	(78)	150.5	(36.1)	10.0	(20.0)	10.4	(20.9)N
304	70	30	229	(253)	94.6	(22.7)	13.6	(27.3)	51.5	(103)
309	80	20	18	(20)	69.6	(16.7)	14.6	(29.3)	25.2	(50.4)N
330	80	20	148	(163)	133.4	(32.0	-	(-)	-	(-)
239	85	15	176	(194)	73.8	(17.7)	9.6	(19.2)	32.1	(64.3)
325	-	-	59	(65)	72.5	(17.4)	-	(-)	-	(-)
Average					95.9	(23.0)	11.3	(23.7)	35.3	(70.7)
Average (for all mills)					95.5	(22.9)	11.5	(23.1)	34.0	(68.1)

*Trade Secret
**Not included in subcategory average

TABLE 53
RAW WASTE LOADS
NI TISSUE (HYP) SUBCATEGORY

Mill	Production kkg/day(tons/day)	FLOW-NOV* kl/kkg(kgal/ton)	BOD5 kg/kkg(lbs/ton)	TSS kg/kkg(lbs/ton)
330	18 (20)	79.2 (19.0)-NA	11.6 (23.2)**	- -
320	60 (66)	109.0 (26.1)-3	13.0 (26.0)	88.0 (176)
313	34 (37)	27.9 (6.7)-345	11.5 (23.0)**	- -
312	14 (15)	205.0 (49.1)-29	- -	133.0 (266)

*NOV=Number of Values reported
**Primary treatment effluent

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

WASTE WATER PARAMETERS OF SIGNIFICANCE

A thorough analysis of the literature, mill records, sampling data which has been derived from this study, and the NPDES data demonstrate that the following constituents represent pollutants according to the Water Pollution Control Act for the subcategories under study:

BOD_5
Total Suspended Solids
pH
Color (Not including Groundwood, Deinked, and Non-Integrated subcategories)
Ammonia Nitrogen (Ammonia base Sulfite and Ammonia Base Dissolving Sulfite only)
Zinc (Groundwood subcategories only)

Selection of Pollutant Parameters

The U.S. Environmental Protection Agency published (Federal Register, Volume 38, No. 199, pp. 28758-28670, October 16, 1973) 40 CFR 136 "Guidelines Establishing Test Procedures for the Analysis of Pollutants." Seventy-one pollutant parameters were covered. This list with the addition of pH, which was not included, provides the basis for the selection of pollutant parameters for the purpose of developing effluent limitations and standards. All listed parameters are selected except for those excluded for one or more of the following reasons:

1. Not harmful when selected parameters are controlled
2. Not present in significant units
3. Not controllable
4. Control substitutes a more harmful pollutant
5. Insufficient data available
6. Indirectly controlled when selected parameters are controlled.
7. Indirectly measured by another parameter

Biochemical Oxygen Demand (BOD)

Two general types of pollutants can exert a demand on the dissolved oxygen regime of a body of received water. These are: (1) chemical species which exert an immediate dissolved oxygen demand (IDOD) on the water body due to chemical reactions; and (2) organic substances which indirectly cause a demand to be exerted on the system because indigenous microorganisms utilizing the organic wastes as substrate flourish and proliferate; their natural respiratory activity utilizing the surround dissolved oxygen.

The biological oxygen demand is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The term "decomposable" may be interpreted as meaning that the organic matter can serve as food for the bacteria and energy is derived from this oxidation.

The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Organic effluents exert a BOD during their processes of decomposition which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and less able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration or blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

The BOD5 test is widely used to determine the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into natural watercourses in which aerobic conditions exist. The test is one of the most important in stream pollution control activities. By its use, it is possible to determine the degree of pollution in streams at any time. This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacities of receiving bodies of water.

The BOD5 test is essentially a bioassay procedure involving the measure of oxygen consumed by living organisms while utilizing the organic matter present in a waste under conditions as similar as possible to those that occur in nature. The problem arises when the test must be standardized to permit its use (for comparative purposes) on different samples, at different times, and in different locations. Once "standard conditions" have been defined, as they have (Standard Methods , 1971) (191) for the BOD5 test, then the original assumptions that the analysis simulated natural conditions in the receiving waters no longer applies, except only occasionally.

In order to make the test quantitative the samples must be protected from the air to prevent reaeration as the dissolved oxygen level diminishes. In addition, because of the limited solubility of oxygen in water (about 9 mg/l at 20°C), strong wastes must be diluted to levels of demand consistent with this value to ensure that dissolved oxygen will be present throughout the period of the test.

Since this is a bioassay procedure, it is extremely important that environmental conditions be suitable for the living organisms to function in an unhindered manner at all times. This requirement means that toxic substances must be absent and that accessory nutrients needed for microbial growth (such as nitrogen, phosphorus and certain trace elements) must be present. Biological degradation of organic matter under natural conditions is brought about by a diverse group of organisms that carry the oxidation essentially to completion (i.e., almost entirely to carbon dioxide and water). Therefore, it is important that a mixed group of organisms commonly called "seed" be present in the test.

The BOD5 test may be considered as a wet oxidation procedure in which the living organisms serve as the medium for oxidation of the organic matter to carbon dioxide and water. A quantitative relationship exists between the amount of oxygen required to convert a definite amount of any given organic compound to carbon dioxide and water which can be represented by a generalized equation. On the basis of this relationship it is possible to interpret BOD5 data in terms of organic matter as well as in terms of the amount of oxygen used during its oxidation. This

concept is fundamental to an understanding of the rate at which BOD_5 is exerted.

The oxidative reactions involved in the BOD_5 test are results of biological activity and the rate at which the reactions proceed is governed to a major extent by population numbers and temperature. Temperature effects are held constant by performing the test at 20°C, which is more or less a median value for natural bodies of water. The predominant organisms responsible for the stabilization of most organic matter in natural waters are native to the soil.

The rate of their metabolic processes at 20°C and under the conditions of the test (total darkness, quiescence, etc.) is such that time must be reckoned in days. Theoretically, an infinite time is required for complete biological oxidation of organic matter, but for all practical purposes the reaction may be considered to be complete in 20 days. A BOD test conducted over the 20 day period is normally considered a good estimate of the "ultimate BOD." However, a 20 day period is too long to wait for results in most instances. It has been found by experience with domestic sewage that a reasonably large percentage of the total BOD is exerted in five days. Consequently, the test has been developed on the basis of a 5-day incubation period. It should be remembered, therefore, that 5-day BOD values represent only a portion of the total BOD. The exact percentage depends on the character of the "seed" and the nature of the organic matter and can be determined only by experiment. In the case of domestic and some industrial waste waters it has been found that the BOD_5 value is about 70 to 80 percent of the total BOD.

Although the amount of BOD per kkg (ton) of product in the discharge from an industrial process varies to a large degree between subcategories, and even significantly from mill to mill within a given subcategory, the waste waters can essentially be treated by the same treatment systems.

Total Suspended Solids

Suspended solids include both organic and inorganic materials. The inorganic components discharged by pulp and paper mills include sand, silt, clay and other papermaking additives. The organic fraction includes such materials as fiber and other wood components such as lignin, tannins, and sugars. These solids may settle out rapidly creating bottom deposits which often are a mixture of both organic and inorganic solids. This bottom deposit may cover the bottom of the recieving stream with a blanket of material that adversely affects the fish-food bottom fauna or the spawning ground of the fish.

The organic fraction of this bottom deposit will have several adverse effects. It will exert an oxygen demand depleting the available supply of oxygen. Also anoxic or anaerobic conditions may be produced which would result in dark colored areas with gas

evolution. Another factor attributable to the organic fraction is the excessive nutrient load associated with high suspended solids. This can cause aquatic vascular plants to increase to a nuisance proportions with subsequent interference with recreational opportunities, development of breeding areas for insects, and occurrence of an objectionable odor from plant decay.

The inorganic fraction of the bottom deposit has a major impact on the toxic materials concentration. Clay minerals and other inorganic particles have the ability to adsorb materials and hold them tightly. When toxins are present they will be adsorbed to the inorganics and an increase in the concentration of dissolved toxic materials will be realized due to existing waste discharges.

Of special interest is the BOD or oxygen demand exerted due to the microbial floc which are discharged from secondary treatment facilities. The microbial solids in secondary effluent are not inert and will exert an oxygen demand as the microbes continue to metabolize. The predominant metabolic reaction is endogenous respiration which exerts the remaining oxygen demand. The endogenous oxygen demand is exerted at a slow, continuing rate. The traditional five day BOD test will not provide a complete estimate of the total demand of the solids. The total oxygen demand will be exerted after a long period of time and hence a long term BOD test is necessary to obtain a reasonable estimate of such a demand. Therefore it is in the best interest of the receiving water to reduce the suspended solids level of a discharge to as low a level as possible.

State and regional agencies generally specify that suspended solids in raw water sources for domestic use shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may also interfere with many industrial processes and thus necessitate more extensive treatment before use. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles. While in suspension, they increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

This parameter is a measure of nondissolved solids in the waste water which are trapped or "suspended" on a test filter medium. Total suspended solids are divided into settleable and nonsettleable fractions, the former being those solids which will settle in one hour under quiescent conditions. Pulp and paper mill effluents are normally analyzed for total suspended solids.

Most suspended solids of mill origin can be removed by proper treatment, as described in Section VII. Suspended solids of biological origin which are generated by biological treatment are included in the test, but are generally more difficult to remove.

pH

The term pH is a negative logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the "taste" of the water. The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous in providing safe drinking water to keep the pH close to 7. Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in pH. For example, ammonia is more lethal with a higher pH.

As shown in Section VII, the pH of biologically treated wastes is normally within the 6.0 to 9.0 range, which is not detrimental to most receiving waters.

Color

Color is defined as either "true" or "apparent" color. In Standard Methods for the Examination of Water and Wastewater (191), the true color of water is defined as "the color of water from which the turbidity has been removed." Apparent color includes "not only the color due to substances in solution, but also due to suspended matter." In the various chemical pulping processes, lignin and lignin derivatives are solubilized and removed from the wood during the cooking process. The spent cooking liquors containing these highly colored compounds are removed from the pulp in a washing sequence following the cooking process. The wash water is highly colored, and large amounts of color are ultimately discharged to the receiving stream despite some recovery operations.

Colored effluents may have the following detrimental effects upon receiving waters; 1) color retards sunlight transmission and may interfere with photosynthesis thereby reducing the productivity of the aquatic community; 2) natural stream color is altered, thus detracting from the visual appeal and recreational value of the receiving waters; 3) color has effects upon downstream municipal and industrial water users, such as higher water treatment costs, difficulties in water treatment, and a multitude of industrial process operating problems; 4) color bodies complex with metal ions, such as iron or copper, forming tar-like residues which remove the metals from the stock available to stream organisms for normal metabolism, and the complexes can

have direct inhibitory effects on some of the lower scale of organisms in the aquatic community and thereby reduce the productivity of the receiving water; 5) color, derived from lignin, is an indicator of the presence of potentially inhibitory compounds and in addition may have direct inhibitory effects upon some of the lower scale organisms in the food chain, 6) color in receiving waters may affect fish movements and fish productivity, 7) color bodies exert a long term BOD (20-60 days up to 100 days) not measured by the BOD_5 test.

Ammonia

Ammonia is a common product of the decomposition of organic matter. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. In more natural water the pH range is such that ammonia ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of non-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions.

Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrates are considered to be among the objectionable ingredients of mineralized waters, with potassium nitrate being more deleterious than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease charecterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants. Ammonia can also exist in several other chemical combinations including ammonium chloride and other salts. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products.

Pulp and papermaking waste flows normally contain only minor concentrations of this nutrient, and nitrogen compounds must often be added to provide desired biological waste treatment efficiencies. As a result, effluent limitations on nitrogen are not considered necessary except for ammonia base sulfite and ammonia base dissolving sulfite mills.

Insufficient data exists to determine representative ammonia nitrogen levels discharged by these mills, but sparse data indicate that their effluents contain 1 to 3 kg/kkg (2 to 6

lb/ton). No technology is currently available or anticipated for 1983 for removing ammonia nitrogen at the flows and concentrations found in these effluents.

Zinc

Occurring abundantly in rocks and ores, zinc is readily refined into a stable pure metal and is used extensively for galvanizing, in alloys, for electrical purposes, in printing plats, for dye-manufacture and for dyeing processes, and for many other industrial purposes. Zinc salts are used in paint pigments, cosmetics, pharmaceuticals, dyes, insecticides, and other products too numerous to list herein. Many of these salts (e.g., zinc chloride and zinc sulfate) are highly soluble in water; hence it is to be expected that zinc might occur in many industrial wastes. On the other hand, some zinc salts (zinc carbonate, zinc oxide, zinc sulfide) are insoluble in water and consequently it is to be expected that some zinc will precipitate and be removed readily in most natural waters.

In zinc mining areas, zinc has been found in waters in concentrations as high as 50 mg/l. In most surface and ground waters, it is present only in trace amounts. There is some evidence that zinc ions are adsorbed strongly and permanently on silt, resulting in inactivation of the zinc.

Concentrations of zinc in excess of 5 mg/l in raw water used for drinking water supplies cause an undesirable taste which persists through conventional treatment. Zinc can have an adverse effect on man and animals in high concentrations.

In soft water, concentrations of zinc ranging from 0.1 to 1.0 mg/l have been reported to be lethal to fish. Zinc is thought to exert its toxic action by forming insoluble compounds with the mucous that covers the gills, by damage to the gill epithelium, or possibly by acting as an internal poison. The sensitiviity of fish to zinc varies with species, age and condition, as well as the physical and chemical characteristics of the water. Some acclimatization to the presence of zinc is possible. It has also been observed that the effects of zinc poisoning may not become apparent immediately, so that fish moved from zinc-contaminated to zinc-free water (after 4-6 hours of exposure to zinc) may die 48 hours later. The presence of copper in water may increase the toxicity of zinc to aquatic organisms, but the presence of calcium or hardness may decrease the relative toxicity.

Observed values for the distribution of zinc in ocean waters vary widely. The major concern with zinc compounds in marine waters is not one of acute toxicity, but rather of the long-term sub-lethal effects of the metallic compounds and complexes. From an acute toxicity point of view, invertebrate marine animals seem to be the most sensitive organisms tested. The growth of the sea urchin, for example, has been retarded by as little as 30 ug/l of zinc.

Zinc sulfate has also been found to be lethal to many plants, and it could impair agricultural uses.

RATIONALE FOR PARAMETERS NOT SELECTED

Settleable Solids

Settleable solids are a measure of that fraction of suspended solids which settles after one hour in a quiescent vessel. While a few mills have measured settleable solids, reliable data are not generally or widely available. Since settleable solids are measured as a part of the suspended solids, settleable solids are not considered a separate pollutant.

Turbidity

Turbidity is an expression of the optical property of the fine suspended matter in a sample of water. The suspended matter may be clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. The suspended matter causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Turbidity is in part measured by the total suspeneded solids test and thereby, turbidity is not considered as a separate pollutant.

Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) represents an alternative to the biochemical oxygen demand, which in many respects is superior. The test is widely used and allows measurements of a waste in terms of the total quantity of oxygen required for oxidation to carbon dioxide and water under severe chemical and physical conditions. It is based on the fact that all organic compounds, with a few exceptions, can be oxidized by the action of strong oxidizing agents under acid conditions. Although amino nitrogen will be converted to ammonia nitrogen, organic nitrogen in higher oxidation states will be converted to nitrates that is, it will be oxidized.

During the COD test, organic matter is converted to carbon dioxide and water regardless of the biological assimilability of the substances; for instance, glucose and lignin are both oxidized completely. As a result, COD values are greater than BOD values and may be much greater when significant amounts of biologically resistant organic matter is present.

One drawback of the COD test is its inability to demonstrate the rate at which the biologically active material would be stabilized under conditions that exist in nature.

Another drawback of the chemical oxygen demand is analogous to a problem encountered with the BOD also; that is, high levels of chloride interfere with the analysis. Normally, 0.4 grams of mercuric sulfate are added to each sample being analyzed for

chemical oxygen demand. This eliminates the chloride interference in the sample up to a chloride level of 40 mg/l. At concentrations above this level, further mercuric sulfate must be added. However, studies by the National Marine Fisheries Service Technological Laboratory in Kodiak, Alaska, have indicated that above certain chloride concentrations the added mercuric sulfate itself causes interference.

The major advantage of the COD test is the short time required for evaluation. The determination can be made in about 3 hours rather than the 5 days required for the measurements of BOD. Furthermore, the COD requires less sophisticated equipment, less highly-trained personnel, a smaller working area, and less investment in laboratory facilities. Another major advantage of the COD test is that seed acclimation need not be a problem. With the BOD test, the seed used to inoculate the culture should have been acclimated for a period of several days, using carefully prescribed procedures, to assure that the normal lag time (exhibited by all microorganims when subjected to a new substrate) can be minimized. No acclimation, of course, is required in the COD test.

The relationship between COD and BOD_5 before treatment is not necessarily the same after treatment. Therefore, the effluent limitations will include the BOD_5 parameter, since insufficient information is available on the COD effluent levels after treatment.

Coliform Organisms

The fecal coliform test is the most valid microbiological parameter for pulp and paper effluents presently available. The excessive densities of fecal coliforms and more specifically, Klebsiella pneumoniae, as measured by the fecal coliform test, in pulp and paper mill effluents are significant. Klebsiella can complicate E. coli detection, they can be pathogenic, and they are coliforms by definition. In addition, Klebsiella are found in the intestinal tract of approximately 30% of humans and 40% of animals. Klebsiella reflect the high nutrient levels in pulp and paper mill wastes. With adequate treatment for reduction of nutrients, densities of Klebsiella and also total coliforms should be significantly reduced.

A geometric mean density of fecal coliforms of 1000/100mls or less is generally indicative of adequate treatment.

Resin Acids

Soaps of resin acids (isopimaric, abietric, and dehydroabietric) have been identified as causing biologically deleterious effects in kraft mill effluents. Studies in Canada indicate that these compounds are contained mainly in combined condensates rather than black liquor. The most recent studies indicate that a reduction in adverse effects can be achieved by a well designed and operated biological treatment system. This parameter is not considered as a separate pollutant parameter for any of the subcategories because adequate biological treatment systems generally will reduce resin acids.

Polychlorinated Biphenyls

Polychlorinated biphenyls (PCB's) are chemically and thermally stable compounds found in paper and paperboard manufacture and are known to cause deleterious effects upon biological organisms. Exposure to PCB is known to cause skin lesions and to increase liver enzyme activity that may have a secondary effect on reproductive processes. It is not clear whether the effects are due to the PCB's or their contaminants, the chlorinated dibenzofurans, that are very harmful, while chlorinated dibenzofurans are a byproduct of BCP production, it is not known whether they are also produced by the degradation of PCB's. They have been shown to concentrate in food chains and few restrictions for their control exist at present. Recycled office papers are the main source in the paper industry at present, although occasionally paperboard extracts show evidence of Monsanto's Aroclor 1254 (PCB) from environmental and other sources. Quantities of PCB in recycled paper are generally between 1 and 10 mg/l, but may be more or less.

Heavy Metals

"Heavy metals occur in paper mill effluents as corrosion products, contaminants of bleach chemicals and caustic solutions and as a result concentrating trace metals in cooking and recycle operations. However, with the gradual discontinuation of zinc hypochlorite bleaching chemicals, gradual increase use of non-metallic wires, and high corrosion resistant materials in other areas, the discharge of heavy metals by the industry is being minimized. The limited data available indicates that concentrations of heavy meatals being discharged should have a minimum effect on most receiving streams. Therefore, heavy metals were not selected as parameters of significance. Where problems with water quality of receiving streams may occur, however, heavy metals should be considered.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGIES

The pollution loads of effluents discharged to receiving waters from all subject subcategories can be reduced to required levels by conscientious application of established in-plant process controls and water recycle measures together with well designed and properly operated external treatment facilities.

This section describes both the internal and external technologies which are either presently available or under intensive development to achieve various levels of pollutant reduction for each of the subcategories. In some cases "in-plant" and "external" technologies merge. For example, a mill may employ extensive suspended solids removal equipment internally, reusing the clarified water in the process and the recovered solids in the product, whereas another similar mill may depend to a greater extent on "external" suspended solids removal to arrive at a similar end point.

Tables 54 and 55 summarize present use of alternative internal and external technologies among the mills surveyed. The percentage of use of the internal methods by the surveyed mills can be expected to be representative of the degree of utilization by all mills in a subcategory. The use of various external treatment technologies in each subcategory is discussed more specifically later in this section.

In those discussions, and in the internal control subcategory discussions, where numbers of mills are given by type of pulp produced, these numbers refer to the mills assigned to that particular subcategory according to the criteria discussed in Section III. This is done to eliminate the duplication of mills which would occur if complex pulping operations were reported in more than one subcategory.

Present control and treatment technology precludes zero discharge of pollutants in virtually all subcategories although a few non-integrated paper mills have approached this goal. As discussed in Section V, significant water use reductions have occurred in every subcategory during recent years and new means are continually being found for increased water reuse.

The products manufactured are a crucial determinant in the degree of recycle possible for a given operation (181). For example, in contrast to the non-integrated papermaking operations mentioned above, there is no proven combination of systems by which bleached kraft and other chemical pulp mills can be designed and operated at zero discharge on a continuous basis (182). One of the surveyed paper mills, on the other hand, has no pulping capacity and produces less than 18.14 kkg/day (20 tpd) of coarse toweling paper, a product whose specifications permit complete

Table 54

INTERNAL MEASURES USED AT SURVEYED MILLS

	SUBCATEGORY																	
	GWD		BK		BO		S		DS		D		F		T		C	
Number of Mills	14		26		3		4		4		9		17		16		9	
Percent Used*	S	E	S	E	S	E	S	E	S	E	S	E	S	E	S	E	S	E
Knots collecting and disposal	7	22	46	23	33	34		50										
Fourth stage brown stock washer		14	38	62	34	66	50	25		50	11	56						
Decker filtrate for stock washer showers		14	38	62	34	66	50	25		50	11	56						
Pulp mill spill collection			27	19	33	34	50	25			22	34						
Jump stage countercurrent washing in bleach plant			76	12	100		50	25	100			34						
Evaporators boil out tank			31	31		34												
Liquor storage tank spill collection			27	19	33	34	50	25										
Reuse of blow steam & evaporators condensate			54	27	33	34												
Green liquor dregs filtering			46	24	33	34												
High level alarms for chemical tanks			27	19	33	34	50	25			22	34						
Hot water collection and reuse	43	21	62	30	66	34	75	25	50	50	22	44	56	17	31	25		22
Paper machine saveall	14	43	23	62	34	66	50	50	25		22	44	50	39	25	69	33	22
Paper machine high pressure showers			8	11	33	34	50		75		34	22		6	24	38	11	33
Paper machine white water showers	58	35	54	46	34	66	50	50	100		34	66	67	27	38	62	56	33
Vacuum pump seal water reuse	7	7	19	19	34				75		44	44	28	16	18	44	11	33
Cooling water segregation and reuse	7	7			34				75		44	44	28	16	18	44	11	33
Felt hair removal	7	7	19	19	34				75		44	44	28	16	18	44	11	33
Sulfite liquor recovery or incineration							50		25									

* % S = % of Mills using to some degree
% E = % of Mills using to an extensive degree

Table 55

EXTERNAL MEASURES USED AT SURVEYED MILLS

	SEGMENT													
	GWD		BK		SO		S		D		F		T	
Number of Mills	19		36		3		11		15		21		25	
Number and percent used*	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Bar screen														
Continuous sampler flow measurement														
Primary clarifier	19	100	36	100	3	100	11	100	11	73	13	62	25	100
Earthen settling basin	9	47	10	28			2	18	1	7	8	38	12	48
Air flotation	1	5					4	36	1	7	1	5	9	36
Activated sludge	3	16	4	11			1	9	1	7	1	5	1	4
Aerated stabilization basin	5	26	35	97	1	33	5	45	5	33	3	14	3	12
Secondary clarifier	2	11	3	8										
Mechanical dewatering							1	9	1	7	1	5		
Sludge press							1	9						
Incineration							1	9						
Landfill														
Sludge lagoon														
Post storage			21	58			5	45	1	7	1	5	2	8
Mixed media filtration														
Sludge lagoon (emergency)														
Trickling filter	1	5			1	33								
Spray irrigation							1	9			3	14		
Thickeners														
Sludge dryers														

*Additional Deink Mills which manufacture news not included.

recycle of process water. Another mill, producing 36.28 kkg/day (40 tpd) of tissue, accomplishes zero discharge by clarifying and filtering white water for use as paper machine showers and seal water, although some white water is directly recycled for stock preparation and dilution. This is economic for this small mill because of its product and size in relation to its arid geographic location.

It is also a much simpler system than would be required for chemical pulp and fine paper mills. This is especially true where there are numerous changes in product grades, a situation where there presently appears no way that high levels of reuse can be consistently achieved (181).

The difficulties encountered by mills in all subcategories as a result of extensive recirculation are discussed in more detail later in this section.

Briefly, in addition to variable product quality, they include scaling, corrosion, foaming, slime deposits, paper formation problems, and decreasing wet felt life. Perhaps the most significant factor is that recycle processes tend to concentrate wastes and the concentrates still require disposal. In order to burn this material, and thus convert it to gases, it must be evaporated in most experimental zero discharge technology. Evaporation requires cooling, cooling at these temperatures requires water, and recycling the water will necessitate heat removal (183). These processes in turn will increase power requirements.

INTERNAL TECHNOLOGIES

General

Internal control measures are procedures to reduce pollutant discharges at their origin, some of which result in the recovery of chemicals, fiber, and by-products and in conservation of heat and water. Similar methods are available to all subject subcategories and include, where applicable, effective pulp washing, chemical and fiber recovery, treatment and reuse of selected waste streams, collection of spills, and prevention of accidental discharges. New processes to reduce pollutant loads are continually being developed and are being incorporated into new mills and, where feasible are being retrofitted into existing mills.

Generally, mills which reduce raw waste loads concomitantly reduce effluent flow through recycle.

A waste management program should include control of losses which occur when the production process is not in equilibrium such as spills, overflow, and wash-up. These losses may account for one-third to one-half of the suspended solids and BOD_5 of the raw waste and can result from a variety of factors, as discussed in

Section V. These include breakdown of equipment, routine maintenance, planned shutdowns and startups, power failures, and grade changes. Where as mill production operations may be regarded as a continuous sequential balanced series of unit operations, in fact there exists a discontinuity in practice making spills, overflows, and accidental discharges a common problem as regards both internal control and influences on external waste treatment facilities. Continuous monitoring within mill sewers (especially conductivity) should be employed to give immediate warning of unknown spills so that corrective action can be taken promptly. Personnel should be trained to respond with immediate remedial procedures in addition to avoiding such spills where possible. In some instances automatic diversion devices operated by conductivity measuring instruments are employed.

Good practice also includes the use of storage facilities adequately sized to avoid overflows of spent liquor and recovering plant chemicals in approximately 90 percent of process upsets. Provision should be made to return these stored materials to the originating subprocess at a later time.

If overflows would cause treatment plant upset or increased discharge of pollutants, production should be curtailed as necessary if the overflows cannot be prevented by some other means. Sewer segregation can be utilized, especially in new mills, to minimize these impacts, in conjunction with adequate storage.

Storage lagoons located prior to treatment may be provided to accept longer term shock loads, the contents of which can then be gradually returned to the process or diverted to treatment without detriment to treatment operations. Provision of storage lagoons also provides some period of time to correct malfunction of external treatment operations or offers temporary facilities for solids sedimentation if properly designed to satisfy such uses.

A storage tank should also be provided to contain material flushed from the evaporators during periodic "boil out," a maintenance procedure to remove scale and incrustations which interfere with efficient evaporator operation. This material can then be slowly returned to the process when it is again in operation.

Fresh water used to cool bearings, variable speed couplings, brake linings in paper rewind applications, and similar areas throughout a mill can be collected and reused. It is not contaminated and can be recycled either directly after heat removal or indirectly by discharge into the fresh water system if heat buildup is not a problem.

Water used to cool condensate from steam dryers can similarly be reused but because of high heat loads it is usually necessary to cool this water with cooling towers or other means. It is

practical in some cases to return dryer condensate directly to the feed water heater at the boiler plant under 1.2 - 1.34 atm pressure (3-5 psig pressure), thereby reducing the cooling water requirement. This approach is more feasible where dryers are operated at pressures above 1.34 atm (5 psig). While a reduction in cooling water discharge does not minimize the pollutant load, it does reduce the total volume of waste water to be treated, thus decreasing the capital and, in some instances, operating cost of waste treatment facilities.

Seal water is used on packing glands of process pumps, agitators, and other equipment employing rotating shafts. It cools bearings, lubricates the packing, and minimizes leakage of the process fluid. Even though the amount of water used per packing is small -- generally in the range of 2 to 11 l/min (0.5 to 3 gpm) -- the total utilized is quite extensive because of the large number of rotating shafts involved and may approximate 4173-8346 l (1000-2000 gal) per kkg (ton) of product. Methods used to reduce quantities of water required include proper maintenance of packings and flow control of individual seal water lines. In some cases, seal water which leaks from the packing can be collected and reused, usually after filtering.

As discussed in Section III, barking of wood prior to pulping is most commonly performed by dry processes which require very little water. This practice is more desirable than wet barking since raw waste loadings are considerably reduced. The small amounts of effluent from dry barking are preferably settled and recycled but are normally disposed of on the land or combined with the general flow of mill effluent.

Reduction of waste loads from wet barking can be achieved through recycle of most of the barking water. If recycled water is to be used in hydraulic barking, however, a high degree of solids removal must be obtained to prevent erosion within pumps and barker nozzles.

As the forest products industry continues its trend toward maximum utilization of the tree, it is likely that more wood will be delivered as chips and less roundwood will be barked by pulp mills, thus reducing or eliminating waste water discharges from this source.

There is little documentation to quantify the magnitude of reductions in raw waste due to the application of a particular technology. However, the reduction in raw waste loads experienced over the past 10 to 15 years is attributable to the successful application of the control measures described in Table 54. This table summarizes, by percentage, the application of internal control measures in the mills surveyed. Blank spaces in this summary indicate that the particular technology is not applicable in that subcategory.

Groundwood Subcategory

Raw wastes from groundwood mills can be reduced by good housekeeping, water reuse, and recycling of screen rejects. Most of the mills studied practice good housekeeping, keeping spills to a minimum and controlling the use of gland seal water so that quantities are minimized. To the contrary, however, it was found that rejects from pulp screening are sewered in some mills. They should be passed through a reject refiner as described in Section III and returned to the process ahead of the screens.

The groundwood mills surveyed represent 40 percent of the total mills in this subcategory. Water recycle is widely practiced in integrated groundwood pulp and paper mills. More than 90 percent of the surveyed mills recycle some paper machine white water either for reuse on showers or more commonly as makeup water in the pulp mill. In some modern newsprint mills the groundwood operation is completely closed with all waste water appearing in the paper machine effluent.

Fifty-seven percent of the surveyed mills employ either vacuum or flotation savealls to reduce losses from paper machines and 64 percent collect and reuse some process hot water. Less than 10 percent of these mills are reusing vacuum pump seal water or cooling waters. A more detailed description of the technology used to reduce effluent loads from paper mills is given later in this section under Papermaking.

Steam softening is employed in some refiner groundwood mills to soften the chips sufficiently for the refiners without the expense and additional effluent involved in chemical addition such as is employed in the cold soda or chemi-groundwood processes. This steam softening does not, however, constitute thermo-mechanical pulping as described in Section III.

Total recycling of effluent has been tried in two of the chemi-groundwood mills studied. Trials have been abandoned because of the severe equipment and piping corrosion encountered. A total rebuild of the mill water system would be required using expensive corrosion resistant material throughout.

Water reuse in a bleached groundwood pulp mill is limited by brightness reversion after bleaching. Several mills report pilot studies to reduce discharge flow but no successful zero discharge processes have been developed at this stage.

Sulfite and Dissolving Sulfite Subcategories

The eight sulfite pulp mills surveyed represent 32 percent of the mills in the sulfite and dissolving sulfite subcategories and were divided equally between them. The waste load of this subcategory is being reduced through switching to kraft pulping, changing from a calcium to a soluble base and burning the liquor (with or without chemical recovery), and producing byproducts from it.

As discussed in Section V, the performance of sulfite recovery systems is less effective in reducing sewer losses than that of kraft systems because of the large quantity of acetates and formates appearing in the condensates. Although methods for the recovery of acetic and formic acid in soluble form have been developed (47) (48) (49), the market for these acids is such that it does not represent a dependable means of solving the problem of their disposal on a continuous basis for more than an occasional mill. Presently on-going research (290) involving steam stripping and activated carbon adsorption of volatiles for fractionation may produce a commercial process for removal of methanol, acetic acid and furfural from sulfite condensates. However, by pre-neutralizing the spent liquor, 90 percent of the BOD normally contained in the condensates can be retained in the liquor and ultimately burned.

At present, fifteen of the operating mills, representing approximately half the total sulfite production, burn the liquor. The continued operation of eight others for much longer is doubtful and most of the remainder are definitely committed to burning in the near future.

A total of eight mills manufacture byproducts ranging from simple evaporates used for road binder and cattle food additives to some more sophisticated formulations and intermediates used in adhesives, dispersants, tanning agents, drilling mud additives, etc. Since all of these products account for only about 10 percent of the liquor solids produced and for other reasons as well, they do not represent a complete or permanent solution to the liquor problem. Two mills produce food yeast and one mill alcohol from fermentation processes utilizing the wood sugars contained in sulfite liquors.

Two mills (95) which have converted from calcium to magnesium base and incorporated liquor recovery have achieved BOD_5 reduction of 82 and 87 percent.

Of the eight surveyed mills five are presently using liquor incineration or recovery, one disposes of its liquor by the manufacture of byproducts; and the other two are presently installing recovery systems.

The majority of sulfite and dissolving sulfite mills were found to reuse filtrates on brownstock washers. Seventy-five percent

of them have liquor and stock spill collection and storage while 50 percent utilize steam stripping and reuse of condensates.

All of the mills surveyed recirculate some white water for use on machine showers and the majority of them use high pressure showers. These mills also collect and reuse some process hot water. Paper machines in the surveyed sulfite mills all incorporate saveralls to reduce suspended solids in their effluent.

Internal technology for effluent reduction in the bleaching of sulfite pulps is included in a later section, Bleaching of Chemical Pulps.

Bleached Kraft Subcategory

In older practice, the decker filtrate accounted for a major portion of the sewer losses in bleached kraft mills. After washing, the pulp was diluted to about one percent consistency in order to promote effective screening for the removal of knots and shives. Thickening on a decker was then required to raise the consistency for storage purposes. The water removed by the decker which contained spent liquor not removed in the washing process typically accounted for one-third or more of the total BOD_5 loss from the mill. Improved washing techniques have now reduced this loss to below a third of the total loss in terms of BOD.

Attempts to apply hot stock refining to reduce the dilution requirement before screening have not been successful in bleached pulp production. Newer type deckers actually provide an additional washing stage which is beneficial to the bleaching operation and lowers the pollution load contained in the bleach plant effluent due to spent liquor carryover (297). In addition less bleaching chemical is required when the brown stock is well washed (298) (8).

While there is a potential for further reducing the pollutants in the decker filtrate by providing greater washing capacity, it has been pointed out (20) that this procedure, if carried too far, succumbs to the law of diminishing returns. Beyond a range of soda loss of 7.5 to 10 kg (15 to 20 lb) per kkg (ton) of pulp, the recovered liquor is diluted to a point where evaporation capacity and attending heat requirements exceed the benefits derived.

Digester and evaporator condensates are also recognized as principal BOD contributors to the effluent load from kraft mills. Consequently, considerable effort is expended in most kraft operations to consume as much of these condensates internally as possible by substituting them for normal fresh water make-up applications. The condensates are more frequently used in brown stock washing and in causticizing make-up. Use of condensates in

lime kiln stack scrubbers and dissolving tank make-up is also a common practice (58).

Despite the extensive condensate recycling practices, these waste streams still constitute, collectively, a serious source of air and water pollution from kraft operations. Many of the problems related to condensates evolve from the recycling practices themselves. In ideal waste recycle the waste stream would be totally consumed in the process -- i.e., the polluting materials destroyed by incineration or homogeneously assimilated into the process streams. This, of course, is not entirely the case with condensates. Since condensates in general are black liquor distillates, a large fraction of the offending chemical substances involved are volatile substances which are not amenable to the basic black liquor processing scheme. If this were not so, the materials would not have distilled during the formation of the condensate steam. Recycling the condensate may thus result in a gradual increase in the concentration of the volatiles in the process stream involved. Consequently, distillate slip streams from the process may become enriched with these volatiles to the extent that serious air and water pollution problems occur in areas where no serious problems exist without the recycling practices. The observed increase in BOD concentration of multi-effect evaporator condensate with extensive recycling of condensates to brown stock washers may serve as an example.

Recycling of condensates to the causticizing system may also result in similar problems. Elevated temperatures at the recovery dissolving tank, slaking and causticizing area, and lime kiln area may provide a means for purging recycled volatiles from condensates to the atmosphere. Since many of these volatiles are malodorous, it is obvious that the kraft mill odor problem may be greatly enhanced by the recycling practice. Normally innocuous emission sources, such as tank vents and vacuum pump exhausts, may also become fortified through extensive condensate recycling.

Extensive condensate recycling may also create operational problems. For example, the necessity for increasing wet strength additive usage has been linked to multi-effect evaporator condensate in brown stock washing. In addition, momentary black liquor carry-over in condensate streams recycled to the causticizing area may seriously disrupt the normal liquor-making process. Unquestionably, many of the side effects of the recycling practices have yet to be defined.

The condensate streams from the continuous pulping process differ markedly from those of batch operations. The continuous digester blow generally occurs at a lower temperature and pressure than that of the batch cook. Thus, the evolution of distillates in this function is inconsequential in comparison to their production by a batch counterpart. On the other hand, relief condensate, characteristic of the batch cook, does not occur as such in the continuous cook. However, condensates from continuous digester steaming vessels may be compared with batch digester relief condensate.

Methanol accounts for about 80 percent of the organic content of evaporator condensates and for most of the BOD_5 (96). Other alcohols, ketones, and small quantities of phenolic substances, sulfur compounds, and turpenes account for the remainder. Because of the odorous compounds, reuse of those condensates has been restricted by air pollution considerations. This led, about 10 years ago, to a search for technology to remove such compounds. Steam stripping of condensates has been studied extensively for this purpose (97) (98) (59) (99) and has been successfully applied at two bleached kraft mills in this country and by several abroad. Recently reported application of steam stripping technology applied to kraft condensates indicates that 75 percent of the condensate BOD_5, due principally to methanol, may be removed without difficulty and without odor problems (291).

Since methanol is readily oxidized by biological treatment there is a valid question as to whether it is more economical to remove it by stripping or in the effluent treatment plant. It is likely that the answer to this question is different from mill to mill and varies with consideration of the other materials removed, and with the relative costs of steam and electric power.

Air stripping combined with biological treatment in packed towers has been tested on a large scale (100). While this procedure is effective in achieving a measurable BOD_5 reduction it releases odorous substances into the atmosphere.

Inert materials originating in the wood and make-up chemicals must be removed from the kraft chemical recovery and cooking liquor preparation process. These are contained in the dregs settled from the green liquor and in the grits separated in the lime slaker. Separate land disposal of these materials as practiced by most mills lowers the total suspended solids content of the raw waste.

An alternative method of kraft chemical recovery is under study. This hydropyrolysis recovery process (101) subjects the black liquor to pretreatment which produces a low ash char and a liquor containing essentially all of the sodium. A standard power boiler is used to burn the char and recover its heat value and conventional recausticizing converts the liquor to white liquor. The process offers economic, environmental, and safety advantages as well as the opportunity to produce new byproducts, particularly activated carbon from the chart. A recent EPA report (292) on this work indicates development of a microlime-carbon process capable of producing an effluent from unbleached kraft production suitable for mill reuse.

Laboratory and pilot experiments have been conducted into the use of oxygen in the pulping process. It was found (103) that soda-oxygen pulping produced a nontoxic waste water which was lower in color and had less tendency to foam than effluents from kraft pulping to the same degree of delignification. Interest in the several oxygen pulping means under investigation is evident in

this country as well as Japan and the Scandinavian countries. A recent symposium (293) served to update progress in this area of research.

Thirty-six percent of the 74 bleached kraft mills were surveyed to provide data for this report. All of the surveyed mills are making considerable use of a large number of the internal controls mentioned above for the reduction of raw waste effluent. Most of these mills are utilizing technologies which do not require major process changes while 40 percent have made major process or equipment modifications to reduce the level of pollutants discharged.

All bleached kraft mills surveyed are reducing the quantity of fresh water used for brown stock washing through reuse of decker filtrates for countercurrent washing. Sixty-two percent of the mills are making extensive use of these methods.

Seventy percent of the surveyed mills segregate knots, dregs, grits, and similar materials from their liquid effluent for disposal in a semisolid form. Black liquor and stock spill collection systems are installed in 46 percent of the surveyed mills while 62 percent collect evaporator boil-out and over 80 percent reuse some evaporator condensates. Collection and reuse of process hot water is widely practiced in this subcategory being utilized in 92 percent of the mills surveyed.

All surveyed paper mills associated with bleach kraft pulping were found to be reusing at least a portion of machine white water although only 20 percent are using high pressure showers. In addition all these mills are making use of savealls with 62 percent of the mills using this equipment extensively. Thirty-eight percent of these paper mills are able to reuse vacuum pump seal water.

Soda Subcategory

Since this process, including chemical recovery is today almost identical to kraft, most of the same control technology can be applied to reduce the effluent discharge. The major difference is the absence of sulfur from the soda process, and thus almost no odor is created. All three soda mills were included in survey visits. All these mills recycle decker filtrate for brownstock washing with two mills making extensive use of this technology. Two of the three mills segregate knots and dregs for separate disposal and also utilize spill collection and reuse of contaminated condensates to reduce the discharge of pollutants.

All three mills also collect and reuse process hot water, employ savealls and recycle white water with two of the three using high pressure showers. One mill reuses vacuum pump seal water and cooling water.

Bleaching of Chemical Pulps

High reduction of the pollution losses from bleacheries handling chemical pulps can only be effected by process change despite the drastic reductions in effluent volume frequently possible to achieve. While water recycle in bleach plants has advanced remarkably in recent years, with flow from high brightness bleaches dropping to as low as 25,000 l (6000 gal) of fresh water per kkg (ton) of product (104), no reduction in pollution load accompanies water economy. This is because conventional bleaching is dependent upon the removal of color bodies and in doing this chemically some hydrolysis occurs and some materials are leached from the pulp. These pollutants are not normally recoverable because of their dilute nature and high chloride content which is corrosive to recovery systems (299) and which in high concentration in the smelt can cause explosions. Water recycle does, however, reduce the total volume of water requiring treatment with consequent savings in size and cost of treatment plants.

Some reduction of bleach plant pollution load can be achieved by controlling digestion where possible in order to remove more lignin in the brown stock washer, leaving less to be discharged at the bleach plant.

Reduction in effluent flows can be achieved by countercurrent recycling of shower and seal box waters. This is possible in most bleach plant configurations, eliminating flows to sewers from downstream stages. Three main types of countercurrent washing are used in bleacheries --direct, split-flow, and jump stage. Direct countercurrent washing produces the least effluent. Some countercurrent washing is practiced by 90 percent of the bleached kraft mills surveyed. The jump stage process is utilized by a majority of the surveyed sulfite and dissolving sulfite mills and to some extent by all three soda mills.

The use of countercurrent flow in existing mills, however, is restricted in that serious corrosion problems are encountered when washers contacted by chlorine dioxide filtrates are not of 317 stainless steel. Partial or jumpstage washing can be used with some savings when washer and pipeline material prohibit a complete recycle system.

Paper mill white water or excess mill hot water can be used as make-up water or for the final stage washer and fresh water added only in time of process problems. The use of 317 stainless steel eliminates shower corrosion but shower pluggage has caused problems in some mills. Some readjustment of chemical dosing rates are required as is pH adjustment in some systems.

In several mills in addition to limiting water use countercurrent washing has considerably reduced steam requirements (104). Laboratory and mill trials have shown (105) a potential for considerable reduction in water use in bleacheries by eliminating some pulp washing without affecting brightness and chemical

consumption. In a five stage operation bleaching softwood kraft pulp, it was possible to eliminate washing after the first chlorine dioxide stage. In a five stage hardwood kraft bleachery, the washing following both the first chlorine dioxide and the second caustic extraction stages was successfully eliminated. Countercurrent washing should be discontinued when dirt is encountered in the bleach plant to avoid prolonged dirt problems.

Rapid chlorine dioxide bleaching at intermediate consistency has been found to be chemically feasible and appears practical economically, using less chemicals, water, and steam (108). Operating conditions, especially temperature and pH, are more critical and must be controlled more carefully. Suitable equipment is being developed for this process and is being installed in a southern mill.

In kraft mills where prehydrolysis is practiced, as is the case in all kraft dissolving mills, the bleachery losses can be reduced if the prehydrolysis step is accompanied by a soft cook. In this case more organic matter goes to the recovery furnace with the spent cooking liquor. In some instances the prehydrolysate is added to the weak black liquor as a means of disposal. Because of the low solids content of the hydrolysate this is a relatively high cost practice and requires that higher than normal evaporation capacity be provided. While low in solids compared to weak liquor, the prehydrolysate contains wood sugars and wood acids providing an added BOD_5 load if discharged to external treatment facilities. It appears possible that membrane processes might provide suitable fractionation of the several components to produce byproducts of value. Prehydrolysate is used as a nutrient source for growth of food yeasts in the USSR.

A process change for reducing high losses from the production of sodium base sulfite dissolving pulp is being installed in a southern mill (118). In simplified terms, soda based pulp from the digester stage is drained of a portion of the waste liquor and passed directly to the hot caustic extraction stage without washing. After hot caustic extraction, the pulp is washed and the wastes removed in washing are added to the digester waste and the combined wastes are then concentrated and burned. It is also possible to utilize the concentrated caustic liquor as salt cake make-up in the kraft process. This is expected to achieve 90 percent reduction in BOD and color.

Other process changes such as oxygen bleaching give promise of reducing bleachery losses, especially with respect to color bodies and inorganic materials, particularly chlorides. There are indications (106) (117) that the wash water from oxygen bleaching stages can be introduced into the kraft recovery system since it is relatively free of chlorides. However, magnesia is added in this process (140) and it could result in accumulative problems in the liquor system. A change to oxygen bleaching involves high capital investment in the bleachery and a plant to

produce oxygen and, since other bleaching stages continue to utilize chlorine compounds, not all bleach plant effluent is eliminated. However, the existance of a mill operated oxygen production plant, producing in excess of that needed for bleaching, allows for other oxygen uses as black liquor oxidation or supplemental addition to the lime kiln as required.

Laboratory studies do indicate (105), with 100% reuse of oxygen stage effluent, large reductions in BOD (81%), COD, chlorides and color (89-92%). Such oxygen stage effluent is evidently easily handled by conventional secondary treatment facilities as BOD reductions ranging from 75-97% were obtained employing aeration periods of 1 to 10 days. The U.S. kraft mill with an operating oxygen bleaching system predicts that recycling the oxygen stage effluent to brown stock washing could result in BOD and color reductions of about 60 and 90 percent respectively from the levels produced by the conventional CEDED sequence (177). As a further refinement on this approach, experiments have indicated that the use of an oxygen stage alone as part of a brown stock washing system would result in very clean bleaching (81). and reduce BOD and color of total mill raw waste load by 40 and 70% respectively obtained by a reduction in the bleach load of 70-80% BOD and in excess of 90% color difference as compared to conventional bleaching sequences.

The findings from pilot oxygen bleaching have been more fully reported (294) and support earlier information as to significant BOD_5 and color reductions when oxygen bleaching is employed.

A Swedish kraft mill employing oxygen bleaching as a first stage, has incorporated a large surge tank 510,000 l (135,000 gal) for effluent control. By containing the oxygen stage wash water with digester and screening system effluent, it anticipates reducing the BOD load more then 50 percent and discharged color by 70 percent over conventional systems.

It has been found (110) (111) that oxygen bleaching can also be successfully employed as a pre-bleaching stage for sulphite pulps. The oxygen stage is capable of delignifying pulps to a low lignin content with simultaneous preservation of viscosity. The advantages of the process in chemical recovery and water pollution control are only achieved with a sodium base cooking process in which the oxygen bleaching stage provides sodium make-up.

As noted in Section V, pilot plant experience indicates that washing between stages may be eliminated by the new displacement bleaching process and effluents reduced to the amount of water introduced with new chemicals.

Continued progress is reported for the Rapson process (112) (113) (114) in which bleaching wastes concentrated by recycling are introduced into the recovery system with the black liquor. Chloride content of the liquor system is controlled by evaporating white liquor to a sufficiently high concentration to

allow sodium chloride to crystalize out (115). Total chlorides in the system are reduced by replacing most of the chlorine used in the chlorination stage by an equivalent amount of chlorine dioxide (116). The salt obtained can be used in the production of chlorine dioxide by the R-4 process (117). The Rapson process has been tested in a pilot plant and a full scale operation is planned at a Canadian mill. Both of these processes are described in Section III.

Deinking Subcategory

No dominant system for secondary fiber pulping and deinking has emerged from the many different systems developed for these processes. The significant differentiations are whether the process is batch or continuous, hot or cold, low consistency or high consistency, and whether it uses countercurrent washing or flotation as the main ink separation process. Technology for the reduction of pollution within these systems differs greatly and is often unique to a single mill. Hence only general comments are included in this section.

Pulp which is still contaminated after the process should not be discharged to the sewer but should be run over a wet lap machine for disposal or sale to a mill capable of using a lower grade of stock.

The flotation deinking system does not remove clay and dissolved contaminants so it has a cleaner effluent than a washing system. However, these contaminants appear in the paper mill effluent unless a closed water system is used in this area. A special solvent process is the only truly closed system (119); the contaminant removal operation generates no liquid effluent, and the contaminants are discharged in a dry state. The economics of this process, however, are such that only one small plant is in operation in the U.S.

Survey data was obtained from 53 percent of the 17 mills in this subcategory. Of these nine mills, 67 percent reported using countercurrent brownstock washing and 50 percent were found to be operating spill collection systems. Seventy-five percent of the mills using multistage bleaching are making extensive use of countercurrent washing in the bleachery. Process changes have recently been made in 22 percent of the surveyed mills to reduce the liquid effluent.

All paper machines associated with the surveyed deinking plants recycle white water with 66 percent using extensive recycle and 50 percent using high pressure showers. Paper machine savealls are used in 66 percent of these mills and almost 90 percent of those surveyed reuse some cooling water and vacuum pump seal water.

Papermaking

Since the papermaking process is virtually identical in all subcategories, this discussion is applicable to each of them.

Recycling of white water within the stock preparation/papermaking process has long been practiced in the industry. In the last 10 years further strides in reuse have been made. Problems associated with increased reuse usually manifest themselves in reduced machine speed and/ or product quality. Slime growth due to increase of BOD_5 and temperature has been encountered. This problem can be reduced by the proper application of biocides, by better housekeeping, and by design for higher liquid velocities in pipelines, shorter detention time in tanks, and avoidance of pockets in the system. Scale buildup is another problem which can be reduced, principally by chemical and mechanical design techniques. Buildup of dissolved solids can also cause product quality problems, but in the typical case, reuse is limited by slime growth and scale buildup. Combinations of temperature and dissolved solids buildup interfere with sizing and other chemical reactions. In addition, corrosion is a significant factor in increased recycling within the white water system.

Most mills employ a saveall to recover fibrous and other suspended material escaping from the paper machine. This is considered by many mills to be a necessity for both economic and pollution control reasons, although some mills can obtain equivalent results by other means. Savealls are of three principal types. The older type consists of a screen covered drum immersed in a vat through which the water passes leaving a mat of fiber. This is removed continuously for reuse directly in the manufacturing process. A number of improved variations of this device are in use which employ filtration through the mat of fiber. These include the cloudy port drum vacuum filter and traveling wire devices operating on the same principle. Second is the newer disc type, which utilizes a series of screen-covered discs on a rotating shaft immersed in the vat. The action is similar to the drum saveall, but the disc type has the advantages of greater filtering area per unit volume and the use of vacuum, both of which reduce space requirements. In both of these types of savealls a side-stream of "sweetener" fibrous stock is added to the influent to improve the efficiency of suspended solids removal in the main influent feed. The third type is the dissolved air flotation saveall (DAF). In this type unit air bubbles, formed on the dissolution of air under pressure, attach themselves to the fibers, causing them to float to the surface where a continuous mechanical rake collects them for reuse.

The disc type saveall has enjoyed recent popularity because of its flexibility and higher removal efficiencies in most cases. In addition it provides a positive barrier for fibers preventing their introduction into the clarified white water thus preventing problems arising on reuse.

Clarified effluent from saveall is on the order of 10,433-25,038 l (2500-6000 gal) per kkg (ton) (58), with a suspended solids content of 120 mg/l or less, whereas the influent may contain 2398 mg/l or more.

All or a part of the clarified effluent may be discharged directly to an outfall sewer, but most mills reuse a significant portion of it for such services as (58):

1. Vacuum pump seals
2. Machine showers
3. Stock cleaner elutriation
4. Cooling waters
5. Pulp washing
6. Wash-ups
7. Consistency regulation dilution
8. Barometric evaporator condensers (pulp mill)
9. Repulping of broke and purchased fiber

Water showers are used in both the forming and pressing sections of the paper machine to clean the wire, felts, and other machine elements subject to contact with the stock. Formerly, large volumes of fresh water were used for this purpose. In recent years, attention has focused on the use of recycled white water on showers, and this trend has increased with the development of self-cleaning showers. Even with self-cleaning showers, however, a suspended solids content of less than 120 mg/l is generally desired to avoid plugging. Concurrently, the use of high pressure (up to 52 atm or 750 psig), low volume showers using fresh water has increased. These are employed where product, operability, cleanliness, or other factors mitigate against the use of white water showers. In many such cases, it is possible to operate these high pressure showers on a time cycle, so that flow occurs only a small percentage, (10 to 20 percent) of the time.

Showers are also used on grooved presses to keep the grooves clean and operable. These presses were developed within the last 10 years and have enjoyed increasing popularity because of their efficiency in water removal, and lower capital and operating cost than the suction (i.e., vacuum) presses which they replace. Recycle of this shower water, usually after filtering to remove fibrous and other suspended solids, is commonly employed.

Since the 1950's, free-discharge cleaners have been used increasingly to remove dirt and other undesirable materials from the dilute stock prior to its application to the paper machine. These cleaners are the cyclonic type and operate on the centrifugal force principle, utilizing hydraulic pressure drop as the source of energy. They increase cleaning efficiency through a continuous discharge of rejects although significant quantities of usable fiber are also rejected. To reduce such losses, the cleaners are usually arranged in stages, so that rejects from previous stages are sent through subsequent stages of smaller size. Rejects from the last stage have a consistency of about

three percent and are usually sewered. Well designed and operated cleaner systems reject one-half to one weight percent of the feed to the primary stage. To reduce such losses further, elutriation water is added at the final stage. In some cases, a closeddischarge cleaner replaces the free-discharge unit in the final stage.

Vacuum pumps are utilized in paper mills to provide a vacuum source to accelerate the removal of water from fourdrinier machines, presses, savealls, and other devices and thus the vacuum pump demand for water is somewhat product dependent. Most such pumps are of the ring seal type which require large amounts of water. This water provides a seal between the moving and stationary parts of the pump, and is necessary to avoid backflow of air to the vacuum side. Water used for this purpose approximates 10,433 to 16,692 l/kkg (2500 to 4000 gal/ton). It must be sufficiently free of suspended solids to avoid plugging of the orifices or other control devices used to meter it to the pump. Further, it must not promote formation of scale inside the pumps or corrode their mechanical parts, and it must be relatively cool (typically less than 34°C (90°F) to permit development of high vacuums of 0.67-0.74 atm (20-22 in. Hg). For lower vacuum requirements 0.17-0.40 atm (5-12 in Hg), somewhat higher temperatures are permissible.

As more extensive recycling is employed in machine systems, the significance of water used to seal or lubricate packings for rotating shafts increases. These shafts are used for pumps, agitators, refiners, and other rotating equipment. The use of mechanical seals as an alternative has reduced the volume of seal water, but they have so far not proven satisfactory in many applications. Reduction of seal water usage is an area which requires more study and development.

Meantime several methods are used to minimize fresh water requirements depending on product as well as mill configuration. Seal water is collected and passed through for reuse directly back to the pumps or to another water-using system. The use of excess white water for vacuum pump sealing, before discharge to sewer or back to process, is also practiced. Another procedure is to utilize the discharged vacuum pump water for cooling of heat exchangers.

Fine Paper Subcategory

All modern fine paper mills recycle most of the machine waters and employ a saveall system to capture materials lost through the fourdrinier wire (120). These employ sedimentation, filtration, and flotation with the separated materials being returned to the papermaking process and a portion of the clarified water returned for stock preparation and other uses in the paper machine system.

In the 32 percent of the 56 mills in the non-integrated fine paper subcategory surveyed, the most common factor limiting water

reuse was found to be product quality. Many mills experienced a reduction in product quality when excessive recycle produced a build-up of dirt or high dissolved solids in the process water. Three mills are experimenting with total recycle by using mixed media filtration or other fine filtration processes after conventional solids removal in a clarifier or flotation unit. This equipment is normally associated with fresh water treatment plants rather than waste water treatment.

Ninety-four percent of the mills surveyed are recycling white water and 89 percent utilize savealls to some extent with 39 percent using them extensively. Some hot water is collected and reused in 73 percent of survey mills while vacuum pump seal water or cooling water is reused in 44 percent of mills.

Tissue Subcategory

There are 72 tissue mills in this subcategory and 26 percent of them were included in the survey. All the mills surveyed are recycling at least a portion of machine white water and more than 50 percent are using high pressure showers to reduce water use. Ninety-four percent of survey mills are using savealls to reduce effluent solids with the flotation saveall being widely used. While the flotation units give poor results on many effluents, this is not the case in tissue mills where solids removal up to 90 percent are consistently obtained and one mill with two stages of flotation averages 94 percent removal.

Pilot tests using a lean-water system successfully improved the performance and increased the capacity of the saveall in one tissue mill (121). This system involves taking rich white water from the wire trap and feeding it onto the sheet by means of a secondary headbox. A final white water of lower consistency than that of conventional methods was produced.

More than 60 percent of the tissue mills surveyed reuse cooling waters and vacuum pump seal water.

Summary

The entire area of in-plant control provides for the industry both a means to partially satisfy effluent limitations, and to reduce both volume and pollutional materials in the raw waste discharges with resulting reduced scale, and some reduction in operating cost, of external treatment facilities.

While the principal presently functioning in-plant control technologies are covered in previous paragraphs, as well as yet unproven but developing means of in-plant waste control, it is evident that significant advances in continued reduction of wastes from the industry must be found through further advances in partial closure of the various unit processes employed by the various segments of the industry. The principal waste sources as

barking, pulping, bleaching and papermaking are all vulnerable to altered technology which will reduce or eliminate the discharge of waste loadings from the process. Some of this technology is only appearing on the horizon and some is yet buried in research laboratories of the industry and industry research organizations. The awareness the industry shows concerning environmental matters will certainly see any new means, as for example pulping or bleaching, evaluated as to its impact on the environment.

While waste reduction is of prime interest in meeting environmental obligations in air and water pollution control, the areas of energy consumption, fiber conservation, increased yield and reduced production costs also dictate the research avenues and routes considered most rewarding for development.

Some portion of the new technology will probably first appear in new mills although significant advances in demonstrated profitability, if only from the pollution control standpoint, may encourage installation of process changes and in-plant waste control measures by older mills. Table 54 covers the in-plant control processes, now practiced in the industry in varying degrees. The number of mills surveyed in the separate categories, and the percent of those mills employing the specified in-plant measures is tabulated. Evidently there exists considerable opportunity for the addition of present day accepted in-plant control measures based upon the percentage of mills not employing a specific waste control technology. One must question why only 27% of bleached kraft mills employ high level alarms for chemical tanks to avoid spills, why only 62% of bleached kraft mills use a four stage washer, why only 50% of sulfite mills employ a pulp mill spill collection system, why only 43% of the groundwood subcategory employs paper machine savealls, etc. Alternately, one may similarly question why those mills installing and operating such in-plant control facilities decided on this route of action. The question elicits a generally obvious answer.

EXTERNAL TECHNOLOGIES

External technologies are those processes which are employed after the effluent leaves a mill for the reduction of suspended solids, BOD, color, etc., before it enters the receiving waters. These technologies are first described in terms of their general application in the industry and are illustrated in Figure 42. Subsequently, use of these technologies by mills in the various subcategories is discussed. This information for all mills subject to this report is summarized in Table 56, and schematics drawings of treatment systems in use by surveyed mills are shown in Figure 42A.

Removal of Suspended Solids

Screening is always necessary to remove trash materials which could seriously damage or clog treatment equipment. Automatically cleaned screens, operating in response to level control, are commonly employed and generally represent preferred practice. Screens are particularly useful for barking and wood washing effluents where screenings can be recovered as boiler fuel.

The physical process of removing suspended organic and inorganic materials is accomplished by sedimentation (with or without flocculants or coagulants), flotation, or filtration.

Sedimentation can be accomplished in mechanical clarifiers, flotation units, or sedimentation lagoons. Although the latter enjoyed wide-spread use in the past, the large land requirement coupled with inefficient performance and high cost of cleaning has made them less popular in recent years (5).

The most widely used method for sedimentation of pulp and paper wastes is the mechanically-cleaned quiescent sedimentation basin (5). Large circular tanks of concrete construction are normally utilized with rotating sludge scraper mechanisms mounted in the center. Effluent usually enters the tank through a well which is located on a center pier. Settled sludge is raked to a center sump or concentric hopper and is conveyed to further concentration or disposal by solids handling pumps. Floating material is collected by a surface skimmer attached to the rotating mechanism and discharged to a hopper.

Dissolved air flotation has been applied to effluents from pulp and paper mills and has achieved removal efficiencies of up to 98 percent of the suspended solids (123). The relatively high cost of flotation equipment, however, along with its requirements for flocculating chemicals, high power requirements, and its mechanical complexity make it unsuitable for application in other than the capacity of a saveall, except where space is at a premium. Its ability to handle high concentrations and shock loads of solids is somewhat limited. It normally is not efficient on wastes containing pigments, fillers, or fines.

FIGURE 42

ALTERNATIVE TREATMENT SYSTEMS

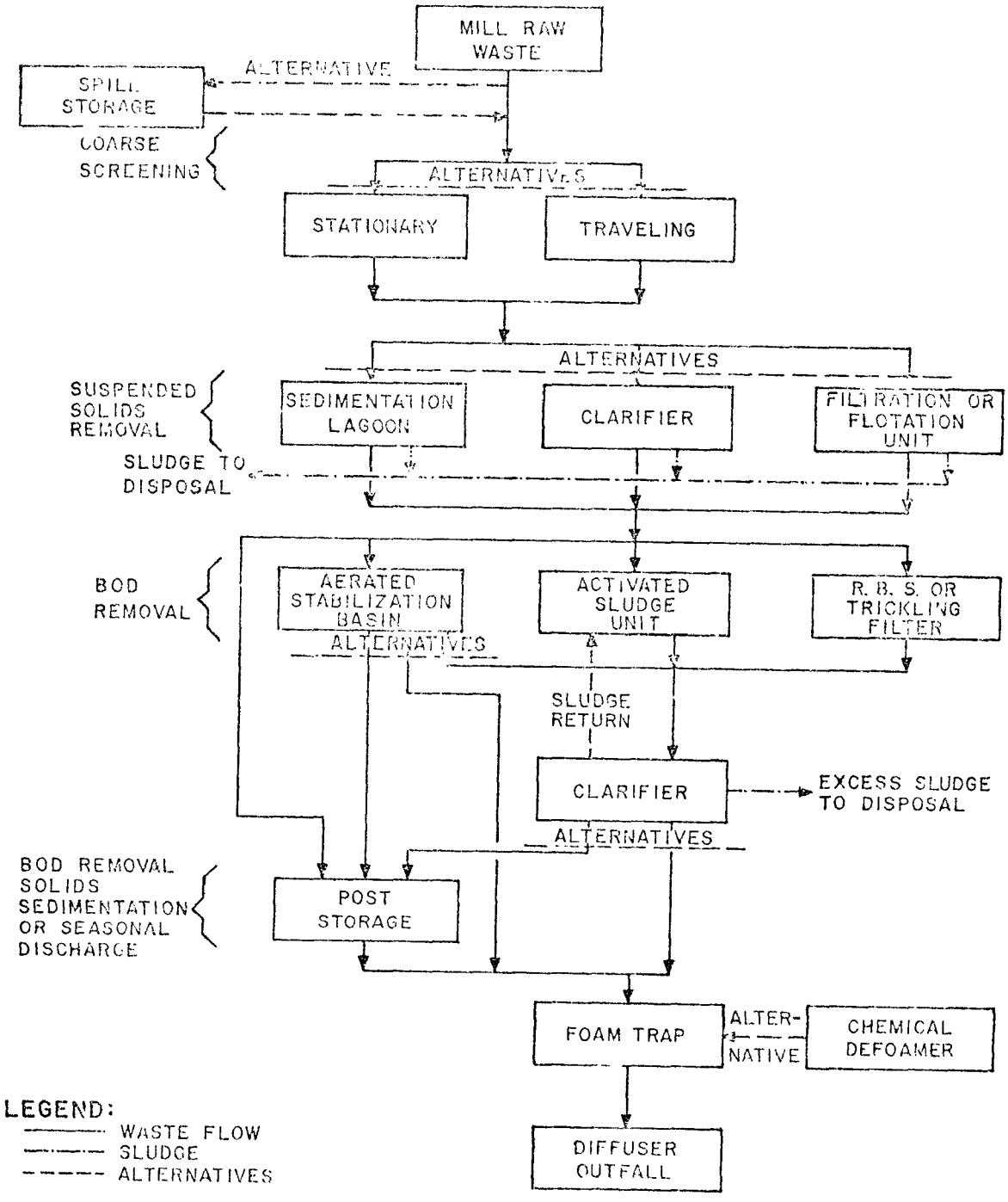


Figure 42A

EXTERNAL TREATMENT FACILITIES

Bleached Kraft Segment

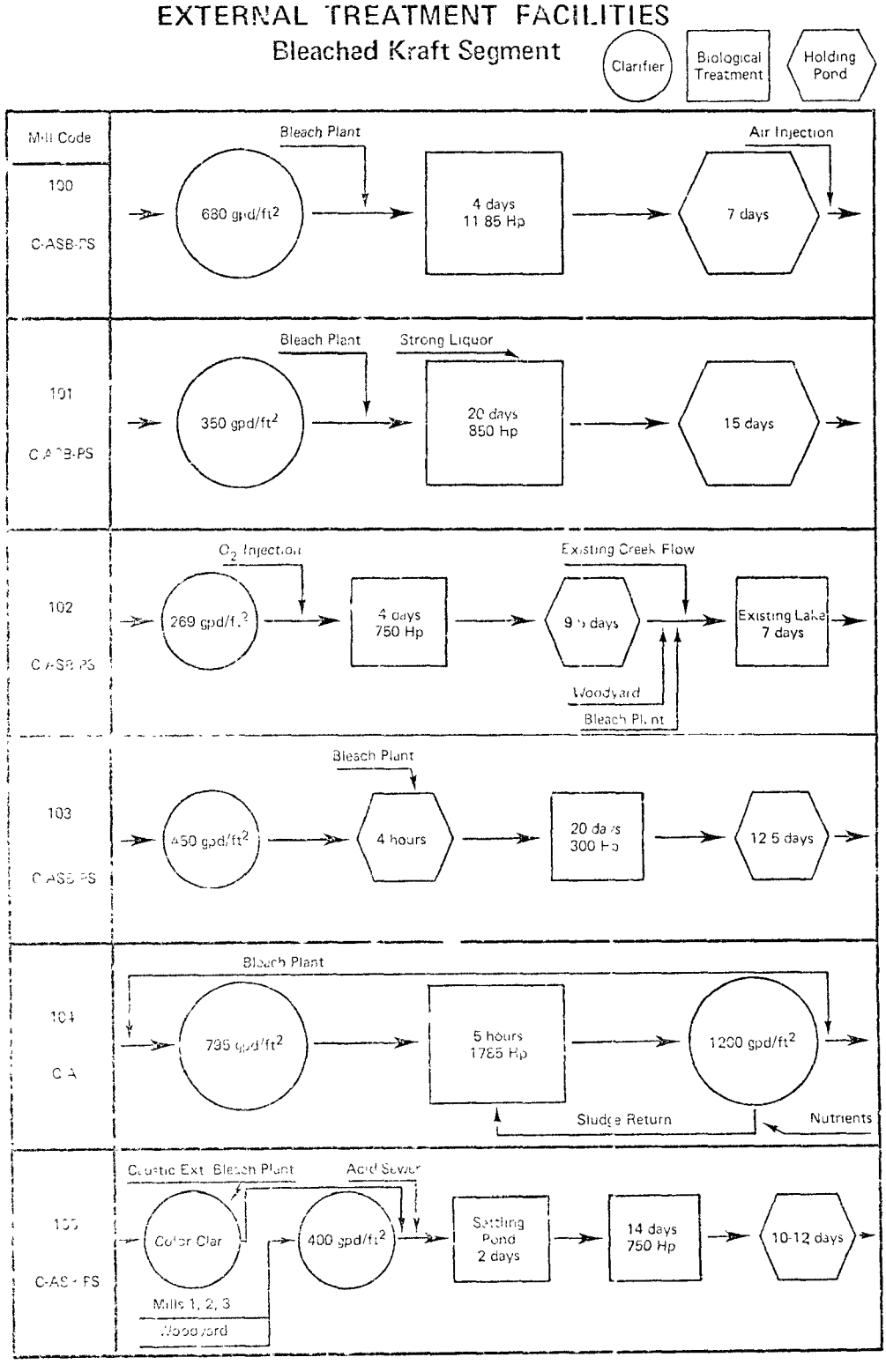


Figure 42A (Cont'd)

EXTERNAL TREATMENT FACILITIES
Bleached Kraft Segment

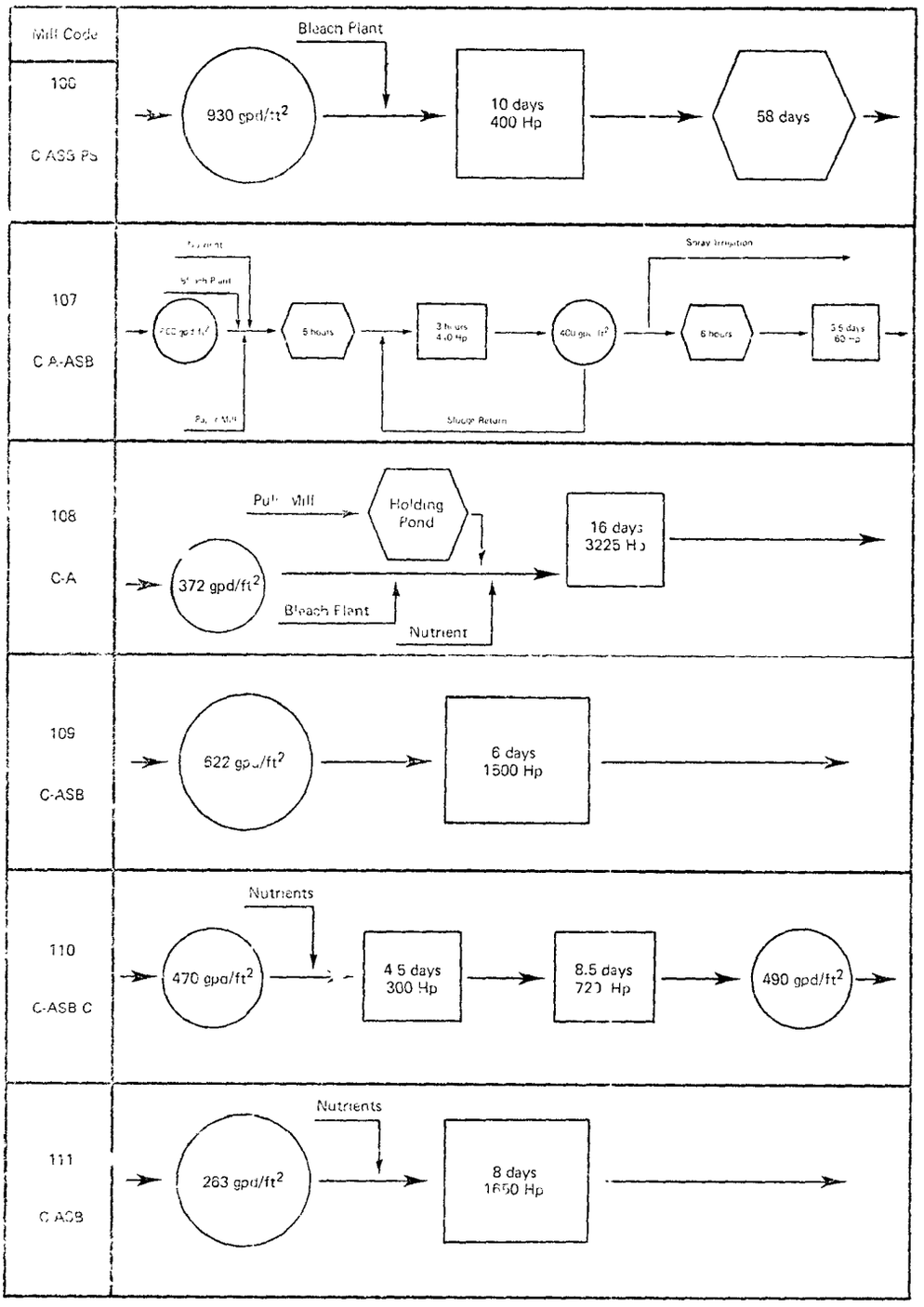


Figure 42A (Cont'd)

EXTERNAL TREATMENT FACILITIES
Bleached Kraft Segment

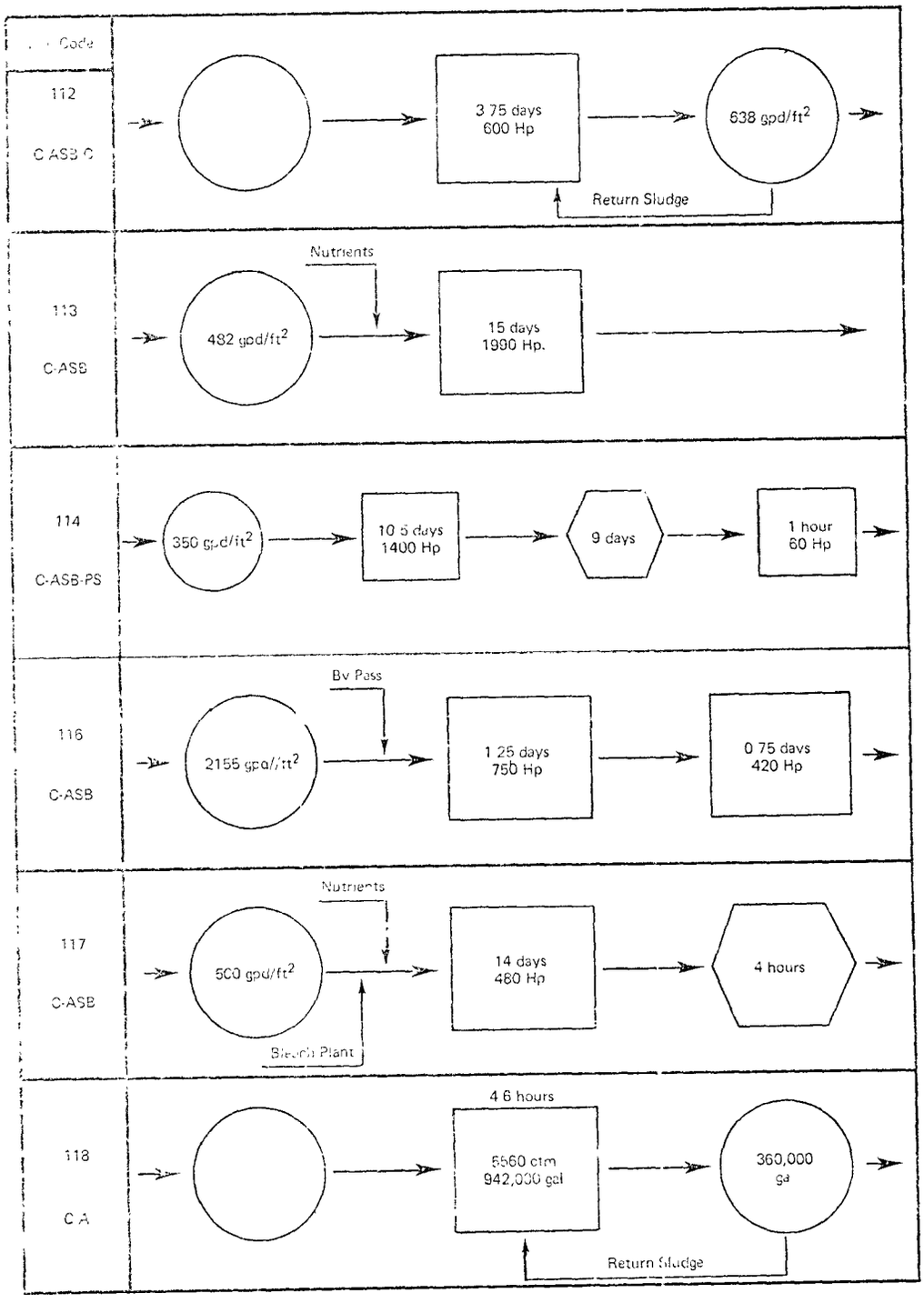


Figure 42A (Cont'd)

EXTERNAL TREATMENT FACILITIES
Bleached Kraft Segment

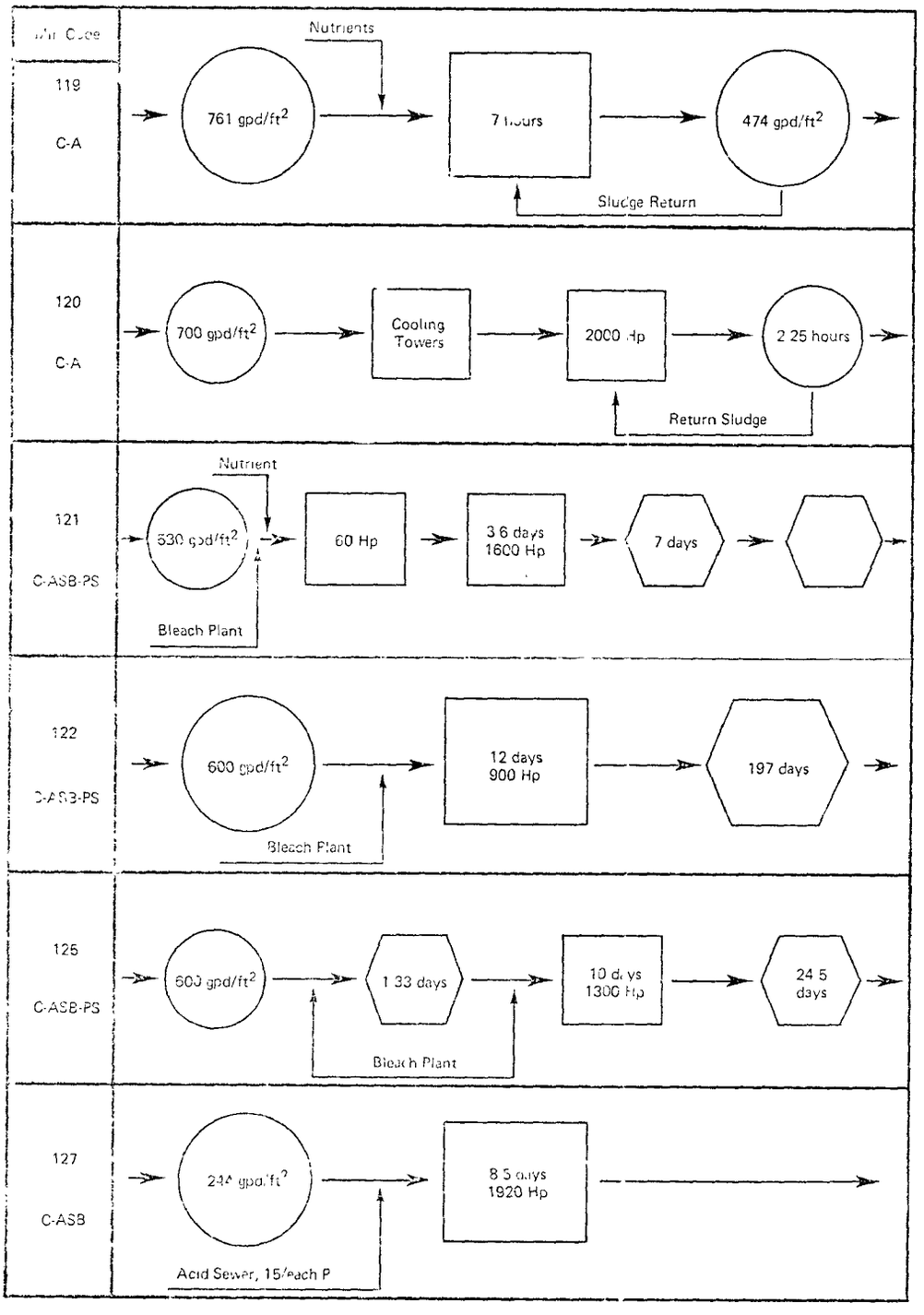


Figure 42A (Cont'd)

EXTERNAL TREATMENT FACILITIES
Bleached Kraft Segment

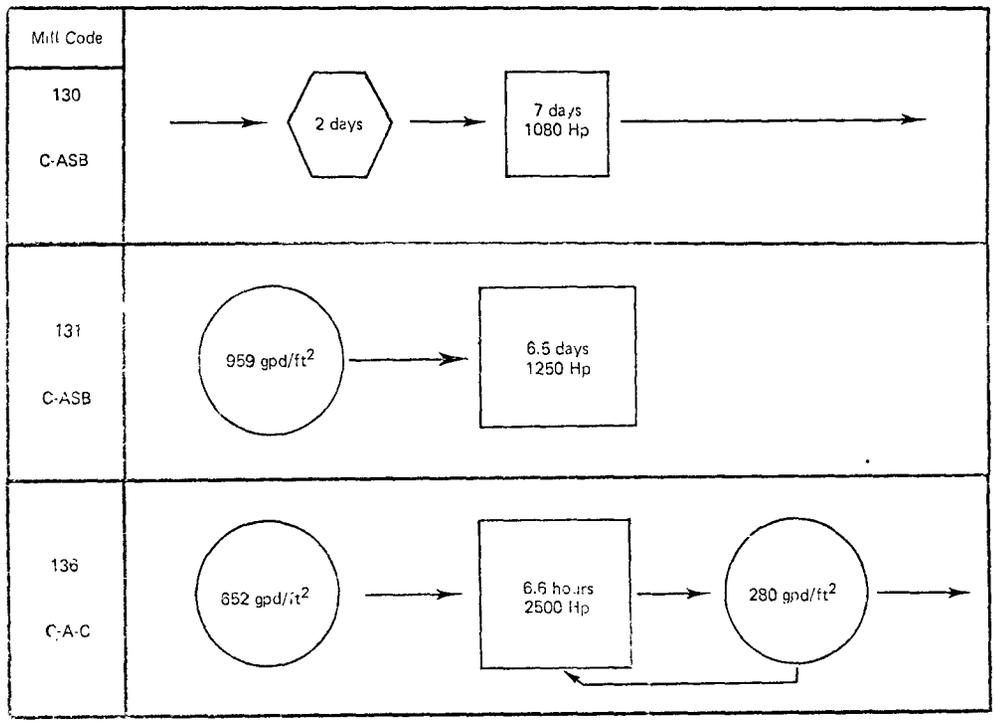


Figure 42A (Cont'd)

EXTERNAL TREATMENT FACILITIES
DEINK Segment

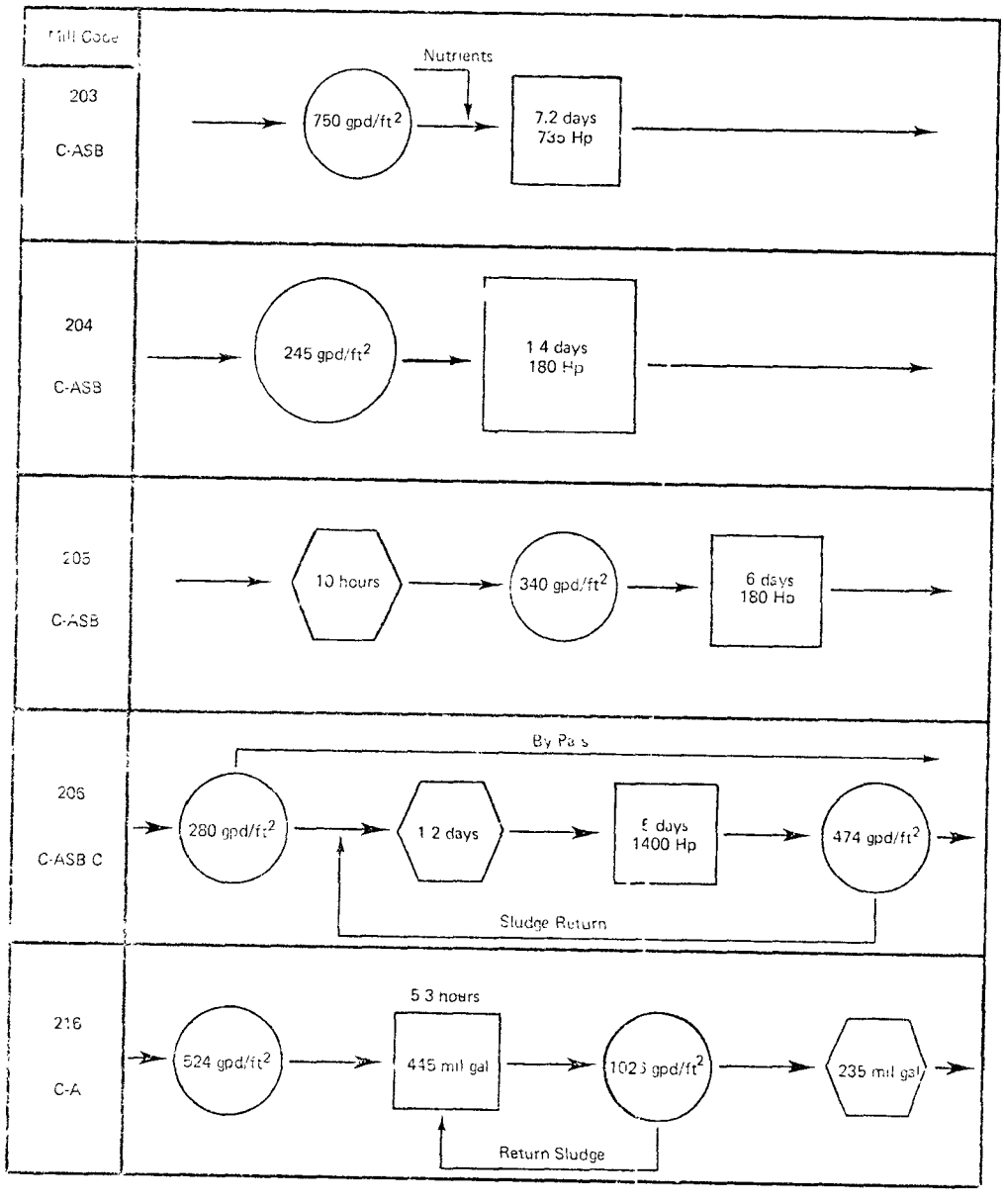


Figure 42A (Cont'd)

EXTERNAL TREATMENT FACILITIES
Sulfite Segment

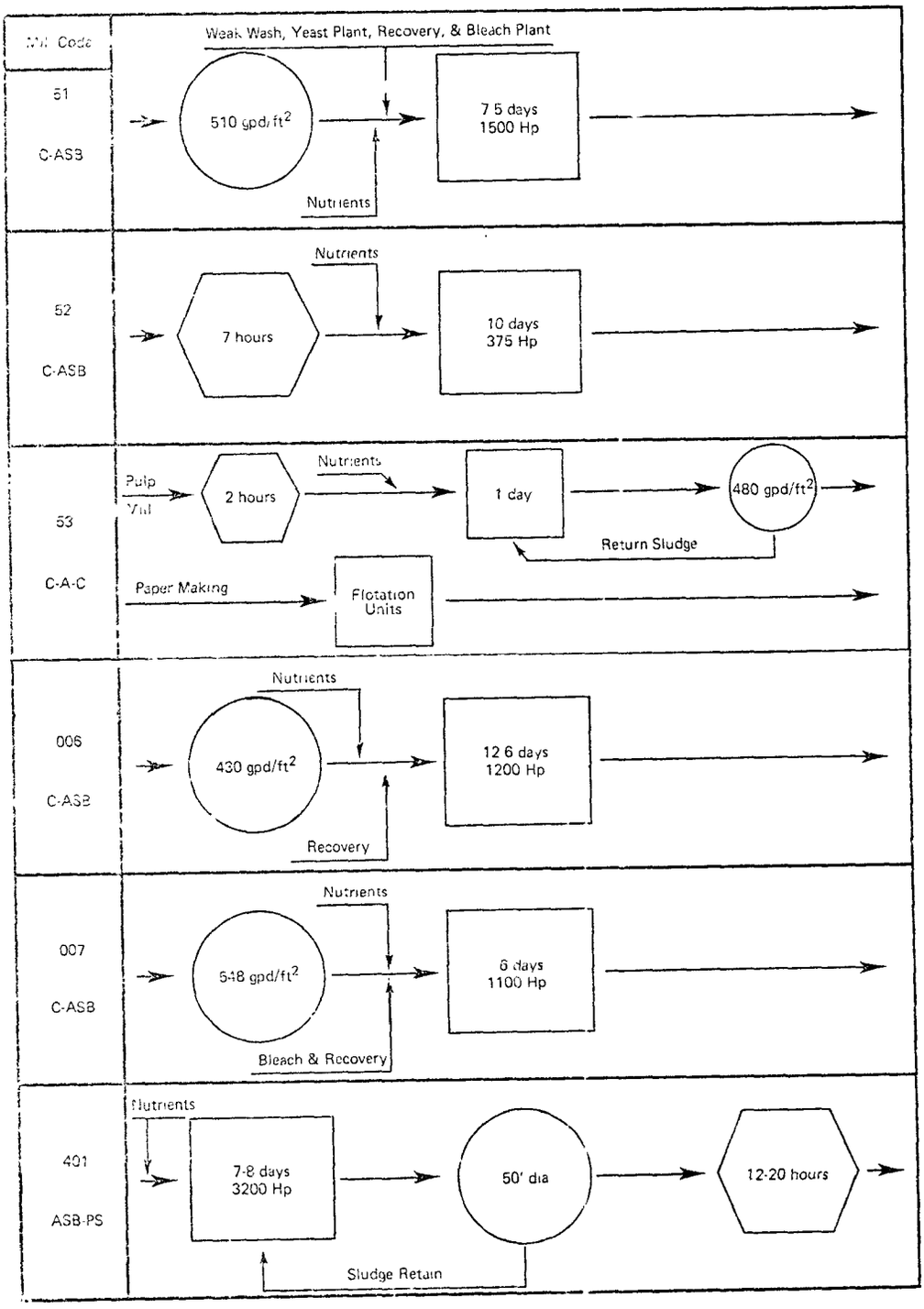


Figure 42A (Cont'd)

EXTERNAL TREATMENT FACILITIES
GroundwoodSegment

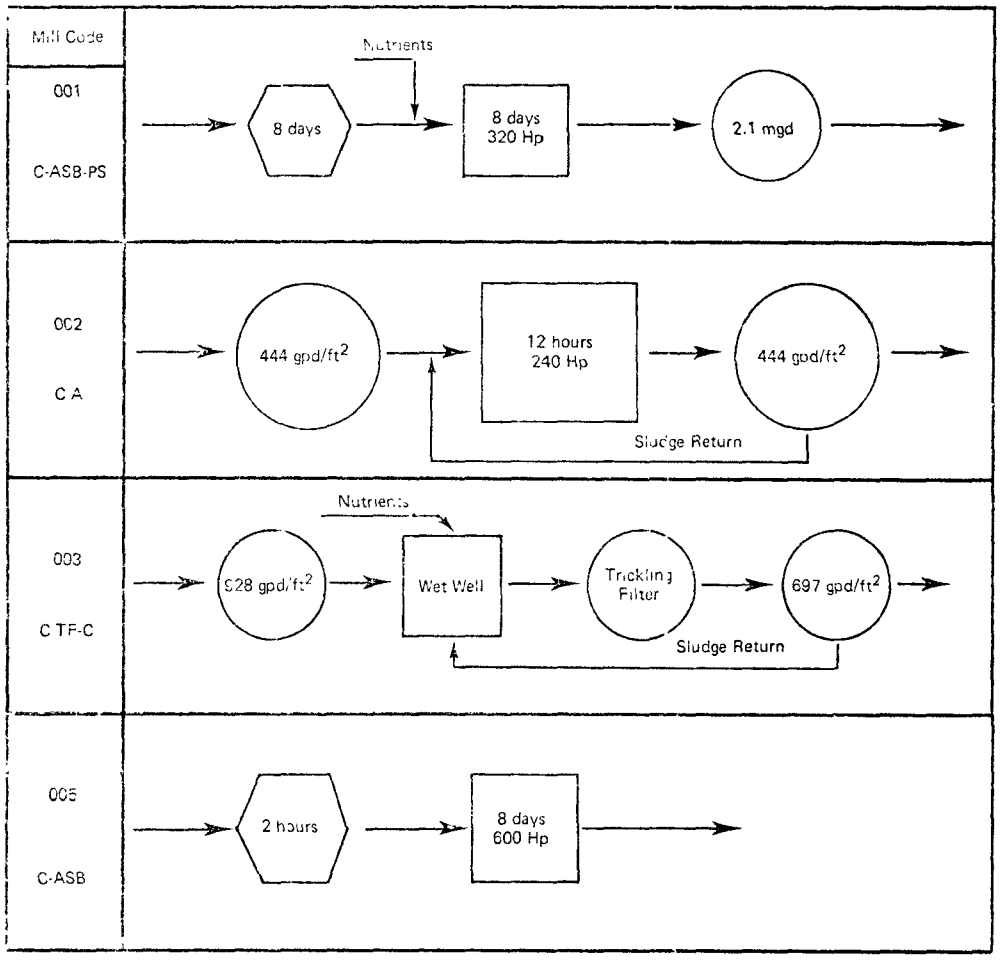
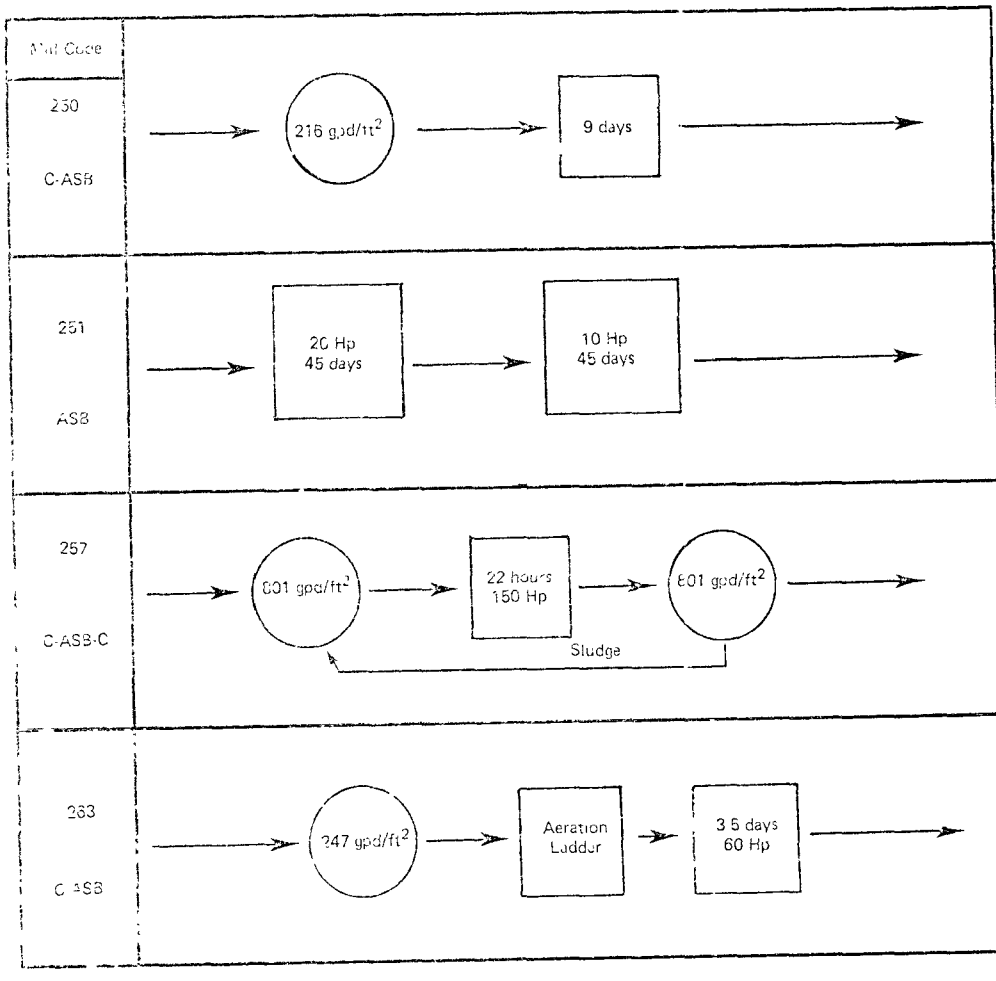


Figure 42A (Cont'd)

EXTERNAL TREATMENT FACILITIES
Fine Segment



EXTERNAL TREATMENT FACILITIES
Soda Segment

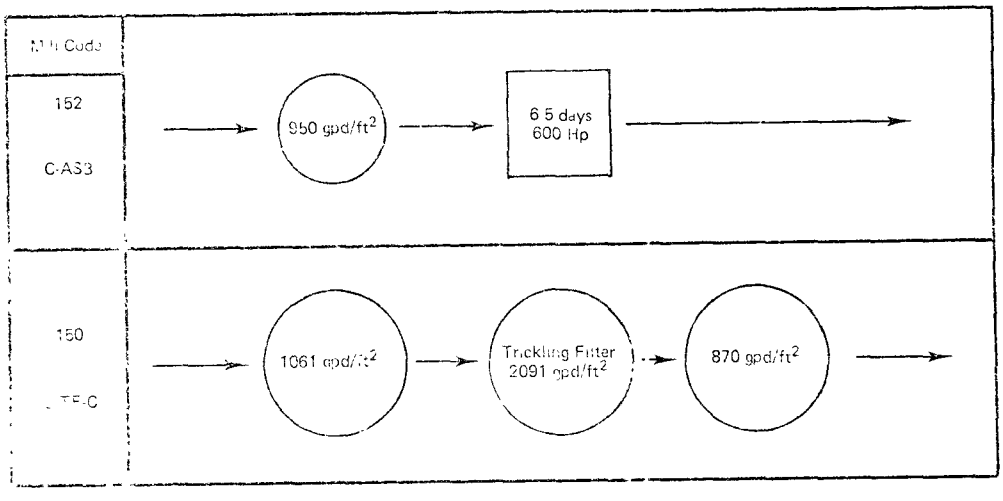


Table 56

EXTERNAL TECHNOLOGIES CURRENTLY IN USE

Data are approximate percentages of use in each subcategory.

SUBCATEGORY	PRIMARY CLARIFICATION	BIOLOGICAL TREATMENT A*	BIOLOGICAL TREATMENT ASB**	POST STORAGE
GROUNDWOOD	60	10	20	35
BLEACHED KRAFT	60	10	40	50
SULFITE	50	5	10	25
DISSOLVING SULFITE	80		20	
SODA	65		35	
DEINKED	40	5	15	20
TISSUE	40		5	35
FINE	30	5	5	25
COARSE	25	5	5	25

*Activated Sludge
**Aerated Stabilization Basin

Because of the blinding and plugging nature of pulp and paper wastes, fine screens, micro-strainers, and pressure filters are not commonly used for suspended solids removal. Adequate screening systems cost approximately the same as an equivalent clarifier and have more inherent problems (124).

Because of the biodegradable nature of a portion of the settleable solids present in the effluent of these mills, clarification results in some BOD reduction.

Reduction of BOD

BOD_5 reduction is generally accomplished by biological means because of the relative biodegradability of most of the organic substances in the waste except lignin. Too, advances in reducing internal chemical losses and recycling have removed most of the factors which interfere with biological activity.

While BOD_5 reduction by biological methods represents common practice today, it should be understood that other methods discussed under "Color Removal" and "Advanced Waste Treatment" may, in the future, avoid the need for biological treatment.

Currently, the most common biological treatments utilized in the pulp and paper industry include the use of large storage oxidation basins, aerated stabilization basins, and the activated sludge process and modifications thereof. Biochemical oxygen demanding materials can be precipitated from most pulp and paper mill wastes by the use of coagulating chemicals but the percentage reduction obtained is small compared to that obtained in biological treatment.

The principal benefit obtained from biological treatment is to avoid depletion of dissolved oxygen in receiving waters. Fish are particularly sensitive to depressed levels of dissolved oxygen, as are many other forms of aquatic life. Other benefits include the destruction of toxicity to aquatic life (125) reduction in foaming tendencies (126), and reduction of turbidity-producing inorganic coating additives. High degree treatment also eliminates the tendency of pulping effluents to stimulate slime production in receiving waters (55). Biological treatment fails to remove color since color bodies are not oxidized and at best only a fraction of them are absorbed into the biomass. In fact, there is frequently a slight rise in color level after biological treatment.

The first type of biological treatment adopted in the industry was storage oxidation. This consists of large natural or man-made basins of various depths which rely on natural reaeration from the atmosphere. Since storage oxidation is a relatively low-rate process, large land areas of suitable topography and remoteness from dwellings are required, making it unsuitable for many locations. Because of the availability of land and the warmer climate which helps to maintain consistent biological

activity, most oxidation basins are found in the southern states. Nutrients do not accelerate the slow oxidation occurring under these conditions so they are not employed.

It is imperative that settleable solids be effectively removed ahead of these basins since if they are deposited therein they will decompose and add a large BOD load to the wastewater.

BOD loadings for which these basins are designed are from 56 to 67 kg/ha surface area/day (50 to 60 lb/ac/day). Retention times range from 20 to over 60 days giving BOD reductions up to 50 percent or more.

This method of treatment has two principal advantages. It is capable of handling (buffering) accidental discharges of strong wastes without upset and has no mechanical devices with inherent maintenance problems. Thus they perform well on a continuous basis. Generally this method also accomplishes significant removal of suspended solids.

Aerated Stabilization Basins (ASB)

The aerated stabilization basin, as used in all subcategories, evolved out of the necessity of increasing performance of existing oxidation basins due to increasing effluent flows and/or more stringent water quality standards. Induced aeration provides a greater supply of oxygen and allows a substantial reduction of retention time over the oxidation basin. To fully realize the potential of this method nitrogen and phosphorus nutrients must usually be added since most pulp and paper effluents are deficient in these elements. These additions are usually made in the form of ammonia and phosphoric acid. The longer the retention period of the waste undergoing biological oxidation, the lower the nutrient requirement. Five to 10 days retention are normally used in order to obtain a BOD reduction of more than 80 percent (127) (128) (129).

Aeration is normally accomplished using either gear-driven turbine type surface aerators or direct-drive axial flow-pump aerators. Diffused air can be employed but is less efficient. Recently a downflow bubble aerator has been developed for use in deep basins. Oxygenation efficiencies under actual operating conditions range from 0.61 to 1.52 kg of oxygen/ kw/hr (1.0 to 2.5 lb of oxygen hp/hr) depending on the type of equipment used, the amount of aeration power per unit lagoon volume, basin configuration, and the biological characteristics of the system (130) (131). It is necessary to maintain a dissolved oxygen (DO) level of 0.5 mg/l in the lagoon to sustain aerobic conditions.

BOD_5 and suspended solids levels, oxygen uptake, and dissolved oxygen levels throughout the basins are related to aerator location and performance and basin configuration. There have been extensive studies of (132) eleven existing basins which have developed aids for the design of future basins.

The world's largest ASB system covers 98.8 ha (244 ac) and has 43- 56 kw (75-hp) aerators installed. It treats a flow of 295 million l (78 million gal) per day with a BOD_5 loading of 77,180 kg (170,000 lb) per day. BOD_5 removal is 66,284 kg (146,000 lb) per day or 86 percent.

Some sludge accumulates in the bottom of these basins but is relatively inert and can be removed with periodic cleaning. Sludge accumulation diminishes as the detention time and degree of mixing within the basin increases. At some mills a settling basin or clarifier follows the aeration unit in order to improve effluent clarity.

Aerated stabilization basins provide a high degree of BOD reduction without very extensive land use and at capital and operating costs lower than those for highly accelerated oxidation processes.

Activated Sludge (A)

The activated sludge process is similar to the ASB except that it is much faster, usually being designed for four to eight hours of total retention. The biological mass grown in the aeration tanks is settled in a secondary chamber and returned to the aeration tanks, building up a large concentration of active biological material. Since there are approximately 3000-4000 mg/l of active sludge mass in the aeration section of this process as opposed to 50-200 mg/l in the aerated stabilization basin, oxidation is much more rapid. Loadings in excess of 1.6 kg of BOD/cu m (100 lb of BOD/1000 cu ft) of aeration capacity per day are obtainable, allowing the use of relatively small aeration tanks. Since biological organisms are in continuous circulation throughout the process, complete mixing and suspension of solids in the aeration basin is required. Mechanical surface aerators similar to those used in aerated stabilization basins are normally used although diffused air is used in some cases.

Rates of about 24,445 l/day/sq m (600 gal/day/sq ft) are used for the secondary clarifier settling the activated sludge. The waste activated sludge is the major difficulty of this process as it is extremely slimy and must be mixed with more freely draining materials such as primary sludge, bark, or fly ash before it can be successfully dewatered. Experimental work employing centrifugal thickening and heat treatment is now underway in the hope of finding a solution to this problem. Carry-over of suspended solids has also been a problem with this process.

Short detention times and low volumes make the activated sludge process more susceptible to upset due to shock loads. When the process is disrupted, several days are usually required to return the biological activity and high BOD_5 removal rates back to normal. Thus, particular attention is required to avoid such shock loads in mills utilizing this process. The greater shock load tolerance of aerated stabilization basins, lower nutrient

requirements, reduced sludge handling problems, and lower cost, explains their general popularity. Exceptions occur particularly where the high cost or unavailability of land dictates the use of the activated sludge process with its much lower land requirement.

The contact stabilization process is a variation of activated sludge in which two aeration steps are utilized rather than one. First, the incoming waste is contacted for a short period with active organisms prior to sedimentation. Settled solids are then aerated for a longer period to complete waste assimilation. Contact stabilization has been applied successfully to integrated kraft mill effluent while conventional activated sludge is used at most other mills.

Another form of the activated sludge process uses high purity oxygen for oxygenation within a closed activated sludge tank. Pilot plant studies (133) indicate that such plants can operate at very high active sludge levels (5000-7000 mg/l) at high dissolved oxygen concentrations (greater than 5 mg/l) with high overall utilization of oxygen feed gas (greater than 90 percent) and give BOD_5 removal in excess of 90 percent. The amount of secondary sludge produced is reported to be less than is generated by conventional activated sludge and can be successfully dewatered on a vacuum filter at low primary to secondary ratios at low feed consistencies without chemical conditioning.

Mill 124 has recently installed the first such system in the pulp and paper industry.

Ditch Aeration

The oxidation ditch treatment process is essentially an extended aeration or activated sludge process providing aeration in excess of 24 hours. For economy and simplicity, an earthen ditch in the shape of a racetrack is used for the aeration tank and air is provided by a horizontally mounted aeration rotor or brush aerator. The ditch overflow is clarified and the settled sludge returned to the aeration basin.

A pilot plant using nutrient addition on kraft effluent (134) demonstrated 68 to 80 percent BOD_5 removal at one-day detention and 80 to 94 percent efficiency at two-day detention.

Rotating Biological Surfaces

Pilot studies have been done on the application of the rotating biological surface (RBS) concept for biological treatment of pulp and paper effluents (135). The RBS process can be described as a dynamic trickling filter. Plastic discs, supported on a common shaft rotating at from 7 to 17 rpm, serve as a media for biological growth. The rotating discs are approximately 40

percent submerged in a vat having a constant flow of waste water. In pilot tests, the RBS process has demonstrated its ability to provide high levels of BOD_5 and TSS reduction (301) (302). Biological solids generated have a low sludge volume and exhibit good settling characteristics although dewatering properties are similar to those of activated sludge. The RBS process recovers quickly from organic and hydraulic overloads, has no major operational difficulties, and has low maintenance and manpower requirements. Ninety percent BOD removal has been demonstrated (300) with a BOD loading of 1.2 kg/100 sq m (2.5 lb/1000 sq ft) of disc surface area per day and detention time greater than 2 hr. One mill reportedly plans to install a full scale RBS system.

Trickling Filters

The use of trickling filters in all subcategories is very limited, primarily due to the inability of such systems to accomplish high degrees of BOD_5 removal at high loading levels (136). A kraft mill employing trickling filters with artificial plastic media achieved 50 percent reduction of BOD_5 with 50 percent recycle at a loading rate of 64.3 kg of BOD_5/cu m of media/day (500 lb of BOD_5/ 100 cu ft of media/day) (136).

Small plastic media filters are sometimes used as pre-cooling towers and as such also remove some BOD.

One mill surveyed during this project uses a trickling filter for treatment of effluent from an integrated groundwood and kraft pulping and papermaking operation. This installation suffered from a continual problem of filter media plugging with fungus growths until a satisfactory biocide was developed and utilized.

One pilot study (300) reported up to 72 percent BOD removal at loadings of 1 kg/cu m (62 lb BOD/1000 cu ft) per day but, the percent dropped sharply as the loading was increased. When the loading exceeded 3.2 kg/ cu m (200 lb/1000 cu ft) per day the BOD removal was below 40 percent.

Two-Stage Biological Treatment

Two stage biological treatment, consisting of two biological treatment systems, usually in series can be employed in an attempt to enhance the BOD removal obtained with either single stage. For example, a trickling filter may precede an aerated stabilization basin or an activated sludge system. This arrangement may be employed where the second stage is required because of insufficient performance of the trickling filter alone. It may also be used in cases where cooling of the waste is desired the trickling filter serves as a partial cooling tower, and also accomplishes some BOD_5 reduction.

Two stage aerated stabilization basins, operated in series, have recently been employed in this industry to minimize adverse temperature effects. Examples include Mills 006 and 007. For the first stage, a detention time of two days or more is typical, and up to 10 days or more for the second stage. If sufficient land is available at reasonable cost, this system is usually a less expensive approach than a two stage system involving activated sludge. It has the further advantage of providing more detention time which is helpful in handling surges of flow or pollutant load. Under conditions of proper design and operation, including nutrient addition, BOD_5 removals of 90 percent can be expected with these systems.

A two stage biological system currently employed by some southern bleached kraft mills utilizes an aerated stabilization basin followed by storage oxidation. Typically, detention time of the former is eight to 14 days and for the latter is eight to 40 days. In these installations, overall BOD_5 removal (compared to raw waste) of over 85 percent is being achieved, with 70 percent removal after the first stage. These data do not, however, reflect usage of nutrients. It is probable that the addition of nutrients, proper aeration, and mixing capacity, will ultimately permit BOD_5 reductions of 90 percent. For mills with adequate land and other favorable factors, this system may be the most economical approach.

Other combinations of two biological treatments are, of course, possible, but many would not be practical or economical.

Temperature Effects

All biological treatment systems are sensitive to temperature. In support of this statement, Pelczar and Reid (138) in their text, "Microbiology", stated that all the processes of growth are dependent on chemical reactions, and the rates of these reactions are influenced by temperature. It follows that temperature, in part, will determine the rate of growth and the total amount of growth as well as the metabolism and morphology of the organism. This is applicable to the design and operation of a biological waste treatment facility through the following relationship. Because temperature, inpart, will control the rate and total amount of bacterial growth, the amount and speed with which biodegradable waste materials will be consumed or oxidized by bacteria in a mixed environment, such as an aerated stabilization basin, will be directly related to the activity at the biological population. If the basin temperature is at the optimum for biological growth then a maximum amount of waste material will be consumed. If the basin temperature is not at the optimum for biological growth then the amount of material consumed will be less than maximum, the amount of variance from the maximum consumption being dependent on the degree to which the temperature has varied from the optimum.

An optimum range of temperatures exist in which bacteria will grow best and the biological treatment systems will operate at its highest efficiency. This range is 16°C to 40°C (61°F to 104°F). However, theoretically a biological treatment plant will yield maximum effiency when operated isothermally at an optimum temperature. This is not feasible for practical application, however, it shows the need to maintain stable temperatures as frequently as possible.

Problems encountered due to temperature variations are related to the bacterial population's ability to acclimate to the variance in temperature. If the temperature falls outside of the optimum range a certain acclimation period must be incorporated to allow for the recovery of normal bacterial functions. The failure at most biological treatment units related to temperature variance is due to the lack of a sufficiently long acclimation period. The necessary acclimation period for mixed cultures at low temperatures has been reported at 2 weeks after a temperature change of 10° to 15°C (139). For high temperatures the acclimation period is on the order of months, with these necessary time periods for acclimation it is obvious that biological upsets will occur if biodegradable material is loaded at a normal rate while there has been a significant temperature change.

Temperature over 40°C (104°F) may be encountered in warm climates where heat is also added to the waste stream during processing. Cooling towers or trickling filters have been employed to reduce these higher temperatures prior to biological treatment. In colder climates, waste water temperature is likely to drop below 16°C (61°F) in the winter. Particularly susceptible to this temperature drop are treatment units with detention times greater than 12 to 24 hours.

An aerated stabilization basin is one such unit. It's temperature related problems stem from the large surface area available for heat tranfer and from the action of the mechanical aerators creating more contact between the atmosphere and the surface of the liquid therefore, accelerating heat loss. This problem could be corrected through the use of surface insulation or by the addition of heat to the waste stream initially. Techniques are available to control and compensate for all undesirable temperature related effects on effluent quality, and to create a margin of safety in order to assure that high effluent quality is maintained.

Of the mills surveyed in this study 22 with aerated stabilization basins had temperature data available at their final discharge. A tabulation of the months in which the maximum monthly average BOD at final discharge occurs for these mills (Table 57) shows that 77 percent had their maximum BOD discharge during the colder months, December to March, with a remainder randomly distributed throughout the year.

Table 57

MONTH OF MAXIMUM AVERAGE BOD AT FINAL DISCHARGE
FOR SURVEYED MILLS WITH ASB

Mill Code	Month Of Max. BOD At Final Discharge	°C Of Discharge For Month Of Max. BOD °C
001	Feb.	20.2
005	Nov.	18.1
006	Feb.	16.5
007	Feb.	17.6
051	April	17.8
052	Nov.	19.6
100	Feb.	16.3
101	Feb.	4.4
106	Mar.	14.2
109	June	36.0
110	Feb.	10.4
113	Feb	15.2
114	May	25.1
116	Mar.	27.7
117	Jan.	14.6
121	Dec.	17.0
125	Feb.	13.6
203	Jan.	10.5
204	Sept.	27.6
205	Dec.	5.8
263	Mar.	13.1
359	Jan.	5.6

In an attempt to quantify this apparent low temperature effect, monthly average final BOD was plotted against temperature and a correlation of BOD versus temperature was obtained for 13 ASB's. The ratio of final BOD during cold months to final BOD for the warmer months for the 13 was plotted against detention time in the biological treatment system as shown in Figure 43.

This figure also includes similar plots for eight hour short detention biological treatment plants. These eight results give a scatter of results around 1.0 indicating little temperature dependence of these treatment systems.

The plots for ASB systems do show a temperature dependence but the scatter of results and the small number of mills with adequate data make any numerical evaluation impossible. Also a large number of other factors can and will influence these results, thereby concealing the true temperature effect.

Sludge Handling and Disposal

The disposal of sludges obtained from the clarification of pulp and papermaking effluents is still a major problem despite many years of research, development work, field studies, and applications. In early practice, these sludges were placed in holding basins from which free water from natural compaction and rainfall was decanted. When a basin was full it was abandoned, or if sufficient drying took place the sludge cake was excavated and dumped on waste land and the basin was returned to service. Odor problems from drying as well as land limitations have now demanded the adoption of more advanced practices (64) such as sludge thickening, dewatering, and incineration. The alternative uses of these processes are shown in Figure 44.

In practically all systems, the dewatering operation is more efficient and economic when the feed sludge solids content is high. Hence, it is desirable, even if not necessary, to prethicken sludge. This is accomplished by providing a high level of sludge storage capacity within the mechanical clarifier or by gravity thickeners of the "picket-fence" type. Small mills sometimes employ high conical tanks which contain no mechanism but have wall slopes in excess of 60° and which act as both storage tanks and thickeners.

Vacuum filters are in common use for dewatering sludges from pulping and papermaking and produce cakes ranging from 20 to 30 percent solids. The filtration rates vary greatly depending on the nature of the sludge. The range of rates for each subcategory is shown in Table 57.

Observed capacities for the poorly filterable sludges can generally be about doubled by chemical conditioning with ferric chloride, alum, or polyelectrolytes at a cost of from $3.30 to $5.50 per metric ton ($3.00 to $5.00 per short ton) of dry solids. Such treatment is generally necessary when activated sludge is included in the sludge to be dewatered since the

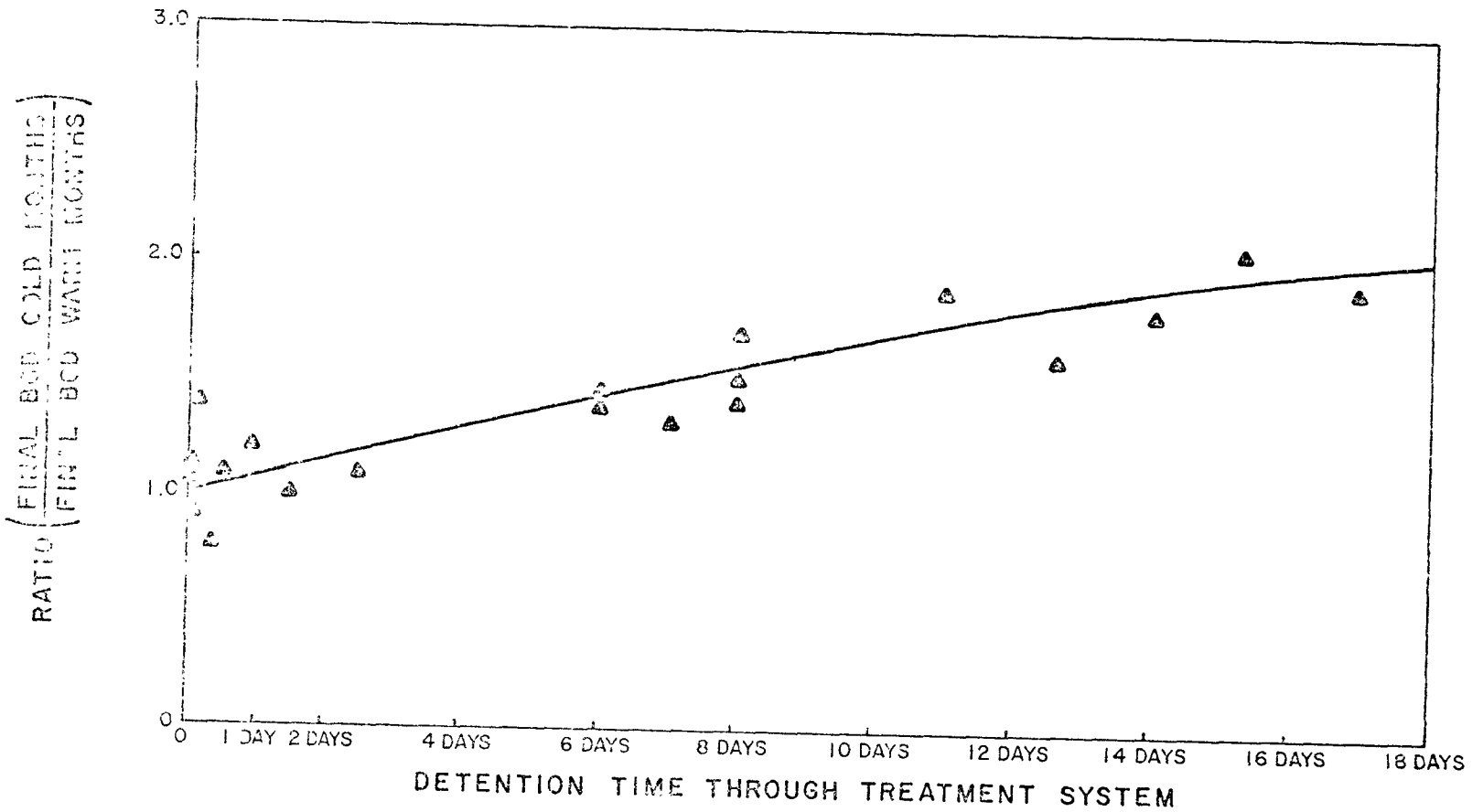
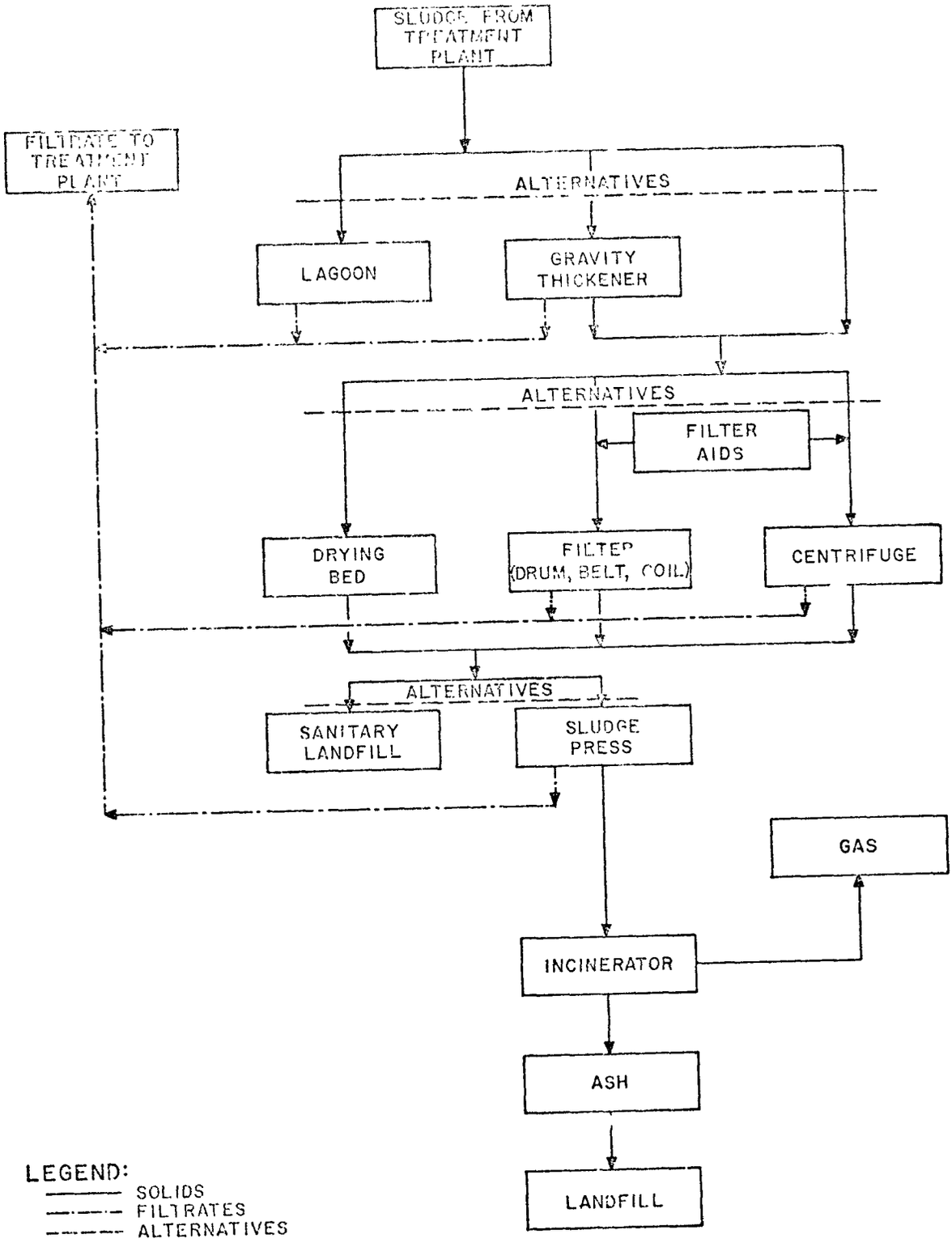


FIGURE 43

EFFECT OF TEMPERATURE ON BIOLOGICAL TREATMENT SYSTEMS

FIGURE 44

SLUDGE DEWATERING AND DISPOSAL



addition of 20 percent of this material on a dry solids basis can reduce filtration rates as much as 50 percent.

A number of different types of filters are in service, with the continuous rotary vacuum filter, similar to the drum filter used in pulp washing being widely used. Among recent installations coil or belt types are the most popular.

Centrifuges have proved successful in dewatering pulp and paper mill sludges and generally produced cakes with lower moisture than those generated by vacuum filters. Cakes range from 25 to 35 percent dry the solids in the feed stream.

The application of drying beds for dewatering sludges is limited to small mills and they are not constructed as elaborately as are those employed for sanitary sewage. They generally consist only of multiple beds of gravel or cinders without a complex underdrain system.

Additional water can be removed from vacuum filter and centrifuge sludge cakes by pressing; cakes approaching 50 percent solids can be obtained.

Recent efforts have been toward direct use of presses on thickened sludge, thus eliminating the first dewatering step (141). Pressing is normally employed when incineration is to be used for disposal since it reduces or eliminates the need for supplementary fuel to maintain combustion.

Land disposal, via dumping or lagooning, has been a common means of disposing of waste sludges and other solid wastes from many pulp and paper mills. Several factors have made such practices generally undesirable, however. Odors form upon decomposition of these materials, there is a potential for pollution of nearby surface waters, and affected lands are eliminated from potential future uses. If proper sanitary landfill techniques are applied, however, most solids from the pulp and paper industry should create no environmental problems. In the rare cases where sludges contain leachable quantities of taste- or odor-imparting, toxic, or otherwise undesirable substances, simple sanitary landfilling may not be sufficient to protect ground water quality.

Three types of incineration are practiced in pulp and paper mill sludge disposal. These are 1) burning in an incinerator specifically designed to handle sludge (142), 2) in the bark boiler (65), and 3) in a power boiler burning fossil fuel. All these methods are successful but costs are relatively high and technical problems are encountered in the incinerators as ash contents are high. A number of other methods of combustion have been tried including multiple hearth, kiln types, wet air oxidation, and fluidized bed although only the latter appears promising.

A fluidized bed has been successfully used to dispose of groundwood and sulfite mill sludges at 25 percent solids in combination with waste wood debris and surplus bark (143). The system operates without producing any air pollution problems.

Interest has been stimulated in utilizing sludge from kraft mills in low grade products such as roofing felts, but lack of uniformity mitigates against such practice. Several researchers (144) experimented with the use of this material as an organic soil supplement and with hydromulching. The incorporation of high sludge levels into soil, after permitting it to stand for a year, increased bean and corn crops for two successive plantings as compared to control crops. However, equivalent amounts of sludge added to the soil each successive year caused a reduction in crop yields which was apparently due to nitrogen unavailability. In the hydromulching tests when sludge was applied to a simulated highway cut, sludge with or without the addition of bark dust was found to be competitive with a commercial product for establishing a grass stand.

Several mills are presently experimenting with using the sludge as a soil supplement in reclaiming land for growing pulp wood. Primary sludge is being applied to the land at loads (dry solids) of 224-448 kkg/ha (100-200 tons/ac). Cottonwoods are planted with planned harvest and reapplication of sludge in three to five years.

Production of bacterial protein from cellulosic sludges continues to attract the attention of researchers despite the failure to date of similar products to gain a foothold in the market in this country. A satisfactory product has been produced by growing thermo-monospora fusca, srongly cellulolytic thermophylic organism on low lignin pulp mill fines (145). This process is attractive in that acid hydrolysis of the cellulose prior to fermentation is not required. The substantial reduction of organic matter attained is of considerable interest. Preliminary tests show that the thermo-monospora fusca is palatable and nontoxic as animal feed and could be competitive in cost with other protein sources.

Irrigation and Land Disposal of Effluents

Total effluents of some non-integrated paper mills, have been disposed of by means of irrigation and land disposal. Specific effluents from pulp mills such as cooking liquors, foul condensates, and turpentine decanter water, have also been treated in this manner.

The advantage of land disposal, when properly practiced, is that a very high degree of purification occurs as the water passes through the soil. Approximately 20 percent or more of the waste is evaporated by this process. When the remaining waste finally reaches either the adjacent stream or ground water, it is practically devoid of suspended matter, BOD, and color. The

disadvantages are 1) the relatively small volume that can be disposed of per acre per day, 37,850 to 113,550 l (10,000 to 30,000 gal) under most soil conditions, and 2) freezing problems during the winter months. In some instances, this process is applied only during the critical months when temperatures are high, stream flowages low, and crops, which increase the allowable application rate appreciably, can be grown.

The use of land for the disposal of pulp and paper mill effluents has been applied in the following forms:

1. Seepage ponds

2. Direct application to fallow soil with a wide range of textures by both spray and ridge-and-furrow distribution

3. Application by similar means to soils whose absorption capacity has been modified by development of suitable cover vegetation

4. Controlled effluent application designed to produce crops by use of suitable irrigation practices.

Since these effluents contain little in the way of basic fertilizer elements, any value they add to the soil other than their irrigating effect is the increased water-holding capacity and friability induced by the stable organic matter present. The use of land disposal and irrigation for disposing of these wastes has been described in detail in the literature (146). An assessment of the effectiveness of irrigation on crop growth and the parameters for application of water, BOD, cellulose, and sodium for soils of different character and textures are set forth.

Foam Control

Effluent foaming in receiving waters is a problem experienced particularly by kraft and soda pulp mills since alkaline liquors have a strong propensity to impart this quality to water. Other waste constituents can do likewise but these are the most common offenders in both treatment plants and receiving streams. Some paper mill wastes can also cause this effect due to residual amounts of additives present in the white water discharged, as can coating kitchen wash waters.

There is relatively little literature on the measurement of foaming capacity or its control in pulp and paper effluents despite the fact that control methods are well established, widely used, and quite effective. A method has been developed (126) for comparing foaming potential based upon methods employed in the detergent industry which appears to be the only technique presently available to measure this factor in pulp and paper effluents.

Foaming problems are common within kraft and soda mills themselves and these difficulties are frequently the cause of the problem in effluents, foam or black liquor being carried directly into sewers. In-mill sewering arrangements can also give rise to foaming. This can be avoided by rearranging the sewer system to prevent direct admixture of alkaline and acid waste waters within them and correcting arrangements and pumping systems which give rise to air entrapment, a major cause of foaming in itself. Maximum control of black liquor losses is mandatory if foaming is to be kept at a reasonable level both during effluent treatment and in discharge.

Since some biological treatment processes depend upon aeration of the waste, foam is bound to develop. Under normal conditions with most wastes this can be maintained at a minimum level by in-plant control or by the use of surface sprays installed in treatment basins. In most instances with good mill loss control, foam levels will stabilize in treatment units and not become unmanageable. Biological treatment is effective in itself in reducing foaming tendencies.

Variability of Effluent Discharges from Surveyed Mills

The treated effluent from pulp and paper mills varies on a daily basis. This is demonstrated by examining data from the mills, as illustrated by Figure 45 which gives the effluent BOD_5 from an ASB for mill 117. In developing effluent limitations, consideration was given to the annual average, the 30 day average, and dasily maximum.

Of major importance in establishing maximum 30 day averages and daily maximums is the technique of data analysis. A variety of approaches were analyzed. A summary of these techniques is as follows:

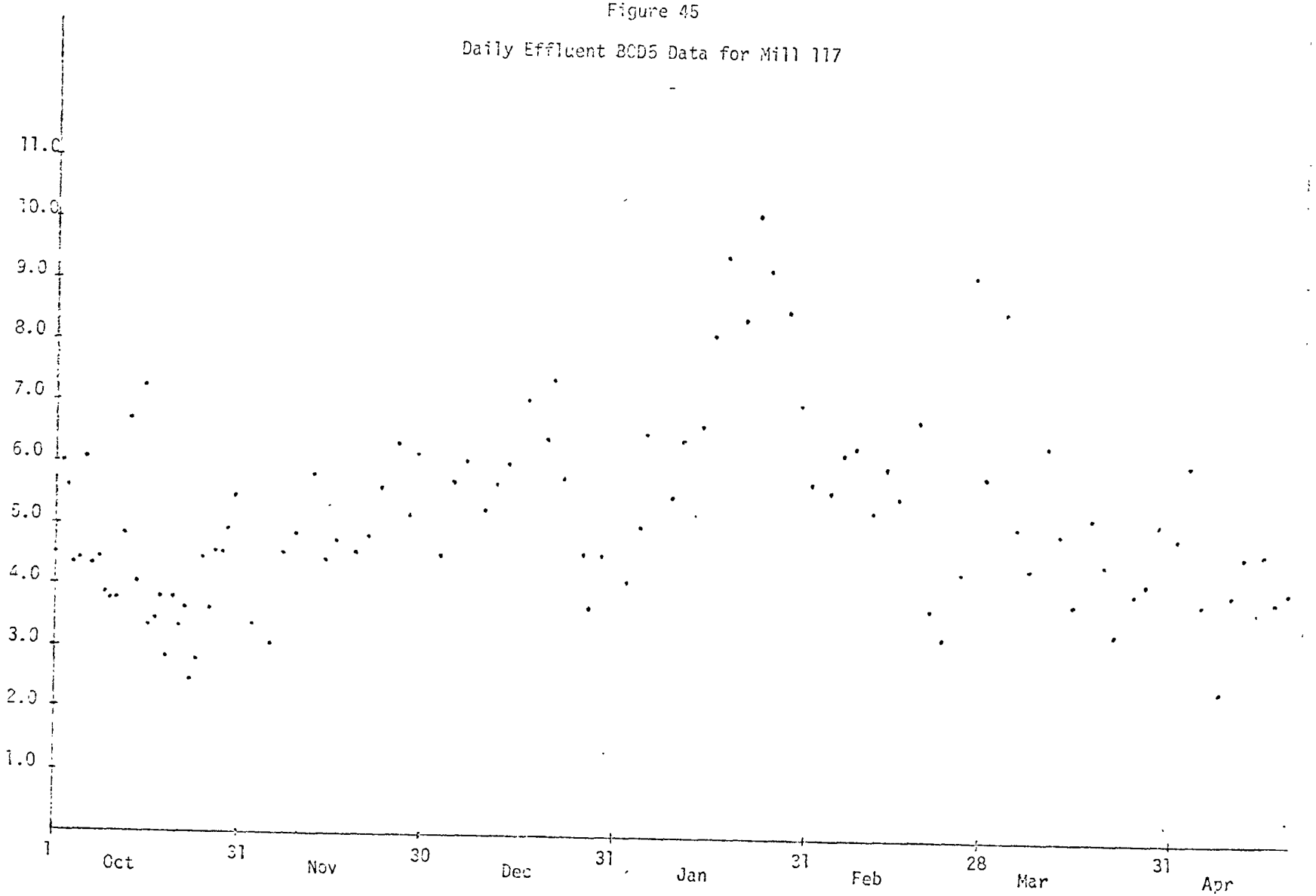
Plant Selection
Data Screening
Normal Probability
Log-Normal Probability
Number of Standard Deviations
Actual 30 Day Maximum
Actual Daily Maximum
Variability of Mill Effluent
Variability of the Mill relative to Annual Average Bases
Application of analysis (i.e. taking the max, ave, etc.)

In addition, a number of factors are felt to possibly have an effect upon the effluent variability, of which the major are:

Temperature
Process
Treatment System

Figure 45

Daily Effluent BOD5 Data for Mill 117



The purpose of the analysis of these factors was to evaluate their effect or lack thereof on variability and then to consider them within the regulations, or to set the limitations at a level in which mills affected by these factors can reasonably achieve compliance.

Plant Selection

The selection of mills for variability is based upon whether the mill has historically complied with the annual average basis. Other mills which are not in compliance with the annual averages were examined; however, they are considered to be unreliable representations of the variability which would occur if the annual average limitations were met.

The selection of mills for BOD variability is more extensive than for TSS because many mills report TSS measured by non-standard methods. The mills utilized are as shown in Table 58.

Table 58

Mill Selection For Variability Analysis

Mill	Complying with BOD AA	Complying with TSS AA*
1	yes	yes
5	yes	yes
101	yes	yes
105	yes	N.D.
106	yes	yes
107	yes	N.D.
111	yes	yes
112	yes	N.D.
113	yes	N.D
114	yes	yes
117	yes	yes
119	yes	yes

*N.D. refers to no data

The first criteria for mill selection is compliance with the annual average BOD and TSS (if data is available). The mills which comply with both the annual average BOD and TSS were be strongly weighed during variability analysis.

Screening Data

The recommendation has been made to EPA not to screen any data, however situations do arise for which data points do not reflect proper operations and should be excluded. EPA expects that some occurrances are not preventable such as one aerator breaking down and thereby resulting in a slightly higher pollutant discharge. This type of case has not been excluded from analysis. Other cases such as a substantial number of aerators being shut down is not considered normal operation and therefore is not included in the data base. As an example, mill 113 has a daily BOD maximum of 19.6 kg/kkg (39.2 lbs/ton); however, aerators were reported by the mill to be down from 12/72 thru 3/73. Examination of data outside this tim period yields 8.4 kg/kkg (16.8 lbs/ton) for a daily maximum. The difference in the two maximums is substantial; 19.6 kg/kkg (39.2 lbs/ton) is not an acceptable outside this time period yields 8.4 kg/kkg (16.8 lbs/ton) for a BOD_5 daily maximum. The difference in the limit. Besides aerator shut downs other factors can create excessive variability; mill 121 had an acid spill which caused poor biological treatment for two months. For mill 121 data during this time span was excluded. Most of the mills analyzed had no periods of time where data was excluded; indicating that the causes of exclusion were not typical or frequent. In most instances, plants neglected to make an indication as to why certain peaks occured. These unexplained peaks were included within the data analysis, however the possibility does exist that preventable actions were the source of these peaks and therefore EPA has over estimated the 30 day and daily maximum. The variability of most of the mills appears consistant; groups of mills have peaks in the same range indicating a common phenomenon which should be included. If an isolated mill with high peaks occurs and no justification is known, greater concern would be needed.

A breakdown of the data screening is as shown in Table 59.

Table 59

Data Screening

Mill	Data Screening Justification
2	no data was excluded, however there is a general lack of confidence in BOD and TSS peaks - composite sampler malfunctions, ammoniator failures, and sample mix-ups occurred.
106	Data from January thru March 1973 excluded because aerators were down.
113	Excluded data from 12/72 - 3/73 aerators down.

Probability Distribution

The most commonly utilized probability is the normal distribution which describes occurrances further from the mean as less probable.

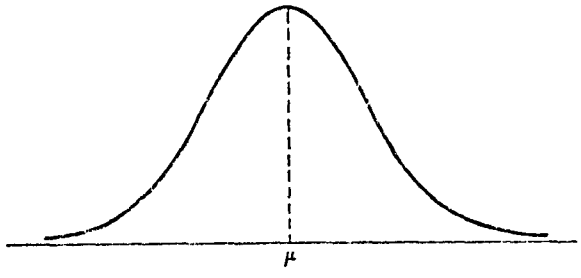


Figure 46

Normal Probability Distribution

The development of this distribution was for describing errors of measurements which occurred according to the laws of chance. In utilizing this type of distribution, it is assumed that the data behaves in the same manner as the plot. Fundamentally the data is unlikely to be properly described by such a plot; human control tends to be nonrandom. Another factor to consider is that the normal distribution states that there is a finite probability that negative values will occur. In actuality pollutants can not exist in negative concentrations. A method of correcting for these discrepancies is to take the log of the values thereby opening the possible range of values to negative numbers. Recommendations have been made for the use of log normal distributions, claiming that a closer fit to the data is obtained. EPA examined its data base for both log normal and normal distributions. Calculations were made on both the symmetry and kurtosis, as measurements of the accuracy of the fit between the data and the probability distributions. In general, log normal provides a more accurate description of the data. For further analysis, log normal distributions are examined in lieu of normal which was found to be less exact.

Accepting log normal as a more accurate approximation of the data does not eliminate the inherent assumptions which may be invalid, i.e., the probability distribution allows for infinitely high values; this can not occur in actual operations. The reliability of using log and normal probability will be examined, as to its ability to predict the daily allowable maximum. The use of 3 standard deviations in predicting the daily maximum would yield a number which the probability curve indicates would not be exceeded 99.9% of the time. EPA chose to examine this level of confidence with the purpose of determining whether or not this was a consistantly accurate technique for establishing maximums. For the examination, comparisons were made between the mean + 3 standard deviations and the actual maximum that occurred. In general, the probability analysis yields results which are higher than the maximum value (some cases are lower). Close predictions would indicate that the use of log normal analysis would be proper, however special consideration must be given to values where discrepancies occurred. These cases may cause an improper evaluation of variability. The BOD5 mean plus 3 standard deviations for mill 106 is 40.8 kg/kkg (81.6 lbs/ton) while the data bsse which included 315 data pints actually had a daily maximum of 17.75 kg/kkg (35.5 lbs/tons). A dilemma is reached as to whether this plant should be described by a daily maximum of 17.75 kg/kkg (35.5 lbs/ton) or 40.8 kg/kkg (81.6 lbs/ton). It may be that 17.75 kg/kkg (35.5 lbs/ton) would likely be exceeded and that insufficient data was examined. This assumption was evaluated as follows:

For mill 106
lbs BOD5/ton

log mean log S.D.
0.8211 0.3635

log (Daily Max) = log (35.49) = 1.5501

From probability tables the probability of a value being greater than 1.5501 (log scale) is 0.0228

What is now desired is to find the probability that none of the 315 values would exceed 35.49.

The probability of getting x successes in n independent trials is given by

$$f(x) = \binom{n}{x} p^x (1-p)^{n-x} \qquad \text{for } x = 0, 1, 2, \ldots, n$$

where p is the constant probability of a success for each individual trial.

x = 0
n = 315
p = 0.0228

Solving for f(x)
f(o) = 0.0006995 = 0.0007

This indicates that the probability of not obtaining a data point higher than 35.49 out of 315 trials is 7 in 10,000 (less than 1 in a 1000).

The previous example utilized data which was not screened. As indicated previously screening is justified for this mill and the BOD5 daily maximum during proper operations is only 7.33 kg/kkg (14.65 lbs/ton). Mill 106 appears to require a daily maximum of 7.33 kg/kkg (14.65 lbs/ton) during proper operations and not 40.8 kg/kkg (81.6 lbs/ton) indicated by statistical analysis without data screening.

The above analysis was based upon log normal being an accurate description of the data. Factors do exist for mills which render log normal probability distribution analysis improper, as illustrated above. From a non-theoretical viewpoint a strong point should be made for examining the actual daily maximum (especially from large data sets where values become statistically significant). Permitting and possible subsequent prosecution of violations will be based on actual numbers not on log normal or any other type of curve fitting and therefore a close examination shall be made of the actual maximums.

After establishing the daily maximum, actual or statistical the use of the numbers has a great effect on the final regulations. Typically, the maximum is rationed to the plant's yearly average, and sets of ratios are examined. EPA considered a possible flaw in this approach with the following hypothesis: Plants achieving effluent qualities substantially lower than BPCTCA limitations may have a higher variability. If this theory is correct, the transfer of plant variability to the limitations would be improper and would result in limitations which would be

Table 60
Symmetry and Kurtosis of BOD Log and Normal Distributions

Mill	BOD Symmetry		BOD Kurtosis	
	Normal	Log	Normal	Log
1	0.50	-0.15	2.28	2.18
5	1.09	-0.26	3.92	3.22
101	1.93	-0.31	9.11	3.49
105	0.27	-0.88	2.11	4.96
106	1.20	-0.02	3.60	2.06
107	3.67	-0.30	22.32	6.50
111	0.55	-1.50	2.90	8.98
112	2.24	-1.03	10.55	5.22
113	1.40	0.01	5.17	2.20
114	1.02	-0.13	3.88	2.68
117	0.57	-1.85	3.82	10.41
119	1.52	-0.10	7.27	3.32

Table 61
Symmetry and Kurtosis of TSS Log and Normal Distributions

Mill	TSS Symmetry		TSS Kurtosis	
	Normal	Log	Normal	Log
1	0.83	-0.46	3.49	2.74
5	0.52	-1.24	2.91	5.89
101	1.39	-0.66	4.75	4.59
106	0.86	-1.19	4.38	4.39
114	0.56	-1.10	3.45	4.77
117	1.02	-0.28	3.70	3.46
119	2.22	-0.15	10.85	3.73

Table 62
BOD Daily Maximum Relative to 99 and 99.9% Probability Confidence

Mill	Maximum	Mean + 2.33 Standard Deviation	Mean + 3.0 Standard Deviation
1	8.47	10.19	13.55
5	12.54	14.53	20.93
101	12.86	9.37	14.47
105	8.91	14.11	19.42
106	35.49	46.57	81.61
107	25.96	15.56	21.36
111	11.88	14.90	20.22
112	12.45	13.19	21.77
113	39.16	37.64	60.57
114	14.53	15.81	21.68
117	13.07	10 98	12.50
119	7.26	5.39	7.20

Table 63
TSS Daily Maximum Relative to 99 and 99.9% Probability Confidence

Mill	Maximum	Mean + 2.33 Standard Deviation	Mean + 3.0 Standard Deviation
1	20.37	22.92	34.85
5	8.99	14.06	20.3[illegible]
101	8.97	12.21	19.98
106	35.24	44.23	73.55
114	26.43	17.92	20.84
117	24.98	28.01	39.10
119	32.11	22.93	34.74

erroneously high. The bleached kraft mills listed in Table 64 were examined:

Table 64

Comparison of Plant Variability to Limitations Variability

Mill	Daily Max/AA Basis	Daily Max/Plant AA	Plant AA
105	1.2	1.74	5.13
121	2.5	2.01	9.23
109	4.5	2.56	13.01
117	1.39	2.17	4.36
113	2.44	1.84	9.10
114	2.67	1.80	12.64
101	1.86	5.21	2.47
106	2.03	1.59	9.22
107	2.83	3.33	5.4
120	4.83	4.49	7.12
110	2.63	2.70	6.29
119	1.30	3.36	2.16
112	2.22	4.29	2.90

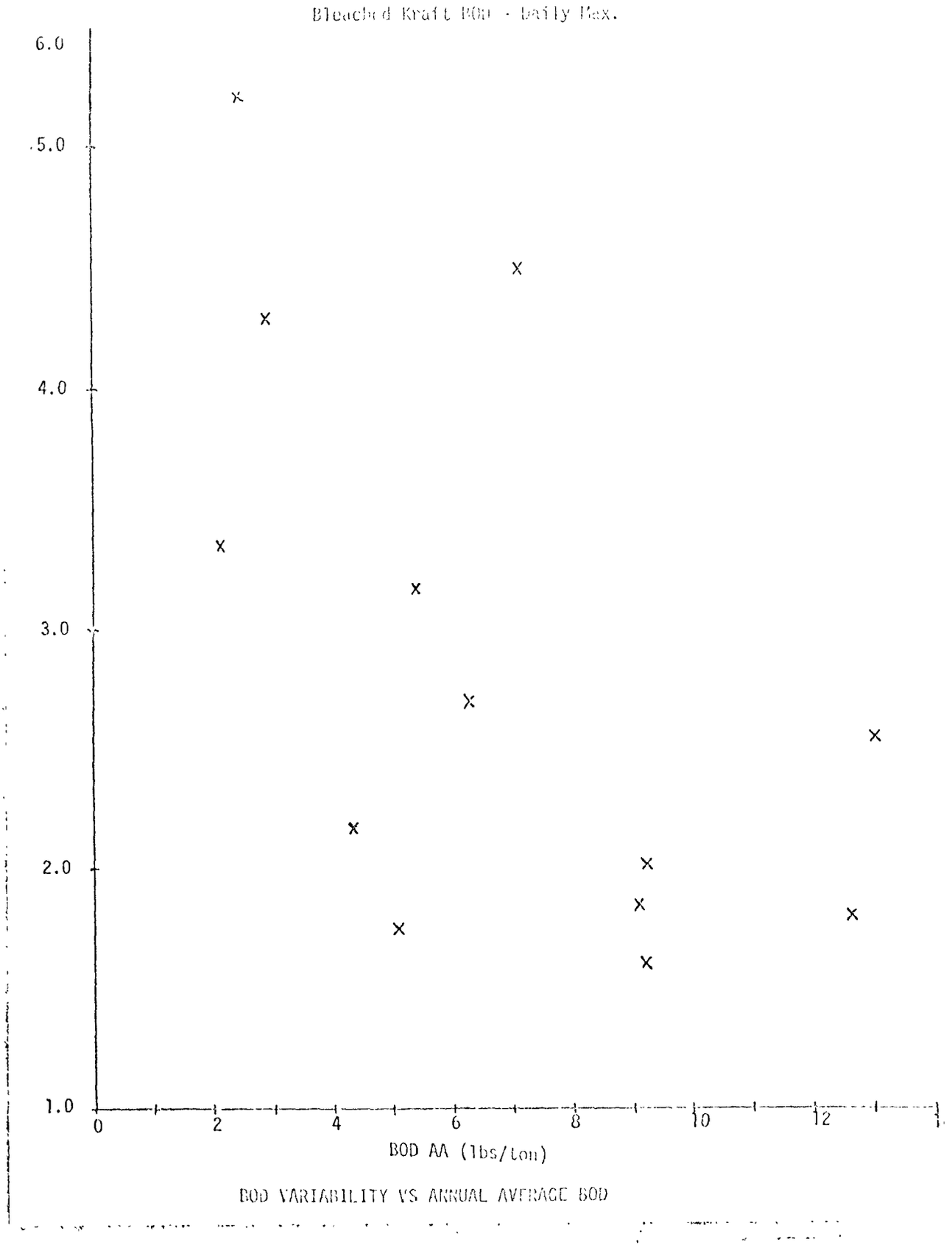
Note from Table 64 and Figure 47 that three of the four highest "Daily Max/Plant AA" are from plants with the 3 lowest effluent values thereby giving strong credence to the theory that there is a tendency for greater variability for more stringent treatment systems.

To further illustrate the analysis, mill 101 will be examined. The daily maximum/AA for this mill is 5.21; if this was applied to the estimated limit of 3.45 kg/kkg (6.9 lbs/ton), the plant would be allowed 18.0 kg/kkg (36.0 lbs/ton). The maximum value this mill reached was 6.45 kg/kkg (12.9 lbs/ton). This additional allowance would be totally unnecessary for this plant and would contribute to an unjustified higher allowance for all the plants. Since examination of Daily max/AA can yield erroneously high values, examination will be made of the plant's maximum to the AA basis. This will yield a ratio of how many times higher than the AA bases the 30 day and daily maximums must be so that the plant will not have violated the allowable deviations. The largest ratios obtained for well operated and designed plants will be utilized as the allowable deviation from the annual average. None of the acceptable plants will therefore have ever exceeded the 30-day or daily maximum (except for a few cases where data was discounted due to system failures or shutdowns). The historical compliance of these plants with the calculated 30 day and daily maximums limitations firmly illustrates the achievability of these limitations.

Variability Results

The mills shown in Table 65 have historically complied with both the BOD and TSS annual average bases.

Figure 47



BOD VARIABILITY VS ANNUAL AVERAGE BOD

Table 65

Variability of Mills Complying with the BOD and TSS AA's

Mill	BOD Daily Max BOD AA Basis	TSS Daily Max TSS AA Basis	BOD 30 Day Max BOD AA Basis	TSS 30 Day Max TSS AA Basis
1	2.07	2.34	1.67	1.32
101	1.86	0.83	0.85	0.29
106	2.03	3.16	1.02	1.02
114	1.71	2.34	1.24	0.94
117	1.97	2.00	1.16	1.61
119	1.30	3.53	0.57	1.11
111	1.61	2.70	1.13	1.34
5	1.79	1.13	1.31	0.82

Some of the mills do not report TSS and therefore EPA has not been able to judge whether they would be in compliance with annual average TSS. From this group of mills, the mills in Table 66 comply with the BOD annual average.

Table 66

Variability of Mills Complying with the BOD AA and not Reporting TSS

Mill	BOD Daily Max BOD AA Basis	TSS Daily Max TSS AA Basis	BOD 30 Day Max BOD AA Basis	TSS 30 Day Max TSS AA Basis
105	1.20	-	1.06	-
112	2.22	-	0.62	-
113	2.44	-	1.46	-
107	2.83	-	1.39	-

Mills achieving annual average BOD and not meeting annual average TSS are not expected to increase the effluent BOD by controlling solids. Current variability for these mill should be on upper limit on BOD that will exists after retrofit to control solids (control of TSS should dampen the BOD variability). The mills are as shown in Table 67.

Table 67

Variability of Mills Complying with the BOD AA and Not Meeting the TSS AA

Mill	BOD Daily Max BOD AA Basis	TSS Daily Max TSS AA Basis	BOD 30 Day Max BOD AA Basis	TSS 30 Day Max TSS AA Basis
206	3.11	8.62	1.30	2.49

The following mills do not comply with the BOD annual average but are examined to find out what value the daily and 30 day average maximums would have to be for them to be in compliance. These are presented in Table 68 in increasing order for mills with secondary treatment.

Table 68

Variability of Mills not Complying with the BOD AA

Mill	BOD Daily Max BOD AA Basis	TSS Daily Max TSS AA Basis	BOD 30 Day Max BOD AA Basis	TSS 30 Day Max TSS AA Basis
110	2.24	3.45	1.74	2.27
51	2.56	2.55	2.14	1.72
284	2.63	2.73	-	-
204	2.87	N.D.	1.96	-
205	3.39	N.D.	1.86	-
257	3.53	N.D.	2.15	-
109	4.50	N.D.	2.50	-
14	4.58	N.D	2.94	-
2	4.67	36.27	2.66	4.61
120	4.84	19.33	1.63	5.30
203	5.32	N.D.	-	-
118	5.53	N.D.	-	-
116	5.77	19.88	3.62	11.39
122	5.86	6.27	2.95	1.24
104	9.42	7.06	3.54	4.17
100	14.76	2.61	10.00	0.48
103	15.87	4.87	7.99	1.39

Variability limitations will be set such that all the mills listed as not violating the BOD and TSS annual average will also not violate the thirty day average and daily maximums. Included are those mills which do not report TSS. From this list of 13 mills, 2565 BOD data points were utilized as well as 1501 TSS data points. None of the 30 day averages or daily values violated the limitations. Included within this data base are

mills from northern climates, and C - ASB's C - A's and other treatment systems. By utilizing the highest value, EPA has set variability limitations which should be achievable by all mills meeting the annual average. The BPCTCA variability ratios are as follows:

BOD Daily Max
BOD Annual Ave = 2.83

BOD 30 Day Max
BOD Annual Ave = 1.67

TSS Daily Max
TSS Annual Ave = 3.53

TSS 30 Day Max
TSS Annual Ave = 1.61

Non-Integrated tissue mills should be capable of meeting the limitations with primary treatment. The variability of this type of technology for the non-integrated tissue subcategory may be different. Limited data from mill 306 indicates the BOD Daily Max to BOD AA equal 0.77, while for mill 309 this ratio is 2.40. No TSS data was available from these mills. Since the data on this type of treatment is limited, the variability allowed for the other subcategories will also be allowed for non-integrated tissue mills. The BOD data available from mills 306 and 309 does indicate the achievability of the variability utilized for this subcategory.

BATEA and NSPS Variability

Having analyzed 30-day and daily maximum levels for BPCTCA, values must be computed for BATEA and NSPS. For pulp and paper mills EPA has demonstrated a tendency for higher variability from reduced pollutant discharge. However, BATEA limitations include the addition of mixed media filtration which may strongly influence the variability. Daily data which is necessary for variability analysis is not available on mixed media filtration for pulp and paper mills. Therefore, the method of calculation will be to use the best available alternative and that is to assume that plants currently achieving these limitations without MMF have the same or greater variability as mills which will have with MMF. Since BATEA describes best available technology economically achievable, EPA will utilize the best effluent variability within the range of BATEA limitations. Only three plants are in the range of the BATEA BOD limitations. The one achieving the best results is mill 119 which attains a pollutant discharge of 1.08 kg/kkg (2.16 lbs/ton) and is close to the BATEA limit of 1.05 kg/kkg (2.10 lbs/ton). The variability on BOD_5 Daily Max/AA for this mill is 3.36. Assuming that this mill could lower its annual average to 1.0 kg/kkg (2.0 lbs/ton) and maintain the same daily maximum, the ratio to the limitation would be 3.46 which was utilized in lieu of the BPCTCA ratio. The maximum 30 day average ratio for this mill is less than that

utilized for BPCTCA, however, the higher number will be utilized (1.67 versus 1.49). The system is a C-A, clarifier followed by activated sludge, and as stated previously does not have the add on of MMF; however, it is close to the BOD limitation with just secondary treatment and therefore presents a currently achievable variability with an alternative treatment system. No current evidence exists that a C-ASB-MMF or C-A-MMF would be more or less variable. Analysis of TSS indicates that levels of variability achieved by the best mill in the range of BATEA and NSPS annual average limitations is less than the BPCTCA ratios. Due to the limited information currently available on BATEA and NSPS variability the higher TSS ratios from BPCTCA will be utilized. The BATEA and NSPS variability ratios are as follows:

BOD Daily Max / BOD Annual Ave = 3.46

BOD 30 Day Max / BOD Annual Ave = 1.67

TSS Daily Max / TSS Annual Ave = 3.53

TSS 30 Day Max / TSS Annual Ave = 1.61

COLOR REMOVAL

The generation of color bearing waste waters by the pulp and paper industry is caused by three distinct operations: 1) chemical pulping, 2) pulp bleaching, and 3) colored paper production. The majority of the color comes from the pulping and bleaching sequences. It is not uncommon to realize the generation of 272.16-317.52 kg (600-700 lb) of color per ton of bleached pulp produced, especially in the bleached kraft segment of the industry.

Because of this, technology is being developed to minimize the industry's color discharges. This technology includes both the internal management of waste generation and external treatment.

Internal process modifications are being proposed which minimize the volume and/or color intensity of the waters in question as well as promise recovery of chemicals used in the various pulping and papermaking operations. On the other hand, new and existing advanced waste treatment techniques are being developed for the industry which hold promise of yielding effluents containing less color. The purpose of this subsection is to identify, document, and verify the full range of control and treatment technologies applicable to color reduction including potential technologies. It is applicable to all subject subcategories, unless otherwise indicated, because of possible transferability from subcategory to subcategory. Also for this reason, work performed on pulping

wastes not subject to this report is included. Any considerations peculiar to specific subcategories will be noted.

Sources of Color

In the various chemical pulping processes, highly colored lignin and lignin derivatives are solubilized during the cooking process. The spent cooking liquors, containing these highly colored compounds, are removed from the pulp in a washing sequence following the cooking process. In various types of pulping processes, this wash water is sent to a recovery area where the cooking chemicals are recovered and the organic materials are burned in a recovery furnace. The washing and recovery operations are efficient; however, small losses of cooking liquor and the discharge of evaporator condensate result in colored effluents. Additionally, most pulp mills discharge the water removed from the pulp in the last operation before it goes to the paper mill or bleach plant. This water is known as unbleached stock decker seal pit overflow. This effluent can be the most significant colored discharge from the production of unbleached pulp. Average values of color discharged from various pulping operations are shown in Table 69 (5).

The caustic extraction stage of kraft bleaching produces a highly colored effluent since the caustic soda employed leaches previously chlorinated lignins from the fiber. The color significance of this discharge from one mill can be seen in Table 70 (247).

Characteristics of Color

Color is defined as either "true" or "apparent" color. In Standard Methods (191) color of water is defined as "the color of water from which the turbidity has been removed." Apparent color includes "not only the color due to substances in solution, but also due to suspended matter." The National Council for Air and Stream Improvement has published a tentative procedure for the measurement of color in pulping wastes (192). This procedure measures the "true" color of the waste by spectrophotometric comparison of a waste sample with a standard curve of potassium chloroplatinate solutions of varying concentrations. The procedure first adjusts the pH of the sample to 7.6. The color of the effluent is pH sensitive, increasing with increasing pH. The sample is next filtered through a 0.8 micron membrane filter to remove turbidity which also affects the color determination. The sample is then analyzed in a spectrophotometer using a wavelength of 465 nm. The color of the sample is determined by comparing the absorbance with a standard curve.

In a laboratory investigation of the characteristics of kraft effluent color, eight series of samples of decker filtrate collected over a period of fifteen months were anlyzed (248). The absorption characteristics of the samples through the visible

Table 69

VALUES FOR COLOR DISCHARGED FROM VARIOUS PULPING PROCESSES [5]

Effluent	Pounds of Color Units per Ton of Product
Kraft Pulping	50 to 300
Kraft Papermaking	3 to 8
Kraft Bleaching	200 to 300
NSSC Pulping (Recovery)	200 to 250
Sulfite Pulping (Recovery)	30 to 200
Sulfite Bleaching	50 to 300

Table 70

CONTRIBUTION OF EFFLUENT SOURCES TO TOTAL MILL EFFLUENT COLOR [231]

Source of Effluent	Color Load (lb color/bl ton)	Contribution to Combined Effluent Color (APHA Color Units)
Pulp mill--general	31	129
Paper Mill	5	21
Bleach chlorination stage	111	462
Bleach caustic extraction stage	460	1916
Remainder of bleaching process	27	113
Total	634	2641

(750-350 nm) and ultraviolet (350-230 nm) spectra were measured. Generally, the samples exhibited an increase in absorbance with a decrease in wavelength. The investigators concluded that no single color is present in the waste, rather, they are mixtures of different colors.

The investigators also measured the effect of dilution, pH, and time on the absorbance characteristics of the samples. It was found that absorbance of diluted samples was linear, following the Beer-Lambert law, and that a direct correlation existed between absorbance and dilution. This is shown in Figure 48. The effect of pH was measured between 2.0 and 11.0. It was found that the absorbance at pH 2.0 was the lowest and that the absorbance was pH sensitive, increasing up to pH 5.0, decreasing between 5.0 and 7.0-8.0, and then increasing to pH 11.0. The reason for the erratic behavior was beyond the scope of the investigation. Figure 49 gives the results of the pH analysis.

The effect of time was measured at three wavelengths for periods of one, three, six, and 24 days. As shown in Figure 50, the absorbance increased up to a storage time of three days, decreased sharply between three and six days, and then decreased slowly from six to 24 days. The reason for this was not known; however, it was suggested that limited oxidation might tend to increase color.

The investigators also conducted experiments to characterize the color bodies in the effluent. Two classes were identified. The first were the high molecular weight, acid-insoluble bodies, and the second were the low molecular weight, acid-soluble bodies. The acid-insoluble bodies were found to have molecular weights from 400 to 30,000 and contained a high proportion of carboxyl groups conjugated with an aromatic ring. The acid-soluble bodies were found to have molecular weights from 400 to 5000 and contained nonconjugated carboxyl groups, apparently associated with carbohydrate material. The investigations further showed that most of the color bodies were ligninlike in character, apparently consisting of lignins degraded to varying degrees, and were negatively charged. An important aspect of this investigation was a comparison of the character of color bodies before and after lime treatment. The significant conclusions will be covered in subsequent sections of this report.

Internal Methods of Color Reduction

The methods of effluent color reduction through in-plant operations considered here include modifications to the kraft pulping process, processes to replace kraft pulping, spill controls, and bleach plant modifications.

Kraft Process Modifications

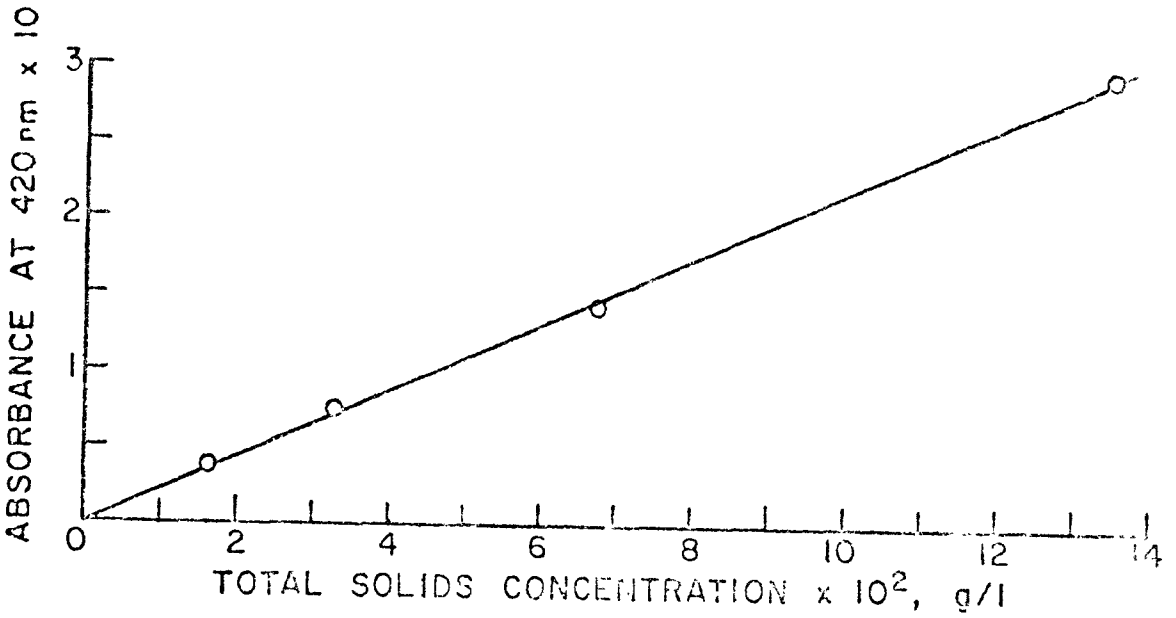


Figure 48 Correlation of Solids Concentration with Absorbance (at 420 nm) of Untreated Waste [233]

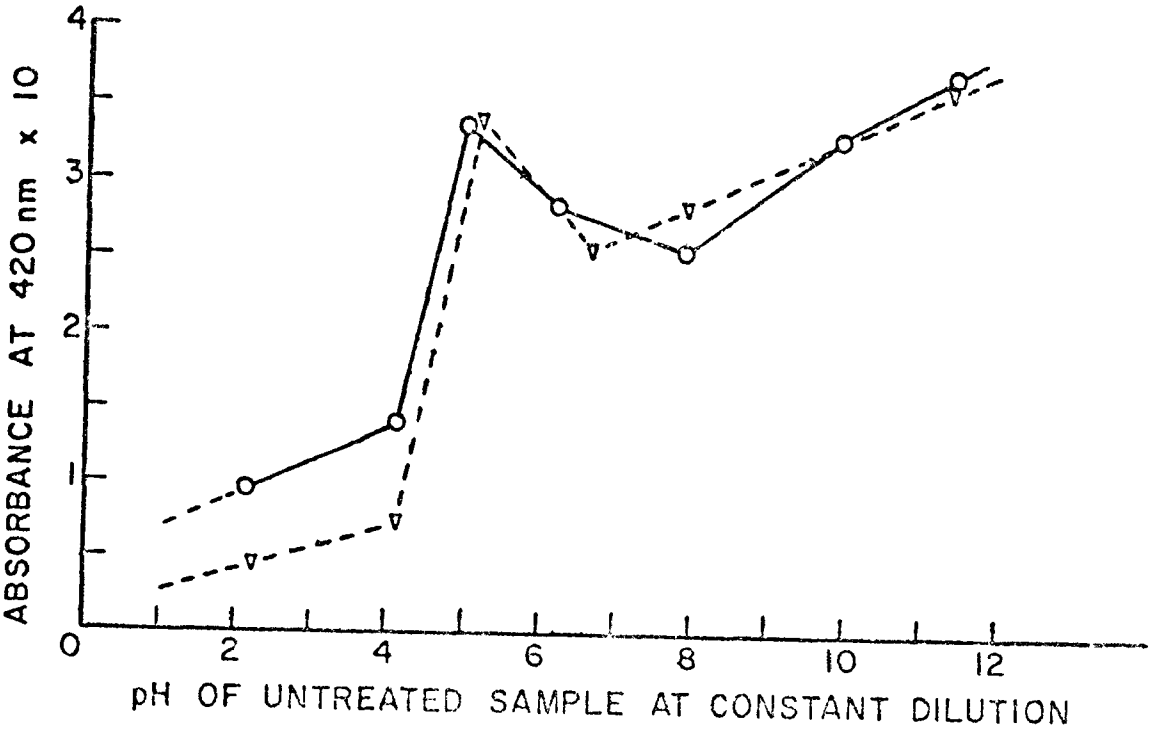


Figure 49 Effect of pH on Absorbance (at 420 nm) of Untreated Waste [233]

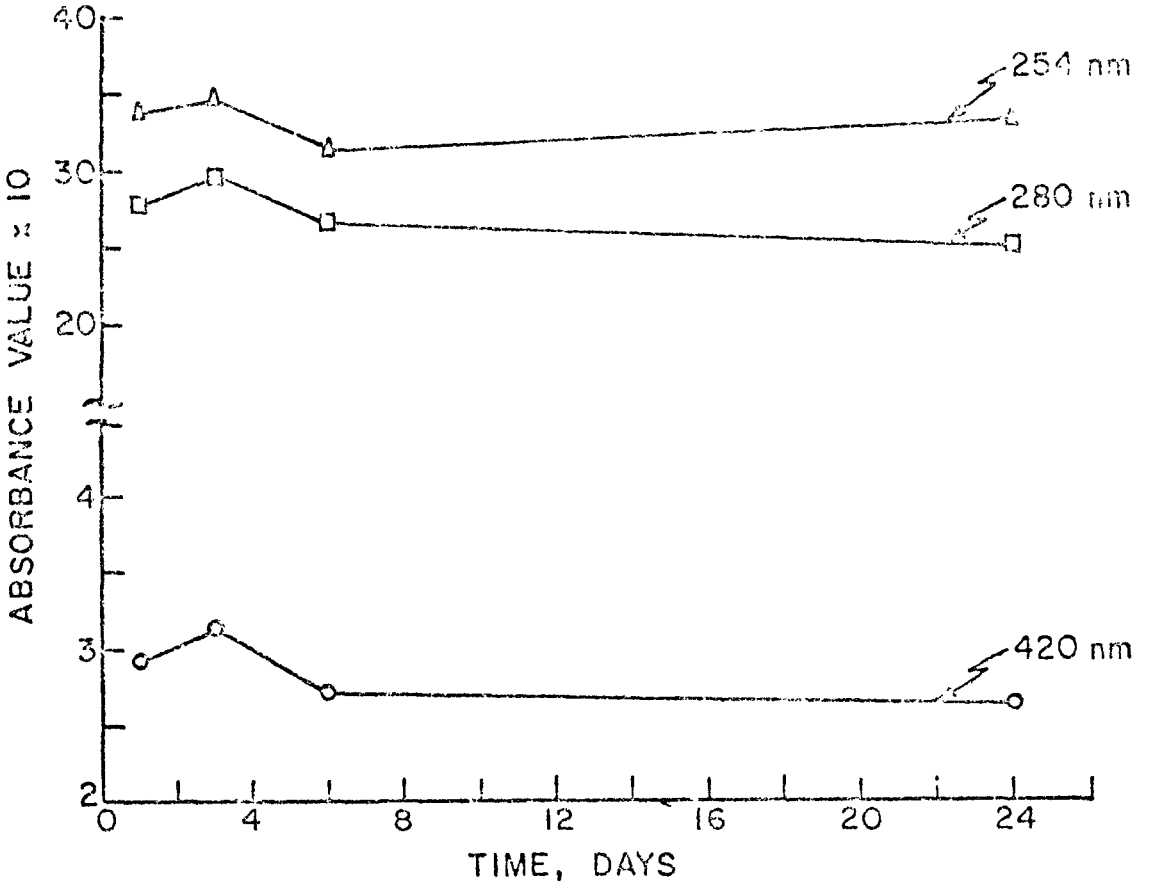


Figure 50 Effect of Storage on Absorbance (at pH 7.6) of Untreated Waste [233]

Most efforts to modify the kraft pulping process have been aimed at increasing pulp yield. Since there is essentially no published data on resulting color reduction, they will not be reviewed in detail. These systems include hydrogen sulfide pretreatment, addition of polysulfide to white liquor as used by several companies in the United States, and irradiation of wood chips (249).

In the mid 1960's Dr. W. Howard Rapson of the Univeristy of Toronto, proposed the completely closed pulp bleaching and chemical recovery system. The system would utilize complete countercurrent washing from the bleach plant through brown stock washing with sufficient recycling to reduce total water consumption to 12.5-16.7 kl/kkg (3000-4000 gal/ton) of pulp.

The bleach plant effluent passes to the black liquor and through the evaporators to the recovery furnace, where color bodies are burned. Digester and evaporator condensate stripping with steam or air are used to remove the total reduced sulfur compounds and the condensates are returned to the system, with the evaporator condensate fraction returned to the last washer in the bleach plant (see Figure 51).

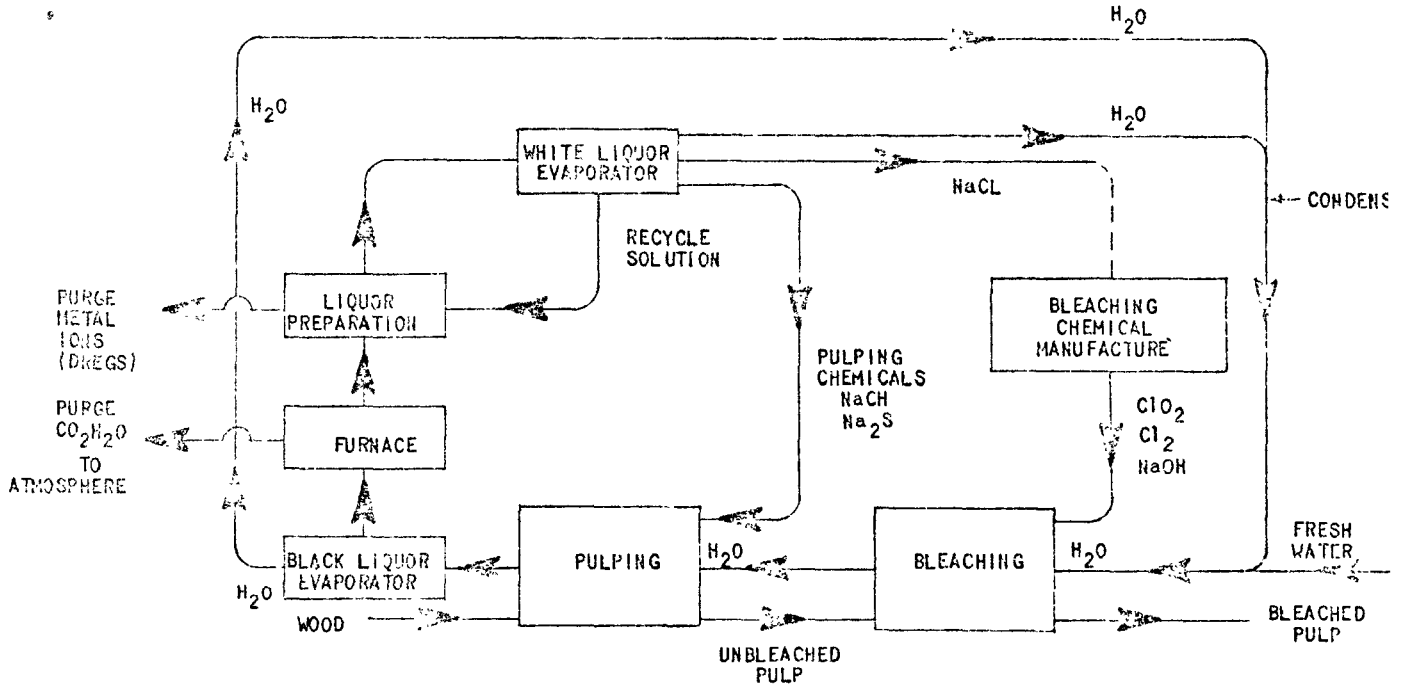
The use of countercurrent washing in the bleach plant results in a high chlorination stage temperature. Serious pulp degradation could result. This problem is eliminated by replacing about 70 percent of the chlorine with an equivalent of chlorine dioxide. The use of chlorine dioxide also results in a reduced caustic requirement in the first caustic extraction stage. The sodium chloride in the spent bleaching chemical (resulting from the use of chlorine and sodium hydroxide) must be removed from the system. The salt would be removed by evaporating white liquor and crystalizing out the bulk of the sodium chloride present as part of the liquor reconstitution process. The recovery of the salt prevents the concentration of chlorides from building up within the process and consequently causing problems in the recovery furnace and corrosion of equipment. The recovered sodium chloride would be used in the ClO_2 generation process (250).

The total enclosed system was proposed with the DcEDED sequence since this is most similar to the commonly used CEDED. However, the proposed system would be compatible with an oxygen bleaching sequence or hypochlorite in place of the standard caustic extraction second stage (251). Hypochlorite is not recommended because it introduces more sodium chloride into the system than the standard caustic extraction stage.

It is felt that a mill producing special grades of paper, such as colored grades, would have trouble completely closing their water system and some form of internal water treatment may be necessary (252). It is also indicated that a groundwood and kraft mill combination could be closed more easily than a kraft mill alone. This approach has not been applied and research on specific aspects of it are underway.

Figure 51

Rapson Closed Cycle [235]



New Experimental Processes in Various Stages of Development

Oxygen and soda-oxygen pulping is being investigated by Syracuse University, University of Washington, Forest Products Laboratory, North Caroline State University, and Toyo Pulp Co. (249). Mill trials have been run at the SAPPI mill in Enstra, South Africa. The pulps produced by oxygen pulping are generally comparable, but inferior in specific quality parameters to bleach kraft pulp (253). The Toyo Pulp Co. of Japan has been operating a 1.81 kkg (2-ton) per day plant for several years and has a 90.72 kkg/day (100-tpd) plant under construction. The oxygen for this process is normally ordinary air (249).

MacMillan Bloedel has reported on a high yield, two stage, alkaline sulfite-oxygen pulping process to produce a pulp that could be used as linerboard base sheet furnish. Canadian International Paper Co. and others have been developing an alkaline sulfite process that produces a pulp similar to kraft without the associated air pollution problems. A chemical recovery process must be developed to make the alkaline sulfite process commercially attractive. Other contenders to replace kraft pulping include holopulping, developed in the late 1960's at the Institute of Paper Chemistry, Owens-Illinois' sulfite-sulfide pulping, nitric acid pulping marketed by Alscope Consolidated Ltd., and several chemical solvent processes which include Weyerhaeuser's ammonia-ketone process and J. N. Kleinert's aqueous alcohol process (249). It is unlikely that a substantial number of the kraft mills in the U.S. will radically alter their present pulping process.

Internal Spill Control

Internal "spills" may be designated as continuous and intermittent. The continuous losses are part of the accepted method of operation and the pollution load they impose is, therefore, predictable. These are losses incurred through the law of diminishing returns as applied to such processes as pulp washing and liquor evaporation. The intermittent spills are caused by system upsets and equipment failures, and are normally unpredictable. The intermittent spills can amount to 30 percent of the effluent load from a bleached kraft pulp and paper mill (20).

A significant amount of color can result from caustic or black liquor carry-over in the pulp from the brown stock washers. Most of this color normally finds its way to the sewer with the screen rejects and decker filtrate. Where the caustic carry-over is substantial, the addition of a brown stock washing stage or use of the decker filtrate on the brown stock washers can reduce effluent color. Pulp mills that sewer their knots can eliminate a small but concentrated stream of color and BOD by incinerating the knots, returning them to the digester, or hauling them to

landfill. Washed green liquor dregs is another small stream with high color and BOD. Filtering the dregs and hauling them to landfill results in chemical savings and a better weak wash liquor balance in the causticizing and lime recovery area.

A black liquor boil-out tank to hold some of the weak liquor at the end of an evaporator boil-out can be used to keep colored effluent out of the sewers. The liquor is metered back to the recovery system during normal plant operation. Evaporator capacity must be available or added in order to handle the additional evaporation load.

Black liquor spills also occur because of liquor carry-over in the evaporators. This liquor could be recovered and pumped to a holding tank (e.g. boil-out tank) and returned to the weak black liquor system during normal operation.

Stock spills from upsets on the brown stock washers can result in a significant color load going to the sewer. Collecting these spills and returning them to the blow tank would eliminate this source.

In order to minimize the duration of chemical and liquor spill, high level alarms may be used to alert operators of overflowing tanks. Spillage collected from tank aprons can be returned to recovery or collected and metered into the treatment system.

Color can also be kept out of the mill sewer by closing up the brown stock screening operation. There is a limitation on the amount of water recycling that can be utilized in a bleach plant. This is normally determined by pulp quality requirements and chemical consumption (254) (255). The number of bleaching stages and the sequence used also affects the effluent quality and color. A survey of 22 North American bleached kraft pulp mills conducted in 1971 (255) determined that bleach plants using the CEDED bleaching sequence has an effluent volume of 30.67 kl to 51.78 kl (8000 to 13,680 gal) per air dry kkg (ton) of pulp, compared to 53.63 kl to 85.73 kl (14,170 to 22,650 gal) per air dry kkg (ton) of pulp for the CEHDED bleaching sequence.

Direct countercurrent washing cannot normally be used in existing mills since the materials of construction used for the caustic and hypochlorite stages are attacked by chlorides. Mills may use jump stage countercurrent washing where the caustic and acid filtrates are kept separate or a combination of direct and jump stage or split-flow countercurrent washing. Effluent from finishing stages can be employed for washing first stages and extraction stages can be recycled.

Benefits of countercurrent washing are reduced volume and high concentration of pollutants. Laboratory tests have shown the possibility of reducing the bleachery effluent volume to 637.8 l (1685 gal) per air dry kkg (ton) of bleached pulp on a DcEDED bleaching sequence by closing the bleach plant filtrate operation through recycling, including using chlorination stage effluent

for decker stock dilution. To achieve this, the modern mill would require modification and changes in materials of construction, along with additional chemical requirements. The color reduction achieved would amount to 40 percent (256). For the CDEDED sequence, effluent was reduced to 14,762 l (3900 gal) per air dry kkg (ton). Color reduction achieved is not discussed (256).

Alteration of Bleaching Sequence

Oxygen bleaching is a primary avenue through which effluent color from the bleach plant may be reduced. This aspect of the process is discussed separately in ensuing pages.

The standard CEDED bleach plant effluent color can be reduced significantly by replacing the first caustic extraction stage with a sodium hypochlorite stage and replacing the normal chlorination stage with a sequential chlorine dioxide-chlorination stage (257). These modifications are called the anti-pollution sequence or APS. Table 71 presents a laboratory comparison of the effluent from various conventional and APS bleaching sequences on both hardwoods and softwoods.

On the basis of laboratory tests it is claimed that the APS is equivalent to the lime processes in pollutant reduction and is also superior from an economic aspect. The color reduction is equivalent to that obtained through ion exchange with both a lower capital and operating cost. In addition, it is estimated that color reduction equivalent to that of recovering bleach plant effluent through the recovery system by use of oxygen bleaching can be achieved. However, the capital requirement for an oxygen bleaching system is much greater than for the APS. Table 72 presents a tabulated comparison of color reduction through lime treatment, ion exchange, oxygen bleaching, and the APS sequence. The application of the APS process may be limited, however, in that it produces pulp low in strength and thus is not suitable for all pulps.

Dynamic (displacement) bleaching is discussed in other Sections of the report. However, there is no published data on the effluent color resulting from this process.

The patented Papribleach Process* (258) was developed at The Pulp and Paper Research Institute of Canada. The process reduces the reaction time required to produce a pulp of 90 brightness from ten hours in a conventional bleach plant to forty-two minutes for kraft pulps, and twenty-two minutes for sulfite pulps.

The Papribleach Process* utilizes chlorine gas at 25-35°C (77 to 95°F) in the first stage which takes about one minute. The use of chlorine gas enables the pulp to have a stable Kappa number at the end of the chlorination as well as keeping chemical costs at a minimum and providing stable brightness levels. The second stage uses ammonia gas and steam for extraction of the

Table 71

COMPARATIVE EFFLUENT ANALYSIS - CONTROL VS. APS [242]

	Softwood						Hardwoods		
Pollutants	CEHD lb/ton	D_CH_SED[a] lb/ton	% Red	CEDED lb/ton	D_CH_SDED lb/ton	% Red	CEHD lb/ton	$D_CH_SDE/_HA$ lb/ton	% Red lb/ton
Color	653	120	82	685	231	66	188	63	66
Chlorides									
Analyzed[b]	136	108	21	116	98	16	92	71	23
Calculated	157	122	22	149	121	19	113	97	14
Solids	306	212	31	239	211	12	213	162	24
COD	144	93	35	142	117	18	84	54	36

a - Hypochlorite in H_S stage 1.3 to 2.0%

b - Does not include organically bound chlorine

Table 72

COMPARISON OF COMMERCIAL TREATMENT PROCESSES FOR BLEACH PLANT EFFLUENT vs APS [242]

	Pollution Reduction %						
	Extraction Stage			Total Bleach Plant Effluent			
	Color	COD	BOD	Color	Cl-	COD	BOD
				External Treatment			
Primary & Secondary Treatment				10			77
Lime Treatment	80 to 95	70 to 75	25 to 45	65 to 90		25 to 30	15 to 25
Ion Exchange	85 to 95	85 to 90	55 to 60	75 to 85	2 to 5	45 to 65	25 to 30
				Internal Treatment			
Oxygen Bleaching				60 to 85	55 to 85	70 to 80	30 to 35
APS	85 to 95	35 to 70	30 to 50	60 to 85	15 to 25	15 to 35	25

chlorinated lignins. This offers mechanical advantages since it is achieved in ten seconds. Ammonia dissolves chlorinated lignins without attacking the carbohydrate of the cellulose. The third stage uses chlorine dioxide gas at 100°C (212°F) for twenty minutes. This permits more accurate control of bleaching as well as lower chemical costs. The second and third stages would be repeated when bleaching kraft pulp to 90+ brightness. Sodium hydroxide can be substituted for ammonia in the second stage using a five-minute detention time.

The Papribleach Process (use of a trade name does not constitute endorsement.) has many advantages over the conventional bleaching process. As already mentioned, the time required for bleaching is greatly reduced; second, higher yields are possible; and, third, costs, both initial investment and operating costs, are considerably less; and, fourth, water and steam requirements are drastically reduced. Consequently, mill bleach plant effluent is reduced. There are no known full scale applications of this process.

Oxygen Bleaching

Five mills that have used or are using oxygen bleaching include the SAPPI kraft mill at Enstra, South Africa, the Chesapeake Corporation of Virginia in West Point, Virginia, LaCellulos d'Aquitaine in St. Gaudens, France, Munksjo AB in Aspa Bruk, Sweden, and Billingsfors Bruk AB in Husum, Sweden. Another Swedish mill has recently installed an oxygen stage.

From September of 1970 to September 1972, the 136.1 kkg (150 ton)/day oxygen bleach plant now owned by Billingsfors was operated by MoDoCell AB in Husum. The plant used the OCEDED bleaching sequence. COD, BOD, and color values were determined and compared with a CEHDED bleaching sequence. These are presented in Table 73.

Assuming an 80 percent washing efficiency on the washer following the oxygen bleaching stage, a 70 percent reduction in color in the total bleach plant effluent can be achieved according to the work at the Husum mill (259). A 45 percent reduction in BOD was also achieved.

Additional work at the Husum mill showed that in the production of chemical pulp for newsprint using an oxygen bleaching stage followed by two stages of washing, more than 90 percent of the color could be removed from the bleach plant effluent. This would be accompanied by a 70-80 percent reduction in BOD and a 79 percent reduction in COD (81).

The original bleaching sequence at Enstra, South Africa was AODED; however, because of a shortage of chlorine dioxide, their bleaching sequence was changed to AOCEH. When using the AODED sequence, the mill operated at a production rate of 258.6 kkg (285 tons) per day on hardwood (gum) and 195.1 kkg (215 tons) per

Table 73

BLEACHERY EFFLUENT SURVEY [244]

NO.	Effluent or Pulp Stream	BOD_7 kg/tkg	COD kg/tkg	COLOR kg PT/tkg
	OCEDED Sequence			
1	Unbleached pulp entering		3.9	3.5
2	O stage press liquor	8.0	31.5	49.5
3	O stage reactor exit	11.9	69.1	93.3
4	C stage	3.2	19.3	14.0
5	E stage	4.6	26.1	58.1
6	Pulp leaving E stage washer	1.2	4.0	7.6
	Total effluent (2+3+4+5)	27.7	146.0	214.9
	CEHDED Sequence			
7	Unbleached pulp entering	1.4	4.4	4.0
8	C stage	5.4	20.5	24.6
9	E stage	8.1	92.0	251.7
10	H stage	5.2	29.5	33.8
11	Pulp leaving H stage washer	1.1	5.6	6.8
	Total effluent (8+9+10)	18.7	142.0	310.1
	Ratios of totals OCE/CEH	1.48	1.03	.70

day on pine. After brown stock washing and screening the brown stock was acidified with sulfuric acid, then treated with magnesium oxide before oxygen bleaching. Data taken from the individual bleaching stage filtrate are presented in Tables 74 and 75. The necessity of sending the filtrate from the oxygen stage through the pulp mill to the recovery boiler is illustrated in these tables (106).

The data shows an 85 percent reduction of color in the bleach plant effluent and there was also an associated 75 percent reduction in total dissolved solids (106). When recycling or recovering all of the oxygen stage filtrate, the reductions shown in Table 76 can be achieved.

The only U.S. mill utilizing oxygen bleaching, Chesapeake Corp. of Virginia, is also discussed in other sections of this report. High process water and screened stock temperatures have forced the mill to use a sequential chlorine dioxide-chlorine first stage of bleaching, followed by the oxygen stage and a third stage using chlorine dioxide. It produces an 88 brightness 4ulp from brown stock cooked to a K-No. of 15. The total bleach plant effluent color is 42.5 kg/kkg (85 lb/ton) (23). This bleach plant is illustrated in Figure 18 in Section III.

Results from operations at the Cellulose d'Aquitaine mill in France are based on the OCEDE/HD sequence. There is no reuse of the oxygen stage filtrate through the brown stock washing system and consequently there is not much reduction in effluent color from the bleach plant. The oxygen bleaching stage includes the use of 0.2% $MgSO_4$ to protect the cellulose from caustic attack. Caustic is used in order to maintain the required pH. The present color in the bleach plant effluent when operating at a production rate of 408.2 kkg (450 tons)/day is 40.8 kkg (45 tons)/day of color. This is expected to be reduced to 22.7 kkg (25 tons)/day of color when filtrate from oxygen stage is used on the brown stock washers and the color subsequently destroyed in the recovery furnace.

Laboratory studies at Cellulose d'Aquitaine compared OCEDED and ODED to the CEDED bleaching sequence. In the OCEDED process the oxygen stage treated pulp at 25 percent consistency and 0.5 percent magnesium sulfate and 1.8 percent sodium hydroxide were added. Retention time was thirty minutes at 100-105°C (212-221°F). These laboratory results showed a 77 percent reduction in color from the bleach stage along with a 52 percent reduction in BOD. When using the ODED sequence, color was reduced by 90 percent and BOD by 77 percent (260). Table 77 is a summary of their results. These results assume that all of the oxygen stage filtrate can be processed through the pulp mill.

During these tests it was also realized that there is a linear relationship between Kappa number and color.

Laboratory tests conducted by the National Council for Air and Stream Improvement at North Carolina State University are shown

Table 74

INDIVIDUAL FLOW OF EFFLUENT DURING BLEACHING [102]

	Acid Treatment	Oxygen	Chlorine Dioxide	Caustic Extraction	Chlorine Dioxide
	Normal Wattle/Eucalyptus Pulp, Kappa No. 13-14				
pH	3.0	9.7	3.5	10.5	7.0
COD/ppm	416	5396	448	544	224
OA,ppm	78	492	130	58	42
Dissolved Solids,ppm	2465	8370	1865	1415	660
SO_4,ppm	1050	382	71	83	33
Cl,ppm	120	170	300	150	190
Na,ppm	215	1500	95	180	100
Ca,ppm	61	19	58	7	47
Color,ppm	260	3000		Combined 100	

Table 75

INDIVIDUAL FLOW OF EFFLUENT DURING BLEACHING [102]

	Acid Treatment	Oxygen	Chlorine Dioxide	Caustic Extraction	Chlorine Dioxide
		High Kappa No. Pine Pulp, Kappa No. 35			
pH	2.7	9.2	6.6	11.0	3.3
COD,ppm	184	10300	600	432	357
OA,ppm	49	2200	207	68	93
Dissolved Solids,ppm	2080	16100	1700	1306	1018
SO_4,ppm	974	550	50	143	42
Cl,ppm	150	115	315	155	200
Na,ppm	228	2625	192	237	216
Ca,ppm	59	33	17	15	38
Mg		60			
Color,ppm	50	11000	45	240	30

Table 76

EFFLUENT LOADING OF PINE KRAFT, KAPPA NO. 35
(Assumes all oxygen stage filtrate is recycled and reclaimed.)

	A	O[a]	Total ADED	C	E	H	D	E	D	Total
	Oxygen system						Chlorine System			
Dissolved Solids lb/ton	20	280	87	50	129	130	Combined		79	388
OA lb/ton	2	65	12	2.6	43	6.0	Combined		3.3	55
COD lb/ton	3.4	190	29	32	73	23	Combined		14	142
Color lb/ton	0.7	120	2.8	16	396	7	Combined		1	420
BOD[a] (5 day) lb/ton										24-50

a) Bottle method Canadian Standards H_2P (1967)
The oxygen filtrate was reused as indicated in Tappi, Vol. 54, No. 6, June 1971, pp 966.

Table 77

COMPARISON OF CEDED SEQUENCE WITH AND WITHOUT O_2 STAGE AND REPLACING CE STAGES WITH O_2 STAGE [245]

	Unbleached Kraft	Pulp After Oxygen Bleaching	
Kappa No.	18.0	9.7	
Sequence	CEDED	CEDED	DED
Color, Kg Pt/ton	43	10.0	4.5
% Red.		77%	90%
COD, kg O_2/tp	32	18.0	15.2
% Red.		44%	53%
BOD, kg O_2/tp	10.2	5.3	2.4
% Red.		52%	77%

in Table 78. Their tests also showed that the effluent from the oxygen bleaching stage was more readily biodegradable by standard aeration methods than conventional bleach plant effluent (261). As shown in Table 78, effluent from the oxygen stage must be recycled in order to reduce color in the effluent.

Tables 79, 80, and 81 present laboratory results comparing CEH with OCE bleaching sequences, the CEDED with the OCED bleaching sequence, and the CE with the OC bleaching sequences.

Table 82 points out the importance of recycling the oxygen stage effluent. An 80 to 85 percent washing efficiency should be attained by most mills. Assuming an 80 percent washing efficiency this would result in approximately 70 percent effluent color reduction from the bleach plant (262).

External Methods of Color Reduction

Massive Lime Treatment

The development of the lime color reduction process has been traced by several authors (5) (263) (264) (59). A brief review of this history is in order. In the early 1950's, the results of a laboratory program in which several coagulants were tested for their effectiveness in reducing the color of kraft pulping and bleaching effluents (246) were reported. This investigation measured the effectiveness of alum, ferric sulfate, lime, sulfuric acid, char, clay, activated carbon, activated silica, ferric chloride, chlorinated copperas, phosphoric acid, waste pickle liquor, and a barium alumina silicate compound. In general, it was found that good color reduction could be obtained with several of the agents. It was concluded, however, that the cost of chemical treatment was prohibitive with the exception of lime treatment which afforded the possibility of lime recovery by utilizing existing mill equipment. In addition to the prohibitive costs of chemical treatment, large volumes of difficult to dewater gelatinous sludge formed in the chemical treatment processes.

Based on the results of this early work, research continued towards development of a lime precipitation process. The overriding problem in this work continued to be the difficulty of dewatering the lime-organic sludge. Specific studies were conducted for resolving the sludge problem with limited success (265) (266). These studies led to investigation of the surface reaction process (267) (268) (269). This process, wherein effluent was filtered through a precoat of hydrated lime, had good success in the laboratory. However, severe operational problems with the pilot plant scale system forced this process to be abandoned.

Continuing efforts to improve the dewatering of the lime sludge led to consideration of using large dosages of lime for color reduction. It was believed that a large quantity of rapidly draining materials would reduce the effect of the organic matter

Table 78

COMPARISON OF CEHDED W/OCEDED
(% REDUCTION ASSUMES 100% RECYCLE & CONSUMPTION OF O_2 FILTRATE) [247]

	CEHDED	OCEDED	OCEDED O stage recycle	% Reduction
Color	464	413	58	87
BOD_5	43	70	10	77
Chloride	139	43	42	70
COD	335	473	79	76

Table 79

COMPARISON OF CEH w/OCE [247]

	Softwood			
	CEH	OCE	OCE 0 Recycled	% Reduction
Color	290	213	24	91
BOD	23	34	3.6	85
COD	136	271	58	57
Chloride	11	30	26	76

Table 80

COMPARISON OF CEDED w/OCED [247]

	Hardwood			
	CEDED	OCED	OCED 0 Recycled	% Reduction
Color	166	144	8	95
BOD	28	37	5	82
COD	112	157	43	72
Chloride	58	48	43	26

Table 81

COMPARISON OF CE w/OC [247]

	Hardwood			
	CE	OC	OC 0 Recycled	% Reduction
Color	107	95	10	90
BOD	16	31	3	81
COD	90	142	10	88
Chloride	51	21	19	62

% Reduction assumes 100% recycle and consumption of O2 filtrate.

Table 82

EFFECT OF RECYCLE ON OVERALL PERCENT REDUCTIONS OF EFFLUENT CHARACTERISTICS BY USE OF AN ALTERNATE ALKALI-OXYGEN STAGE [247]

	SOFTWOOD*		HARDWOOD*	
ANALYTE	100% - Recycle -	80%	100% - Recycle -	80%
Color	87	68	95	77
BOD	77	41	82	47
COD	76	25	72	41
Chloride	70	64	26	24

*Percentages Recycle refer to Oxygen Stage Effluent.

on dewatering. This thinking led to the development and patenting of the "massive lime" process by the National Council for Air and Stream Improvement (218). In this process, the mill's total process lime is slaked and reacted with a highly colored effluent stream, usually the caustic extraction effluent. The lime sludge is then settled, dewatered, and used for causticizing green liquor. During the causticizing process, the color bodies are dissolved in the white liquor and eventually burned in the recovery furnace. A flow diagram of the patented process is shown in Figure 52. Although the massive lime process had been demonstrated as an effective color removal system, the process was not taken beyond the pilot stage for several years.

International Paper Company, Springhill, Louisiana

The first installation of the NCASI's massive lime color removal system was operated at the International Paper Company's mill in Springhill, Louisiana. The demonstration plant was sized to treat an effluent flow of 2006 lpm (530 gpm). Sources of effluent used in the EPA sponsored demonstration project were the bleach plant caustic extraction and the unbleached stock decker. These effluents were selected for their relative contribution to the color of the total mill effluent (60 to 75 percent).

In this project, part of the selected effluents were first used to slake the lime in an agitated reaction tank providing five minutes detention. The lime slurry was then fed to the effluent at a dosage of 20,000 mg/l. The lime sludge was then settled out in a clarifier. Overflow from the clarifier was to a carbonator clarifier where lime kiln flue gas was reacted with the effluent to precipitate the dissolved calcium as the carbonate. This carbonator clarifier had a 20-minute retention center well and was covered to minimize the escape of foam.

Sludge from the primary clarifier was pumped to a storage tank at 18 to 22 percent solids. A two-hour capacity was provided. Sludge from this tank was dewatered on a precoat vacuum filter to approximately 50 percent solids. This sludge was then discharged to the pulp mill green liquor slaker. After processing through the cooking liquor causticizing system, (shown in Figure 53) the lime mud was burned in the kiln, recovering the lime for reuse in the color removal system. Makeup lime was added as required. The color bodies removed in the effluent treatment system were dissolved in the cooking liquor, eventually being burned in the recovery boiler.

The demonstration plant at Springhill was first tested using 100 percent bleach plant caustic extraction effluent. Various amounts of unbleached decker effluent were then added until 100 percent decker effluent was treated. Color removal ranged from 90 to 97 percent with an average of 94 to 95 percent (232). Organic carbon removal ranged from 55 to 75 percent and generally increased with higher colored effluent. The values reported are shown in Table 83. BOD removals of 25 to 45 percent were

Figure 52

Massive Lime Process [232]

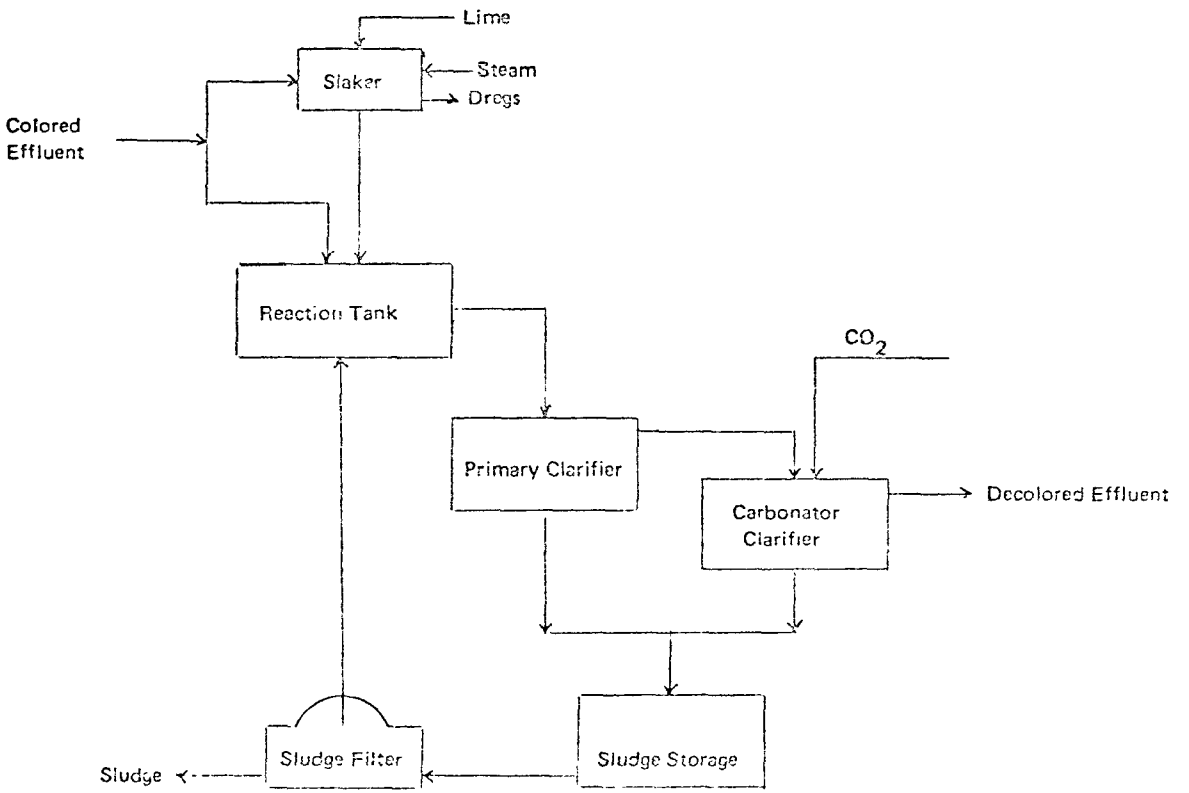


Figure 53

Causticizing Process for a Kraft Pulp Mill [232]

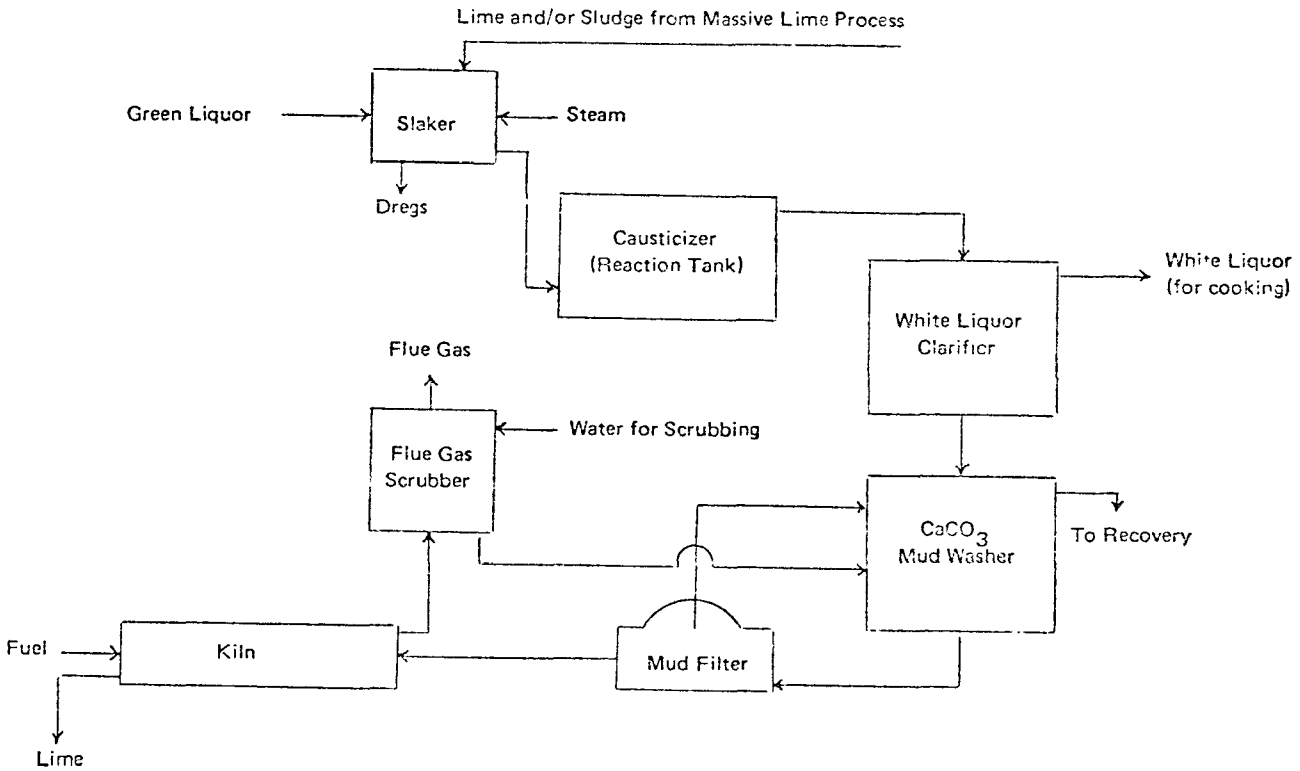


Table 83

COLOR AND ORGANIC CARBON REMOVAL

Composition of Treated Effluent		Effluent Color (APHA Color Units)			Organic Carbon Content (ppm)		
Bleach Caustic Extraction Stage Effluent, %	Kraft Decker Effluent, %	Before Treatment	After Treatment	Color Removal, %	Before Treatment	After Treatment	Organic Carbon Removal, %
100	0	21,540	1265	94.2	1446	373	74.2
67	33	14,325	745	94.8	1016	253	75.1
60	40	12,125	624	95.1	905	248	72.6
50	50	10,043	451	95.5	798	245	69.3
33	67	6612	331	95.0	560	183	67.8
20	80	4960	298	93.6	470	173	63.2
0	100[1]	1640[1]	140[1]	91.5[1]	270[1]	120[1]	55.6[1]
0	100[2]	900[2]	234[2]	74.0[2]	268[2]	126[2]	53.0[2]

[1]Very little paper mill white water reuse in decker pulp washing and make-up water.

[2]Practically all water used in decker system was white water from paper mill.

reported, with the lower values found during treatment of the most highly colored effluent.

The most serious problems encountered during operation of the demonstration plant were foaming and carryover of solids in the primary clarifier. As a result, it was recommended that equipment throughout the system be designed to prevent air entrainment to eliminate or control foaming. Sludge settling rates and filter rates varied inversely with the concentration of organics for effluents of over 5000 APHA color units. The system causes dilution of the cooking liquor by about 15 percent, therefore, increasing the required capacity of most of the chemical preparation and recovery equipment. Additionally, organic compounds carried into the liquor caused foaming problems. No adverse effects on pulp bleachability or quality were found.

In an analysis of the impact of the massive lime system on a hypothetical 907.2-kkg (1000-ton)/day bleached kraft mill, it was calculated that the volume of effluent that could be treated with the normal amount of lime required by such a mill would be 15.14 kkl/d (4 MGD). The untreated color loads contributed by the individual process areas are shown in Table 59.

All of the caustic extraction effluent and 4.73 kkl/d (1.25 MGD) of the unbleached decker effluent, with a combined color of 14,500 APHA units, could be treated. With a 95 percent color reduction, the treated effluent would theoretically have the characteristics shown in Table 84.

The net effect of the treatment would be a 72 percent color reduction. Based on water and material balances, the following increases were predicted in the required capacity of the mill process equipment.

	Increased Capacity Requirements, %
• Green liquor slaker or mixing tank	17.7
• Causticizers and associated equipment	17.7
• White liquor clarifier, storage, and associated equipment	17.7
• Mud washers, storages, and associated equipment	15.8
• Mud filter	6.4
• Lime kiln	6.4
• Pulp washing accessories	5.8
• Evaporators and accessories	5.8
• Recovery boilers and accessories	1.9

Minimum Lime Treatment

The massive lime process, as developed, relied on high concentrations of lime (on the order of 20,000 mg/l). Because of this, only a relatively small effluent stream could be treated with the quantity of lime used for causticizing green liquor.

Table 84

CONTRIBUTION OF EFFLUENT SOURCES TO TOTAL MILL EFFLUENT COLOR WITH MASSIVE LIME TREATMENT OF BLEACH EXTRACTION STAGE AND DECKER EFFLUENTS [232]

Source of Effluent	Color Load (lb color/bl ton)	Contribution to Combined Effluent Color (APHA Color Units)
Pulp mill-general	12	50
Paper mill	5	21
Bleach chlorination stage	111	462
Bleach caustic extraction stage	23	96
Remainder of bleaching process	27	113
Total	178	742

Additionally, the use of this process required modifications to the recovery system. These restrictions and the need for color removal from total unbleached kraft mill effluents led to the independent development of three lime precipitation processes employing a "minimum" lime dosage for decolorization followed by various methods of sludge disposal or recovery. Two of these systems have been in full-scale operation on the total mill effluent from unbleached kraft production and a kraft/NSSC operation (270) (271). Lime dosages at both mills have been about 1000 mg/l. At the kraft mill, the lime sludge is not recovered. The kraft/NSSC mills, however, dewaters the lime sludge by centrifuge and recovers the lime in the process lime kiln.

In the third "minimum" lime treatment system caustic extraction stage effluent from a bleached kraft mill is treated with 2000 mg/l of lime (272). The resulting lime sludge is then mixed with prefiltered lime mud; the mixture then is dewatered on a belt filter and burned in the lime kiln.

Interstate Paper Corporation, Riceboro, Georgia

The first full scale color removal facility in the pulp and paper industry was put in operation at Interstate Paper Corp., Riceboro, Georgia in March of 1968. The mill effluent is discharged to Riceboro Creek, a dead-end estuary where, at times, the mill effluent occupies the entire cross-section. Because of the nature of the receiving water and the shrimp and sport fishing in the adjacent waters, the mill was required to meet the following state effluent criteria:

Effluent Discharge (10 MGD)	37.85 kkl/d
Biochemical Oxygen Demand (800 lb/day)	362.9 kg/day
Suspended Solids	10 mg/l
Color (APHA cobalt units)	30 mg/l

The mill was designed to produce 362.9 kkg (400 tons) per day of unbleached kraft linerboard with a process water requirement of 52.15 kkl/ kkg (12,500 gal/ton) exclusive of cooling water. As of March 15, 1970, production had increased to 510.8 kkg (563 tons)/day; process water requirements were 40.89 kkl/kkg (9800 gal/ton); and BOD to the effluent treatment system was 10 kg/kkg (20 lb/ton).

The color removal system was designed from laboratory bench test data without pilot scale testing. The original design provided for a 190.5 kkg (210 ton) capacity lime silo which is filled from the process kiln. Lime is slaked in a 58.97 kkg (65 ton)/day slaker and stored in an agitated 2.84 kl (750 gal) slurry tank at

about 15 percent solids. Lime is metered into the total plant effluent proportional to flow and was originally mixed with the effluent using an in-line mixer. The mixer has since been removed with no apparent loss in process efficiency. From this point, the effluent is pumped to a 13.72-m (45-ft) diameter, 10.06-m (33-ft) high flocculation tank which provides a retention time of about 35 minutes. The effluent then flows to a 60.96-m (200-ft) diameter clarifier which provides six hour retention at the maximum flow of 37.85 kkl/d (10 MGD). Sludge is withdrawn from the clarifier and pumped to a sludge lagoon of 20.61 hectare-m (167 acre-ft) capacity. Lime is not recovered.

The effluent from the clarifier is saturated with calcium hydroxide at a pH of about 12. Overflow is to a 263.16 hectare (650 acre) natural stabilization pond. In the first 40.49 hectares (100 acres) of the lake, carbon dioxide is absorbed from the atmosphere, precipitating the calcium as the carbonate. The effluent undergoes natural biochemical oxidation in the remaining area of the pond and is mechanically aerated to raise the dissolved oxygen to saturation prior to discharge to the creek. The stabilization pond provides 180 days retention of the average flow of 18.93 kkl/d (5 MGD). The process flow diagram for this system is shown in Figure 54.

The Interstate system produces a relatively constant effluent color of 125 ppm APHA color units at lime dosages of 1000 mg/l (270). Untreated effluent color is reported as 1200 mg/l (±200 mg/l). The system performance was found to be related to control of lime feed.

Separate analysis of samples shipped to the Institute of Paper Chemistry showed the treatment process to be 86 percent efficient in removing color (248). Additionally, a 57 percent reduction in TOC was reported. The analysis further showed that color bodies with a molecular weight of less than 400 were not removed by lime treatment and that those with a molecular weight over 5000 were completely removed.

Several conclusions can be drawn regarding the operation of this color removal system (270). First, experience showed that flash mixing of the lime slurry with the effluent has no effect on color reduction. The presence of solids, such as fiber, aid clarification which would allow a conservative clarifier rise rate of 20.37 lpm/sq m (0.5 gpm/sq ft) for similar installations. The process conditions the effluent allowing rapid biochemical degradation and foaming problems are said to be eliminated. Ninety percent of the maintenance costs of the system was for lime handling. The inference is taken that attention should be given to the lime handling system in any future design to minimize operating and maintenance costs.

The Interstate system has several design features that may not have industry-wide application. First, lime is not recovered. Make-up lime at the mill is in the form of lime rock, a relatively inexpensive source of lime. With a different source,

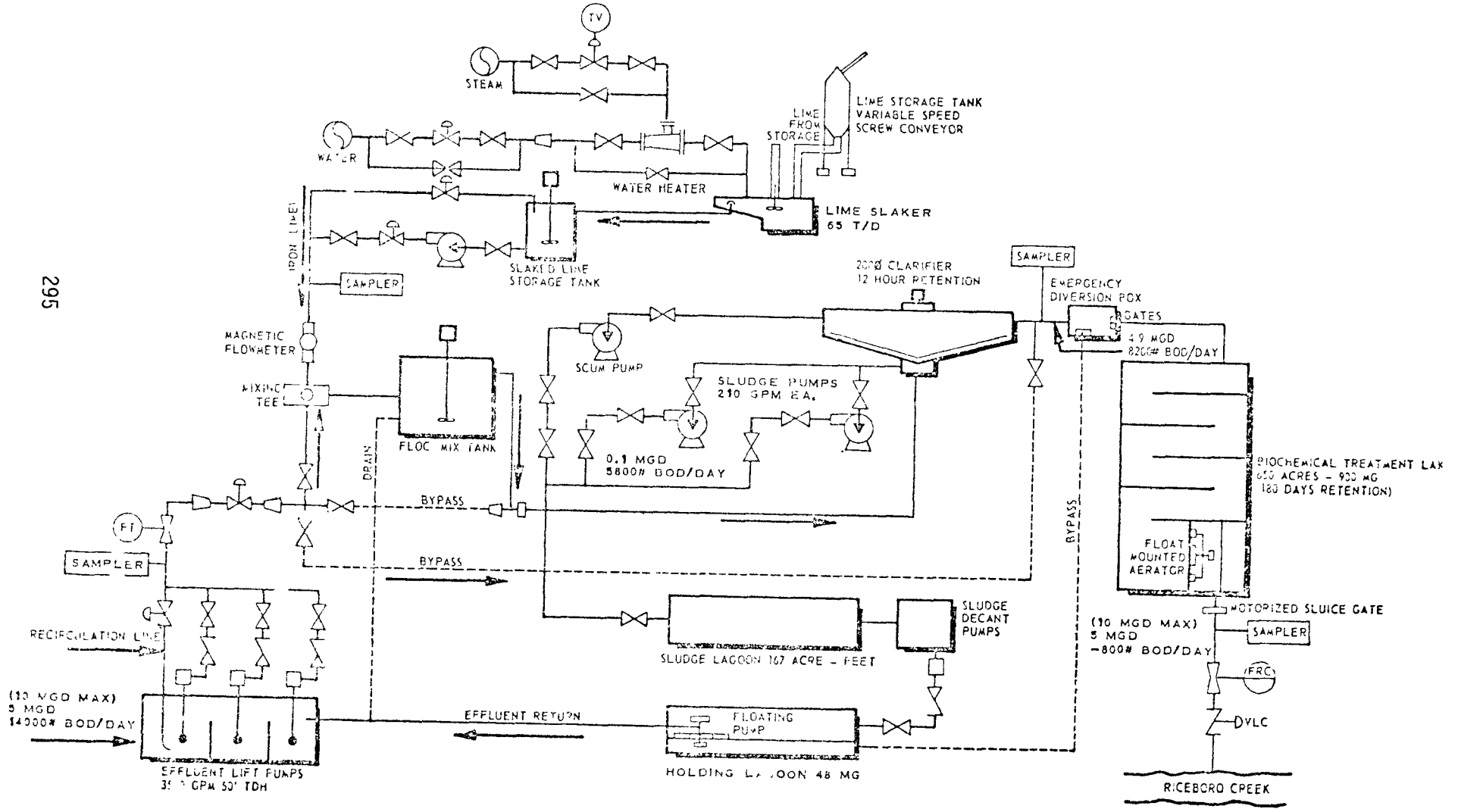


Figure 54

Effluent Treatment Flow Diagram
Interstate Paper Company [253]

the chemical costs could increase. Second, this lime treatment system is followed by a large natural stabilization pond. In the first 40.5-56.7 hectares (100-140 acres) of the pond, natural carbonation of the effluent occurs and the dissolved calcium is precipitated as carbonate. This also reduces the pH and allows biological activity to proceed normally throughout the rest of the pond. For installations not having the benefit of large amounts of land, recarbonation of the effluent might be needed to the extent required to adjust pH for efficient biological oxidation in addition to improved lime economy. Third, the method of sludge disposal is in holding lagoons where some dewatering occurs. Again, lime is not reclaimed. Although two sludge lagoons were constructed, one of these has been designated as an emergency lagoon which is used whenever the clarifier is by-passed. The dikes on the one sludge lagoon have been raised 0.91-m (3 ft) to provide additional storage capacity and a new sludge lagoon is needed. Again, the availability of land at this mill site makes this method of sludge removal practicable, but other installations may be required to consider alternate methods.

Finally, the lime treated effluent shows a dramatic increase in color as it proceeds through the natural stabilization basin. This color change is attributed to leaching of natural color from the soil in the bottom of the pond. The color change at various points through the pond is shown in Figure 55 which also shows the reduction in BOD through the pond. The sodium content of the treated effluent appears to have an effect on the magnitude of the color increase in the pond (250).

The observation has been made that the color bodies which are not removed by lime in this system are of low molecular weight and addition of multi-valent cations could be used to achieve over 99 percent color removal. Another recommendation also concerns the color bodies not removed by lime treatment. If biological oxidation of the wastes before lime treatment were practiced, it could reduce the negative effect, if any, of the low molecular weight color bodies on color removal. These points need laboratory investigation as does the effect of varying degrees of pulping on molecular weight of color bodies and the subsequent treatment efficiency.

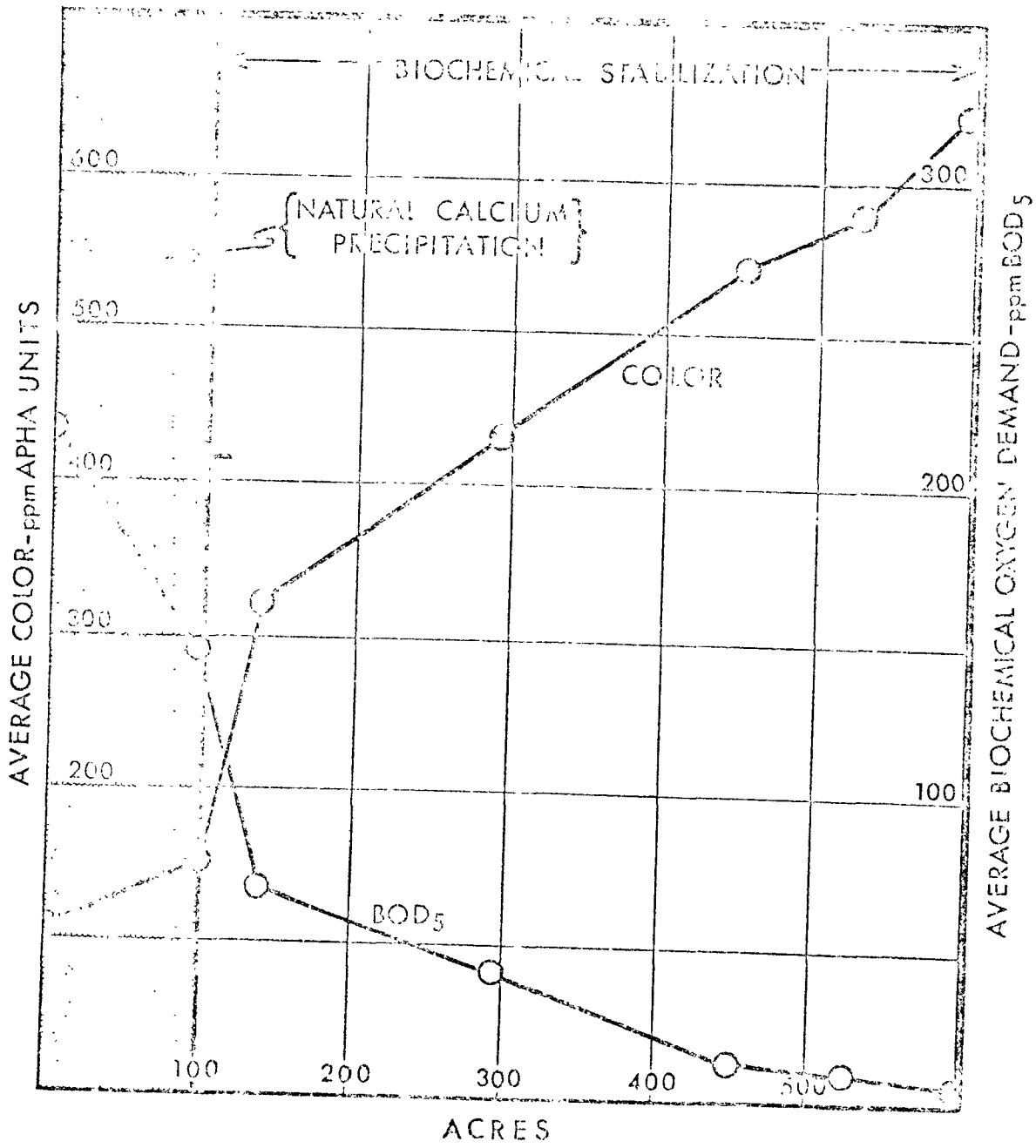
Continental Can Company, Inc., Hodge, Louisiana

The second full scale color removal facility put in operation on an unbleached kraft mill effluent was at Continental Can's Hodge, Louisiana mill. The mill is rated at 562.5 kkg (620 tons)/day of unbleached kraft linerboard and 181.4 kkg (200 tons)/day of NSSC corrugating medium. An expansion program is underway which will increase the unbleached kraft production to about 1360.8 kkg (1500 ton)/day. Treated effluent is discharged to a small creek, which in the summer months, has little or no flow.

Figure 55

STABILIZATION LAKE COLOR
& BOD PROFILE

March 1969 - March 1970



During research leading to the development of the color removal system at Hodge (273), consideration of the massive lime system was dismissed because of the large volume of effluent to be treated. Mill personnel concluded that the mechanism of color removal by lime precipitation was accomplished by absorption of color bodies on solid calcium hydroxide. This led to experimentation with other solid-phase substances together with moderate amounts of lime. Experimentation using ferric hydroxide, calcium carbonate, starches, polyelectrolytes, and recausticizing sludge produced marginal results. It was found, however, that the presence of fiber fines in the paper mill effluent enhanced the removal of color with lime additions well below the solubility of calcium hydroxide (1000 to 1500 mg/l.)

Further experimentation and pilot plant work led to the development design criteria for a full-scale installation. The experimentation concentrated on three goals:

1. To establish predictability of the process
2. To provide for disposal of the precipitated color bodies
3. To recover the substantial amounts of lime used

The system consists of a grit chamber followed by a revolving disc trash screen for the removal of large and heavy solids (264). The effluent is then pumped to a flocculator-clarifier. Experimental work concluded that settling rates of the lime treated effluent were greater than untreated effluent. Clarifiers were designed on the basis of a 40.74 lpm/sq m (1.0 gpm/sq ft) rise rate. The primary clarifier is 41.15 m (135 ft) in diameter with a 4.57-m (15-ft) side water depth. The flocculation zone is 2.19 m (40 ft) in diameter. The clarifier mechanism has a continuous torque rating of 165,960 m-kg (1,2000,000 ft-lb) with a peak load of 248,940 m-kg (1,800,000 ft-lb). Clarifier overflow is through submerged orifices to a peripheral launder.

Lime is drawn from the mill causticizing system and slaked in a renovated slaker. The slaker overflows to a 3.66-m (12-ft) diameter, 3.05-m (10-ft) deep slurry tank. Water is added to the tank to maintain constant level. Lime pumps operate continuously at designed capacity. Lime is added to the raw effluent in the lift station.

Overflow from the primary clarifier flows by gravity to a carbonation tank, 9.14-m (30-ft) in diameter and 3.66-m (12-ft) deep. Entrance to the tank is submerged. The tank is equipped with four, 29.83-kw (40-hp) agitators. Lime kiln stack gas (source of carbon dioxide) is discharged to the carbonator tank through four specially designed outlets below the agitators for contact with the effluent. The reaction of the stack gas with the effluent forms a calcium carbonate precipitate which is settled in the following carbonation clarifier. The design of this clarifier is identical to the primary clarifier. Foam generated in the carbonation tank is spread over the surface of the primary clarifier where it breaks down.

Primary and carbonator clarifier sludge pumps are centrifugal and were designed on the basis of a 10 percent consistency sludge. Sludge consistencies from both clarifiers have been higher than design expectancies, however, and the initial pumps have been replaced with pumps having larger suction openings. Sludge consistencies have been 15 to 20 percent. Primary lime-organic sludge is pumped to an agitated storage tank and then to a centrifuge for dewatering. A considerable amount of experimental work led to the selection of centrifuges over vacuum filtration (264). It is stated that a high "G" force is required in the selection of a centrifuge for this purpose.

Underflow from the carbonation clarifier is pumped to the causticizing process "mud" storage tank for dewatering on the lime mud filter.

The dewatered primary lime sludge and the dewatered lime mud are combined and fed to the lime kiln. The kiln was designed for the expected color removal sludge and the normal requirements of a 544.3-kkg (600-ton) per day kraft mill. This necessitated about a 25 percent increase in normal kiln capacity.

Overflow from the carbonation clarifier discharges to a basin where additional CO_2 is added for final pH adjustment. Water can be recirculated to the mill from this basin for selective reuse. The treated effluent overflows the basin to either a holding pond for regulated discharge to the creek or to a series of six secondary treatment basins. One mechanical aerator is installed in the first basin. The flow diagram for the second color removal system is shown in Figure 56.

The results of the first year's operation showed an average of 80 percent color reduction when treating kraft effluent alone (264). This value was reported at a lime dosage of 1100 mg/l. With lime dosages resulting in a dissolved calcium concentration of about 400 mg/l, color removal averaged 85 to 93 percent. It was reported that when NSSC effluents contributed more than half of the color, efficiency of color removal was reduced by about 15 percent. The high color of the NSSC waste was attributed to poor pulp washing efficiency. This has been improved and effluent color is reported to be improved when NSSC wastes are included (274).

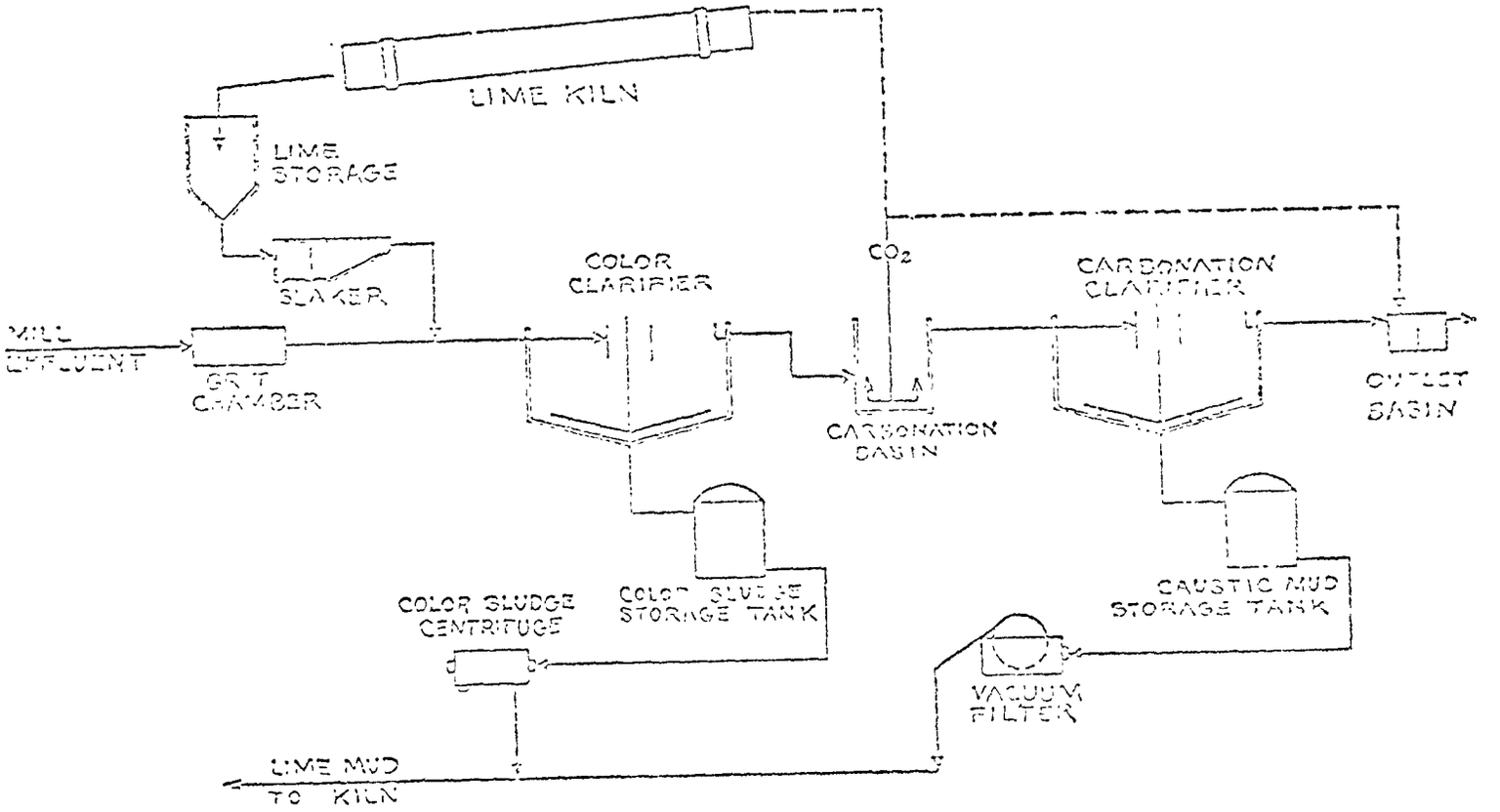
An increase in effluent color was noted across the carbonation system. This difference amounted to a 25 percent increase over the color of the effluent after the primary clarifier. The cause of this increase is not known.

Average TOC reduction through the color removal system was found to be 37 percent. Lime recovery of the system was 93 percent requiring an increased kiln capacity of about 25 percent.

A general observation of the operation at Hodge is that scaling and foam are two considerations that must be addressed in the design of similar facilities. These problems have been

Figure 56

Flow Sheet for Plant Design Continental Can Corporation [249]



encountered and either changes in equipment or normal maintenance procedures were necessary to cope with the problem. The largest foam problem occurs in the carbonator. This has been partially resolved by spreading the foam across the primary clarifier where it breaks down rapidly.

Several performance factors are worthy of mention. First, in using kiln gas for carbonation, attention must be given to the type of fuel used in the kiln which affects the CO_2 content of the gas and consequently the efficiency of carbonation. Additionally, the sodium alkalinity of the effluent exerts a demand for CO_2 and must enter into the design of gas volume required. A related consideration is evidenced by the requirement of a continuous supply of CO_2 for carbonation which can be especially important depending on the type of biological system following the lime system. In times of kiln down-time, a standby source of CO_2, other means of adjusting pH, or holding ponds may be required to protect the biological system.

There is an increase in color, following the biological oxidation ponds similar to that observed at Interstate. The reason for the increase is not certain. However, it may be extracted from natural organic materials. The sodium alkalinity of the effluent is perhaps a major influence on the color change.

An important consideration in the design of this system was the effect of the lime-color body sludge on the kiln operation. However, the color body sludge has no effect on the formation of "rings" or "balls" in the kiln. Additionally, it was reported that the reburned lime is similar in appearance to "normal" reburned lime and no adverse effects have been noted in using this lime in the mill processes.

Georgia Pacific Corporation, Woodland, Maine

The Georgia Pacific mill in Woodland, Maine produces 498.9 kkg (550 tons) of bleached kraft pulp per day. The mill is located on the St. Croix River, an international river falling under the jurisdiction of the International Joint Commission (IJC). A patent has been issued covering the design of its color removal system (272).

Initial plans at the mill called for combined treatment with the town. As negotiations proceeded, it was apparent that costs would be excessive and that the availability of federal funds was questionable. The mill decided to proceed on its own. The treatment plant requirements called for 85 percent removal of BOD and 90 percent removal of suspended solids. In addition, Georgia Pacific personnel felt color removal would be aesthetically desirable even though not required.

The initial color removal system was developed at the company's Crossett, Arkansas, mill in 1967 which treats effluent from caustic extraction in the bleach plant. This effluent is usually

reused in the woodroom first. This supplies a necessary source of fiber which aids in the settling and dewatering of the lime sludge. In the patented process description, the addition of 20 to 200 mg/l of cellulosic fiber is called for to aid in settling and dewatering of the sludge solids.

As developed, the process calls for the addition of 1500 to 2000 mg/l of slaked lime to the caustic extraction effluent ahead of a solids-contact clarifier. Polyelectrolytes are also added to aid settling. Overflow from the clarifier is mixed with other effluents prior to discharge. The sludge underflow is pumped at 10 to 15 percent solids to a mixing tank. In the mixing tank, filtered lime mud is added, raising the solids concentration to 23 percent. The sludge is dewatered on a conventional belt filter to about 50 percent solids and then burned in the lime kiln.

The flow diagram for this process is shown in Figure 57. Certain of the design criteria used at Woodland are presented in Table 85.

The Woodland, Maine color removal facility reported achieving 90 percent reduction in color when treating the bleach plant caustic extraction effluent (275) (276). When the caustic extraction was reused in the woodroom prior to color removal, a 94 percent color reduction was obtained. Lime dosages for the above reductions were 2000 and 1500 mg/l, respectively. The caustic extraction effluent color went from 12,000 to 1300. Additionally, a 47 to 55 percent BOD reduction was reported. Lime recovery efficiency was 75-80 percent with a 6.80 kkg (7.5 ton)/ day lost.

The Woodland color removal facility has not been operated for the past year and one-half for two different reasons (277):

1. River flow has been high and, thus, adequate dilution of the colored effluent has been naturally attainable.

2. The green liquor causticizing clarifier has been in the process of being rebuilt.

For the above reasons, no additional data are available. Conclusions drawn indicate that the key to successful operation of the system is a well designed solids contact clarifier discharging sludge at 10-15 percent solids (276). It is also reported that high sodium levels in the effluent adversely affect color removal.

The characteristics of the reburned lime are essentially the same as conventional calcined lime except for a tan color. No adverse effects on the kiln operation were observed. Color removal added 20.87 kkg (23 tons)/day to the normal 362.9 kkg (400 ton)/day kiln loading.

Considerable foaming was incurred at the clarifier at start-up. This was corrected by installing a ring of water sprays.

Figure 57

Georgia Pacific Lime Process for Color Removal [261]

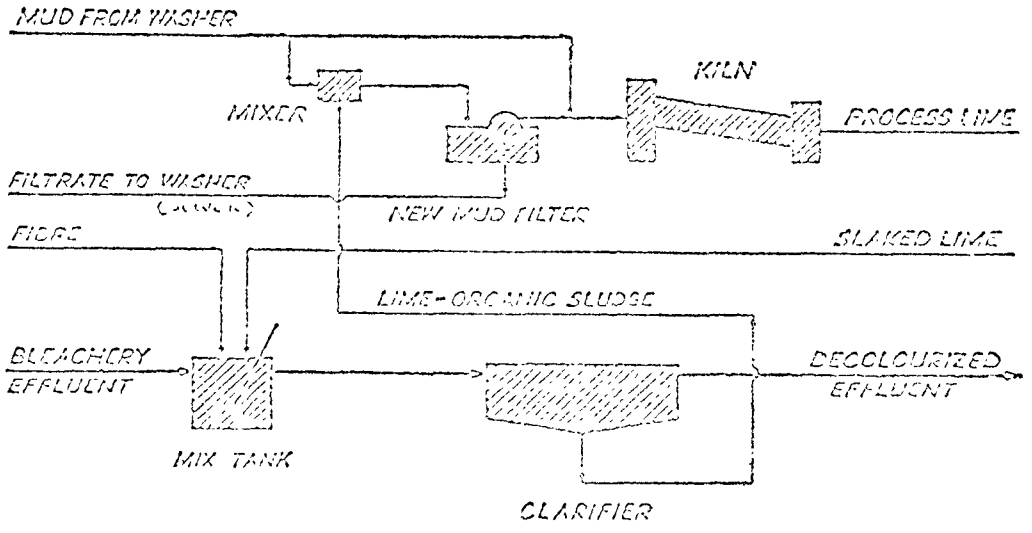


Table 85

STATISTICAL DATA

Equipment Description

Color Clarifier 70-ft Dorr-Oliver	*Rise rate, gal-ft²/day*	*Retention time, hr*
flow 2000 gal/min	750	2.9
flow 3000 gal/min	1120	1.9

Sludgepumps Moyno (two): 0-300 gal/min at 200-ft head

Slaker—Dorr-Oliver No. 6 65 ton/day

Filter-Eimco Belt 10 ft × 12 ft—effective area 376 ft²

Lime Feed, Typical Data

Lime slurry, 10% as CaO

Dosage, 2500 ppm-42 lb/min-30 ton/day

Lime recovery efficiency, 75-80%

Lime lost to sewer, 7.5 ton/day

Color Removal Sludge, Typical Data

At 2500 ppm lime dose sludge flow is 36 gal/min at 10% solids and sp gr of 1.08.

To bring underflow to 30% solids before filtration, 80 ton/day of prefiltered lime mud added at mix tank.

Thickened sludge to belt filter, 45 gal/min at sp gr 1.28

Kiln Operation, Typical Data—2500 lime dosage

Color removal system has added an additional 23 ton/day to the normal 400 ton/day (dry basis) lime mud load to the kiln.

Filtration Rate Data

Leaf filter tests on 25% solids sludge

Vacuum	25 in.
Form time	20 sec
Drying time	20 sec
Cake thickness	¼ in.
Cake wt. o.d.	56 g
Wet cake solids	57%
Filter rate	112 lb/ft² hr[a]

Calcining

Incineration of above cake yields 58% ignited solids containing 1.5% sodium and 0.7% silica as SiO_2. This compares with the 58.6% solids and 1.9% sodium level in the original lime mud.

No change in silica or other properties observed other than slight tan coloration of reburnt lime.

[a] If sludge solids drop from 25 to 20%, filtration rate declines about 90%, from 112 to 9-14 lb/ft² hr.

Georgia Pacific Corporation, Crossett, Arkansas

Operation of the original Crossett color removal facility was sporadic, the reason being that color removal was undertaken only when the flow in receiving stream reached a critical low rate. The initial treatment system employed the use of a converted water treatment clarifier. The hydraulic capacity of this unit was less than the flow rate from the bleach plant. As a result, new facilities of proper design are currently under construction. Design criteria used at the new Crossett removal facility are essentially the same as those used at Woodland. Operationally, the water to be treated (caustic extract) will come directly from the bleach plant and will not go through the woodroom first as it does at the Woodland facility. Start-up of the new facility was scheduled for mid-July 1974.

Lime Mud Treatment

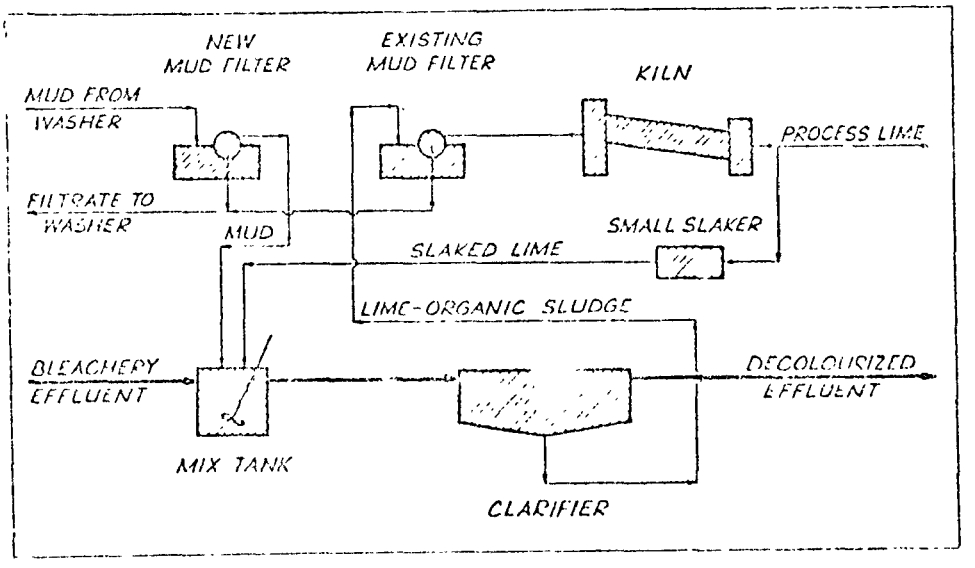
An indepth review of minimum and massive lime treatment techniques has been presented above. However, one scheme -- the lime mud process -was not included. This is a modification of the minimum and massive lime processes. A minimum quantity of slaked lime and the total mill lime mud production are mixed together and reacted with the effluent. The lime-organic sludge is dewatered and burned in the lime kiln. This process has the advantage that the organics are not introduced into the white liquor since the lime mud-color body sludge goes directly to the kiln and in no way comes in contact with either green or white liquor. A flow diagram of the lim mud process is presented in Figure 58.

International Paper's Springhill, Louisiana, bleached kraft mill operated their color removal facility on the lime mud process after the completion of their EPA massive lime demonstration project in 1971. A number of studies, each of two- to three-week duration, were conducted at the 1892.5 l/min (500 gpm) facility. Unbleached decker effluent, when treated with approximately 900 mg/l reburned lime and 12,000-15,000 mg/l lime mud, yielded an 85-90 percent reduction in color. Treatment of a 1:1 mixture of decker and first stage caustic extract effluents required a 3,000-4,000 mg/l dose of reburned lime plus 12,000-15,000 mg/l of lime mud to reduce the color by 80-85 percent. Treatment of straight caustic extract required reburned lime concentrations approaching those used in the massive lime process. No operational problems were encountered except when straight caustic extract effluent was treated. However, an extremely voluminous, non-consolidating sludge was produced. Because of comparative analyses of the lime mud study results with those of other treatment schemes, further development and evaluation were discontinued (278). No published data are available for IP's trial studies on the lime mud process.

Alum Coagulation and Precipitation

Figure 58

NCASI Lime Mud Process
for Color Removal [289]



The coagulation of pulp and paper waste waters by numerous chemicals has been evaluated by many researchers starting with the early work discussed previously which led to the development of the lime process (254). Of all other chemicals investigated, alum seemed to yield the most promise as a color removing coagulant.

The effect of pH on coagulation of biologically treated kraft mill effluent with alum has recently been studied (279). The concentration of Al in the treated effluent and the effect of pH at which coagulation was carried out on residual effluent color were examined. The minimum concentration of Al was observed at a pH of 5.9 to 6.3 and the optimum pH for a minimum effluent color of 50 PCU and minimum residual Al content was said to be 5.5 to 5.8.

Organic polyelectrolytes used with alum or ferric chloride for color and solids removal from both bleached and unbleached kraft pulp and paper mill aerated basin effluents have produced better than 85 percent color removal, low turbidity, and eventually zero BOD at an optimum pH of 4.5 to 5.5 (280). Chemical sludge recycle increased the effectiveness of alum up to 270 percent.

Laboratory tests of the effects of alum and ferric chloride for the removal of color from kraft mill effluents have been run on both hard and soft woods (281). The optimum dosage of alum on hard wood wastes was found to be 150 mg/l. A color reduction of 89 percent was achieved from an initial color of 710 units. Soft wood kraft effluent was found to require a dosage of 30 mg/l. Ferric chloride coagulation of soft wood waste required an optimum dosage of 286 mg/l and produced 87 percent removals.

A laboratory investigation of alum and six organic polyelectrolytes for the removal of color from kraft mill waste water found little difference in the performance of the six polyelectrolytes (282). Alum produced good results, but resulted in approximately three times the volume of sludge. Color removals averaged 95 percent.

A 287.7-kkl/day (76 MGD) tertiary waste treatment facility of a Baikal, U.S.S.R. pulp mill treats the wastes from the production of 273.1 kkg/ day (301 ton/day) of tire cord cellulose and 29.94 kkg/day (33 tons/day) of kraft pulp (283). Treatment consists of neutralization, nutrient addition, equalization, activated sludge treatment, alum coagulation, sedimentation, sand filtration, polishing lagoon, reaeration, and discharge to Lake Baikal. In the coagulation stage, alum is used at a rate of 30 mg/l as Al_2O_3 and polyacrylamide flocculant is fed at a rate of 1 mg/l. Detention time in the chemical precipitation clarifiers is six hours. Color of the raw waste water averaged 1000 units and the treated water color averages 101 units. Thus, the system yields an overall removal approaching 90 percent.

At Gulf States Paper, Tuscaloosa, Alabama (284), a 45.42-kkl/day (12-MGD) treatment facility is in final construction which is to

be capable of reducing the final effluent color to less than 50 APHA units. Raw waste water color from the unbleached kraft mill is in the range of 800-1200 APHA units. Treatment is to consist of primary clarification, bio-oxidation using high purity oxygen, secondary sedimentation, and finally, alum coagulation and sedimentation before discharge. Primary clarifier sludge, excess biological solids, and the alum sludge are to be blended, thickened, pressure filtered, and burned in a multiple hearth furnace. The residue from the incineration process, which will be high in Al_2O_3, will be reacted with sulfuric acid to recover the aluminum as aluminum sulfate. Projected recovery of alum is 94 percent. Final effluent from the treatment plant should be of a quality suitable for reuse and it is planned to recycle 50 percent of this flow 22.71 kkl/day (6-MGD). Startup date is scheduled for early August 1974.

Hyperfiltration and Ultrafiltration

Hyperfiltration (Reverse Osmosis)

At present there are essentially three types of reverse osmosis systems available on the commercial market:

1. Spirally wound sheet modules
2. Capillary fiber modules
3. Hollow core tube modules

The life of the membranes used in all of these modules are greatly influenced by the pH and temperature of the waste waters being treated. In general, a pH less than 7 and a temperature less than 38°C (100°F) are required to minimize unnecessary deterioration of the membrane. In addition, membrane fouling due to buildup of materials on the membrane surface causes a marked decrease in permeate yield rate. Fouling is inherent in all existing systems but may be minimized by pretreatment of the waste waters to remove particulate and colloidal materials and/or pressure pulsing and cleaning of the membranes. In addition, fouling of tubular modules is further decreased by maintaining a water velocity over the membrane surface of approximately 0.91 m/sec (3 ft/sec).

Because of the wide spectrum in size of dissolved and particulate materials found in pulping and papermaking waste waters, the spirally wound and capillary fiber modules have been found to be more prone to irreversible fouling problems than tubular modules.

The following average results were obtained with tubular type module reverse osmosis treatment of various pulping waste waters (208):

1. Ca-base acid sulfite pulp wash water
   Water intake - 166.54 kl/day (44,000 gpd)
   Permeate yield - 84 percent
   Flux rate - 244.46 lpd/sq m (96 gpd/sq ft)

Color removal - 99 percent

2. NSSC white water
   Water intake - 200.61 kl/d (53,000 gpd)
   Permeate yield - 82 percent
   Flux rate - 285.2 lpd sq m (7 gpd/sq ft)
   Color removal - 99 percent

3. NH_3-base sulfite liquor
   Water intake - 158.97 kl/d (42,000 gpd)
   Permeate yield - 65 percent
   Flux rate - 285.2 lpd/sq m (7 gpd/sq ft)
   Color removal - 98 percent

4. Caustic extraction effluent (kraft mill)
   Water intake - 5.68 kl/d (1500 gpd)
   Permeate yield - ---
   Flux rate - 285.2 lpd/sq m (7 gpd/sq ft)
   Color removal - 99 percent

Pretreatment of the wastes was necessary and included filtration through a 40-mesh screen, pH adjustment, and cooling to less than 38°C (100°F).

Operating at a flux rate of 285.2 lpd/sq m (7 gpd/sq ft), the Green Bay Packaging, Inc. reverse osmosis treatment system obtained 90 percent permeate yield and 99 percent color reduction (207).

Ultrafiltration (Macromolecular Filtration)

Because of the relatively high molecular weights of color bodies in pulp mill effluents, ultrafiltration has been proposed as a method of color reduction. Laboratory scale studies achieved a color reduction of 98.6 percent, from 12,750 to 180 color units, for pine pulp caustic extraction effluent (210). The membrane used which had a molecule weight "cut-off" of 1000, was pressurized to 90 psig for the test. Resulting flux rate was 1825.3 lpd/sq m (44.8 gpd/sq ft) and permeate yield was 93.4 percent of the feed volume.

In another ultrafiltration study, decker and caustic extract effluents were treated in a 26.49 lpm (7 gpm) unit which operated at a pressure of 7.03 kg/sq cm (100 psig) (285). The wastes had to be neutralized (pH 6-7), cooled 38-40.5°C (100-105°F), and filtered (down to 2 um) to yield a continuous flux rate of 611.1-814.9 l/day/sq m (15-20 gpd/sq ft) and a permeate recovery of 98-99 percent of the feed volume. Color removal was found to be a function of the molecular weight of the compounds separated, the color of the feed, and the type of membrane used. The major problem encountered in operation of the system was particulate collection within the ultrafiltration cartridges which hindered the continuance of a uniform flux rate at a constant pressure loss. Average color removals and water recoveries for the

various effluents tested during the six-month study are presented in Table 86.

A method of tubular ultrafiltration for removing contaminants with molecular weights greater than 500-1000 has recently been announced (286). In laboratory tests, secondary effluent samples from sulfite and unbleached kraft mills were subjected to this mode of treatment and 85-95 percent color removal from the untreated water was realized. In addition, 95-98 percent permeate yield was obtained. Operation of the system was said to be independent of pH (1-14) as well as temperatures up to about 93°C (200°F). Flux rate through the coated graphitic carbon medium was reported to be 4074.3-6111.4 l/day/sq m (100-150 gpd/sq ft) at a pressure of 7.03 kg/sq cm (100 psig).

Polymeric Adsorbent and Ion Exchange Treatment

Polymeric Adsorbents

Pilot plant work has been performed on the effectiveness of a synthetic polymeric adsorbent for decolorization of kraft bleach plant effluents (287). Since 85 percent of the bleach plant's total color output was contained in the chlorination and first stage caustic extract effluents, major efforts were placed on treating these combined flows. The average color of the waste water was 2203 APHA units and ranged from 779 to 2923 APHA units. Average pH of the waste was 2.2.

The efficiency of the polymeric adsorbent used was found to be very pH dependent. At a pH of 4.5, 40 percent decolorization was realized while at a pH of 2.0, 90 percent decolorization was obtained. The adsorption system is defined as working on the principal of Van der Waals attractive forces and not on the phenonenon of ion exchange.

The system included prefiltration of the chlorination and first stage caustic extract effluents for suspended solids removal. The filter was made with 20- to 50-mesh sand and reduced the total suspended solids of the filtrate to an average of 36 mg/l. By passing the wastes through the adsorption columns at a rate of 12 bed volumes per hour, about 23 bed volumes could be treated before regeneration of the adsorbent was required. Volume of adsorbent in the column was 0.0142 cu m (0.5 cu ft). Therefore, flow rate through the column was approximately 2.84 l/min (0.75 gpm). Regeneration was most advantageously accomplished by using white liquor at a rate of 1.1 bed volumes per regeneration. The concentrated waste water resulting from the regeneration of the resin is returned to the pulping loop where it is concentrated in the evaporators and eventually burned in the recovery boiler. In addition to the above mentioned color removal, 33 percent BOD removal and 43 percent COD removal from the treated waste stream was realized.

Ion Exchange

Table 86

COLOR REMOVAL EFFICIENCY [270]

Influent	Initial Color, mg/l*	% Water Recovery	% Solids in Concentrate	% Color Removal
Pine caustic extraction filtrate	19,000	98.5-99	15-20	90-92
Pine Decker effluent	4,000	98.5-99	5-8	95-97
Hardwood Decker effluent	8,000	98.5-99	5-8	95-97

* pH of feed adjusted to 6.5 - 6.9, filtered, and color measured at 465 mu.

Ion exchange systems have been used for many years for the softening and demineralization of water. Until recently, this unit operation has received little attention as a waste treatment technique because of a number of technical and operational problems. Some of these and pretreatment requirements to minimize pending inefficiencies of the systems are as follows (245):

	Constitutent Problem	Pretreatment Required
Suspended Solids	Blinding of columns	Coagulation and/or filtration
Organics	Fouling of strong base resins	Carbon adsorption or use of weak base resins
Oxidants	Oxidation of resin functional groups	Oxidant reduction
Fe and Mn	Coating of resin	Aeration

With the advent of new resins and more advantageous pretreatment techniques, ion exchange treatment of waste waters is becoming more technically and economically feasible.

A full-scale ion exchange system treating the first stage caustic extraction effluent from a 272.16 kg (300 tons)/day bleached kraft mill using the CEHDED bleaching sequence has been in operation nearly a year (288). This waste stream averaged 100 cu m/hr (3531.32 cu ft/hr) in flow, 14,000 PCU in concentration, and 95 percent reduction of the color from the entire bleach plant 31.8 out of 33.6 kkg (35 out of 37 tons)/day of color.

After prefiltration to remove fibers, the waste was passed through the ion exchange columns at a rate of five bed volumes per hour. Sixteen bed volumes of the waste could be treated to an average 90 percent color removal before regeneration of the resin was necessary. The concentrated waste resulting from regeneration of the columns is sent to the evaporators and is then burned in the recovery boiler. At this level of treatment, total bleach plant effluent color reduction was 86 percent. Schematic diagrams of the actual system and additional data are presented in Figures 59 and 60.

In addition to the full scale ion exchange operation, this type of treatment has been applied on a laboratory scale to waste waters from a four stage bleach kraft plant (CEHD bleaching sequence) which had been pretreated by massive lime precipitation (287). The twenty resins investigated were generally unacceptable for decolorizing the wastes from the chlorination, hypochlorite, and/or chlorine dioxide stages because of the aggressiveness of these waters on the resin functional groups. Desalination of the pretreated bleach plant waste water (85 per-

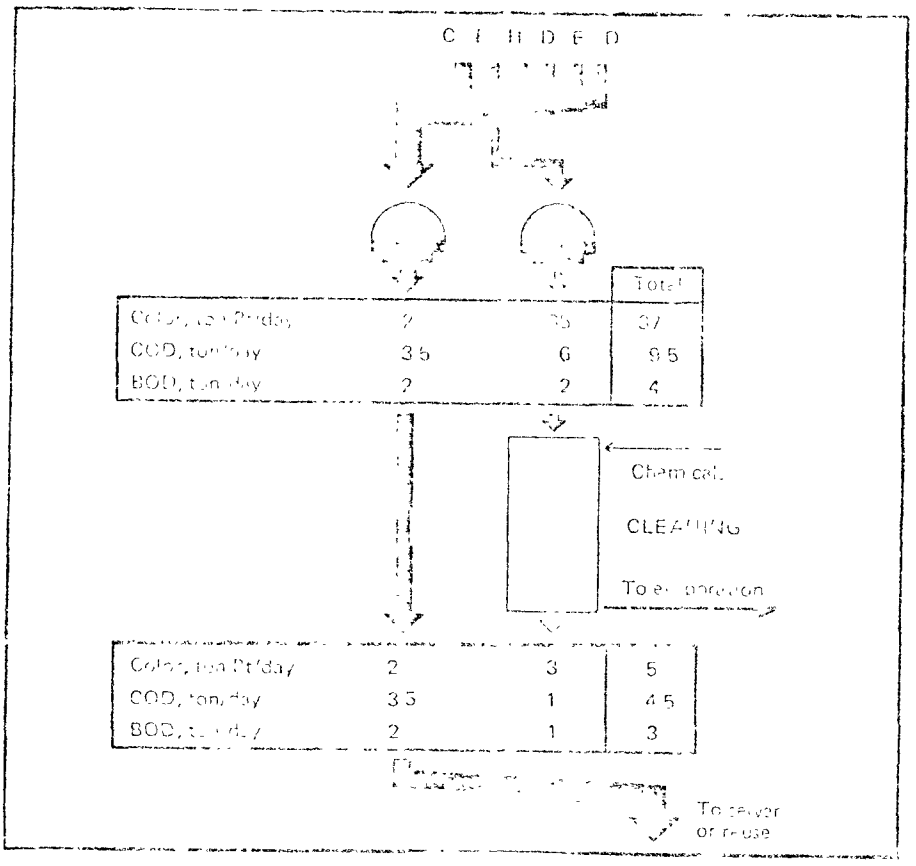


Figure 59

Bleach Plant and Ion Exchange System [274]
(Courtesy of TAPPI)

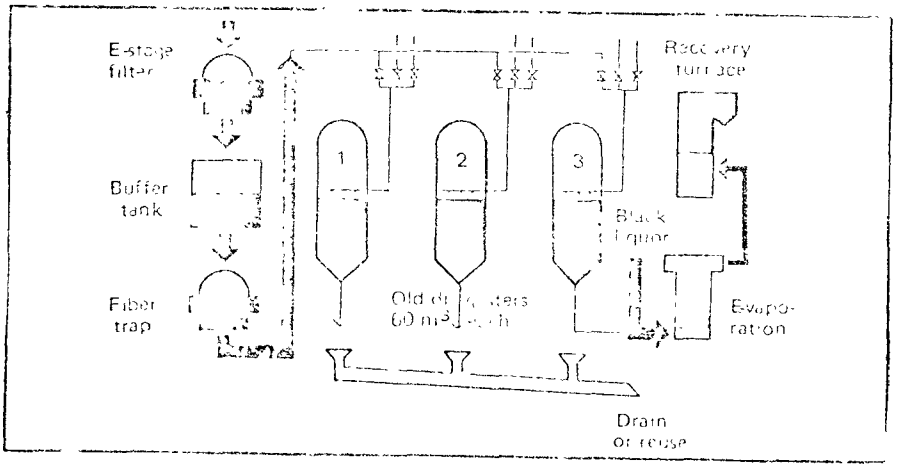


Figure 60

Full Size Color Removal System [274]
(Courtesy of TAPPI)

cent chlorination and 15 percent caustic extract effluents) with a strong acid cation weak base anion exchange system yielded effluents comparable to those obtained with massive lime-activated carbon treatment.

Activated Carbon Treatment

Activated carbon is a material characterized by extremely large surface area to unit weight ratios, typically 450-1800 sq m/gram (2,362,8299,451,317.1 sq ft/lb). The large surface area available results in substantial adsorptive capacity. The rate of adsorption is a function of carbon particle size, powdered carbon having a faster rate than granular carbon. Ultimate adsorptive capacity, however, is essentially in the same for both (234).

Activated carbon has been used in combination with other treatment processes on a pilot scale for the treatment of unbleached kraft mill effluent (234). The treatment sequences were:

1. Primary clarification; activated carbon
2. Lime treatment; clarification; activated carbon
3. Clarification; biological oxidation; activated carbon

The flow diagram of the pilot system is shown in Figure 61. Two carbon systems were evaluated. The first used four standard down-flow columns for series or parallel operation. The second system is called the FACET (Fine Activated Carbon Effluent Treatment). Use of a trade name does not constitute endorsement of the product system and is a multistage stage countercurrent, agitated system with continuous countercurrent transfer of both carbon and liquid from stage to stage. It uses a carbon size between standard granular and powdered classifications. The system is the subject of a patent application.

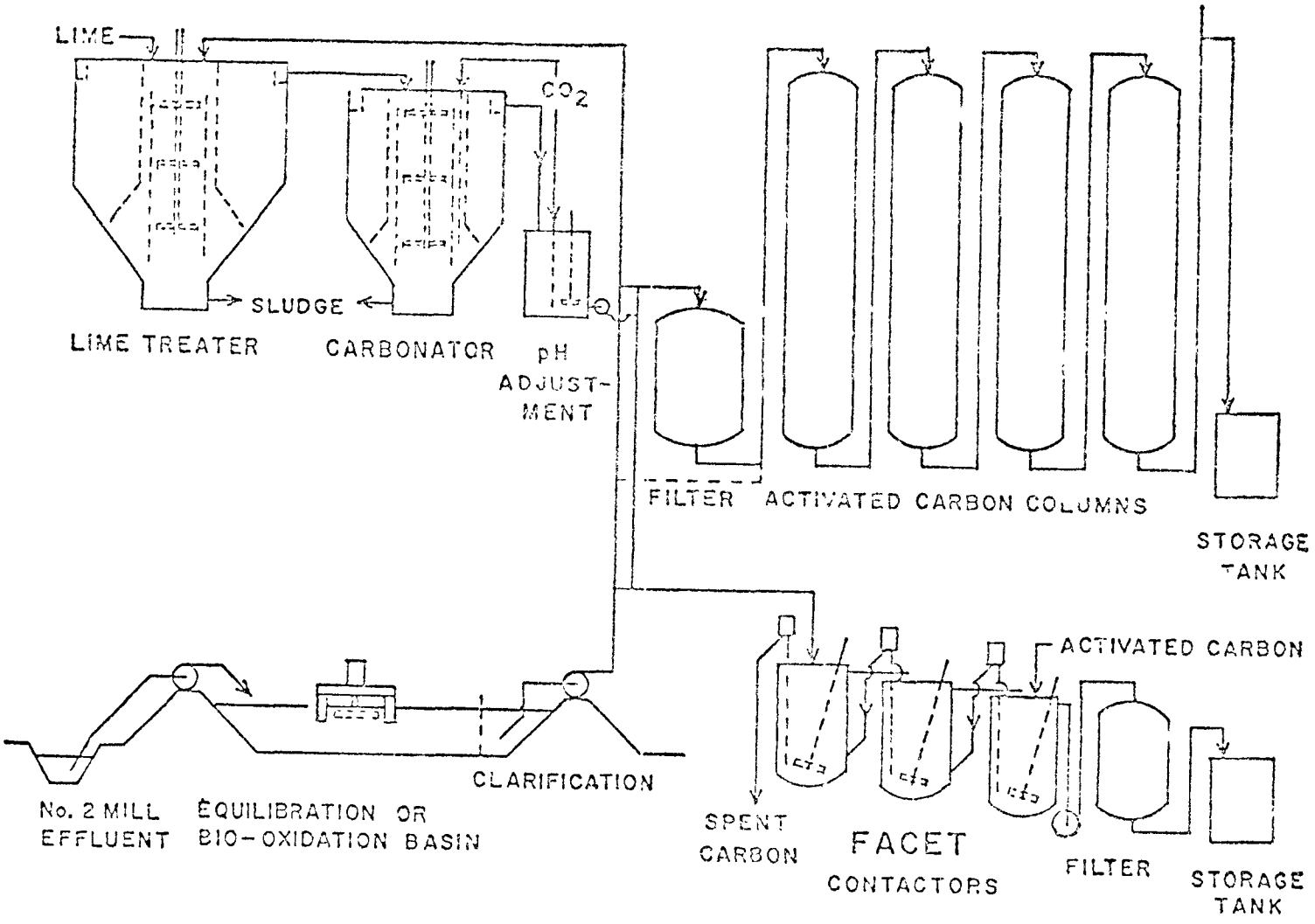
In the lime-carbon system, lime dosages were from 318 to 980 mg/l CaO. This system is referred to as "micro" lime treatment as compared to the "minimum" lime treatment used by others (247) (270) (271). With these dosages, recarbonation of the effluent was unnecessary for reuse of the treated effluent. It should be noted that the intent of this investigation was to treat the effluent to a degree allowing reuse in the mill. A combination of systems capable of producing an effluent suitable for discharge was not necessarily being sought.

The efficiency of activated carbon absorption preceded by massive lime treatment and carbonation both with and without extended aeration has been investigated in a batch treatment pilot plant (232).

Similar studies were undertaken on a pilot scale (219) to investigate the effects of massive lime treatment, biological oxidation, and absorption in granular carbon columns. Others

Figure 61

Activated Carbon Effluent Treatment Pilot Plant [219]



investigated the effect of activated carbon as a polishing step following biological oxidation and lime treatment (280). This process was tested on total kraft mill effluent on a semi-pilot plant scale and was also run without the lime treatment step to test the effectiveness of carbon in reducing the effluent color.

The biological-carbon treatment sequence utilizing four columns in series reduced color of total kraft effluent to 212 units which was too high for reuse in some areas of the mill. This is shown in Table 87. It is estimated that an additional three columns would be required to produce the goal of 100 color units (234).

The primary clarification-carbon system also used four columns. Color was reduced to 185-202 units. This is shown in Table 88. As with the biological-carbon system, it was estimated that an additional three columns would be required to reach 100 color units.

The clarification-lime-carbon system produced the best results of the three systems. Color removal increased from 70 percent at a dissolved Ca concentration of 80 mg/l to 86 percent of a Ca concentration of 400 mg/l. Lime dosages ranged from 318 to 980 mg/l. Color reduction is shown graphically in Figure 62. Color removal in the carbon columns (2 columns in series) was also found to be dependent on Ca concentration. Color in the effluent remained at about 60 units at calcium concentrations above 40 mg/l. Color removal through the carbon columns in the soluble calcium range of 69-83 mg/l averaged an additional 21 percent, to give an overall reduction of 90 percent. This is shown in Table 89. Water of this quality was considered suitable for reuse.

Operation of the FACET* system following lime treatment produced similar results to the two carbon columns after filtration. This is shown in Table 90.

A four-stage (lime-carbonation-oxidation-carbon) system achieved a total color removal of 99.5 percent (232). In a three-stage system (no oxidation) the total removal was again 99.5 percent. This is shown in Table 91.

The color of unbleached kraft effluent was reduced to 10 and 15 units in two separate pilot runs using the massive lime-biological-carbon system (289). Raw effluent color was 4800 and 3000 units respectively. This is shown in Tables 92 and 93.

A final color of 40 units was readily achievable by a biological oxidation-lime-carbon treatment system (290).

It was concluded that the use of a sand filter ahead of the carbon system did not provide enough benefit to warrant consideration in a fullscale installation (234). Concentrated bio-activity was noted in the top one or two foot layer of the first column in series which caused plugging. Backwashing was

Table 87

COLOR REMOVAL IN BIOLOGICAL OXIDATION
CARBON ADSORPTION SEQUENCE AT 15 GPM (2.13 GPM/FT^2) [219]

	Range	Average
Feed to bio-oxidation, APHA CU	430-2600	1100
Feed to carbon, APHA CU	460-1100	740
Product from carbon, APHA CU	42-400	212
Removal by bio-oxidation plus filter, %	-	33
Removal by carbon, % of feed to carbon	-	71
Total removal % of feed to bio-oxidation	-	81
Rate of removal by carbon, CU/g hr	0.51-1.00	0.77

Note: Color measured at pH 7.6 after 0.8 micron Millipore filtration

Table 88

COLOR REMOVAL BY PRIMARY CLARIFICATION
CARBON ADSORPTION SEQUENCE [219]

	Range	Average
Flow rate, gpm	10	5
Flow rate, gpm/ft^2	1.42	0.71
Feed to carbon, APHA CU	925	1160
Product from carbon, APHA CU	185	202
Removal by carbon, %	80	83
Rate of removal by carbon, CU/g hr	0.69	0.64

Note: Color measured at pH 7.6 after 0.8 micron Millipore filtration

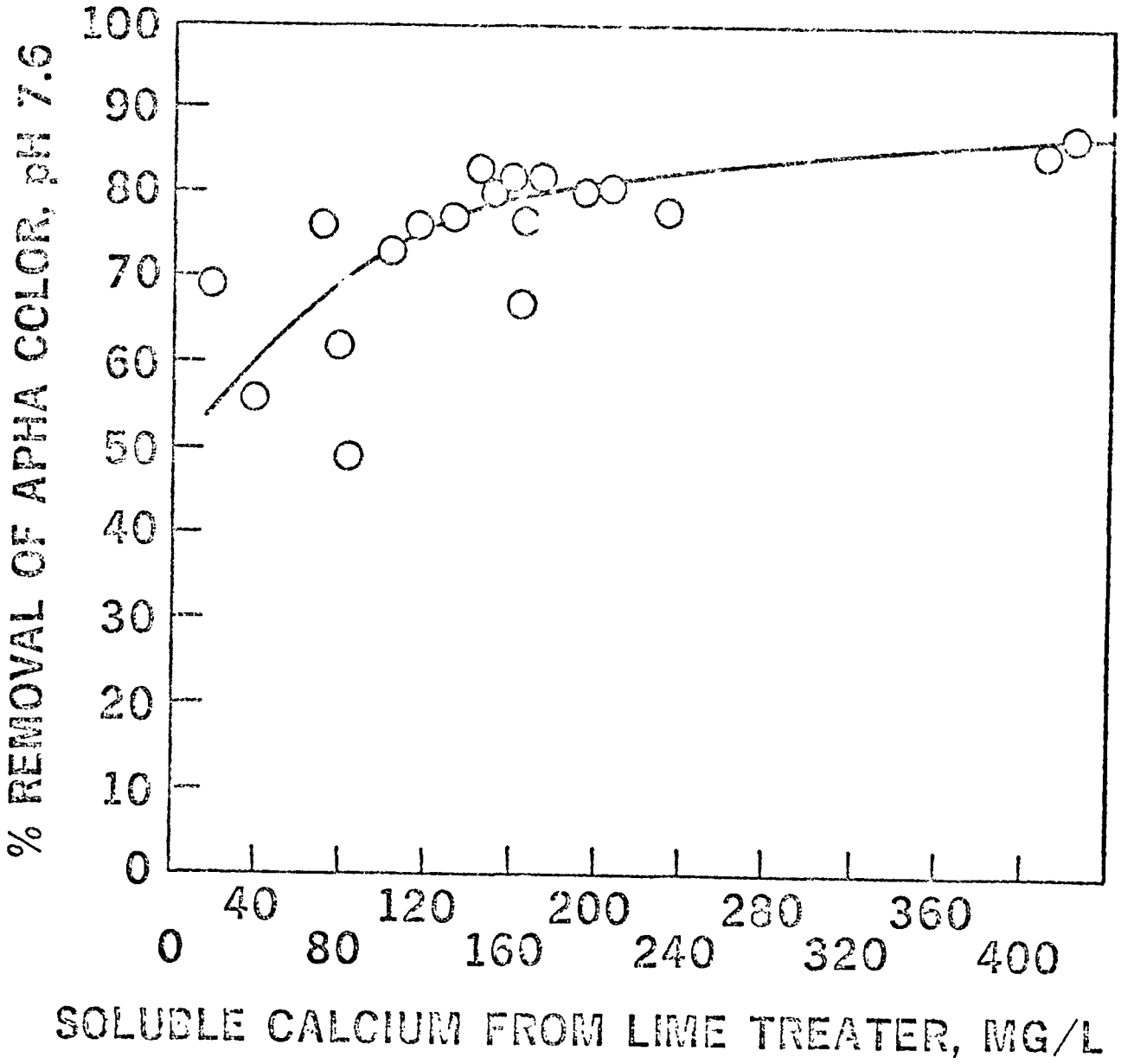


Figure 62

Color Removal in Lime Treatment as a Function of Soluble Ca In Water [219]

Table 89

COLOR REMOVAL BY LIME TREATMENT - CARBON ADSORPTION SEQUENCE AT SOLUBLE CALCIUM RANGE OF 69 - 83 mg/l [219]

lime dosage, CaO, mg/l		523
pH of feed to carbon adsorption		11.3
flow rate to carbon adsorption, gpm		10
No. of carbon columns		2
Concentrations:	Color, APHA pH 7.6	TOC, mg/l
to lime treatment	852	272
to carbon columns	252	177
from carbon columns	76	100
% removals from feed to lime treatment:		
in lime treatment	70	35
in carbon adsorption	21	28
total	91	63

Table 90

REMOVAL OF COLOR AND TOC BY
FACET*CARBON ADSORPTION FOLLOWING LIME TREATMENT FOR 12-DAY PERIOD
10/20 THROUGH 11/6 [219]

Conditions:

Water feed rate	10 gpm
Carbon feed rate	2.7 lb/hr = 4/5 lb/1000 gal
Carbon in system	605 lb
Carbon slurry density	14.3 g/100 ml slurry
Stages	3

Removals:	Color, C.U. APHA pH 7.6	TOC mg/l
Feed	157	158
Product	73	101
Percent removal	54	36
Removed, mg/g carbon	214	136
Removal rate, mg/g x hr	0.71	0.46

*Use of a trade name does not constitute endorsement of the product.

Table 91

WASTE WATER RENOVATION--SUMMARY OF RESULTS

Treatment Step		5-DAY BOD				COLOR			
		Four-stage process		Three-stage process		Four-stage process		Three-stage process	
		mg/liter	% Removal	mg/liter	% Removal	Units	% Removal	Units	% Removal
Raw	Max.	1430		265		12,000		5250	
	Min.	225		206		1,000		240	
	Avg.	723		221		5,200		3553	
Lime	Max.	740		144		1,000		450	
	Min.	170		69		90		10	
	Avg.	395	45.5	102	54	358	93	185	95
Biol.	Max.	135				1,000			
	Min.	21				200			
	Avg.	48	88			365	0		
Carbon	Max.	80		84		15		55	
	Min.	0		15		10		0	
	Avg.	23	53	32	68.5	13	96.5	23	87.5
Total		23	97	32	85.5	13	99.5	23	99.5

Table 92

RENOVATED WATER ANALYSIS [204]

UNBLEACHED KRAFT LINERBOARD TOTAL MILL EFFLUENT
PILOT PLANT RUN NO. 1 50 GALLON BATCH OPERATION

Constituent	Desired Range	Effluent	Obtained by Treatment		
			Lime(a)	Bio(b)	Carbon(c)
Turbidity, ppm	5-25	–	–	65	10
Color, units	0-80	4800	140	200	10
pH	6.5-7.7	8.7	11.5	9.1	8.7
Hardness, ppm $CaCO_3$	5-200	107	7.1	86	61
Dissolved solids, ppm	50-500	3380	2510	2650	2500
Chloride, ppm	10-150	110	140	36	36
COD, ppm	0-12	–	–	201	1
BOD, ppm	0-5	818	460	8	2
Na, ppm	–	1400	1130	1600(d)	1400

Notes: (a) 8.40 lbs, reburned lime slaked and added to raw effluent (equivalent to 20,000 ppm $Ca(OH)_2$).

(b) Extended aeration for 10 days. One gallon fertile lake water added as seed material. NH_4OH, HNO_3 and H_3PO_4 added as nutrient. H_2SO_4 added to neutralize.

(c) Carbon columns containing 12x40 mesh activated carbon furnished by Pittsburgh Carbon. Contact time in the carbon bed was 8.2 minutes.

(d) Possible NH_4^+ interference.

Table 93

RENOVATED WATER ANALYSIS [204]

UNBLEACHED KRAFT LINERBOARD TOTAL MILL EFFLUENT
PILOT PLANT RUN NO. 2 50 GALLON BATCH OPERATION

Constituent	Desired Range	Effluent	Obtained by Treatment		
			Lime[a]	Bio[b]	Carbon[c]
Turbidity, ppm	5-25	–	–	–	–
Color, units	0-80	3000	100	200	15
pH	6.5-7.7	7.5	12.1	8.2	8.5
Hardness, ppm $CaCO_3$	5-200	–	964	1000	866
Dissolved Solids, ppm	50-300	4190	2610	3070	2800
Chloride, ppm	10-150	160	200	130	130
COD, ppm	0-12	–	–	–	–
BOD, ppm	0-5	1430	740	(135)[d]	(80)[d]
Na ppm	–	320	230	230	230

Notes: (a) 2.87 lbs. reburned lime slaked and added to raw effluent (equivalent to 7500 ppm $Ca(OH)_2$).

(b) Extended aeration for 8 days. One gallon fertile lake water added as seed material. KNO_3, H_3PO_4 added as nutrient. H_2SO_4 added to neutralize.

(c) Carbon columns containing 12x40 mesh activated carbon furnished by Pittsburgh Carbon. Contact time in carbon bed was 1.6 minutes.

(d) Estimate, incubator problems.

required every one or two days. It was also noted that mechanisms other than adsorption contributed substantially to color removal. This mechanism has been referred to as a coagulation of the colloidal color bodies at the surface of the carbon particle.

Previously, it was explained that in the lime-carbon system, lime dosages were recommended to control the dissolved calcium concentration at about 80 mg/l. A reported benefit of this is the elimination of the necessity to carbonate the effluent to remove the calcium. Higher dosages could require carbonation prior to reuse of the effluent. The lime treatment system also produced a sludge that dewatered readily to 70 percent solids. Lime treatment to higher dissolved calcium levels of 400 mg/l, followed by carbonation and carbon treatment, did not improve color reductions.

The possibilities of the FACET* system have aroused some enthusiasm. A rate of TOC removal of 4.7 times the rate of removal in columns has been observed and the degree of color removal was the same as in the columns, but with one-fifth the amount of carbon. More work is planned.

In the work directed towards reuse of the treated effluent, the degree of treatment obtained is greater than typical discharge standards. At this time, the effect of recycled effluent on mill processes has not been tested. However, it appears that the kraft process contains unit processes by which any buildup in contaminants due to recycling can be purged from the system.

Elimination of biological oxidation in the lime-carbonation-biologicalcarbon sequence did not affect color reduction and BOD reduction remained about 85 percent when treating effluents with a moderate raw BOD. Further research is planned to improve BOD reduction in the lime stage and to use more effective carbons. These researchers also look to requirements for advanced treatments leading to recycle of waste waters and see the possible elimination of biological systems as recycle becomes more important.

A 22.71-kl/day (600-gpd) two month pilot study treating 80 percent deinking and papermaking effluents and 20 percent domestic waste water utilized the following treatment train: chemical coagulation (using ferric chloride), sedimentation, high-rate filtration, and carbon adsorption (215). Color levels exhibited by the untreated waste water ranged from 25 to 250 units. Effluent color levels from the treatment system ranged from 5 to 20 units. Average color removal was 88 percent.

A number of researchers have undertaken investigations to determine the adsorptive capacities of activated chars produced from bark. One found the chars to be relatively ineffective in removing color, BOD, and COD from samples of caustic extraction stage effluent (241). Others treated NSSC spent liquor first

with coagulants, then with oxidants, and finally bark derived activated char (292). Residual color in the effluent from the treatment train approached that of fresh water. Another experiment produced an activated char from bark which was capable of removing both color and BOD from the first stage caustic extraction effluent of a kraft bleach plant (228). The char was made in the laboratory by heating the bark to 818°C (1600°F) and activating for 30 minutes with steam. Yield was about 6.80 kg (15 lb) of activated char per 45.86 kg (100 lb) of bark. In laboratory jar tests, 95 percent color and 75 percent BOD removal were obtained when the selected waste water was treated with 20 grams/liter (.166 lb/gal) of the activated char.

Extraneous Treatment Techniques

Ozonation

Kraft mill secondary treatment plant effluent has been subjected to pilot plant treatment by ozonation (294). The mill produced 453.6 kkg (500 tons)/day of fully bleached pulp and 544.3 kkg (600 tons)/day of fine papers. Color of the waste water subjected to treatment ranged from about 400 to 900 color units.

Color removal was found to be primarily a function of the applied ozone concentration, but was also influenced by initial color, COD, and suspended solids concentrations. The amount of color removal obtained from the 18.93 l/min (5 gpm) pilot plant operation is shown in Table 94.

Enzymatic Pretreatment

The removal of dyes from the effluent of a fine paper mill has been reported (156). The waste water was intially subjected to alum precipitation (with caustic added) which was followed by pressure filtration through a dual media filter. Colloids and associated color were not effectively removed because of the dispersant powers of the starch sizing in the waste water. By chlorinating the effluent from the filter with an applied dose of 3.5 mg/l Cl_2, the color could be reduced to an acceptable level for waste recycle about 80 percent of the time. However, when attempts were made to recycle the water to the paper mill, slime problems developed which could not be rectified. Next, an enzyme was introduced to destroy the dispersing power of the starch sizing. By feeding the enzyme to the system at 6 mg/l along with the alum and caustic, the dyes were precipitated out of solution along with the clays, titanium dioxide, and other colloids. By filtering the supernatant from the clarifier and applying a chlorine dose of 5.5 mg/l, any residual color was destroyed and there was adequate chlorine residual to minimize slime growth. Overall suspended solids removal for a three-month period was 99.1 percent. The filtrate contained 6 mg/l (0.05 lb/1000 gal) and had a turbidity of 25 JTU when 1.3 kl/m (350 gpm) was treated.

TABLE 94

COLOR REMOVALS FOR VARIOUS APPLIED OZONE DOSES [279]

Ozone Applied, ppm	% Color Removal
10	32
20	56
30	67
40	72

Precipitation With Seawater

Laboratory studies (295) have indicated that 80 percent removal of color from bleached kraft mill effluent is possible by mixing mill effluent and seawater in a ratio of 100:5 to 100:10, aerating the mixture to remove bicarbonates as CO_2, adding slightly more than the stoichiometric lime requirement, flocculating, and clarifying the mixture. The addition of lime produces a flocculant precipitate of magnesium hydroxide which, as it settles, removes the color matter and suspended solids. The authors point out the possible recovery of MgO from the clarifier underflow.

Extraction

Laboratory scale studies of color extraction using high molecular weight amines dissolved in a water immiscible solvent. Color reductions in the range of 90-98 percent were obtained (296). The waste water pH must first be adjusted to 3 after which the amine solution is blended with the waste. Phase separation is allowed to occur and the clarified effluent is discharged, and the amine solution containing the color bodies is sent to regeneration. Alkaline treatment removes the color bodies from the amine which is returned for reuse. One benefit of this approach is that no sludge is generated. One problem encountered is a small volume of water-amine solution emulsion which forms and must be treated separately to recover the relatively expensive amine.

ADVANCED WASTE TREATMENT

The purpose of this subsection is to identify, document, and verify potential control and treatment technologies. The present state of the art of advanced waste treatment (AWT) is evaluated in terms of its applicability to the wastes of the subject subcategories of the pulp and paper industry. AWT systems are discussed as they apply to:

1. Removal of turbidity and colloidal and suspended solids
2. Removal of dissolved salts and dissolved solids
3. Removal of refractory organics
4. Removal of nutrients

Each technology is described and its efficiencies and operational considerations are discussed. It will be noted that the pilot plant or demonstration work on certain AWT systems has been performed in connection with mills in subcategories not covered by this report. This material is presented, however, because of possible transferability of the technology to other subcategories.

This discussion on AWT is not broken down by subcategories for the same reason. It may be interpreted as applying to all subject subcategories unless otherwise noted.

The primary exception is the application of treatment technology for the removal of nutrients. With the exception of ammonia base sulfite mills, the wastes of all the subcategories covered contain very low concentrations of phosphorus and nitrogen. In fact, nutrient supplements must be supplied to their biological treatment systems to insure efficient BOD reductions; the resulting residual nutrients should be neglible and insufficient to cause eutrophication problems in receiving waters.

Removal of Turbidity and Colloidal and Suspended Solids

The primary advanced waste treatment systems under investigation for the removal of turbidity and colloidal and suspended solids from pulp and paper mill wastes are: coagulation and flocculation followed by settling; filtration; and reverse osmosis. The majority of the work undertaken on coagulation and flocculation has been in conjunction with color removal and is discussed in preceding pages.

Filtration

Filtration has long been applied in the treatment of municipal and industrial water supplies. Today various types of filtration are widely used for wastewater treatment, both in up-grading existing conventional plants and in designs of new advanced treatment facilities. Next to gravity sedimentation, filtration is the most widely used process for separation of wastewater solids.

Filtration as a wastewater treatment process is not a new concept. Mechanical filtration of primary settled sewage dates back to 1883. It was not widely used as biological treatment methods became popular, but again it was considered in the 1930's because of the development of chemical sewage treatment methods. During the last decade, filtration has been widely used following biological treatment to meet increasingly stringent effluent requirements. Filtration applications in wastewater treatment include: 1) removal of biological floc from secondary effluent, 2) removal of precipitates from phosphorus removal, and 3) removal of solids remaining after chemical treatment.

Tertiary filtration of wastewaters has long been practiced in Great Britain. While the British practice tends toward the upflow pressure mode, their experience includes gravity downflow, biflow, and radial flow methods, many of which are patented processes. In the United States the tendency is toward the

conventional downflow gravity method, although some pressure filters are being used. Information on the use of filtration in waste treatment is summarized in Table 95 (196).

Many tests have been conducted on both pilot plant and plant scale operations to determine the effectiveness of filtration for suspended solids and BOD removal and to develop design criteria. Gravity downflow filtration has been found to be a cost-effective means of reducing suspended solids in the effluent of wastewater treatment facilities. Both conventional and special design filter beds have been tested. The effectiveness of chemical addition to improve filterability of secondary effluents from pulp and paper mill wastes has been established in an NCASI Technical Bulletin, No. 266 (213).

This report gave details of a study to evaluate the effectiveness of various filtration systems for the removal of suspended solids and BOD from three separate and different mills. Comparisons were made between removal efficiencies for filtration without the use of chemical additives and filtration with the use of chemical additives. The conclusion of this study was that chemical addition, either alum or polymers, would improve greatly the filterability of these wastes as compared to their filterability without chemical addition.

Treatment Efficiencies

Tchobanoglous (199) evaluated the performance of various filter configurations including conventional and special bed designs and the effects of chemical addition. His conclusions were: 1) filtration efficiency without chemical addition is a function of filter bed grain size, 2) in most dual-media filters as presently designed the sand underbed contributes little to overall suspended solids removal, and 3) polyelectrolytes can be used to aid in removal of suspended solids. At a filtration rate of 209.82 lpm/sq.m 5.15 gpm/sq ft) and with polyelectrolyte addition, an average influent suspended solids concentration of 23.5 mg/l was reduced to 1 to 3 mg/l. Run lengths were between 4 and 5 hours. Removals ranged from 87 to 96 percent.

Tchobanoglous and Eliassen (200) investigated filtration of activated sludge effluent in a pilot plant study. They developed a generalized rate equation based on size of filter medium, rate of filtration, influent characteristics, and the amount of material removed within the filter. Using 0.488 mm sand, suspended solids were reduced from 6.3 mg/l to 2 mg/l, a 68 percent removal. Filtration rate was 236.30 lpm/sq.m. (5.8 gpm/sq ft) and run length was 6.25 hours. The top 0.0254 (1-inch) of the filter captured 75 percent of the suspended solids, and no solids were retained below a depth of 6 inches.

Culp and Hansen (201) found that up to 98 percent of the suspended solids found in an extended aeration plant effluent with 24-hour aeration of domestic sewage could be removed by

Table 95

SUMMARY OF AVAILABLE INFORMATION ON FILTRATION IN WASTE TREATMENT [190]

Source Information	Waste-water Charact.	Type, Size Filter media (mm)	Depth (in)	Rate (gpm/ft^2)	Max. terminal head (ft water)	Run length (hr)	SS (ppm) Infl.	SS (ppm) Effl.	SS (ppm) % Removed	BOD_5 (mg/l) Infl.	BOD_5 (mg/l) Effl.	BOD_5 (mg/l) % Removed	Backwash Information	Remarks
Dr. Mohr in Germany Rapid Gravity filter (from Zack[97], 1937)	Primary settled effluents	Sand 1~2		1.47	4.1	8								
	"	Sand 2~3		0.82	4.1	25								
Atlanta, reported by A. Potter (from Zack[97], 1937).	Chem. treated primary effluent	Anthracite E.S. 0.45		2	5	12	9~75		79				twice as many backwashings required for influent of 57 ppm as for 19 ppm SS.	
		"		3.5	5	3	9~75		79					
Wuppertal pilot filter (German) (from Streander[83], 1940)	Primary settled influent	Sand 3~4	28			40~50								low efficiency. Reduction 12% of oxygen consumption.
	"	Sand 2~3	12	0.75~1.5	3.9	20~25								Reduction 12 to 21% of oxygen consumption.
	"	Sand 1~2	28	0.75~1.5	3.9	16~0			80~90				Prior to the advent of high velocity wash mechanical rakes and low velocity backwash or air agitation followed by water washing	Reduction in O_2 Consumed 20% for 1.5 gpm/ft^2 25-30% for 1.1 gpm/ft^2 35% for 0.75 gpm/ft^2 Retained solids well distributed throughout the bed
Wuppertal full scale plant 26' 3" x 123' (from Streander[83], 1940)	Primary settled effluent	Sand 1~2	28	0.83	4.25				40				Air wash, supplied by centrifugal blower - 2.4 $ft^3/min/ft^2$. The rate of backwash in a deep sand filter is controlled by the size of, 5 ~ 8 in/min.	Low removed by SS was due to the inability to thoroughly remove the retained solids from the sand bed. Backward rate used was too low.

Table 95 - Cont'd.

Source Information	Wastewater Charact.	Type, Size Filter media (mm)	Depth (in)	Rate (gpm/ft^2)	Max. terminal head (ft water)	Run length (hr)	SS (ppm) Infl.	SS (ppm) Effl.	SS (ppm) % Removed	BOD_5 (mg l) Infl.	BOD_5 (mg l) Effl.	BOD_5 (mg l) % Removed	Backwash Information	Remarks
South River plant, N. J. (from Streander[83], 1940)	Primary settled effluent	Sand 1.0 U.C. 1.5	6	0.64		1.9	132	70	47			28	37% treated water used	Total washing time/day = 190 min.
Sayerville, N. J. (from Streander[83], 1940)	Primary settled effluent	Sand 1.0 U.C. 1.5	6	0.6		2.7	154	76	51			13	47% treated water used	Total washing time/day = 135 min.
Sayerville, N. J. (from Streander[83], 1940)	Chem. treated primary settled effluent	Sand 1.0 U.C. 1.5	6	0.6		3	40	20	50			9	41% treated with water	Total washing time/day = 120 min.
Laughlin filter, Atlantic City (from Streander[83], 1940)	Primary settled effluent	Sand, E.S. 0.4 ~ 0.5 U.C. 1.8 ~ 2.0	6	2			88	39	56	187	137	26		Reduction in BOD is not proportional to reduction of SS
Aucor Sewage Works, pilot plant, South Africa (from Wosloo[9], 1947).	Secondary settled effluent	Sand 0.5 ~ 1.7	29	2	10	6~18	24.3	0.7	97				5% of total flow used for backwash	
Pilot plant at Luton, England 1949-1950 (from Pettet, Collett, Waddington[7], 1952)	"	Sand 0.85~1.7	24	2	7	24	24	3.4	86	26	10	61.5	2~3% of treated water, 13.3 gpm/ft^2 rate	No appreciable difference in head loss for sand filters with 2 ft and 3 ft 6 in depth, respectively. Also little difference in effluents from two filters at rates below 2.92 gpm/ft^2, but at higher rates, the effluent from filters of 3'-6" of sand was slightly superior.
	"	Anthracite 1~2	24	2	7	24	25	3.3	87	26	9	65.5	2~3% of treated water, 10 gpm/ft^2 rate	
	"	Sand 0.85~2	24	2.34~3.42			19.3	0.9	95	23.8	7.2	70		
		"	42	2.34~3.42			19.3	0.7	96	23.8	6.3	74		

Table 95 - Cont'd.

Source Information	Wastewater Charact.	Type, Size Filter media (mm)	Depth (in)	Rate, (gpm/ft^2)	Max. terminal head (ft water)	Run length (hr)	SS (ppm) Infl.	SS (ppm) Effl.	SS (ppm) % Removed	BOD_5 (mg/l) Infl.	BOD_5 (mg/l) Effl.	BOD_5 (mg/l) % Removed	Backwash Information	Remarks
Luton Plant, England May 1951 ~ April 1952 (from Evans, Roberts[19] (1952)	Secondary final effluent	Sand 0.85 ~ 1.67	8	3.33	8~9	24	15.4	4.2	73	13.0	6.7	49	By air-scour, 2.5% of treated water	1. During storm flow and high loading, backwash every 12 hrs. 2. Lower DO in filter effluents. 3. Oxidation of ammonia range from 35 to 53%. 4. Cost per lb of SS removed = 4.25 d Cost per lb of BOD removed = 7 d. 5. Visible color reduce 6.5%; thiocyanate, 50%, phenols, 8%.
Full scale sand filter at Luton, England (From Evans[17], 1957).				2.5		24.	13.4	3.3	76	9.2	4.0	56.5	Use 3% of treated water	
Pretoria Sewage-treatment works, Johannesburg, South Africa (from Nicolle[64] 1955; Nicolle[65], 1957)	Secondary final effluent	Sand 0.84 ~ 0.59		3	6.5	8~10	22	4.6	79				Air-water rate: 25% gpm/ft^2	
		1.40 ~ 0.65		3	6.5	8~10		8					9.5% of treated water used	
Los Angeles Hyperion treatment plant (preliminary tests)(from Laverty et al.[45], 1961).	Activated sludge effluent	Sand E.S. 0.95 U.C. 1.6	11	2			26.1	12.7	46	9.8	4.8	51	automatic backwash	

Table 95- Cont'd.

Source Information	Wastewater Charact.	Type, Size Filter media (mm)	Depth (in)	Rate (gpm/ft^2)	Max. terminal head (ft water)	Run length (hr.)	SS (ppm) Infl.	SS (ppm) Effl.	SS (ppm) % Removed	BOD_5 (mg/l) Infl.	BOD_5 (mg/l) Effl.	BOD_5 (mg/l) % Removed	Backwash Information	Remarks
Lab study at Peoria Sanitary District Treatment Works (from Fail & Kraus[21] 1964).	high rate activated sludge effluent			1.12			16.0	8	50	28.3	17	40		Filter clogged easily and run length was only a few hours.
Research at Iowa State University. Pilot plant was located at Ames Sewage treatment plant. (Mern[37], 1965)	Trickling filter final effluent	Sand E.S.0.55 U.C.2.36	24	2 4 6	6.25	10 6.25 4.67	19.8 18.5 17.7	5.7 6.0 6.3	71.2 67.6 64.4	56 52.6 50.4	24.2 23.4 24.4	56.8 55.5 51.6	No air wash 20-25 gpm/ft^2 for 10 min.	Clogged filters might have not been cleaned properly
Philomath Municipal sewage treatment plant, Oregon (from Culp, Hansen[12], 1967)	Extended aeration effluent	mixed-media	30	5			59	4	93	26	2.5	90	Automatic control, No air wash	Remove phosphate by adding chemical
Gravity sand filter and pilot up-flow filter at Luton, England 1966 (from Naylor, Evans, and Duncombe[63], 1967)	final settled (down-flow full scale)	Sand 0.85~1.7	36	4.0			12.8	7.5	41	5.3	3.1	42		up-flow filte. produced a better effluent.
	(up-flow pilot plant)	Sand 0.85~1.7	60	4.2			12.8	5.7	56	5.3	2.6	51		
Cambridge, England, 1967 (by Holden Discussion[24], 1967)	final settled effluent (down-flow)	Sand 0.85~1.7	24	2.5	3	6	20-40		77					1. Tertiary treatment could only be successful when the influent was well oxidized 2. Effluent poorer at higher rate
	(up-flow)	Sand 0.85~1.7	24	2.5		24	20-40							

Table 95- Cont'd.

Source Information	Wastewater Charact.	Type, Size Filter media (mm)	Depth (in)	Rate (gpm/ft^2)	Max. terminal head (ft water)	Run length (hr.)	SS (ppm) Infl.	SS (ppm) Effl.	SS (ppm) % Removed	BOD_5 (mg/l) Infl.	BOD_5 (mg/l) Effl.	BOD_5 (mg/l) % Removed	Backwash Information	Remarks
West Hertfordshire authority, England, 1968 (from Hood, Smith, Murry[95] 1968)	final effluent of trickling filter (up-flow)	Sand 1~2	60	1.8	5		44.3	1.3	95.7	57.7	3.9	93.1	Air scour then backwash with untreated effluent	1. Sharp fall in efficiency for flow greater than 4 $g.p.m/ft^2$ 2. Little or no nitrification or denitrification took place in the filter
		Sand 1~2	60	3.33	5		37.3	3.7	90.1	53	4.6	91.3		
		Sand 1~2	60	4.16	5		55.5	7.1	87.1	42	5.6	86.6		
		Sand 1~2	60	5.0	5		37.3	9.9	73.5	34.6	14.7	57.5		
Letchworth Plant, England 1965 ~ 1967 (from Truesdale and Birkbeck[91] 1969)	final effluent of activated sludge (up-flow)	Sand 1~2	60	4.4			17.2	6.9	60	19.2	9.0	53	Air scour then washed by upward flow to about 11.7 gpm/ft^2. 6% treated water used	Effluent from filter was inferior at high flow rates. (>6.6 gpm/ft^2)
Lebanon pilot plant, Ohio (from Berg & Brunner[2], 1969)	Activated sludge final effluent with pol/electrolyte (2.5 mg/l) and/or alum (12 mg/l)	Single coal E.S. 0.75 U.C. 1.5	20	5	28.3	3~6	5~25						1. rate of 15~20 gpm/ft^2 2. backwash water used 6.6% (for 2.5 hr run) 11% (for 1.5 hr run) of treated water	1. Effluent quality less than 0.5 JTU 2. Total cost 6.7¢/1000 gal. 50% of cost for electric power and chemicals.
				10		1.5~3								
		dual-media 14" coal E.S. 0.75, U.C. 1.5 6" sand E.S. 0.75, U.C. 1.6		5	28.3	2.5~4								
				10										
Hanover treatment plant Metro Chicago, Harza design filter (from Arnett & Bacon[3] 1969, from Lyman, Ettelt, & Weisenberg, 1969, from Lyman, Bacon[58], 1970)	final effluent of activated sludge	Sand E.S. 0.51 U.C. 1.62	12			4~5			77			89	traveling backwash	1. Efficiency of tertiary treatment depend on the efficiency of secondary treatment. 2. Additional solids removal provided by coagulation with alum plus polymer was not sufficient to warrant inclusion with filtration into tertiary treatment design.

Table 95 - Cont'd.

Source Information	Wastewater Character.	Type, Size Filter media (mm)	Depth (in)	Rate (gpm/ft^2)	Max. terminal head (ft water)	Run length (hr.)	SS (ppm) Infl.	SS (ppm) Effl.	SS (ppm) % Removed	BOD_5 (mg/l) Infl.	BOD_5 (mg/l) Effl.	BOD_5 (mg/l) % Removed	Backwash Information	Remark
Pilot scale sand filter at Derby, England (from Oakley & Cripps[66], 1969; Joslin & Green[39], 1970)	Trickling filter final effluent	comm. sand		2.5	12	14-17			59-60			23-38		
		1.2~2.4	24	3.33	12	20			57-66			50-64		
				5.0	12	17-18			47-58			32-37		
		comm. sand		3.33	12	19			65			67		
				5.0	12	16-17			60			43-46		
		1.2~2.4	36											
		L.B. sand 1.2~1.68	24	2.5	12	10-12			59-60			54		
				3.33	12	11-15			52-64			53-65		
	Trickling filter final effluent	Three-layer filter Anthracite 8"-2.4~1.5		2.5	12	13			64			69		
		Sand 8"-1.5~1.19		3.33	12	13-17			57-70			59-71		
		Garnet 8"-0.85~0.7		5.0	12	12-14			53-65			34-46		
		Sand 4'-1~2		3.33	12	25-26			57-74			60-67		
		Gravel 2'-2" (up-flow)		5.0	12	12-17			47-58			48-50		
High Rate filtration of Mill Scale waste (from Donovan[13],)	Mill scale waste	Anthracite 5.1	84	8	15	46	150	11	92.5				Air scour for 5 min. at 8 cfm/sf then flush with water at 20 gpm/sf for 10 min.	The cationic polyelectrolyte produced the best results. The cost of feeding polyelectrolyte was less than $1.00 per million gallons water filtered.
				16	15	38	150	36	76					
				23	15	33	150	83	45					
				30	15	23	150	85	43					
		Sand 2-3	84	8	15	20	150	2	99					
				16	15	9.5	150	4	98					
				23	15	20.5	150	30	80					
				30	15	3.5	150	7	95					
		Anthracite 4'-5.1 Sand 3'-2.3		8	15	28	150	3	98					
				16	15	20.5	150	3	98					
				23	15	12	150	10	93					
				30	15	8.5	150	9	94					

filtration. Turbidities as low as 0.3 JTU were obtained without the use of coagulants.

Culp and Culp (202) report that filterability of sewage solids is affected by the degree of flocculation attained in the secondary process and that activated sludge achieves the best flocculation results as compared to trickling filter and physical-chemical processes. Flocculation is proportional to aeration time and inversely proportional to load factor. MLSS variations in the normal operating ranges of 1,500 to 5,000 mg/l do not affect filterability. With domestic wastes, suspended solids removals from 70 to 98 percent can be obtained at aeration times of 6 to 10 hours respectively. Biological processes, in general, produce a better floc than chemical coagulation, and the higher removal percentages were obtained with the effluent from an extended aeration plant. Culp and Culp present the following levels as guides to the suspended solids concentration that might be achieved when filtering a secondary effluent of reasonable quality without chemical coagulation:

Process Effluent TSS	
High-rate trickling filter	10-20 mg/l
Two-stage trickling filter	6-15 mg/l
Contact stabilization	6-15 mg/l
Conventional activated sludge	3-10 mg/l
Activated sludge with load factor less than 0.15	1-5 mg/l

Culp and Culp indicate that, although mixed-media filters can tolerate higher suspended solids loadings than other filtration processes, there still is an upper limit at which economically long runs can be maintained. The authors state that "with activated sludge effluent suspended solids loadings of up to 120 mg/l, filter runs of 15-24 hr at 203.71 lpm/sq.m. (5 gpm/sq ft) have been maintained when operating to a terminal head loss of 4.57 m. (15 ft) of water. Suspended solids concentrations of 300 mg/l or more will lead to uneconomically short filter runs, even when using a mixed-media filter...should the secondary plant involved have a history of frequent, severe upsets resulting in secondary effluent suspended solids concentrations of 200-500 mg/l, an intermediate settling tank between the secondary clarifier and the filter with provision for chemical coagulation during upset periods should be made."

An advanced wastewater treatment plant that includes dual-media filtration has been in operation since 1968. The effluent is of such high quality that turbidity is monitored rather than suspended solids. The effluent from this plant is used to recharge the water table in Nassau County, New York. The process as reported by Vecchioli et al (203) provides for the removal of suspended solids, phosphates, dissolved organics, and MBAS. Treatment after activated sludge includes a reactor-type clarifier (where alum is added), dual-media filter, and activated

carbon adsorption. Suspended solids removals of 99 percent are obtained.

Most filtration rates reported in the literature vary from a low of 40.74 to a high of about 307.42 lpm/sq.m. (1 to 10 gpm/sq. ft). In optimization studies, the rate has been established at about 244.45 or 285.19 lpm/sq. m. (6 or 7 gpm/sq. ft). Ultra-high filtration of activated sludge effluent in Cleveland concluded that no significant relationship existed between filtration rates and effluent BOD, COD, and TSS concentrations in the range of rates 325.93 to 1303.74 lpm/sq. m. (8 to 32 gpm/sq ft) used in the studies. The investigation also revealed that for influent concentrations of less than 30 mg/l, the filter effluent generally remained in the range of 1 to 12 mg/l with or without polymer or coagulant and polymer, but for influent concentrations above 60 mg/l, filtration with coagulant and polymer addition produced a higher quality effluent.

Operational Considerations

In evaluating granular media filtration as a method for upgrading waste treatment facilities, Middlebrooks et al (204) stated: "The simple design and operation of this process makes it applicable to wastewater streams containing up to 200 mg/l suspended solids. Filtration rates can range from 1018.54 to 2037.09 lpm/sq.m. (25 to 50 gpm per sq ft) for coarse solids to 81.48 to 203.71 lpm/sq.m. (2 to 5 gpm per sq ft) for colloidal suspensions. The versatility of filter bed designs (media sizes and depths) is such that nearly any effluent quality can be achieved."

Tertiary filtration has been applied successfully to many types of industrial wastes. Industries that are either employing filtration or have successfully tested and are installing filters include: steel manufacturing, petroleum refining, brewing, corn wet milling, wine processing, and food processing.

Table 96 is a summary of results from using filtration on a variety of biologically treated effluents. It can be deduced from this table that high quality effluents can be obtained from typical secondary biological treatment sources with the use of sand or multi-media filters.

Table 96
Effluent Quality from Conventional
Filtration of Various Biologically Treated Wastewaters

Influent Source	Filter Type	Filter Influent (mg/l) BOD	Filter Influent (mg/l) TSS	Filter Effluent (mg/l) BOD	Filter Effluent (mg/l) TSS
Activated Sludge	Gravity mixed media	15-20	10-25	4-10	2-5
Activated Sludge	multi-media	11-50	28-126	3-8	1-17
Extended Aeration plus settling	pressure, multi-media	7-36	30-2180	1-4	1-20
Trickling Filter	Gravity, Sand	15-130	8-75	2-74	1-27
Activated Sludge with Clarifier	multi-media	-	18 (AVE)	-	2-4 (AVE)
Contact Stabilization (raw waste includes cannery)	mixed-media	-	-	2-4	2-8
Miscellaneous	sand (slow and rapid)	10-50	15-75	2-6	3-10
Trickling Filter with Nitrification	sand	-	-	9-28	3-7

A positive feature of filtration is the ability to handle reasonable fluctuations in solids loadings without serious impairment of effluent quality. These fluctuations can be absorbed by increased backwash frequency. This point is discussed by E. R Baumann in Design of Filters for Advanced Wastewater Treatment: (205)

> "The process of filtration is one which is unusual in that it will never, if properly designed, provide a grossly inferior quality of effluent. In general, if a filter can provide the desired effluent quality under normal conditions, upsets in pretreatment processes will provide shorter filter runs and not significantly poorer effluent quality. Thus, if under normal conditions the effluent SS are running at 18 mg/l and suddenly increase to a level of 30 or 40 mg/l, the principal effect will

Table 97

SOLIDS CAPTURE PER FOOT OF HEAD LOSS INCREASE
INDIRECT FILTRATION OF SECONDARY EFFLUENT [197]

Secondary Effluent Type	Filtration Rate gpm/sq ft	Mode of Operation	Top Media Size, 10% Finer, mm	Solids capture, lb/ft^2/ft of head loss increase
T.F.*	3.33		0.85	0.052
"	2		0.85	0.074
"	3		0.59	0.035
"	2	C**	1.84	0.064
"	4	C	1.84	0.070
"	6	C	1.84	0.079
"	2	C	0.42	0.065
"	4	C	0.42	0.070
"	6	C	0.42	0.073
"	7	C	0.92	0.078
A.S.*	16	C	1.78	0.35
"	24	C	1.78	0.093
"	32	C	1.78	0.093
"	16.0	D**	1.78	0.23
"	22.2	D	1.78	0.21
"	27.6	D	1.78	0.12
A.S.	2 to 5	C	Upflow	0.26
A.S.	5.1	C	1.08	0.24
A.S.	5.1	C	1.45	0.34

*T.F. = Trickling filter plant final effluent.
*A.S. = Activated sludge plant final effluent.
**C = Constant rate.
D = Declining rate.

be a significant decrease in run length but a relatively lesser increase in effluent SS."

Reverse Osmosis

The reverse osmosis (hyperfiltration) process has received considerable attention within the pulp and paper industry during recent years as a possible means of treating spent pulping process waters sufficiently for major internal reuse. The initial work with membranes was in conjunction with electrodialysis systems (191) which provided important background on ultrafiltration and reverse osmosis. The application of reverse osmosis membranes has been centered on concentrations of dilute streams in the range of 1/2 to one percent suspended solids (207) (208).

The Pulp Manufacturers Research League and The Institute of Paper Chemistry have investigated the reverse osmosis process for treatment of pulp and paper mill waste waters under a project partially sponsored by EPA's Office of Research and Monitoring (208). Their studies led to confirming trials conducted in field demonstrations ranging from 5000 to 50,000 on five different waste flows as follows:

1. Ca base pulp wash and cooling waters
2. NSSC white water
3. NH_3 base pulp wash water (also Ca hypochlorite bleach effl
4. Kraft bleach effluent (also kraft rewash water)
5. Cold soda pulping wash water

It was concluded that the reverse osmosis process is an important tool for concentrating and recovering solutes in dilute pulp and papermaking effluents (208). Membrane rejections of 90 to 99 percent were obtained for most components in the feed. Low molecular weight salts and volatiles were less well rejected. Details of this work have been cited previously under "Color Removal."

An NSSC mill has also undertaken detailed studies on the use of reverse osmosis as a unit operation for producing water suitable for process reuse under a program also partially funded by EPA (207). This project included the operation of proprietary reverse osmosis equipment by vendors simultaneously and continuously on the same feed. This allowed the development of both operating techniques applicable to the particular feed and design criteria for a full scale production facility. This study also concluded that the reverse osmosis process is effective in concentrating a dilute waste stream while producing a clarified water flow that can be recycled for process purposes (207). It is generally felt that the concentrated stream can be directed to a mill's chemical recovery systems or black liquor furnaces.

Three basic types of reverse osmosis membrane surfaces are available:

1. Capillary fiber
2. Sheet membrane (spiral round)
3. Tubular

Tubular membranes have appeared to be the most suitable so far because capillary fiber and sheet membranes were more subject to clogging problems (208). Most of the work undertaken with reverse osmosis has used cellulose acetate membranes, but dynamic membranes, or replaceable membranes, are receiving more attention since they could substantially reduce the cost of reverse osmosis systems (206) (209).

It is felt by some (210) that the reverse osmosis process would best fit into a treatment scheme following primary treatment, prior to activated carbon polishing, if the benefits derived from the improved solids removal and the elimination of pretreatment with massive lime and large scale activated carbon outweigh the incurred loss of membrane capacity resulting from lower flux rates. While hyperfiltration is very effective in removing color and macro-molecular organic compounds, certain lower weight molecular organic compounds are not rejected by the reverse osmosis process and activated carbon polishing would be required, for certain uses.

If color removal only is necessary, then ultrafiltration, which is not as effective as hyperfiltration in removal of organic matter and solids, but very effective in color removal, would be satisfactory (209).

Treatment Efficiencies

Efficiencies achieved by the reverse osmosis process on several pulp and papermaking waste waters are presented in Table 98 (208).

It was necessary to pretreat the waste flows by passing them through a 40-mesh screen and the temperature was adjusted to a safe operating range to protect the cellulose acetate membranes below 40°C (104°F) (208).

The extensive pilot testing undertaken by the NSSC mill showed percent rejections by the reverse osmosis process as follows (207):

Total Solids	-	99.7%
BOD_5	-	98.6%+
Color-Optical Comparator	-	99.6%+
Na	-	99.5%+
Color-Spectrophotometer	-	99.8%+

Experience there had indicated loss levels of 4.986 kg (11.0 lb) BOD/pulp kkg (ton) a 0.771 kg (1.7 lb) of suspended solids/machine kkg (ton). Effluent levels of 2.27 kg (5.0 lb) of BOD/pulp kkg (ton) and 0.454 kg (1.0 lb) of suspended

solids/machine kkg (ton) are expected when an upset control system is in operation (214).

Table 98

SUMMARY OF RESULTS OF TREATMENT BY REVERSE OSMOSIS (208)

Waste Flow	Reported Rejection - %					
	Total Solids	BOD	COD	Base	Color	Water Recovery
Calcium Sulfite	87-98	69-89	87-95	95-99Ca	99	80-90
NSSC	96-98	87-95	96-98	82-95Na	99+	72-92
Ammonium Sulfite	93-96	77-94	92-97	92-98NH_3	99	65
Kraft Bleach	91-99	85-97	97-99	83-95Na	99+	--

Operational Considerations

The work by the Institute of Paper Chemistry (207) indicated that fouling of reverse osmosis membranes by suspended particles, colloidal suspensoids of large molecular weight organics, etc., could be partially controlled by pretreatment, by periodic pressure pulsations, and by periodic washing of the membrane surfaces. Self-cleaning, high velocities of flow were found to be the most likely means of maintaining high flux rates through the membrane, especially with the newer high performance, tight surface membranes that became available in 1971. It was reported that minimum velocities of 0.609m (2 ft)/sec overcame concentrative polarization, but 0.914m (3 ft)/sec were required to maintain adequate mass transfer rates (207). It was also stated that concentration polarization did not appear to seriously affect performance at operating pressures below 54.43 atm (800 psig).

All of the operational and maintenance problems at the NSSC mill, brought about the increase of water temperature from 54° to 71°C (130° to 160°F), and the increased soluble solids in the white water (0.9 percent to 3.7 percent), have been overcome without any serious difficulties (214).

Present commercial hyperfiltration membranes cannot be operated at temperatures much above ambient and cooling of many pulping effluents is therefore necessary. Dynamically formed membranes, however, have been shown to suffer less from these disadvantages and may be preferable when a high degree of salt removal is not required (209). In addition, ultrafiltration membranes are more open than the tighter reverse osmosis (hyperfiltration) membranes and, while rejection for colored lignonsulfonates are high, other components are rejected to a much lesser degree than can be considered satisfactory. Research is being carried out to develop improved rejection with ultrafiltration because it has higher flux rates than hyperfiltration and the advantages of

simplified equipment design (206). In addition, a major roadblock delaying the practical application of reverse osmosis to waste treatment problems lies in the several causes of short life expectancy of the membrane system. It is felt that membrane manufacturers should be encouraged to pursue the goal of a minimum three-year life expectancy for these membranes which would include a capability for operating at wider ranges of pH and temperature and high flux rates (208).

After three years of reverse osmosis pilot plant work at Pomona, membrane fouling was identified as the most important operation problem (215). Physical cleaning methods such as water or air-water flushing were only partially successful.

Dynamic membrane studies should be advanced to achieve higher levels of solid rejection without serious reduction in permeate rates and flux rates. The development of these membranes could substantially improve performance and cost parameters (208) (209) (216).

Removal of Dissolved Salts and Dissolved Solids

The process showing most promise in achieving sufficiently high removal of total dissolved solids and chlorides to permit reuse of effluents as process water are reverse osmosis and ion exchange. Process water requirements for bleached kraft production, for example, do not permit dissolved solids in excess of 500 mg/l; chloride concentration, because of its corrosive nature, should be less than 150 mg/l.

Reverse Osmosis

Both hyperfiltration and untrafiltration have been extensively discussed previously. The former, which is the term commonly used to describe the higher pressure reverse osmosis, is required for high solids and salt rejection. Ultrafiltration is used in reference to lower pressure reverse osmosis systems.

Treatment Efficiencies

The reverse osmosis work at the above mentioned NSSC mill (207) showed average soluble solids rejections of 99+ percent, with product water soluble solids ranging from below 100 ppm to about 750 ppm depending on the percent of feed solids. Average rejection of sodium was 99+ percent, with product water sodium ranging from less than 20 ppm to about 180 ppm depending on the percent of feed solids. The detailed results of the pilot work are described above.

The Institute of Paper Chemistry conducted laboratory, pilot plant, and field demonstrations at various pulp mills and showed total solids removals with reverse osmosis as presented in Table 99 (208).

Chloride and TDS concentrations of caustic extraction stage effluent achieved by reverse osmosis are shown in Tables 100 and 101 (210).

The reported data from pilot and laboratory work shows that reverse osmosis is very effective in removing TDS and chlorides from selected pulp and paper industry flows as presented herein. The ultimate concentration of each element, however, will be dependent on the initial concentrations and the recovery and treatment processes preceding reverse osmosis.

Ion Exchange

Ion exchange has been a well-known method for softening and deionizing water, but application to waste water treatment has been negligible primarily because high molecular weight organic compounds present in waste water have a deleterious effect on most anion exchange materials and disposal of regenerates is a major problem. New types of resins have been developed, however, that are less affected by organics. In addition, separation techniques using ion exchange demineralization are known, but their application to waste treatment is not generally practiced, nor is there sufficient information on such a system to predict performance (217).

Table 99

TOTAL SOLIDS REMOVAL (210)
REVERSE OSMOSIS

Calcium Sulfite	18.47-11.05	87-98	2.04 - 0.37
NSSC	10.75-5.72	96-98	0.68 - 0.32
Ammonium Sulfite	10.31-50.48	94-97	6.44 - 0.66

Table 100

REVERSE OSMOSIS OF RAW AND PARTIALLY RENOVATED HARDWOOD PULP CAUSTIC EXTRACTION EFFLUENT AT 600 psig, 21-22°C, pH 5.2

	After Treatment By			Reverse Osmosis Of		
	Raw	Mass. lime plus Massive	act.	Raw	Mass. lime plus act. lime	carbon
pH	11.7					
Color, units	2800	405	5	5	5	5
COD, mg/l	1460	702	173	42	36	42
BOD, mg/l	523	324	105	41	27	22
TDS, mg/l	4240	3890	3500	152	192	256
Cl-, mg/l	787	751	751	56	51	111
Product recovery as % of feed volume	--	--	--	92	93	92
Avg. Flux, (gal/ft2)/day	--	--	--	13.1	12.8	22.8
Avg. Flux/water flux	--	--	--	0.52	0.48	0.82

Table 101 (210)

REVERSE OSMOSIS OF RAW AND PARTIALLY RENOVATED PINE PULP CAUSTIC EXTRACTION EFFLUENT AT 600 psig, 23-26°C, pH 5.2

	Feed			
	Raw Waste	Massive lime product	UM-2* product	Mass. lime plus act. carbon product
Color, units	5	5	5	5
COD, mg/l	106	96	92	72
BOD, mg/l	--	--	--	--
TDS, mg/l	220	276	--	324
Cl-, mg/l	106	137	320	240
Product recovery as % of feed volume	86	86	74	85
Avg. flux, (gal/ft2)/day	15.7	13.8	29.8	29.9
Avg. flux/water flux	0.58	0.37	0.75	0.77

The DESAL* process is a deionization technique based upon two weak electrolyte ion exchange resins (218). The advantages of this process over conventional ion exchange process are claimed to be:

1. Ability to treat brackish waters at concentrations of 500 to 3000 ppm dissolved solids with negligible leakage.

2. Stoichiometric amount of regenerates required for regeneration versus conventional methods which require 200 to 300 percent of stoichiometric amount; therefore, regeneration costs are significantly less.

3. High degree of utilization of theoretical capacity.

The DESAL process uses three beds of weak ion exchange resins in a cyclic process. The first bed is a weak base anion exchange resin; the second bed, a de-alkalization unit, is a weak acid cation exchange resin; while the third bed is in the free base form for carbonation. The alkalization and de-alkalization units can be regenerated with ammonia and sulfuric acid, respectively. At exhaustion, the third unit is in the bicarbonate form, so the direction of flow through the three units is reversed and the cycle repeated.

Ion exchange studies have been conducted on sewage effluent from an activated sludge plant (217). The waste was pretreated prior to ion exchange with a system that consisted of lime clarification, dual media filtration, and granular activated carbon filtration to reduce the total phosphate, suspended solids, and total organic carbon of the waste water prior to ion exchange. The investigations included the performance of the following resins:

1. Weak base anion exchange - bicarbonate form
2. Strong acid cation exchange - hydrogen form
3. Weak base anion exchange - free base form
4. Weak acid cation exchange - hydrogen form
5. Weak acid : strong acid cation exchange - hydrogen forms

It was concluded that the ion exchange process with the weak base anion exchange resin - bicarbonate form was not sufficiently established to use on domestic sewage containing less than 500 mg/l of dissolved solids. The work did show, however, that a system using a strong acid cation exchange resin and a weak base anion exchange resin can be used without difficulty for a waste water containing as much as 500 mg/l of total dissolved solids. In addition, a weak acid cation exchange resin can be very efficient as the first resin to demineralize certain waste waters.

Treatment Efficiencies

In laboratory and pilot studies on the DESAL* process (219), partially renovated pulp and papermaking effluents were used. The effluents were a bleached kraft mill total effluent and caustic stage extract. Both effluents were clarified and then pretreated with lime and activated carbon to produce samples that were virtually free of all color, BOD, and turbidity, but which were not acceptable for reuse because of the dissolved solids content. Table 102 shows the results of this work (219).

As can be seen from Table 101, only the pH of the caustic extract did not achieve the desired range. The low pH was attributed to laboratory operating conditions and it is felt the system can produce a pH near 7.0 with a commercial system.

Other work (220) showed that a cation-anion exchange system was very effective in the removal of major ions from a secondary effluent. The results of this work are shown in Table 103 (220).

Operational Considerations

Ion exchange is considered technically feasible by some for the deionization of partially renovated domestic and pulp and paper mill wastes (218). In order to successfully use ion exchange processes, the majority of organics and suspended solids must be removed from the waste stream. In one laboratory undertaking the

effluent from a well-operated domestic activated sludge plant was used without any additional treatment (221). In other work (219) which consisted of laboratory sized columns and equipment, the selected kraft mill waste stream was clarified and treated with lime and activated carbon prior to ion exchange; domestic waste used in another project (217) was similarly treated.

If the waste streams are not properly pretreated prior to ion exchange, severe operational problems due to clogging will be encountered. With biological treatment, the waste stream probably would require a minimum of mixed media filtration for suspended solids removal as pretreatment. Depending on the organic nature of the secondary effluent, it may have to be pretreated with activated carbon, or reverse osmosis. If the total dissolved solids of the waste stream exceeds 3000 mg/l, pretreatment with reverse osmosis may be necessary to keep cost of ion exchange within reason.

Table 102

WATER QUALITY FROM "DESAL"* ION EXCHANGE PROCESS (219)

Parameter	Desired Range Bleached Mill Feed	DESAL PRODUCT From Caustic Extract	DESAL PRODUCT From Total Mill Effluent (Bleached)
Color	0-5	5	5
pH	6.8-7.3	3.7	7.2
Cl, mg/l	10-150	120	150
Hardness, $CaCo_3$ mg/l	5-100	25	---
Dissolved Solids mg/l	50-250	250	180
BOD, mg/l	0-2	0	0
Turbidity, JTU	0-5	0	0
COD	0-8	---	---

*Use of a trade name does not constitute endorsement of a product.

Proper disposal of waste regenerates associated with the use of ion exchange treatment of waste waters must be fully recognized. Effective regeneration requires regenerate volumes in excess of stoichiometric quantities. Strong resins require large excesses while weak resins require small excesses only. In order to greatly reduce the regenerate volume to be treated, the ion exchange process should consider fractionation of the total effluent during regeneration and use (217). Acid wastes are easily neutralized, but precipitated sludges and neutral brines must be satisfactorily disposed of. Waste regenerant ammonia

TABLE 103

BEHAVIOR OF MAJOR CHEMICAL CONSTITUENTS IN RENOVATION SYSTEM [205]

	CONCENTRATION OR VALUE						
	Before Coagulation	After Settling	After Recarbonation	After Sand	After Carbon Absorption	After Cation Exchange	After Anion Exchange
Ca^{++} as $CaCO_3$ (mg/l)	62	205	62	---	---	0	---
Na^{+} (mg/l)	49	44	44	---	---	0.7	---
Cl^{-} (mg/l)	53	48	42	---	---	---	2.5
SO_4^{-} (mg/l)	145	130	127	---	---	---	0
Alkalinity as $CaCO_3$ (mg/l)	175	260	139	---	---	---	5.9
COD (mg/l)	131	102	---	61	16	12.5	10.8
Solids							
Total (mg/l)	431	377	336	254	233	68	24
Fixed (mg/l)	312	257	237	172	170	42	15
Volatile (%)	27.6	31.8	29.7	32.3	27.0	38.2	37.5
Turbidity (JTU)	16	1.5	2.3	4.1	0.23	0.25	0.23
pH	7.3	11.4	7.6	8.0	8.8	3.0	4.8

hydroxide from the anion exchange resin can be treated with hydrated lime, with the liberated ammonia recovered and reused.

A summary of common pretreatment requirements prior to the ion exchange process is presented in Table 104 (222).

Removal of Trace Refractory Organics

The advanced waste treatment systems studied for the removal of trace refractory organics, those not removed through a secondary treatment system, include the following: 1) activated carbon, 2) chlorination, and 3) ozonation. The activated carbon process has demonstrated its applicability to the treatment of municipal waste water at full plant scale. In addition, its potential for treating pulp and papermaking wastes has been shown in pilot plant and laboratory studies. The potential of the other processes is not well documented and there are no plant scale operations utilizing them for the removal of trace refractory organics. The removal of one specific refractory organic, color, has been discussed in detail under "Color Removal."

Activated Carbon

Activated carbon has been used at water treatment plants to remove organics that caused taste and odor problems in drinking water supplies. Also, the use of activated carbon as a step in the physical-chemical treatment process for waste waters or an an add-on to existing biological treatment systems is well documented (229). Many researchers have studied the use of activated carbon as a tertiary process for the treatment of pulp and paper mill wastes (230) (231) (232) (233) (234) (235) it has been found that activated carbon is capable of reducing color, COD, BOD, and odor in kraft mill effluents to very low concentrations (235).

One of the highest concentrations of BOD in a kraft pulp mill waste discharge is contained in the evaporator condensate (230). Most of the BOD and COD of the condensate waste is exerted by dissolved organic material. One project demonstrated that 75 percent of the BOD, COD, and TOC could be removed from the condensates by activated carbon adsorption.

Granular activated carbon was proven by pilot plant tests to be a practical means of treatment for two non-integrated paper mill wastes (231). Full-scale design of the facility to treat approximately 56.78 kkl/d (15 MGD) of wastes from both of the mills and a portion of a municipality's domestic wastes was completed in July 1971, and construction is now in progress. Plans are being made for the recycle and reuse of the effluent by one of the paper companies. The effluent BOD and suspended solids concentrations will be less than 5-7 mg/l and 20 mg/l respectively.

Table 104

PRETREATMENT REQUIREMENTS
FOR ION EXCHANGE [207]

Constituent	Problem	Pretreatment Required
Suspended Solids	Blinds resin particles	Coagulation and filtration
Organics	Large molecules (e.g., human acids) foul strong basic resins	Carbon adsorption or use of weak base resins only
Oxidants	Slowly oxidizes resins	Avoid prechlorination
Iron and Manganese	Coats resin particles	Aeration

Activated carbon is characterized by an extremely large surface area (450-1800 sq m/g) (234) which is one of its features which results in its large adsorption capacity. Activated carbon can be separated into two general classifications: powdered and granular. The ultimate adsorption capacities of both powdered and granular carbons are essentially equal (234); however, powdered carbon has faster adsorption rates than granular carbon (234) (236). While there are numerous carbon manufacturers and particular specifications, the selection of a specific carbon cannot be made without first testing the carbon under consideration with the particular effluent to be treated (237).

The activated carbon process has various configurations which include use of granular or powdered carbon, contact in a column or slurry, fixed or moving beds, upflow or downflow of influent, series or parallel arrangement, and continuous or periodic wasting and regeneration of spent carbon. Treatability of a particular waste by activated carbon is described by various analytical adsorption isotherm equations which are covered in depth in the literature. The Freundlich equation is probably the most frequently used to determine adsorption isotherms. However, poor correlation between isotherm results and column tests have been reported. This is partially due to the fact that adsorption is not the only mechanism attributed to the removals through carbon columns. Three functions describe the operation of carbon columns (238): adsorption, biological degradation, and filtration.

Treatment Efficiencies

Most of the researchers studying activated carbon treatment of pulp and paper wastes have made one common assumption: that the effluent from the carbon system should be of a sufficient quality to permit reuse as process water.

Pilot plant tests have shown that renovated waste water suitable for reuse can be obtained without a biological oxidation step, particularly if the renovation process starts with a moderate BOD_5 of 200-300 mg/l (232). Color of a satisfactory low concentration can also be obtained by such treatment. Table 105 presents the pilot plant results.

Other researchers (239) found that adsorption equilibrium increased with a decrease in pH. The effect on the rate of adsorption with changes in temperature is not well defined.

Activated carbon will not remove certain low molecular weight organic substances, particularly methanol, a common constituent of pulping effluents (233), nor some highly polar organic molecules such as carbohydrates (237). However, most of these materials are biodegradable and would not be present in appreciable quantities in a well bio-oxidized secondary effluent (237). Also carbon columns do a relatively poor job of removing turbidity and associated organic matter (237).

Table 105

RESULTS OF GRANULAR ACTIVATED CARBON COLUMN
PILOT PLANT TREATING UNBLEACHED KRAFT MILL WASTE

	Columns* Preceded by Lime Precipitation and Biological Oxidation			Columns* Preceded by Lime Precipitation					
	Influent	Effluent	Removal	Influent	Effluent	Removal	Influent	Effluent	Removal
BOD, mg/l	48	23	52%	102	32	69%	82	12	85%
COD, mg/l	--	--	--	--	--	--	320	209	35%
SS, mg/l	--	--	--	--	--	--	115	74	36%
Turbidity, J.U.	--	--	--	--	--	--	35	35	0%
Color, Units	--	--	--	--	--	--	28	0	100%
Odor	365	13	96%	185	23	88%	--	--	--
pH	--	--	--	--	--	--	11.9	10.5	12%
T.S. mg/l	--	--	--	--	--	--	1285	1205	6%

*Columns loaded at 3.6 - 4.0 gpm/ft^2

Results of laboratory rate studies, using powdered activated carbon to treat municipal secondary effluent, showed that 90 percent of equilibrium adsorption capacity could be obtained in less than five minutes using turbulent mixing (236). Five different contact systems were considered during this laboratory investigation as follows:

1. Countercurrent agitated tank adsorption
2. Flotation adsorption
3. Diffusion adsorption
4. Packed bed columnar adsorption
5. Upflow column adsorption

On the basis of this investigation, the countercurrent agitated tank system was considered the most promising of the five systems for the following reasons:

1. The secondary effluent did not have to be filtered prior to contact.

2. Variable secondary effluent flow rates and effluent COD concentrations could be readily handled.

3. Maintenance costs were low.

4. Design and operation were simple.

5. The system was truly continuous.

6. COD removals to approximately 5 mg/l could be achieved.

7. The potential existed for treating primary treatment plant effluent.

8. Both suspended solids and colloidal material were brought down with the carbon due to flocculation.

The processes investigated for separating the powdered carbon from the treated waste water were not 100 percent effective and filtration of the waste water was necessary to remove the carbon. In a full scale operation, the necessity to filter the effluent might make the use of powdered carbon economically impractical.

Tests of carbon treatment on kraft evaporator condensates (230) showed that 70-75 percent of the organic matter could be removed with 456 mg/l of carbon. It was also determined that an extended contact time (over 1 hr) showed insignificant additional COD removal. However, even after six hours of contact there was an effect on the removal of toxicity which was attributed to other various constituents. The results of this work conflict with the findings of other researchers that activated carbon is not effective in removing low molecular weight organics such as methanol and other major constituents of kraft evaporator condensates (59). The condensate used in that particular study may have been contaminated with black liquor carry over.

Pilot plant tests on the effluent from two non-integrated fine paper mills determined that the necessary carbon dosage, based on a flow of approximately 56.78 kkl/d (15 MGD), amounts to 192 mg/l of carbon, or 2.1 times that needed for settled domestic sewage. Preliminary design of a full scale treatment plant called for 12 carbon columns (ten active) to be preceded by flocculation and sedimentation. Each column would be 6.10 m (20 ft) in diameter with a 4.72m (15.5 ft) depth of carbon. The columns were arranged for parallel operation and would be loaded at 325.94 lpm/sq m (8 gpm sq ft) with a 15 minute contact time at peak hourly flow. Maximum operating pressure was to be 3.40 atms (50 psi). Table 106 presents data from the pilot plant operation as well as the design criteria that was used.

Extensive pilot plant tests were undertaken for treating unbleached kraft mill effluent with activated carbon. The 113.55 l/min (30 gpm) pilot plant utilized four different treatment processes as follows:

1. Clarification followed by downflow granular carbon columns
2. Lime treatment and clarification followed by granular carbon columns
3. Biological oxidation and clarification followed by granular carbon columns
4. Lime treatment and clarification followed by FACET* (Fine Activated Carbon Effluent Treatment). (Subject of a patent application)

The purpose of all treatment processes was to obtain a treated effluent with less than 100 APHA color units and less than 100 mg/l TOC which would be suitable for reuse. The lime-carbon treatment achieved the desired effluent criteria and was considered the most economical of the three processes utilizing carbon columns. A relatively small lime dosage of 320-600 mg/l CaO without carbonation prior to carbon treatment was reported to be the optimum operating condition for the limecarbon process. It should be emphasized that the lack of carbonation was a criteria for optimum treatment. It was determined that the effluent should contain about 80 mg/l Ca for successful optimization of treatment. The required fresh carbon dosage was 300 mg/l of carbon.

With biological oxidation and clarification followed by carbon columns, the fresh carbon dosage was 960 mg/l of carbon.

Table 106

RESULTS OF GRANULAR ACTIVATED CARBON COLUMN PILOT PLANTS AND DESIGN CRITERIA [216]

	Fitchburg Mass. (37) Design Data			Fitchburg Mass. (37) Pilot Plant			Fitchburg Mass. (37) Pilot Plant			Fitchburg Mass. (37) Pilot Plant		
	Inf.	Eff.	Removal	Inf.	Eff.	Removal	Inf.	Eff.	Removal	Inf.	Eff.	Removal
Hydraulic Load	8 gpm/ft^2			0.35 gpm			0.35 gpm			0.35 gpm		
Contact Time min.	15			5.8			13.0			22.9		
BOD mg/l	35-40	5-7	80+%	13.2	7.6	42%	7.6	2.6	66%	2.6	1.7	35%
COD mg/l	---	---	---	53.4	29.2	45%	29.2	11.9	59%	11.9	6.8	43%

It was found that non-adsorptive mechanisms accounted for a significant amount of color and TOC removal in the clarification-carbon process. It was felt that the removals were not due to any biological degradation which might have occurred with the carbon columns. Rather it was determined that the color in colloidal form coagulated on the carbon surface. The color colloids were subsequently removed as large settleable solids during the backwashing process (234). The method of disposal or recycle of the backwash water was not mentioned. This is a major item and cannot be ignored on full scale designs.

The FACET* system is a multi-stage, countercurrent, agitated system with a continuous transfer of both carbon and liquid. One of the major aspects of the FACET* system is the use of an intermediate size carbon endeavoring to combine the advantages of both powdered and granular carbon while minimizing their limitations. Equipment size and carbon inventory are decreased due to the increased adsorption rate of the intermediate carbon. The FACET* system has shown distinct advantages over the column adsorption system. Table 107 tabulated the pilot plant results obtained. A partial list of various physical-chemical and tertiary applications of activated carbon is listed in Tables 108 and 109.

Operational Considerations

The use of granular activated carbon for the removal of trace refractory organics is technically sound. However, when this degree of treatment is obtained, the ability to reuse the effluent for process water is desirable. Powdered activated carbon has not been widely utilized because of difficult handling problems encountered in carbon recovery and regeneration (236). One trial indicated that the control of pH or temperature, though advantageous to the operation of the process, would be economically impractical (236). However, preliminary plans for joint treatment of fine paper mill and municipal waste (231) call for the addition of caustic to raise the pH from 4.2-4.5 to approximately 6.7.

In utilizing a carbon slurry to treat municipal wastes, a tendency of the compacted slurry in the quiescent concentrator had a tendency to form a gelatinous mass. It became necessary to agitate the gel to reliquify it for easy removal (240).

In a study of the use of powdered carbon columns the columns became clogged with colloidal matter within a few hours of operation and pressure drops became prohibitive (236). The upflow contact process was tried but the bed could not be stabilized and serious channeling occurred resulting in poor COD removal efficiencies. Polyelectrolyte flocculation was found to be the most economical method to recover spent powdered carbon. It was also determined that a suspended solids concentration of 500 mg/l or more must be maintained in the carbon slurry to assure flocculation efficiency.

Table 107

RESULTS OF ACTIVATED CARBON PILOT PLANTS
TREATING UNBLEACHED KRAFT MILL EFFLUENT [219]

Description Of Carbon Process	Columns Preceded By Biological Oxidation & Clarification			Columns Preceded By Primary Clarification			Columns Preceded By Primary Clarification			Columns Preceded By Lime Treatment & Clarification			FACET System		
	Inf.	Eff.	Removal	Inf.	Eff.	Removal	Inf.	Eff.	Removal	Inf.	Eff.	Removal	Inf.	Eff.	Removal
Hydraulic Load, gpm/ft^2				1.42			0.71			1.42			N.A.		
Carbon	Granular			Granular			Granular			Granular			Intermediate		
Contact Time, Min.	140									108					
BOD, mg/l										26% Removal					
TOC, mg/l	148	57	61%	220	83	62%	310	121	61%	177	100	44%	158	101	36%
Turbidity, J.U.											5-15				
Color, Units	740	212	71%	925	185	80%	1160	202	83%	252	76	70%	157	73*	54%
Fresh Carbon Dosage lb. carbon/ 1000 gal.	8			20.5			28			2.5			3.9		
pH										11.3					

*Filtered

Table 108

PHYSICAL-CHEMICAL TREATMENT PLANTS

SITE	STATUS 1973	DESIGN ENGINEER	AVERAGE PLANT CAPACITY (MGD)	CONTACTOR TYPE	NO. OF CONTACTORS IN SERIES	CONTACT TIME[1] (MIN.)	HYDRAULIC LOADING (GPM/SQ FT.)	TOTAL CARBON DEPTH (FT.)	CARBON SIZE	EFFLUENT REQUIREMENTS[2] (OXYGEN DEMAND)
1. Cortland, N.Y.	Design	Stearns & Wheler	10	Downflow Pressure	1 or 2	30	4.3	17	8 x 30	TOD < 35 mg/l
2. Cleveland Westerly, Ohio	Design	Engineering-Science	50	Downflow Pressure	1	35	3.7	17	8 x 30	BOD < 15 mg/l
3. Fitchburg, Mass.	Construction	Camp Dresser & McKee	15	Downflow Pressure	1	35	3.3	15.5	8 x 30	BOD < 10 mg/l
4. Garland, Texas	Design	URS Forest & Cotton	30[3]	Upflow Downflow	2	30	2.5	10	8 x 30	BOD < 10 mg/l
5. LeRoy, New York	Design	Lozier Engineers	1	Downflow Pressure	2	27	7.3	26.8	12 x 40	BOD < 10 mg/l
6. Niagara Falls, N.Y.	Design	Camp Dresser & McKee	48	Downflow Gravity	1	20	3.3	9	8 x 30	COD < 112 mg/l
7. Owosso, Michigan	Design	Ayres, Lewis, Norris & May	6	Upflow Packed	2	36	6.2	30	12 x 40	BOD < 7 mg/l
8. Rosemount, Minn.	Construction	Banister, Short, Elliot, Hendrickson, and Associates	0.6	Upflow Downflow Pressure	3 (max.)	66 (max.)	4.2	36 (max.)	12 x 40	BOD < 10 mg/l
9. Rocky River, Ohio	Construction	Willard Schade & Assoc.	10	Downflow Pressure	1	26	4.3	15	8 x 30	BOD < 15 mg/l
10. Vallejo, Calif.	Design	Kaiser Engineers	13	Upflow Expanded	1	26	4.6	16	12 x 40	BOD < 45 mg/l (90% of time)

(1) Empty bed (superficial) contact time for average plant flow

(2) BOD: Biochemical oxygen demand
COD: Chemical oxygen demand
TOD: Total oxygen demand

(3) 90 mgd ultimate capacity

Table 109

TERTIARY TREATMENT PLANTS

SITE	STATUS 1973	DESIGN ENGINEER	AVERAGE PLANT CAPACITY (MGD)	CONTACTOR TYPE	NO. OF CONTACTORS IN SERIES	CONTACT TIME(1) (MIN.)	HYDRAULIC LOADING (GPM/SQ FT.)	TOTAL CARBON DEPTH (FT.)	CARBON SIZE	EFFLUENT REQUIREMENTS(2) (OXYGEN DEMAND)
1. Arlington, Virginia	Design	Alexander Potter Assoc.	30	Downflow Gravity	1	38	2.9	15	8 x 30	BOD < 3 mg/l
2. Colorado Springs, Colo.	Operating Dec. '70 to Present	Arthur B. Chafet & Assoc.	3	Downflow	2	30	5	20	8 x 30	BOD < 2 mg/l
3. Dallas, Texas	Design	URS Forest & Cotton	100	Upflow Packed	1	10	8	10	8 x 30	BOD <10 mg/l BOD < 5 mg/l (by 1980)
4. Fairfax County, Va.	Design	Alexander Potter Assoc.	36	Downflow Gravity	1	36	3	15	8 x 30	BOD < 3 mg/l
5. Los Angeles, Calif.	Design	City of Los Angeles	5(3)	Downflow Gravity	2	50	4	26	8 x 30	COD <12 mg/l
6. Montgomery County, Md.	Design	CH2M/Hill	60	Upflow Packed	1	30	6.5	26	8 x 30	BOD < 1 mg/l COD <10 mg/l
7. Occoquan, Va.	Design	CH2M/Hill	18	Upflow Packed	1	30	5.8	24	8 x 30	BOD < 1 mg/l COD <10 mg/l
8. Orange County, Calif.	Construction	Orange County Water District	15	Upflow Packed	1	30	5.8	24	8 x 30	COD <30 mg/l
9. Piscataway, Md.	Operating Mar. '73 to Present	Roy F. Weston	5	Downflow Pressure	2	37	6.5	32	8 x 30	BOD < 5 mg/l
10. St. Charles, Missouri	Construction	Moran and Cooke	5.5	Downflow Gravity	1	30	3.7	15	8 x 30	
11. South Lake Tahoe, Calif	Operating Mar. '68 to Present	CH2M/Hill	7.5	Upflow Packed	1	17	6.2	14	8 x 30	BOD < 5 mg/l COD <30 mg/l
12 Windhoek, South Africa	Operating Oct. '68 to Present	National Institute for Water Research Pretoria, So. Africa	1.3	Downflow Pressure	2	30	3.8	15	12 x 40	COD <10 mg/l

(1) Empty bed (superficial) contact time for average plant flow

(2) BOD Biochemical oxygen demand
COD Chemical oxygen demand

(3) 50 mgd ultimate capacity

In pilot plant tests on domestic secondary effluent organic matter which was adsorbed on the carbon went septic and produced a breakthrough of turbidity and organic matter (237). Another pilot operation experienced similar results. An H_2S odor in the treated effluent was observed which indicated some biological activity within the first two feet of the carbon column. Some plugging problems occurred if the columns were not backwashed every day or two. It was felt that the biological activity was anaerobic because of the low dissolved oxygen concentration. Chlorination of the influent to the carbon columns appears to eliminate sliming problems caused by biological activity within the columns.

The preliminary design of the joint treatment facilities discussed above (231) allowed a maximum return flow of approximately 12 percent of the incoming flow for the backwashing operation. It was also determined that the effluent from the carbon columns would be depleted of oxygen and would require aeration.

The pilot study of biological-carbon and primary-carbon processes for treating unbleached kraft mill effluent achieved lower rates of adsorption, resulting in larger projected capital and operating costs (234). The lower rates of adsorption were believed to be caused by coagulation of colloidal color bodies on the carbon surface. It was also determined that the use of sand filters prior to the activated carbon was not necessary. The carbon columns operated with a suspended solids concentration of 200 mg/l without problems when backwashed every day or two. Filtration or coagulation of the effluent from the FACET* process was necessary in order to remove the color bodies that formed on the outer surfaces of the activated carbon granules.

Chlorination

Chemical oxidation using chlorine or hypochlorite is an accepted means of disinfection for water supplies and waste water effluents.

Chlorination has also been found useful for the removal of ammonia nitrogen and odors from waste water. However, the use of chlorination for the removal of trace refractory organics is not a well-documented process. Costs indicate that it is not competitive with activated carbon adsorption for removal of relatively large quantities of COD from municipal wastes (222). It may, however, offer an alternative for the removal of very small quantities of organics which have not been removed by activated carbon or as a temporary means of reducing the soluble BOD in the absence of adsorption equipment. No literature has been found that directs its attention specifically to the applicability of chlorination to the pulp and paper industry.

Treatment Efficiencies

A seven-month study of chlorination of approximately 302.8 kkl/day (80 MGD) of effluent from a conventional activated sludge process treating municipal waste water determined that chlorination caused a substantial reduction in the BOD_5, an average of 34.5 percent (241). Very good effluent or effluent from a bulking plant was not significantly improved; however, effluent of 12 to 30 mg/l of BOD was noticeably improved. The suspended solids concentration increased about 20 percent and it was theorizeged that some of the soluble compounds were "precipitated" into a suspended state by the chlorine. The PO_4 and TOD were not significantly affected by chlorination. A study has revealed that chlorine will slowly oxidize only a small fraction of dissolved organic material in domestic waste water in the dark, but in the presence of ultraviolet radiation, rapid elimination of large amounts of COD and TOC is possible (242). The most important factor involved in this process is the selection of the source of radiant energy. It has been determined that short-wavelength radiation (below 300 mu) is more effective than longwavelength radiation in promoting the chlorine oxidation process. Radiation of 254 mu was about six times more effective than polychromatic radiation between 300-370 mu. The rate of organic oxidation is increased by increased radiation intensity; however, lower intensities produce more overall organic oxidation for a specific amount of absorbed radiant energy than do higher intensities. It was also established that the chlorine consumption is directly proportional to the amount of radiant energy absorbed, regardless of intensity. The effectiveness of treatment is dependent on the penetration achieved by the ultraviolet radiation. However, the correlation of treatment efficiencies with influent color and turbidity concentrations was not reported.

Quantum efficiency is the amount of organic oxidation obtained from a given amount of absorbed radiant energy. Higher quantum efficiencies were observed in this process at low intensities and an increase in quantum efficiency as the oxidation proceeded.

Figure 63 shows a schematic flow diagram of a 37.85-l/d (10-MGD) waste treatment plant designed to reduce the COD from 25 to 10 mg/l using light-catalyzed chlorination.

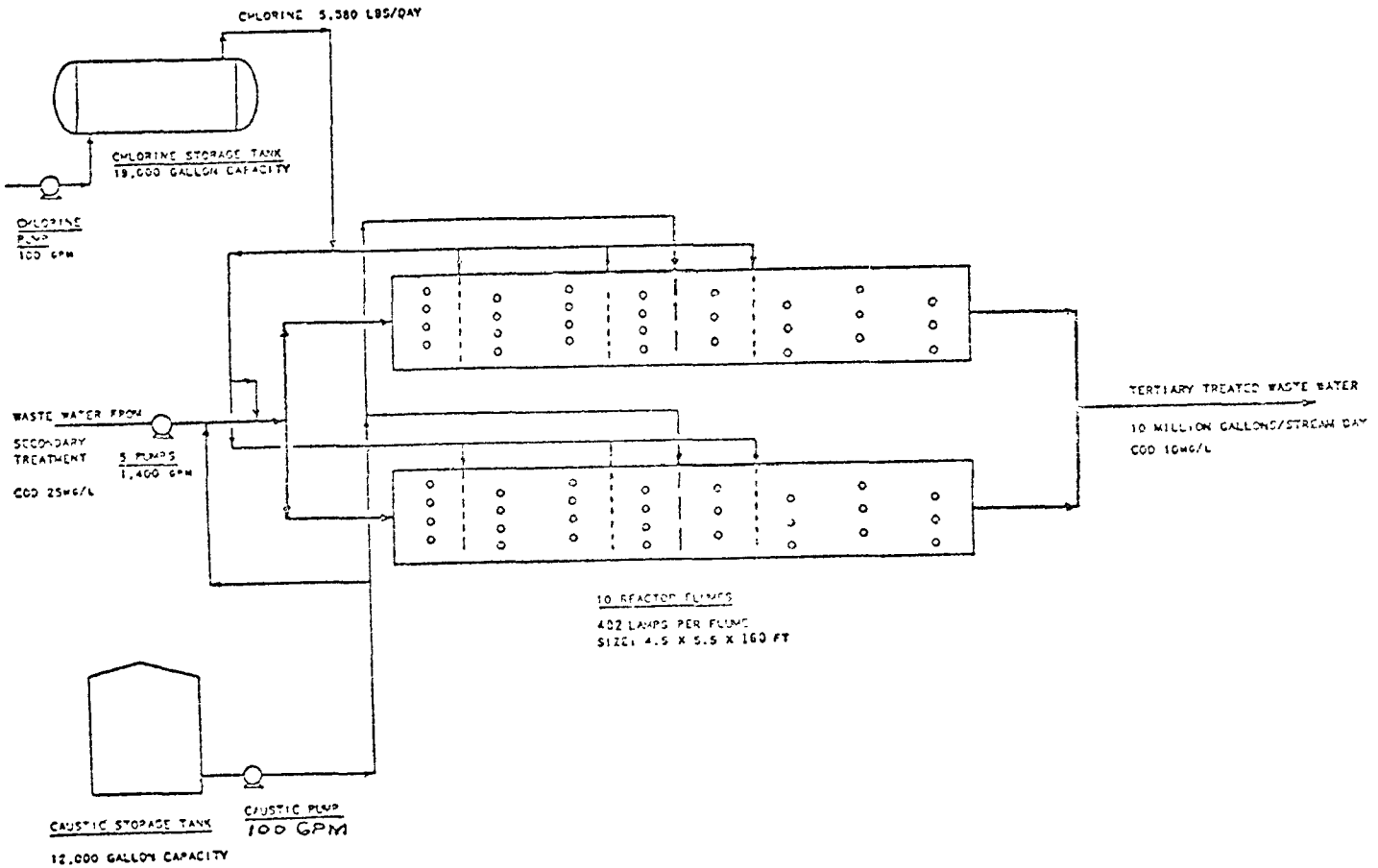
Operational Considerations

The above study determined that mercury-arc lamps were the most practical source of radiant energy. However, the ideal mercury-arc lamp is presently not commercially available. Of those presently available the low pressure mercury-arc is probably the most practical.

The most rapid rate of oxidation and the most efficient use of chlorine was obtained at pH 5. However, the most economical

Figure 63

PROCESS FLOWSHEET FOR TERTIARY TREATMENT BY LIGHT-CATALYZED CHLORINE, CAPACITY 10 MGD



operation may be at ambient pH values without the addition of caustic for pH control.

Chlorine concentrations above 5 mg/l produced no significant increase in the oxidation rate. High concentrations of chlorine were wasteful of both chlorine and radiant energy. It was concluded that an optimum chlorine concentration below 5 mg/l might be established where oxidation rates could be maximized and chlorine consumption minimized.

Ozonation

Ozone has been used for a number of years at water treatment plants as a deodorant and disinfectant. It has recently been utilized at municipal waste water treatment plants to deodorize gases which are emitted and to disinfect the effluent. Ozone is a very effective disinfectant and oxidizing agent. It is about thirteen times more soluble in water than oxygen (243). It has been determined that ozone effectively reduces the COD and TOC content of effluents from municipal waste water treatment plants, as well as odors, color, and pathogenic organisms. The use of ozone for color removal was previously discussed in detail.

Residual ozone decomposes very rapidly. It has a half-life in drinking water of about 20 minutes (243). Because of its instability, ozone must be produced at its point of use. The most common methods of production are (243):

1. Silent electric discharge in air or oxygen
2. Photochemical conversion of air or oxygen
3. Electrolysis of sulfuric acid

Photochemical conversion is used only where small quantities in very low concentrations are required. Silent electric discharge is the only practical and economical method for large-scale production of ozone. In general, for large ozone usage, use of oxygen with recycle is a more economical system than using air (243).

Because of the expense involved, the use of ozonation to oxidize organics has not in the past been considered a practical form of tertiary treatment although this use has been studied (243). However, no investigation of its applicability to the pulp and paper industry has been found. Ozonation of effluents for color reduction is covered under "Color Removal."

Treatment Efficiencies

In laboratory scale tests (about 37.85 l (10 gal)/hr) effluent from a treatment plant using trickling filters was treated with ozone and virtually all the color, odor, and turbidity were removed. No living organisms remained, and the COD was below 15

mg/l. Ozone concentrations from 11 mg/l to 48 mg/l as oxygen proved equally effective (243).

Rates of COD and TOC removal were very dependent on agitation rates. Removals were increased approximately twofold using high-shear contacting rather than low-shear countercurrent contacting. Cocurrent contacting, mixing effluent and ozone in an injector, proved more desirable than the use of a turbine agitator. For effective ozonation, good agitation must be considered the prime objective in contactor design (243). Low pH resulted in lower reaction rates, but higher ozone utilization efficiencies.

Ozone oxidizes many compounds which resist biological oxidation. However, the most readily biooxidizable organics also consume ozone the most efficiently (243). Chemical clarification prior to ozonation will remove a portion of the TOC that is resistant to oxidation by ozone resulting in lower final TOC level and less ozone consumption. Ozonation efficiency was high when COD and TOC concentrations were high. However, the effluent had an unacceptably high COD and TOC content. It was concluded that effluents having high organic content (COD above 40 mg/l) are more economically treated by a combination of chemical clarification and ozonation. Effluents with a low organic content require only ozonation.

The tests showed that, because of the short life of ozone and the slow reaction of ozone with many organics, the best treatment would be achieved with multi-stage, high-shear, gas-liquid contacting. It was also determined that a residence time of ten minutes per stage was reasonable. One hour was needed for a COD reduction from 35-40 mg/l to 14 mg/l; therefore, six stages were necessary. With the required amount of ozone being added to each stage as it was needed, an overall ozone efficiency as high as 90 percent was obtained. Figures 64 and 65 show schematically a 37.85-l/d (10-MGD) ozonation system designed to reduce COD from 35 mg/l to 15 mg/l.

In other feasibilty studies ozonation, catalyzed with activated RaneyNickel, removed 85 percent of the COD and 60 percent of the TOC from secondary treatment effluents in two hours under favorable conditions (244).

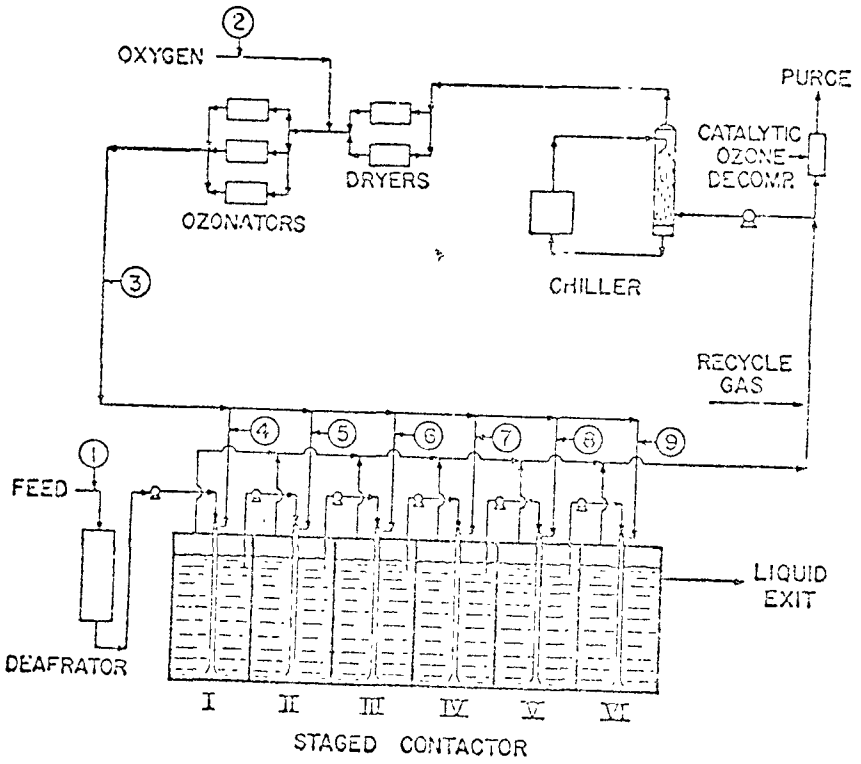
Operational Considerations

Tertiary treatment with ozone appears to have the potential of an automated, trouble-free operation with low maintenance. Initially, it was thought that the ammonia in the waste would react with the ozone, but this was not the case (243).

The reduction of TOC is caused by organic molecules decomposing and giving off carbon dioxide (243). This rate of decomposition was reduced only at a pH below 7. A lower pH resulted in lower rates of COD removal because the activity of dissolved ozone was enhanced by higher pH. Lime dosage resulted in high pH, while alum-acid coagulants gave the lowest pH. A pH from 6.0 to 7.0 seemed to be optimum for multi-stage, cocurrent ozonation.

Figure 64

OZONE TREATMENT PLANT [228]



FLOW RATES FOR 10 MGD PLANT

① EFFLUENT = 6,940 GPM

② OXYGEN MAKEUP = 6,340 lb/day

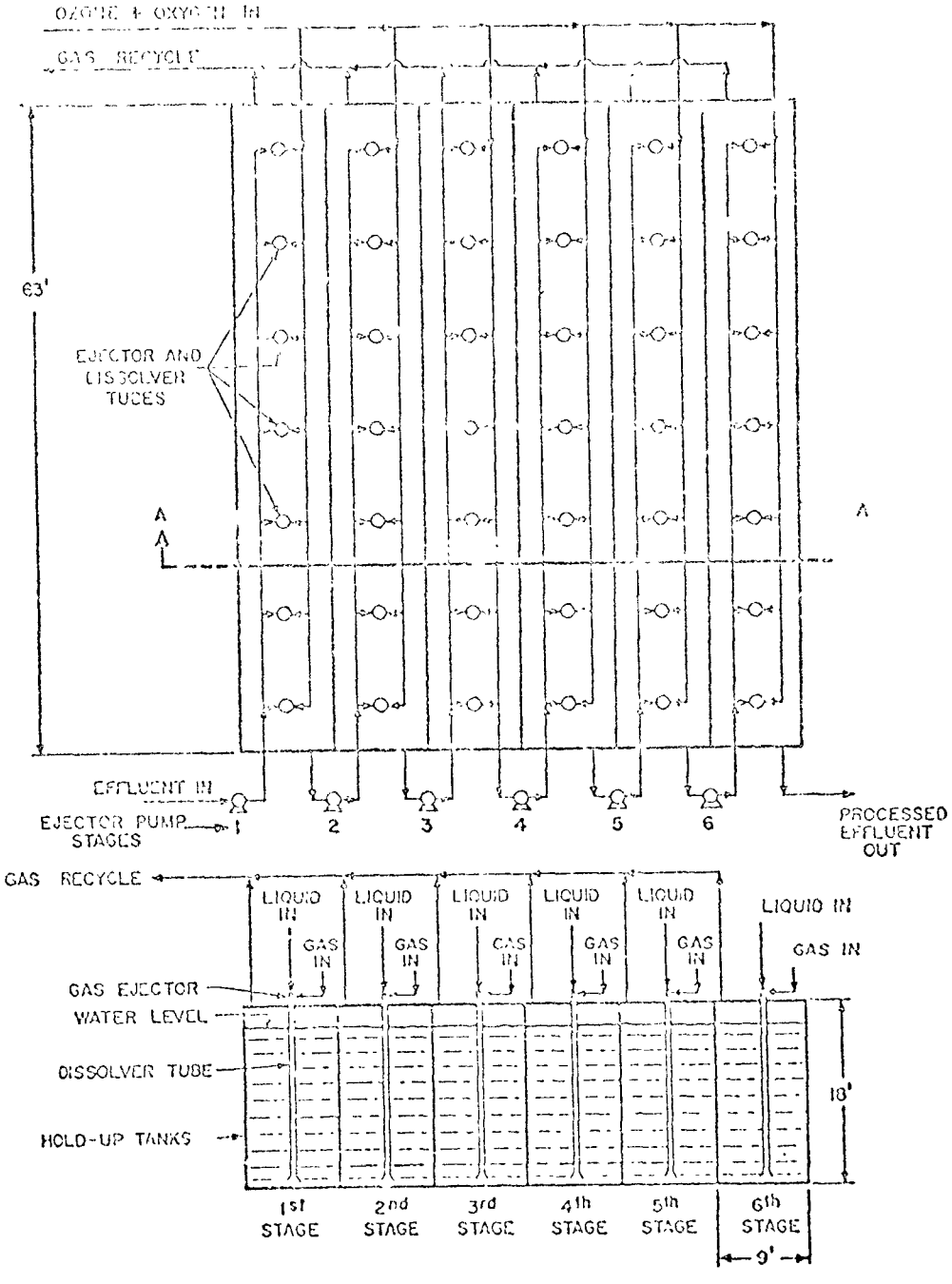
③ OZONE GAS = 309 SCFM FEED (20 lb/min @ 1.7 wt.% OZONE)

GAS FEED TO STAGES

LINE NO	FLOW SCFM	% TOTAL GAS
4	157	51
5	59	19
6	37	12
7	28	9
8	19	6
9	9	3

Figure 65

SCHEMATIC REPRESENTATION OF A 10-MGD PLANT FOR OZONE TREATMENT OF SECONDARY EFFLUENT [223]



Removal of Nutrients

Both phosphorus and nitrogen have received considerable attention in recent years because of the excessive growth of aquatic vegetation which can result from their addition to surface waters. However, with the exception of ammonia base mills, the wastes of most pulp and papermaking operations are very low in these elements.

The removal of phosphorus is of no interest to pulp and paper mills since wood is almost devoid of this element and phosphates are not used for pulping or bleaching. Very small quantities find their way into effluents through their use in coating formulations, in boiler water treatment, and for biological waste treatment. In the case of kraft pulp mills, the limited amount added in this manner is probably precipitated in the primary clarifier by the lime present in the effluent.

Mills pulping with ammonia can burn the spent liquor in which process 85 percent of the ammonia employed is decomposed in the furnace and is discharged as innocuous gases through the furnace stack. Faced with receiving water problems resulting from the discharge of the residual ammonia present in the wash waters, mills pulping with ammonia have the option to change the base rather than resort to costly and unproven methods of treating the effluent for its removal. However, a brief discussion of these technologies -- ammonia stripping, nitrification-denitrification, and ion exchange -- follows.

Ion Exchange

A selective ion exchange system for the removal of ammonia nitrogen from domestic waste waters has been developed but not applied to pulp and papermaking wastes (222) (223) (224). The process uses a natural zeolite, clinoptilolite, which is selective for ammonium ions. Regeneration of the clinoptilolite can be accomplished with a lime slurry, which yields an alkaline aqueous ammonious solution. The spent regenerate can then be processed through an air stripping tower to remove the ammonia, with recycle of the regenerate. It has been shown that the ammonia can be destroyed by electrolysis of the regenerant, which results in the production of chlorine that reacts with the ammonia to produce nitrogen gas (224). Ammonia removals of 93 to 97 percent have been reported (224).

An average ammonia removal of 95.7 percent was obtained in demonstration studies on three municipal wastes having an NH_3-N content of about 20 mg/l (223). It is stated that ammonia removal to less then 0.5 mg/l NH_3-N is technically feasible, but only with shorter runs and greater regenerate requirements.

When using selective ion exchange for ammonia removal, the process of waste waters with high Mg^{+2} concentrations may require clarification of the regenerate to avoid plugging of the bed with $Mg(OH)_2$ (224). In addition, secondary effluents may require

clarification by plain filtration to prevent fouling of the zeolite beds (222).

Ammonia removal by selective ion exchange is probably best suited in areas where prolonged periods of freezing weather are encountered and where very high degrees of ammonia removal must be maintained. Air stripping and biological nitrification-denitrification may be used in the warmer climates at a lower cost, but at a somewhat lower efficiency.

Nitrification-Denitrification

The biological nitrification-denitrification process has been extensively investigated and reported (222) (225) (226) (227) (228). This term refers to the biological treatment process utilized to convert nitrogen compounds (generally ammonia) to nitrates and nitrates to nitrogen gas.

The reduction of nitrate proceeds too slowly to be practical, however, unless a biologically degradable organic material is added to the anaerobic step. Many organic materials such as sugar, ethanol, and acetic acid can be used, but methanol appears to be the least expensive (222) (226). The denitrification step has been demonstrated to be best achieved combined with the columnar operations of granular activated carbon adsorption, or granular mixed media filtration with methanol added to the column influent.

The cell residence time for the biological system must be greater than the growth rate of the nitrifying bacteria or they will be washed out of the system. Sludge ages of two to three days at temperatures greater than 14°C and four to five days at temperatures greater than 8-10°C have produced a stable nitrification condition (228). Best nitrification results may be expected at an organic aeration unit loading kg BOD/Kg MLVSS/day (lb/BOD/lb MLVSS/day) of less than 30 (228 (222). It is reported (225) (226) (222) that the biological nitrification-denitrification process is capable of removing 90 percent of the total nitrogen from municipal waste waters. Other findings indicate that a three-stage biological system can produce an effluent containing 2 mg/l, or less of total nitrogen and that the total nitrogen removal with the biological nitrification-denitrification process will depend on the combined efficiency of both stages (226). The interdependence of the two stages will limit the total nitrogen removal to a practical value of about 90 percent.

The above data are based on pilot plant projects. While there are a number of treatment facilities that have been designed to utilize the biological nitrification-denitrification process, the actual operational results of these facilities has not been widely published.

The nitrifying bacteria are very sensitive to poisoning by simple substances, including heavy metals and free ammonia. Before this

process can be used with industrial wastes, therefore, careful testing must be conducted under realistic conditions.

In addition, the following considerations will influence nitrification:

1. Dissolved oxygen level should be about 1.0 mg/l.

2. pH of activated sludge system should be in the range of 7.5-8.5.

3. The growth rate of the nitrifiers is temperature related. Nitrification below 5°C is minimal, while optimum temperature is about 32°C.

4. The growth rate of nitrifiers is reduced by chlorates, cyanides, alkaloids, mercaptans, urethanes, guanidines, methylamine, and nitrourea.

Overflow and waste sludge rates must be carefully regulated during low temperatures when the bacterial growth rate is low, to assure that the bacteria are not washed out of the system.

Ammonia Stripping

The ammonia stripping process can be generally summarized, as follows:

1. raising the pH of the water to 10.5-11.5;

2. formation, and reformation of water droplets (can be easily accomplished in a stripping tower);

3. circulation of large quantities of air.

Items 2. and 3. above are the same requirements applied to conventional cooling towers and explains the adaptability of these towers with some modifications for the removal of ammonia (222).

There are very few stripping towers that have been designed for treatment of industrial waste waters. Those towers which have been constructed are for the treatment of low strength municipal waste waters (222), the most well known of which is at Lake Tahoe. A countercurrent stripping tower, 7.62m (25 ft) high, 1.83 m (6 ft) wide, and 1.22 m (4 ft) in depth was used to investigate the various parameters affecting air stripping of ammonia. The results showed that the design of air stripping towers can be such to accommodate any desired ammonia removal up to 90-95 percent removal when ambient air temperatures are above 20°C (69°F). The efficiency of the tower was substantially reduced below 20°C (68°F). Data obtained with operation of the tower during winter conditions at Lake Tahoe indicated that the

average lower limit of the process will be in the range of 50-60 percent ammonia removal.

The limitations of the use of ammonia stripping towers was first realized with the winter operations at Lake Tahoe. These limitations are outlined as follows (267):

1. When the air temperatures are at 0°C, or below, freezing problems can occur which will restrict air flow.

2. Ammonia solubility increases at the lower temperatures, which results in higher treatment costs.

2. A calcium carbonate scale formation results on the tower because the lime treated wastes are saturated with $CaCO_3$. The scale could be flushed from the Lake Tahoe Tower, but at the EPA's Blue Plains Pilot Plant it was hard and adhered to the tower fill.

Based on the current status of ammonia stripping towers, they probably will only be used in warm climates. In addition, the hard scale problems will have to be solved.

SECTION VIII

COSTS, ENERGY, NON-WATER QUALITY ASPECTS

Rationale for Development of Costs

This section of the report summarizes the costs of internal and external effluent treatment associated with technology levels of BPCTCA, BATEA, and New Source Standards of Performance. The cost functions used are for conventional treatment methods based on industry experience with full scale installations and equipment suppliers' estimates. For more advanced processes, where full scale installations are few or nonexistent, the cost estimates are largely based on experience with pilot installations and on estimates from and discussions with equipment suppliers.

It should be recognized that actual treatment costs vary widely from mill to mill depending upon the design and operation of the production facilities and local conditions. Furthermore, effluent treatment costs reported by the industry vary greatly from one installation to another depending upon bookkeeping procedures. The estimates of effluent volumes and treatment methods described in this section are intended to represent those of the subcategories covered by this report. However, the industry is extremely heterogeneous in that almost every installation has some uniqueness which could be of importance in assessing effluent treatment problems and their associated costs.

For each technology level, costs of both internal and external technology were established for various sizes of mills in each subcategory in order to reflect the significance of size of mill upon the costs of implementing the technology.

The number of mill sizes and their tonnage were selected from the size range of existing mills so that the ratio of one size to the next approximated 3:1. The selected mill sizes for each subcategory are shown in Table 110. In the case of NSPS, costs are presented only for the larger sizes because it is most unlikely, for economic reasons, that "small" or "very small" new mills will be built in the foreseeable future.

All costs in this report are expressed in terms of June 1974 prices.

The costs of internal and external treatment using aerated stabilization basins for each of the subcategories and the costs using activated sludge in place of ASB are shown in Tables 129 to 158. With the exception of NSPS, costs are cumulative. That is, the costs of BATEA include the capital and annual costs already shown in BPCTCA and the costs for BPCTCA include those already shown for pretreatment. Figures 66-80 are cost curves for pretreatment, BPCTCA, BATEA, and NSPS and relate the costs of achieving the above levels of technology to the size of mills for each subcategory. The internal treatment costs for NSPS in

Table 110

MILL SIZES SELECTED FOR COSTING

kkg/day (tons/day)

Subcategory	Very Small	Small	Medium	Large
Sulfite		145(160)	480(530)	
Dissolving Sulfite			499(550)	
Deink		73(80)	209(230)	454(500)
Dissolving Kraft			544(600)	907(1000)
Market Kraft			318(350)	635(700)
BCT Kraft		227(250)	608(670)	1179(1300)
Fine Kraft		227(250)	608(670)	1179(1300)
Groundwood Chemi-Mech.		91(100)	272(300)	544(600)
Groundwood Thermo-Mech.		91(100)	272(300)	544(600)
Groundwood C-M-N		68(75)	136(150)	454(500)
Groundwood Fine		272(300)	635(700)	
Soda			272(300)	635(700)
Non-Integrated Fine		27(30)	91(100)	254(280)
Non-Integrated Tissue	14(15)	32(35)	100(110)	408(450)
Non-Integrated Tissue (FWP)	14(15)	32(35)	100(110)	408(450)

NO. OF PAPER MCHINES USED IN COSTING

Sulfite		3	7	
Dissolving Sulfite				
Deink		3	3	5
Dissolving Kraft				
Market Kraft				
BCT Kraft		2 Tissue 1 Board	3 Tissue 2 Board	4 Tissue 3 Board
Fine Kraft		5	5	9
Groundwood Chemi-Mech.		2	3	4
Groundwood Thermo-Mech.		2	3	4
Groundwood C-M-N		2	2	3
Groundwood Fine		3	4	6
Soda			2	5
Non-Integrated Fine		2	2	5
Non-Integrated Tissue	2	3	3	5
Non-Integrated Tissue (FWP)	2	3	3	5

Tables 129-158 are the same as for BATEA, and no credit has been taken for the equipment or systems that would be installed if there were no effluent limitation requirements. Table 159, titled "Internal Effluent Treatment Costs for NSPS", takes into account the equipment or system that would be installed. This table was prepared using order of magnitude estimates for inclusion in this report, and will be revised for the final report.

INTERNAL TECHNOLOGY COSTS

The internal technology systems identified are listed on Table 111, titled "Identification of Internal Technology Items". A brief description of each of these 29 systems will be found on the following pages, and schematic drawings of the internal controls are shown in Figure 65A.

It is assumed that operation and maintenance costs are recovered by the mill in the forms of material and/or energy savings for the internal technologies at all levels. Therefore, the annual operating costs for the internal technologies is the depreciation and interest costs. The depreciation costs are the accounting charges which reflect the deterioration of the capital assets over a period of years. Straight line depreciation has been assumed in all annual cost calculations. The interest is the financial charges on the capital expenditures for pollution reduction. Depreciation and interest together are assumed to be 15 percent of the investment costs.

The cost of sulfite liquor incineration and/or recovery is not included in the cost tables for the sulfite and dissolving sulfite subcategory. The capital cost estimate for an MgO recovery system is included at the bottom of each table for reference.

The number of paper machines in the paper mills by each subcategory will be found in Table 110. A very brief description of what is included in each of the 29 internal technology items is as follows.

1. Replace Flume with Mechanical Conveyors

The base mill for this estimate processes 1200 cords per day of 4 to 8 foot rough pulpwood, hardwood and softwood, received by rail and truck. The flume, with coarse and fines removal system, is replaced by four (4) 3-chain log conveyors each 200 feet long, in tandem as shown on the flow diagram in Figure 65A.

Most of the existing unloading facilities and the existing rough wood storage areas are maintained by installing the log haul conveyors over the flume structure. Unloading docks or impact areas are located on one side of the conveyors to reduce the shock of falling wood from cranes or rail car unloading. All conveyors are reversible.

Table 111

IDENTIFICATION OF INTERNAL TECHNOLOGY ITEMS

ITEM NO.	DESCRIPTION
1	Replace Flume with mechanical conveyor.
2	Use of steam in drum barkers.
3	Knotc collection and disposal.
4	Fourth stage brown stock washer.
5	Decker filtrate for brown stock washer showers.
6	Close-up screen room.
7	Pulp mill spill collection from washers.
8	Pulp mill spill collection from tanks, equipment and drains.
9	Jump stage countercurrent washing.
10	Evaporator surface condenser.
11	Steam stripping condensates and reuse.
12	Evaporator boilout tank.
13	Black liquor storage tank spill collection.
14	Green liquor dregs filtering.
15	Causticizing area spill collection system.
16	Evaporator condensate for causticizing makeup.
17	Lime mud storage pond.
18	Alarms on chemical tanks.
19	Prehydrolysate disposal by burning.
20	MgO recovery system.
21	Paper machine vacuum saveall.
22	Paper machine flotation saveall.
23	Paper machine high pressure showers.
24	Paper machine white water showers.
25	Cyliner former white water showers.
26	Cooling water segregation and reuse.
27	Felt hair removal.
28	Vacuum pumps seal water reuse.
29	Paper mill stock spill collection system.

Table 112

INTERNAL TECHNOLOGIES USED IN COSTING

Sulfite Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1				
2.			X	X
3.	50	X	X	X
4.			X	X
5.	50	X	X	X
6.			X	X
7.			X	X
8.			X	X
9.	50	X	X	X
10.	50	X	X	X
11.				
12.	25	X	X	X
13.	33	X	X	X
14.				
15.				
16				
17.				
18.	33	X	X	X
19.				
20.				
21.	75	X	X	X
22.				
23.	33	X	X	X
24.				
25.				
26.			X	X
27.	50	X	X	X
28.	33	X	X	X
29.			X	X

Table 113

INTERNAL TECHNOLOGIES USED IN COSTING

Sulfite Dissolving Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.			X	X
3.	50	X	X	X
4.			X	X
5.	50	X	X	X
6.			X	X
7.			X	X
8.			X	X
9.	50	X	X	X
10.	50	X	X	X
11.				
12.	25	X	X	X
13.	33	X	X	X
14.				
15.				
16.				
17.				
18.	33	X	X	X
19.				
20.	50	X	X	X
21.				
22.				
23.				
24.				
25.	50	X	X	X
26.			X	X
27.	50	X	X	X
28.				
29.				

Table 114
INTERNAL TECHNOLOGIES USED IN COSTING

Deink Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATFA	NSPS
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.	33	X	X	X
19.				
20.				
21.	75	X	X	X
22.				
23.	40	X	X	X
24.				
25.				
26.			X	X
27.				
28.	50	X	X	X
29.			X	X

TAble 115

INTERNAL TECHNOLOGIES USED IN COSTING

Bleached Kraft Dissolving Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.			X	X
3.	90	X	X	X
4.			X	X
5.	35	X	X	X
6.			X	X
7.			X	X
8.			X	X
9.	75	X	X	X
10.	50	X	X	X
11.				
12.	33	X	X	X
13.	33	X	X	X
14.	33	X	X	X
15.			X	X
16.			X	X
17.			X	X
18.	33	X	X	X
19.	67	X	X	X
20.				
21.				
22.				
23.				
24.				
25.	50	X	X	X
26.			X	X
27.	33	X	X	X
28.				
29.				

Table 116

INTERNAL TECHNOLOGIES USED IN COSTING

Market Kraft Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.			X	X
3.	90	X	X	X
4.			X	X
5.	33	X	X	X
6.			X	X
7.			X	X
8.			X	X
9.	75	X	X	X
10.	50	X	X	X
11.				
12.	33	X	X	X
13.	33	X	X	X
14.	33	X	X	X
15.			X	X
16.				
17.			X	X
18.	33	X	X	X
19.			X	X
20.				
21.				
22.				
23.				
24.				
25.	50	X	X	X
26.				
27.	40	X	X	X
28.			X	X
29.				

Table 117
INTERNAL TECHNOLOGIES USED IN COSTING

BCT Kraft Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTC	BATEA	NSPS
1.				
2.			X	X
3.	90	X	X	X
4.			X	X
5.	33	X	X	X
6.			X	X
7.			X	X
8.			X	X
9.	75	X	X	X
10.	50	X	X	X
11.				
12.	33	X	X	X
13.	33	X	X	X
14.	33	X	X	X
15.			X	X
16.			X	X
17.			X	X
18.	33	X	X	X
19.				
20.				
21.	90	X	X	X
22.				
23.	20	X	X	X
24.	20	X	X	X
25.				
26.			X	X
27.				
28.	33	X	X	X
29.			X	X

Table 118

INTERNAL TECHNOLOGIES USED IN COSTING

Fine Kraft Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.				
3.	90	X	X	X
4.			X	X
5.	33	X	X	X
				X
6.				
7.			X	X
8.			X	X
9.	X	X	X	X
10.	75	X	X	X
				X
11.				
12.	50	X	X	X
13.	50	X	X	X
14.	33	X	X	X
15.			X	X
16.				
17.			X	X
18.	33	X	X	X
19.			X	X
20.				
21.				
22.	X	X	X	X
23.	X	X	X	X
24.				
25.				
26.				
27.	40	X	X	X
28.	50	X	X	X
29.			X	X
			X	X

Table 119

INTERNAL TECHNOLOGIES USED IN COSTING

Groundwood Chemi/Mech. Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.			X	X
3.				
4.				
5.				
			X	X
6.			X	X
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.	25	X	X	X
18.				
19.				
20.				
	40	X	X	X
21.				
22.	25	X	X	X
23.				
24.				
25.				
			X	X
26.				
27.	25	X	X	X
28.			X	X
29.				

Table 120

INTERNAL TECHNOLOGIES USED IN COSTING

Goundwood Thermo/Mech. Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.				
3.			X	X
4.				
5.				
6.				
7.			X	X
8.			X	X
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.	25	X	X	X
19.				
20.				
21.	40	X	X	X
22.				
23.	25	X	X	X
24.				
25.				
26.			X	X
27.				
28.	25	X	X	X
29.			X	X

Table 121

INTERNAL TECHNOLOGIES USED IN COSTING

Goundwood C-M-N Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.			X	X
2.				
3.				
4.				
5.			X	X
6.			X	X
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.	25	X	X	X
18.				
19.				
20.				
21.	40	X	X	X
22.	25	X	X	X
23.				
24.				
25.			X	X
26.				
27.	25	X	X	X
28.			X	X
29.				

Table 122

INTERNAL TECHNOLOGIES USED IN COSTING

Groundwood Fine Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.			X	
3.				X
4.				
5.				
6.			X	
7.			X	X
8.				X
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.	25	X	X	
19.				X
20.				
21.	75	X	X	
22.				X
23.	25	X	X	
24.				X
25.				
26.				
27.			X	X
28.	25	X		
29.			X	X
			X	X

Table 123

INTERNAL TECHNOLOGIES USED IN COSTING

Soda Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.			X	X
3.	90	X	X	X
4.			X	X
5.	33	X	X	X
6.			X	X
7.			X	X
8.			X	X
9.	75	X	X	X
10.	50	X	X	X
11.				
12.	33	X	X	X
13.	33	X	X	X
14.	33	X	X	X
15.			X	X
16.				
17.			X	X
18.	33	X	X	X
19.				
20.				
21.				
22.	X	X	X	X
23.	50	X	X	X
24.				
25.				
26.				
27.			X	X
28.	50	X	X	X
29.	50	X	X	X
			X	X

Table 124
INTERNAL TECHNOLOGIES USED IN COSTING

Non-Integrated Fine Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.	25	X	X	X
19.				
20.				
21.				
22.	75	X	X	X
23.	33	X	X	X
24.				
25.				
26.				
27.	33	X	X	X
28.	33	X	X	X
29.			X	X
			X	X

Table 125
INTERNAL TECHNOLOGIES USED IN COSTING

Non-Integrated Tissue Subcategory

Data are percentages of total item cost. $\bar{X}$ = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.	25	X	X	X
19.				
20.				
21.	50	X	X	X
22.				
23.				
24.	25	X	X	X
25.				
26.			X	X
27.			X	X
28.	33	X	X	X
29.				

Table 126

INTERNAL TECHNOLOGIES USED IN COSTING

Non-Integrated Tissue (fwp) Subcategory

Data are percentages of total item cost. X = 100%

Item	Pre	BPCTCA	BATEA	NSPS
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.	25	X	X	X
19.				
20.				
21.	50	X	X	X
22.				
23.				
24.	25	X	X	X
25.				
26.			X	X
27.				
28.	33	X	X	X
29.			X	X

Table 127

EXTERNAL UNIT PROCESS USED IN COSTING

Unit Process	Sulfite				Diss. Sulfite				Deink				Diss. Kraft				Market Kraft			
	73	77	83	NS	73	77	83	NS	73	77	83	NS	73	77	83	NS	73	77	83	NS
1. Preliminary	X			X	X			X	X			X	X			X	X			X
2. Pump Station	X		X	X	X		X	X	X		X	X	X		X	X	X		X	X
3. Primary Clarifier	X			X	X			X	X			X	X			X	X			X
4. Sludge Lagoon	X			X	X			X	X			X	X			X	X			X
5. Aerators		X		X		X		X		X		X		X		X		X		X
6. ASB Basin		X		X		X		X		X		X		X		X		X		X
7. Vacuum Filters		X		X		X		X		X		X		X		X		X		X
8. Press		X		X		X		X						X		X		X		X
9. Monitor	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10. Outfall	X			X	X			X	X			X	X			X	X			X
11. Diffuser	X			X	X			X	X			X	X			X	X			X
12. Foam	X			X	X			X					X			X	X			X
13. Neutralization	X			X	X			X												
14. Black Liquor Lagoon	X	X		X	X	X		X	X	X		X	X	X		X	X	X		X
15. Mixed Media			X				X				X				X				X	
16. Air Flotation				X				X				X				X				X
17. Secondary Clarifier				X				X				X				X				X
18. Mini-Lime															X				X	

Table 127 cont'd
EXTERNAL UNIT PROCESS USED IN COSTING

Unit Process	BCT Kraft				Fine Kraft				Soda				Groundwood Chemi/Mech				Groundwood Thermo/Mech			
	73	77	83	NS	73	77	83	NS	73	77	83	NS	73	77	83	NS	73	77	83	NS
1. Preliminary	X			X	X			X	X			X	X			X	X			X
2. Pump Station	X		X	X	X		X	X	X		X	X	X		X	X	X		X	X
3. Primary Clarifier	X			X	X			X	X			X	X			X	X			X
4. Sludge Lagoon	X			X	X			X	X			X	X			X	X			X
5. Aerators		X		X		X		X		X		X		X		X		X		X
6. ASB Basin		X		X		X		X		X		X		X		X		X		X
7. Vacuum		X		X		X		X		X		X		X		X		X		X
8. Press		X		X		X		X		X		X		X		X		X		X
9. Monitor	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10. Outfall	X			X	X			X	X			X	X			X	X			X
11. Diffuser	X			X	X			X	X			X	X			X	X			X
12. Foam	X			X	X			X	X			X	X			X	X			X
13. Neutralization									X			X								
14. Black Liquor Lagoon	X	X		X	X	X		X	X	X		X	X	X		X	X			X
15. Mixed Media			X				X				X				X				X	
16. Air Flotation				X				X				X				X				X
17. Secondary Clarifier				X				X				X				X				X
18. Mini-Lime			X				X				X									

Table 127 cont'd

EXTERNAL UNIT PROCESS USED IN COSTING

Unit Process	Groundwood Fine 73	77	83	NS	Groundwood CMN 73	77	83	NS	NI Fine 73	77	83	NS	NI Tissue 73	77	83	NS	NI Tissue FWP 73	77	83	NS
1. Preliminary	X			X	X			X	X			X	X			X	X			X
2. Pump Station	X		X	X	X		X	X	X	X	X		X	X	X		X	X	X	
3. Primary Clarifier	X			X	X			X	X			X	X			X	X			X
4. Sludge Lagoon	X			X	X			X	X			X	X			X	X			X
5. Aerators		X		X		X		X		X	X			X	X		X			X
6. ASB Basin		X		X		X		X		X	X			X	X		X			X
7. Vacuum Filters		X		X		X		X	X			X	X			X	X			X
8. Press		X		X		X		X												
9. Monitor	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	
10. Outfall	X			X	X			X	X			X	X			X	X			X
11. Diffuser	X			X	X			X	X			X	X			X	X			X
12. Foam																				
13. Neutralization																				
14. Black Liquor Lagoon	X	X		X	X	X		X	X			X	X			X	X			X
15. Mixed Media			X				X			X				X				X		
16. Air Flotation				X				X				X				X				X
17. Secondary Clarifier				X				X				X				X				X
18. Mini-Lime																				

Table 128

RAW (09) AND FINAL (79) WASTE CHARACTERISTICS

Data in kl/kkg (kgal/ton) For Flow
And kg/kkg (lb/ton) For All Others

PARAMETER	PRETREATMENT	BPCTCA	BATEA	NSPS
Soda				
09 BOD	55 (110)	42.5 (85.0)	30 (60)	30 (60)
09 TSS	150 (300)	105 (210)	65 (130)	65 (130)
Flow	208 (50)	122.7 (29.5)	95.7 (23)	95.7 (23)
79 BOD	46.75 (93.5)	3.45 (6.9)	1.45 (2.9)	1.45 (2.9)
79 TSS	33 (66)	5.15 (10.3)	0.95 (1.9)	1.9 (3.8)
GW-Chemi-Mechanical				
09 BOD	60 (120.0)	50.5 (101)	45 (90.0)	45 (90.0)
09 TSS	32.5 (65.0)	28 (97.0)	22.5 (45.0)	22.5 (45.0)
Flow	99.84 (24)	83.2 (20)	74.88 (18)	74.88 (18)
79 BOD	42 (84)	2.1 (4.2)	0.75 (1.5)	0.75 (1.5)
79 TSS	7.5 (13)	3 .65 (7.3)	0.75 (1.5)	1.5 (3.0)
GW-Fine Papers				
09 BOD	21.0 (42.0)	17.0 (34.0)	16.0 (32.0)	16.0 (32.0)
09 TSS	65 (130)	52 (104)	45.0 (90.0)	45.0 (90.0)
Flow	108.16 (26)	90.69 (21.8)	74.88 (18)	74.88 (18)
79 BOD_5	14.7 (29.4)	2.25 (4.5)	1.0 (2.0)	1.0 (2.0)
79 TSS	13 (26)	4.0 (8.0)	0.75 (1.5)	1.5 (3.0)
Groundwood - CMN Papers				
09 BOD	22.0 (44.0)	17.5 (35.0)	16.0 (32.0)	16.0 (32.0)
09 TSS	80 (160)	70 (140)	48.0 (96.0)	48.0 (96.0)
Flow	120.64 (29)	99 (23.8)	79.04 (19)	79.04 (19)
79 BOD	15.4 (30.8)	2.5 (5.0)	1.05 (2.1)	1.05 (2.1)
79 TSS	16 (32)	4.35 (8.7)	0.8 (1.6)	1.6 (3.2)
Thermo Mechanical				
09 BOD	-	28.0 (56.0)	26.5 (53.0)	28.0 (56.0)
09 TSS	-	25.0 (97.0)	25.0 (50.0)	25.0 (50.0)
Flow	-	62.4 (15)	41.6 (10)	62.4 (15)
79 BOD	-	1.55 (3.1)	0.65 (1.3)	1.55 (3.1)
79 TSS	-	2.75 (5.5)	0.4 (0.8)	1.25 (2.5)

Table 128 cont'd

PARAMETER	PRETREATMENT	BPCTCA	BATEA	NSPS
BCT - Kraft				
09 BOD	42.5 (85.0)	33.5 (67.0)	26.0 (52.0)	26.0 (52.0)
09 TSS	55.0 (110.0)	51.5 (103)	46.5 (93)	46.5 (93.0)
Flow	208 (50)	151.84 (36.5)	112.32 (27)	112.32 (27)
79 BOD	38.93 (77.85)	3.8 (7.6)	1.7 (3.4)	1.7 (3.4)
79 TSS	18.59 (37.18)	6.4 (12.8)	1.15 (2.3)	2.25 (4.5)
Fine Kraft				
09 BOD	40.0 (80.0)	30.0 (60.0)	23.5 (47.0)	23.5 (47.0)
09 TSS	90.0 (180.0)	84 (168)	46.5 (93.0)	46.5 (93.0)
Flow	166.4 (40)	108.16 (26)	95.68 (23)	95.68 (23)
79 BOD	36.64 (73.28)	2.8 (5.6)	1.15 (2.3)	1.15 (2.3)
79 TSS	30.42 (60.84)	4.55 (9.1)	0.95 (1.9)	1.9 (3.8)
Sulfite				
09 BOD	600 (1200)	115.5 (231)	68.5 (137)	91 (182)
09 TSS	100 (200)	82.0 (164)	75.0 (150)	73.5 (147)
Flow	332.8 (80)	208 (50)	176.8 (42.5)	112.32 (27)
79 BOD	468 (936)	9.1 (18.2)	3.85 (7.7)	2.45 (4.9)
79 TSS	15 (30)	13.15 (26.3)	1 95 (3.9)	2.45 (4.9)
Dissolving Sulfite				
09 BOD	650 (1300)	132 (264)	125 (250)	125 (250)
09 TSS	100 (200)	92.5 (185)	85 (170)	85 (170)
Flow	416 (100)	271.23 (65.2)	249.6 (60)	249.6 (60)
79 BOD	507 (1014)	13.6 (27.2)	5.0 (10.0)	5.0 (10.0)
79 TSS	15 (30)	16.3 (32.6)	2.5 (5.0)	5.0 (10.0)
Deink				
09 BOD	92.5 (185)	68.5 (137)	68.5 (137)	68.5 (137)
09 TSS	300 (600)	204 (408)	204 (408)	204 (408)
Flow	124.8 (30)	94.02 (22.6)	74.88 (18)	74.88 (18)
79 BOD	55.5 (111)	4.2 (8.4)	1.5 (3.0)	2.25 (4.5)
79 TSS	45 (90)	7.85 (15.7)	1.5 (3.0)	2.25 (4.5)
Dissolving Kraft				
09 BOD	80 (160)	55 (110)	37.5 (75.0)	37.5 (75.0)
09 TSS	200 (400)	150 (300)	85 (170)	85 (170)
Flow	332.8 (80)	241.28 (58)	216.32 (52)	216.32 (52)
79 BOD	73.28 (146.6)	7.75 (15.5)	3.25 (6.5)	3.25 (6.5)
79 TSS	67.6 (135.2)	9.65 (19.3)	2.15 (4.3)	4.35 (8.7)

Table 128 cont'd

PARAMETER	PRETREATMENT	BPCTCA	BATEA	NSPS
Market Kraft				
09 BOD	60 (120)	41 (82.0)	26.5 (53.0)	27.5 (55.0)
09 TSS	80 (160)	70 (140)	65 (130)	65 (130)
Flow	332.8 (80)	176.8 (42.5)	141.44 (34)	79.04 (19)
79 BOD	54.96 (109.92)	4.25 (8.5)	2.0 (4.0)	1.1 (2.2)
79 TSS	27.04 (54.08)	6.4 (12.8)	1.4 (2.8)	1.6 (3.2)
NI Fine Papers				
09 BOD	17.5 (35.0)	10.75 (21.5)	9.5 (19.0)	9.5 (19.0)
09 TSS	75 (150)	31.0 (62.0)	30.0 (60.0)	30.0 (60.0)
Flow	108.16 (26)	62.4 (15)	38.27 (9.2)	38.27 (9.2)
79 BOD	17.5 (35.0)	2.5 (5.0)	0.75 (1.5)	0.75 (1.5)
79 TSS	75 (150)	2.65 (5.3)	0.4 (0.8)	0.75 (1.5)
NI Tissue				
09 BOD	17.5 (35.0)	11.5 (23.0)	10.0 (20.0)	10.0 (20.0)
09 TSS	62.5 (125)	34.0 (68.0)	28.0 (56.0)	28.0 (56.0)
Flow	141.44 (34)	95.68 (23)	60.32 (14.5)	60.32 (14.5)
79 BOD	17.5 (35.0)	2.8 (5.6)	1.2 (2.4)	1.2 (2.4)
79 TSS	62.5 (125)	2.9 (5.8)	0.6 (1.2)	1.2 (2.4)
NI Tissue (PWP)				
09 BOD	20.0 (40.0)	14.5 (29.0)	13.5 (27.0)	13.5 (27.0)
09 TSS	75 (150)	40.0 (80.0)	35.0 (70.0)	35.0 (70.0)
Flow	141.44 (34)	95.68 (23)	60.32 (14.5)	60.32 (14.5)
79 BOD	20.0 (40.0)	2.8 (5.6)	1.2 (2.4)	1.2 (2.4)
79 TSS	75 (150)	2.9 (5.8)	0.6 (1.2)	1.2 (2.4)

Table 129
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Sulfite Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 160 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	600	2875	3475	1000	7550	8550	2035	8730	10765	2035	7540	9575
2.	90	315	405	150	1450	1600	305	1810	2115	305	1690	1995
3.	90	195	285	150	895	1045	305	1070	1375	305	1145	1450
4.	-	120	120	-	555	555	-	740	740	-	545	545

Mill Size: 530 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1430	6390	7820	2310	15800	18110	4500	18335	22835	4500	15320	19820
2.	215	625	840	345	3135	3480	675	3840	4515	675	3600	4275
3.	215	415	630	345	1825	2170	675	2185	2860	675	2300	2975
4.	-	210	210	-	1310	1310	-	1655	1655	-	1300	1300

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

NOTE: MgO Recovery System not included.
Capital Cost: 160 TPD - $11,300
530 TPD - $34,000

Table 130
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Sulfite Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 160 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	600	2,875	3,475	1,000	8,980	9,980	2,035	10,160	12,195	2,035	6,520	8,555
2.	90	315	405	150	1,820	1,970	350	2,180	2,530	350	1,620	1,970
3.	90	195	285	150	1,110	1,260	350	1,285	1,635	350	980	1,330
4.	-	120	120	-	710	710	-	895	895	-	640	640

Mill Size: 530 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1,430	6,390	7,820	2,310	19,630	21,940	4,500	22,165	26,665	4,500	13,610	18,110
2.	215	625	840	345	3,995	4,340	675	4,700	5,375	675	3,565	4,240
3.	215	415	630	345	2,400	2,745	675	2,760	3,435	675	2,045	2,720
4.	-	210	210	-	1,595	1,595	-	1,940	1,940	-	1,520	1,520

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

NOTE: MgO Recovery System not included.
Capital Cost: 160 TPD - $11,300
530 TPD - $34,000

Table 171

AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Sulfite Dissolving Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 550 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	415	6880	7295	870	16695	17565	2940	19980	22920	2940	19960	22900
2.	60	1320	1380	130	3925	4055	440	4940	5380	440	4955	5395
3.	60	1080	1140	130	2570	2700	440	3065	3505	440	2980	3420
4.	-	240	240	-	1355	1355	-	1875	1875	-	1975	1975

Mill Size: TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.												
2.												
3.												
4.												

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

NOTE: MgO Recovery System not included.
Capital Cost: $35,000

Table 132

WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Dissolving Sulfite Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 550 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	415	6880	7295	870	20,775	21,645	2940	24,060	27,000	2940	18,740	21,680
2.	60	1320	1380	130	4,860	4,990	440	5,875	6,315	440	4,840	5,280
3.	60	1080	1140	130	3,165	3,295	440	3,660	4,100	440	2,810	3,250
4.	-	240	240	-	1,695	1,695	-	2,215	2,215	-	2,030	2,030

Mill Size: TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.												
2.												
3.												
4.												

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

NOTE: MgO Recovery System not included.
Capital Cost: $35,000

Table 133
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS

Deink Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 80 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	400	1225	1625	600	3555	4155	745	3905	4650			
2.	60	255	315	90	855	945	110	980	1090			
3.	60	190	250	90	550	640	110	605	715			
4.	-	65	65	-	305	305	-	375	375			

Mill Size: 230 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	535	2350	2885	835	6405	7240	1110	7140	8250	1110	7670	8780
2.	80	445	525	125	1530	1655	165	1670	1835	165	1795	1960
3.	80	360	440	125	965	1090	165	1075	1240	165	1150	1315
4.	-	85	85	-	565	565	-	595	595	-	645	645

Mill Size: 500 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	965	4,050	5,015	1,485	10,135	11,620	1,930	11,405	13,335	1,930	11,795	13,725
2.	145	720	865	225	2,500	2,725	290	2,915	3,205	290	2,750	3,040
3.	145	610	755	225	1,530	1,755	290	1,715	2,005	290	1,770	2,060
4.	-	110	110	-	970	970	-	1,200	1,200	-	980	980

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 134
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Deink Subcategory
(All Costs in Thousands of Dollars)

Mill Size: 80 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	400	1,225	1,625	600	4,115	4,715	745	4,465	5,210			
2.	60	225	315	90	1,010	1,100	110	1,135	1,245			
3.	60	190	250	90	625	715	110	680	790			
4.	-	65	65	-	385	385	-	455	455			

Mill Size: 230 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	535	2,350	2,885	835	7,405	8,240	1,110	8,140	9,250	1,110	6,675	7,785
2.	80	445	525	125	1,835	1,960	165	2,070	2,235	165	1,780	1,945
3.	80	360	440	125	1,120	1,245	165	1,230	1,395	165	1,005	1,170
4.	-	85	85	-	715	715	-	840	840	-	775	775

Mill Size: 500 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	965	4,050	5,015	1,485	11,985	13,470	1,930	13,255	15,185	1,930	10,755	12,685
2.	145	720	865	225	2,820	3,045	290	3,235	3,525	290	2,870	3,160
3.	145	610	755	225	1,635	1,860	290	1,820	2,110	290	1,615	1,905
4.	-	110	110	-	1,185	1,185	-	1,415	1,415	-	1,255	1,255

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 135
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Bleached Kraft Dissolving Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 600 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	525	5,640	6,165	1,040	14,475	15,515	3,725	18,865	22,590			
2.	80	1,030	1,110	155	3,310	3,465	560	4,725	5,285			
3.	80	845	925	155	2,170	2,325	560	2,830	3,390			
4.	-	185	185	-	1,140	1,140	-	1,895	1,895			

Mill Size: 1000 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	740	8,055	8,795	1,460	20,135	21,595	5,210	26,210	31,420	5,210	22,775	27,985
2.	110	1,470	1,580	220	4,755	4,975	780	6,785	7,565	780	5,540	6,320
3.	110	1,210	1,320	220	3,020	3,240	780	3,930	4,710	780	3,415	4,195
4.	-	260	260	-	1,735	1,735	-	2,855	2,855	-	2,125	2,125

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 136

WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Bleached Kraft Dissolving Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 600 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	525	5,640	6,165	1,040	18,585	19,625	3,725	22,975	26,700			
2.	80	1,030	1,110	155	4,255	4,410	560	5,670	6,230			
3.	80	845	925	155	2,785	2,940	560	3,445	4,005			
4.	-	185	185	-	1,470	1,470	-	2,225	2,225			

Mill Size: 1000 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	740	8,055	8,795	1,460	25,750	27,210	5,210	31,825	37,035	5,210	22,415	27,625
2.	110	1,470	1,580	220	5,975	6,195	780	8,000	8,780	780	5,615	6,395
3.	110	1,210	1,320	220	3,865	4,085	780	4,775	5,555	780	3,365	4,145
4.	-	260	260	-	2,110	2,110	-	3,225	3,225	-	2,250	2,250

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 137
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Market Kraft Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 350 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	360	3,430	3,790	705	8,745	9,450	2,570	11,210	13,780			
2.	55	645	700	105	1,880	1,985	385	2,660	3,045			
3.	55	515	570	105	1,315	1,420	385	1,690	2,075			
4.	-	130	130	-	565	565	-	970	970			

Mill Size: 700 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	565	5,610	6,175	1,115	13,630	14,745	3,980	17,265	21,245	3,980	11,560	15,540
2.	85	1,045	1,130	165	3,000	3,165	595	4,850	5,445	595	2,790	3,385
3.	85	845	930	165	2,050	2,215	595	2,600	3,195	595	1,735	2,330
4.	-	200	200	-	950	950	-	2,250	2,250	-	1,055	1,055

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 138
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Market Kraft Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 350 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	360	3,430	3,790	705	10,865	11,570	2,570	13,330	15,900			
2.	55	645	700	105	2,330	2,435	385	3,110	3,495			
3.	55	515	570	105	1,635	1,740	335	2,010	2,395			
4.	-	130	130	-	695	695	-	1,100	1,100			

Mill Size: 700 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	565	5,610	6,175	1,115	17,140	18,255	3,980	20,775	24,755	3,980	10,235	14,215
2.	85	1,045	1,130	165	3,810	3,975	595	5,075	5,670	595	2,600	3,195
3.	85	845	930	165	2,575	2,740	595	3,125	3,720	595	1,535	2,130
4.	-	200	200	-	1,235	1,235	-	1,950	1,950	-	1,065	1,065

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 139
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
BTC Kraft Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 250 TPD

	1973			1977			1983				NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total		Int.	Ext.	Total
1.	885	2,185	3,070	1,335	6,115	7,450	3,020	7,595	10,615	1.			
2.	135	425	560	200	1,295	1,495	455	1,750	2,205	2.			
3.	135	330	465	200	920	1,120	455	1,140	1,595	3.			
4.	-	95	95	-	375	375	-	610	610	4.			

Mill Size: 670 TPD

	1973			1977			1983				NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total		Int.	Ext.	Total
1.	1,800	3,950	5,750	2,645	10,860	13,505	5,715	14,010	19,725	1.	5,715	12,590	18,305
2.	270	740	1,010	395	2,360	2,755	860	3,340	4,200	2.	860	2,895	3,755
3.	270	595	865	395	1,630	2,025	860	2,105	2,965	3.	860	1,890	2,750
4.	-	145	145	-	730	730	-	1,235	1,235	4.	-	1,005	1,005

Mill Size: 1300 TPD

	1973			1977			1983				NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total		Int.	Ext.	Total
1.	3,030	6,320	9,350	4,365	16,795	21,160	9,050	21,485	30,535	1.	9,050	18,505	27,555
2.	455	1,175	1,630	655	3,790	4,445	1,360	5,215	6,575	2.	1,360	4,455	5,815
3.	455	950	1,405	655	2,520	3,175	1,360	3,225	4,585	3.	1,360	2,775	4,135
4.	-	225	225	-	1,270	1,270	-	1,990	1,990	4.	-	1,680	1,680

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 140

WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS

BTC Kraft
(All Costs in Thousands of Dollars)
Mill Size: 250 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	885	2,185	3,070	1,335	7,475	8,810	3,020	8,955	11,975			
2.	135	425	560	200	1,645	1,845	455	2,100	2,555			
3.	135	330	465	200	1,125	1,325	455	1,345	1,800			
4.	-	95	95	-	520	520	-	755	755			

Mill Size: 670 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1,800	3,950	5,750	2,645	13,870	16,515	5,715	17,010	22,733	5,715	11,260	16,975
2.	270	740	1,010	395	3,060	3,445	860	4,040	4,900	860	2,800	3,660
3.	270	595	865	395	2,085	2,480	860	2,560	3,420	860	1,690	2,550
4.	-	145	145	-	975	975	-	1,480	1,480	-	1,110	1,110

Mill Size: 1300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	3,030	6,320	9,350	4,365	21,715	26,080	9,050	26,402	35,452	9,050	17,225	26,275
2.	455	1,175	1,630	655	4,875	5,530	1,360	6,300	7,660	1,360	4,465	5,825
3.	455	950	1,405	655	3,260	3,915	1,360	3,965	5,325	1,360	2,585	3,945
4.	-	225	225	-	1,615	1,615	-	2,335	2,335	-	1,880	1,880

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 141
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Fine Kraft Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 250 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1,030	1,930	2,960	1,235	5,470	6,705	2,920	7,040	9,960			
2.	155	385	540	185	1,200	1,385	440	1,660	2,100			
3.	155	290	445	185	820	1,005	440	1,060	1,500			
4.	-	95	95	-	380	380	-	600	600			

Mill Size: 670 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1,970	4,425	6,395	2,365	10,690	13,055	5,410	13,510	18,920	5,410	11,565	16,975
2.	295	795	1,090	355	2,385	2,740	810	3,225	4,065	810	2,660	3,470
3.	295	665	960	355	1,605	1,960	810	2,030	2,840	810	1,735	2,545
4.	-	130	130	-	780	780	-	1,225	1,225	-	925	925

Mill Size: 1300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	3,200	5,845	9,045	3,820	15,140	18,960	8,505	19,455	27,960	8,505	17,160	25,665
2.	480	1,065	1,545	575	3,575	4,150	1,275	5,000	6,275	1,275	4,135	5,410
3.	480	875	1,355	575	2,270	2,845	1,275	2,920	4,195	1,275	2,575	3,850
4.	-	190	190	-	1,305	1,305	-	2,080	2,080	-	1,560	1,560

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 142
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Fine Kraft
(All Costs in Thousands of Dollars)

Mill Size: 250 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1,030	1,930	2,960	1,235	6,750	7,985	2,920	8,320	11,240			
2.	155	385	540	185	1,570	1,755	440	2,030	2,470			
3.	155	290	445	185	1,015	1,200	440	1,255	1,695			
4.	-	95	95	-	555	555	-	775	775			

Mill Size: 670 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1,970	4,425	6,395	2,365	13,140	15,505	5,410	15,960	21,370	5,410	10,305	15,715
2.	295	795	1,090	355	2,950	3,305	810	3,820	4,630	810	2,555	3,365
3.	295	665	960	355	1,975	2,330	810	2,400	3,210	810	1,545	2,355
4.	-	130	130	-	975	975	-	1,420	1,420	-	1,010	1,010

Mill Size: 1300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	3,200	5,845	9,045	3,820	19,100	22,920	8,505	23,415	31,920	8,505	15,985	24,490
2.	480	1,065	1,545	575	4,510	5,085	1,275	5,890	7,165	1,275	4,070	5,345
3.	480	875	1,355	575	2,865	3,440	1,275	3,515	4,790	1,275	2,400	3,675
4.	-	190	190	-	1,645	1,645	-	2,375	2,375	-	1,670	1,670

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 143

AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Groundwood Chem/Mech. Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 100 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	160	845	1005	435	3040	3475	930	3460	4390	930	3625	4555
2.	25	190	215	65	645	710	140	785	925	140	780	920
3.	25	130	155	65	460	525	140	520	660	140	545	685
4.	-	60	60	-	185	185	-	265	265	-	235	235

Mill Size: 300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	275	1690	1965	745	5665	6410	1725	6570	8295	1725	6930	8655
2.	40	340	380	110	1230	1340	260	1510	1770	260	1510	1770
3.	40	255	295	110	855	965	260	990	1250	260	1045	1305
4.	-	85	85	-	375	375	-	520	520	-	465	465

Mill Size: 600 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	465	2735	3200	1245	8755	10000	2735	10260	12995	2735	10305	13040
2.	70	515	585	185	1940	2125	410	2395	2805	410	2300	2710
3.	70	410	480	185	1315	1500	410	1540	1950	410	1545	1955
4.	-	105	105	-	625	625	-	855	855		755	755

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 144
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Groundwood Chem/Mech. Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 100 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	160	845	1,005	435	3,430	3,865	930	3,850	4,780	930	3,165	4,095
2.	25	190	215	65	810	875	140	950	1,090	140	775	915
3.	25	130	155	65	520	585	140	585	725	140	475	615
4.	-	60	60	-	290	290	-	365	365	-	300	300

Mill Size: 300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	275	1,690	1,965	745	6,585	7,330	1,725	7,490	9,215	1,725	6,080	7,805
2.	40	335	375	110	1,535	1,645	260	1,815	2,075	260	1,485	1,745
3.	40	255	295	110	990	1,100	260	1,125	1,385	260	915	1,175
4.	-	80	80	-	545	545	-	685	685	-	570	570

Mill Size: 600 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	465	2,735	3,200	1,245	10,315	11,560	2,735	11,820	14,555	2,735	9,255	11,990
2.	70	510	580	185	2,415	2,600	410	2,870	3,280	410	2,280	2,690
3.	70	410	480	185	1,550	1,735	410	1,775	2,185	410	1,390	1,800
4.	-	100	100	-	865	865	-	1,095	1,095	-	890	890

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 145
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Groundwood Thermo/Mech. Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 100 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	160	-	160	430	2300	2730	925	2585	3510	925	2300	3225
2.	25	-	25	65	500	565	140	605	745	140	500	640
3.	25	-	25	65	345	410	140	390	530	140	345	485
4.	-	-	-	-	155	155	-	215	215		155	155

Mill Size: 300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	275	-	275	745	4270	5015	1725	4875	6600	1725	4270	5995
2.	40	-	40	110	925	1035	260	1120	1380	260	925	1185
3.	40	-	40	110	640	750	260	730	990	260	640	900
4.	-	-	-	-	285	285	-	390	390		285	285

Mill Size: 500 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	465	-	465	1245	6275	7520	2735	7255	9990	2735	6275	9010
2.	70	-	70	185	1395	1580	410	1700	2110	410	1395	1805
3.	70	-	70	185	945	1130	410	1095	1505	410	945	1355
4.	-	-	-	-	450	450	-	605	605	-	450	450

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

TAble 146
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Groundwood Thermo/Mech Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 100 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	160	--	160	430	2730	3160	925	3015	3940	925	2730	3655
2.	25	--	25	65	655	720	140	760	900	140	655	795
3.	25	--	25	65	410	475	140	455	595	140	410	550
4.	-	--	-	-	245	245	-	305	305	-	245	245

Mill Size: 300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	275	--	275	745	5050	5795	1725	5655	7380	1725	5050	6775
2.	40	--	40	110	1165	1275	260	1360	1620	260	1165	1425
3.	40	--	40	110	760	870	260	850	1110	260	760	1020
4.	-	--	-	-	405	405	--	510	510	-	405	405

Mill Size: 600 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	465	--	465	1245	7700	8945	2735	8680	11,415	2735	7700	10,435
2.	70	--	70	185	1770	1955	410	2075	2,485	410	1770	2,180
3.	70	--	70	185	1155	1340	410	1305	1,715	410	1155	1,565
4.	-	--	-	-	615	615	--	770	770	--	615	615

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 147

AERATED STABILIZATION BASIN

EFFLUENT TREATMENT COSTS

Groundwood C-M-N Subcategory

(All Costs in Thousands of Dollars)

Mill Size: 75 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	[illegible]	[illegible]	1065	1. 410	2645	3055	1. 830	3000	3830	1. 830	3130	3960
2.	20	200	220	2. 60	575	635	2. 125	695	820	2. 125	700	825
3.	20	140	160	3. 60	400	460	3. 125	455	580	3. 125	470	595
4.	-	60	60	4. -	175	175	4. -	240	240	4. -	230	230

Mill Size: 150 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	175	1355	1530	1. 400	3740	4220	1. 1125	4325	5450	1. 1125	4400	5525
2.	25	280	305	2. 70	805	875	2. 170	995	1165	2. 170	950	1120
3.	25	205	230	3. 70	560	630	3. 170	650	820	3. 170	660	830
4.	-	75	75	4. -	245	245	4. -	345	345	4. -	290	290

Mill Size: 500 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	380	2990	3370	1. 1025	7425	8450	1. 2360	8755	11,115	1. 2360	8565	10,925
2.	55	555	610	2. 155	1610	1765	2. 350	2015	2,365	2. 350	1960	2,310
3.	55	450	505	3. 155	1115	1270	3. 350	1315	1,665	3. 350	1285	1,635
4.	-	105	105	4. -	495	495	4. -	700	700	4. -	675	675

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 148
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Groundwood C-M-N Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 75 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	150	915	1065	410	2990	3400	830	3345	4175	830	2505	3335
2.	20	200	220	60	690	750	125	815	940	125	605	730
3.	20	140	160	60	450	510	125	505	630	125	375	500
4.	-	60	60	-	240	240	-	310	310	-	230	230

Mill Size: 150 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	175	1355	1530	480	4370	4850	1125	4960	6085	1125	3735	4860
2.	25	280	305	70	990	1060	170	1180	1350	170	885	1055
3.	25	205	230	70	655	725	170	745	915	170	565	735
4.	-	75	75	-	335	335	-	435	435	-	320	320

Mill Size: 500 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	380	2990	3370	1025	8895	9920	2360	10,225	12,585	2360	7445	9805
2.	55	555	610	155	1955	2110	350	2,365	2,715	350	1760	2110
3.	55	450	505	155	1335	1490	350	1,535	1,885	350	1115	1465
4	-	105	105	-	620	620	-	830	830	-	645	645

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 149

AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Groundwood Fine Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 150 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	400	1230	1630	610	3435	4095	1244	4060	5315	1255	4290	5545
2.	60	255	315	90	745	835	190	930	1120	190	940	1130
3.	60	185	245	90	525	615	190	610	800	190	645	835
4.	-	70	70	-	220	220	-	320	320	-	295	295

Mill Size: 300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	585	1945	2530	880	5110	5990	1860	6020	7880	1860	6295	8155
2.	90	380	470	130	1105	1235	280	1395	1675	280	1370	1650
3.	90	295	385	130	770	900	280	910	1190	280	945	1225
4.	-	85	85	-	335	335	-	485	485	-	425	425

Mill Size: 550 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	930	2935	3865	1385	7375	8760	2790	8755	11,545	2790	8925	11,715
2.	140	545	685	210	1585	1795	420	2005	2,425	420	1985	2,405
3.	140	440	580	210	1105	1315	420	1315	1,735	420	1340	1,760
4.	-	105	105	-	480	480	-	690	690	-	645	645

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 150
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Groundwood Fine Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 150 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	400	1230	1630	610	4005	4615	1,244	4580	5824	1,255	2865	4120
2.	60	255	415	90	1000	1090	190	1185	1375	190	835	1025
3.	60	285	345	90	705	795	190	790	980	190	530	720
4.	-	70	70	-	295	295	-	395	395	-	305	305

Mill Size: 300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	585	1,945	2,530	880	6,010	6,890	1,860	6,920	8,780	1,860	5,340	7,200
2.	90	380	470	130	1,325	1,455	280	1,605	1,885	280	1,275	1,555
3.	90	295	385	130	905	1,035	280	1,040	1,320	280	800	1,080
4.	-	85	85	-	420	420	-	565	565	-	475	475

Mill Size: 550 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	930	2,935	3,865	1,385	8,705	10,090	2,790	10,085	12,875	2,790	7,685	10,475
2.	140	545	685	210	1,900	2,110	420	2,320	2,740	420	1,825	2,245
3.	140	440	580	210	1,305	1,515	420	1,515	1,935	420	1,155	1,575
4.	-	105	105	-	595	595	-	805	805	-	670	670

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

TAble 151

AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS

Soda Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	825	3,150	3,975	1,195	7,525	8,720	3,070	9,200	12,270	3,070	7,555	10,625
2.	125	585	710	180	1,685	1,865	460	2,170	2,630	460	1,715	2,175
3.	125	470	595	180	1,125	1,305	460	1,380	1,840	460	1,135	1,595
4.	-	115	115	-	560	560	-	790	790	-	580	580

Mill Size: 700 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1,705	5,615	7,320	2,355	12,640	14,995	5,500	15,295	20,795	5,500	12,395	17,895
2.	255	1,020	1,275	355	2,935	3,290	825	3,745	4,570	825	2,910	3,735
3.	255	845	1,100	355	1,900	2,255	825	2,300	3,125	825	1,860	2,685
4.	-	175	175	-	1,035	1,035	-	1,445	1,445	-	1,050	1,050

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 152
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Soda Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 300 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	825	3,150	3,975	1. 1,195	8,985	10,180	1. 3,070	10,660	13,730	1. 3,070	6,690	9,760
2.	125	585	710	2. 180	2,060	2,240	2. 460	2,545	3,005	2. 460	1,645	2,105
3.	125	470	595	3. 180	1,345	1,525	3. 460	1,600	2,060	3. 460	1,005	1,465
4.	-	115	115	4. -	715	715	4. -	945	945	4. -	640	640

Mill Size: 700 TPD

	1973			1977			1983			NSPS		
	Int	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	1,705	5,615	7,320	1. 2,355	15,170	17,525	1. 5,500	17,825	23,325	1. 5,500	10,695	16,195
2.	255	1,020	1,275	2. 355	3,545	3,900	2. 825	4,355	5,180	2. 825	2,610	3,435
3.	255	845	1,100	3. 355	2,280	2,635	3. 825	2,680	3,505	3. 825	1,605	2,430
4.	-	175	175	4. -	1,265	1,265	4. -	1,675	1,675	4. -	1,005	1,005

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

3. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 153
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS

Non-Integrated Fine Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 50 TPD

	1978			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	165	-	165	300	675	975	400	1,010	1,410			
2.	25	-	25	45	180	225	60	290	350			
3.	25	-	25	45	105	150	60	155	215			
4.	-	-	-	-	75	75	-	135	135			

Mill Size: 100 TPD

	1978			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	230	-	230	415	1,190	1,605	575	1,825	2,400	575	2,210	2,785
2.	35	-	35	60	290	350	85	460	545	70	515	585
3.	35	-	35	60	180	240	85	275	360	70	335	405
4.	-	-	-	-	110	110	-	185	185	-	180	180

Mill Size: 250 TPD

	1978			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	540	-	540	935	2,060	2,995	1,245	3,275	4,520	1,245	3,740	4,985
2.	80	-	80	170	470	610	185	795	980	185	835	1,020
3.	80	-	80	140	310	450	185	495	680	185	560	745
4.	-	-	-	-	160	160	-	300	300	-	275	275

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 154
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Non-Integrated Fine Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 30 TPD

	1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	300	675	975	400	1,150	1,550			
2.	45	180	225	60	325	385			
3.	45	105	150	60	180	240			
4.	-	75	75	-	145	145			

Mill Size: 100 TPD

	1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	415	1,190	1,605	575	2,200	2,775	575	1,910	2,485
2.	60	290	350	85	555	640	70	480	550
3.	60	180	240	85	335	420	70	290	360
4.	-	110	110	-	220	220	-	190	190

Mill Size: 280 TPD

	1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	935	2,060	2,995	1,245	4,215	5,460	1,245	3,310	4,555
2.	140	470	610	185	980	1,165	185	795	980
3.	140	310	450	185	635	820	185	500	685
4.	-	160	160	-	345	345	-	295	295

Int.: Internal Cost

Ext.: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 155
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS

Non-Integrated Tissue Subcategory
(All Costs in Thousands of Dollars)
Mill Size: 15 TPD

	1973			1977			1983				NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total		Int.	Ext.	Total
1.	190	-	190	410	560	970	490	745	1,235	1.			
2.	30	-	30	60	150	210	75	220	295	2.			
3.	30	-	30	60	85	145	75	115	190	3.			
4.	-	-	-	-	65	65	-	105	105	4.			

Mill Size: 35 TPD

	1973			1977			1983				NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total		Int.	Ext.	Total
1.	290	-	290	620	835	1,455	720	1,155	1,875	1.			
2.	45	-	45	95	210	305	110	315	425	2.			
3.	45	-	45	95	125	220	110	175	285	3.			
4.	-	-	-	-	85	85	-	140	140	4.			

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 155
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Non-Integrated Tissue Subcategory (Continued)
(All Costs in Thousands of Dollars)
Mill Size: 110 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	335	-	335	720	1,495	2,215	890	2,215	3,105	890	2,375	3,265
2.	50	-	50	110	350	460	135	565	700	135	545	680
3.	50	-	50	110	225	335	135	335	470	135	355	490
4.	-	-	-	-	125	125	-	230	230	-	190	190

Mill Size: 450 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	855	-	855	1,860	3,350	5,210	2,275	5,130	7,405	2,275	5,220	7,495
2.	130	-	130	280	755	1,035	340	1,250	1,590	340	1,355	1,695
3.	130	-	130	280	505	785	340	770	1,110	340	950	1,290
4.	-	-	-	-	250	250	-	480	480	-	405	405

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 156

WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS

Non-Integrated Tissue Subcategory
(All Costs in Thousands of Dollars)

Mill Size: 15 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	190	-	190	410	560	970	490	910	1,400			1.
2.	30	-	30	60	150	210	75	260	335			2.
3.	30	-	30	60	85	145	75	135	210			3.
4.	-	-	-	-	65	65	-	125	125			4.

Mill Size: 35 TPD

	1973			1977			1983			NSPS		
	Int	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	290	-	290	620	835	1,455	720	1,440	2,160			1.
2.	45	-	45	95	210	305	110	390	500			2.
3.	45	-	45	95	125	220	110	220	330			3.
4.	-	-	-	-	85	85	-	170	170			4.

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 156 cont'd
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Non-Intergrated Tissue Subcatetory Con't
(All Costs in Thousands of Dollars)
Mill Size: 110 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	335	-	335	720	1,495	2,215	890	2,870	3,760	890	2,265	3,155
2.	50	-	50	110	350	460	135	695	830	135	535	670
3.	50	-	50	110	225	335	135	430	565	135	340	475
4.				-	125	125	-	265	265	-	195	195

Mill Size: 450 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	855	-	855	1,860	3,350	5,210	2,275	6,910	9,185	2,275	5,220	7,495
2.	130	-	130	280	755	1,035	340	1,575	1,915	340	1,190	1,530
3.	130	-	130	280	505	785	340	1,040	1,380	340	785	1,125
4.	-	-	-	-	250	250	-	535	535	-	405	405

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 157

AERATED STABILIZATION BASIN

EFFLUENT TREATMENT COSTS

Non-Integrated Tissue (fwp) Subcategory

(All Costs in Thousands of Dollars)

Mill Size: 15 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	190	-	190	410	810	1,220	490	920	1,410			
2.	30	-	30	60	205	265	75	255	330			
3.	30	-	30	60	125	185	75	140	215			
4.	-	-	-	-	80	80	-	115	115			

Mill Size: 35 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	290	-	290	620	1,225	1,845	720	1,425	2,145			
2.	45	-	45	95	290	385	110	370	480			
3.	45	-	45	95	185	280	110	215	325			
4.	-	-	-	-	105	105	-	155	155			

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 157 cont'd
AERATED STABILIZATION BASIN
EFFLUENT TREATMENT COSTS
Non-Integrated Tissue (BW_T) Subcategory (Continued)
(All Costs in Thousands of Dollars)
Mill Size: 110 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	330	-	330	720	2,280	3,000	890	2,710	3,600	890	2,870	3,760
2.	50	-	50	110	515	625	135	660	795	135	635	770
3.	50	-	50	110	345	455	135	410	545	135	430	565
4.	-	-	-	-	170	170	-	250	250	-	205	205

Mill Size: 450 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	855	-	855	1,860	5,370	7,230	2,275	6,510	8,785	2,275	6,585	8,860
2.	130	-	130	280	1,180	1,460	340	1,525	1,865	340	1,475	1,815
3.	130	-	130	280	805	1,085	340	975	1,315	340	990	1,330
4.	-	-	-	-	375	375	-	550	550	-	485	485

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 158
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS

Non-Integrated Tissue (fwp) Subcategory
(All Costs in Thousands of Dollars)

Mill Size: 15 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	190	-	190	410	1,070	1,480	490	1,180	1,670			
2.	30	-	30	60	280	340	75	330	405			
3.	30	-	30	60	160	220	75	175	250			
4.	-	-	-	-	120	120	-	155	155			

Mill Size: 35 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	290	-	290	620	1,615	2,235	720	1,815	2,535			
2.	45	-	45	95	395	490	110	475	585			
3.	45	-	45	95	245	340	110	275	385			
4.	-	-	-	-	150	150	-	200	200			

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 158 cont'd
WASTE ACTIVATED SLUDGE
EFFLUENT TREATMENT COSTS
Non-Integrated Tissue (fwp) Subcategory Con't
(All Costs in Thousands of Dollars)
Mill Size: 110 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	330	-	330	720	3,150	3,870	890	3,580	4,470	890	2,540	3,430
2.	50	-	50	110	710	820	135	855	990	135	645	780
3.	50	-	50	110	475	585	135	540	675	135	410	545
4.	-	-	-	-	235	235	-	315	315	-	235	235

Mill Size: 450 TPD

	1973			1977			1983			NSPS		
	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total	Int.	Ext.	Total
1.	855	-	855	1,860	7,230	9,090	2,275	8,370	10,645	2,275	5,935	8,210
2.	130	-	130	280	1,560	1,840	340	1,905	2,245	340	1,415	1,755
3.	130	-	130	280	1,085	1,365	340	1,255	1,595	340	890	1,230
4.	-	-	-	-	475	475	-	650	650	-	525	525

Int: Internal Cost

Ext: External Cost

1. Total Investment Cost

2. Total Operating Cost

3. Depreciation & Interest

4. Operation & Maintenance

Table 159

INTERNAL EFFLUENT TREATMENT COSTS FOR NSPS
(Costs in Thousands of Dollars)

Subcategory	Size of Mill Tons/day	Capital Cost	Depreciation and Interest
Sulfite	160	1165	175
	530	2565	385
Dissolving Sulfite	550	1385	210
Deink	80	555	85
	230	825	125
	500	1450	220
Dissolving Kraft	600	1935	290
	1000	2640	395
Market Kraft	350	1330	200
	700	1990	300
BCT Kraft	250	1745	260
	670	3250	485
	1300	5075	760
Fine Kraft	250	1730	260
	670	3110	465
	1300	4790	720
Goundwood Chemi/Mech	100	595	90
	300	1135	170
	600	1815	270
Goundwood Thermo/Mech	100	590	90
	300	1130	170
	600	1810	270
Goundwood C-M-N	75	525	80
	150	720	110
	500	1555	235
Goundwood Fine	150	820	125
	300	1235	185
	550	1865	280
Soda	300	1780	265
	700	3140	470
Non-Integrated Fine	30	295	45
	100	435	65
	280	940	140
Non-Integrated Tissue	15	370	55
	35	540	80
	110	675	100
	450	1735	250
Non-Integrated Tissue (fwp)	15	365	55
	35	540	80
	110	675	100
	450	1735	260

It is assumed that the existing conveyor receiving wood from the flume will receive the wood from the new log conveyors. Some modification to the existing transfer section is included.

Debris (rocks, etc.) which were removed in the flume by a rock pit and grit chamber systems will be carried into the barking drums. Some removal takes place through the bark slots in the barking drums. A rock drop out station is included in the woodroom conveyor system, before the chippers, to remove large rocks.

The bark burned for fuel will have a higher concentration of non-combustible material using mechanical yard conveyors.

2. Use of Steam in Drum Barkers

This cost estimate is based on processing 1200 cords per day of rough 4 to 8 foot pulpwood, softwood and hardwood, in three barking drums.

In converting from use of hot water to steam in the barking drums, the bark conveyors under the drums were replaced. The bark press is modified to handle bark during the sap period.

It is assumed that the wood handling system preceeding and following the barking drums is the same whether steam or water is used in debarking.

A steam header, from an existing steam main in the woodroom, is run in front of the inlet to each drum. Small branch lines inject steam into the drums. The drumming rate using steam will be slightly lower than with the use of hot water. Cutting bark slots in a solid inlet section is included.

3. Knots Collection and Disposal

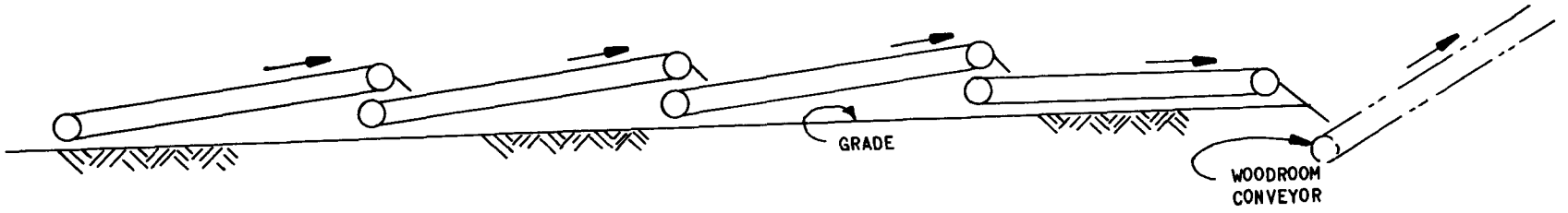
Most mills have a knot handling system and return the knots to the digester. The mills that cannot recycle the knots dispose of them through incineration with bark or haul to landfill. This estimate was based on conveying the knotter rejects to a vibrating screen with showers to recover loose fibers and liquor, then to a container for disposal by landfill.

4. Fourth Stage Brown Stock Washer

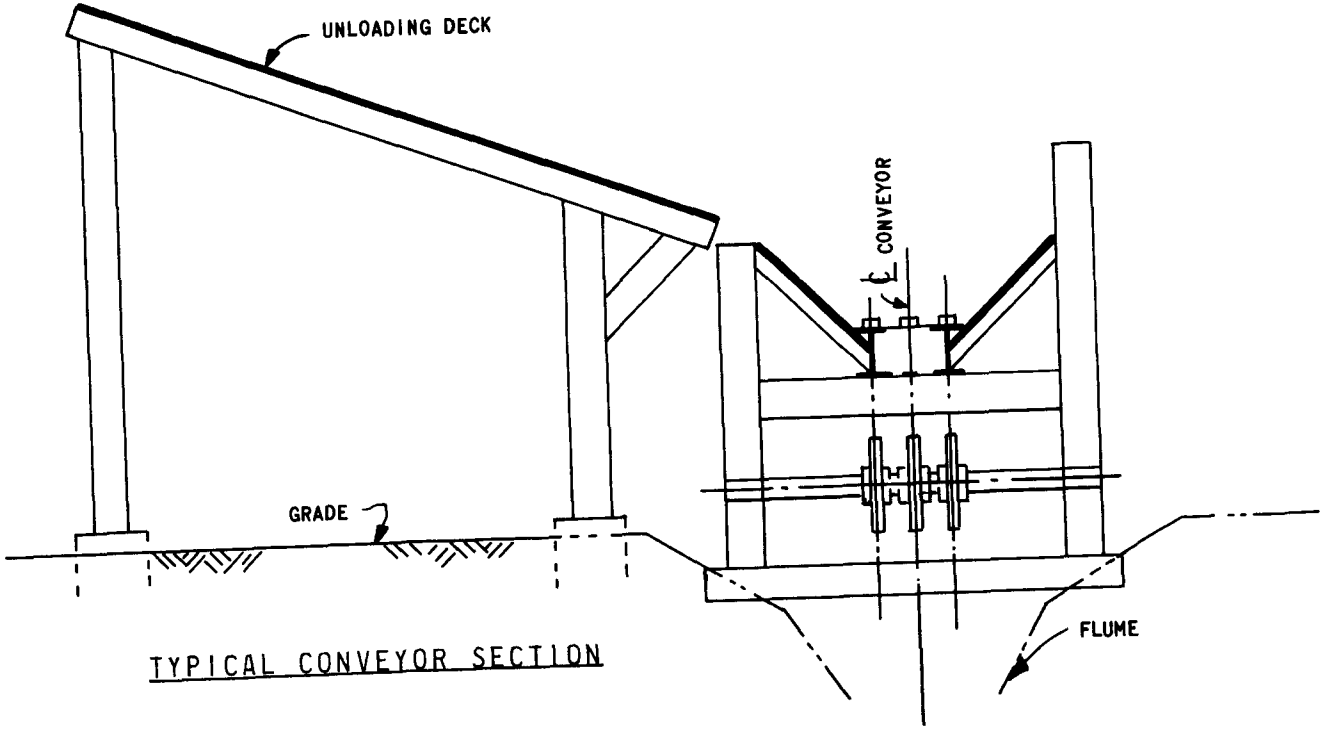
Essentially all kraft mills with recovery have an equivalence of three stages of brown stock drum washing. The amount of liquor held in the pulp after brown stock washing increases as bottlenecks are eliminated and production is pushed beyond design capacity. The liquor carried over is subsequently washed out of the pulp and sewered with the brown stock screen rejects and decker filtrate. The addition of a fourth stage of washing may be necessary to reduce the liquor lost to the sewer to an acceptable level. A vacuum filter washer was used in the estimate, and the system includes a submerged repulper, filtrate

Figure 65A

FLUME REPLACED BY MECHANICAL CONVEYOR



OUTLINE ELEVATION OF CONVEYORS



TYPICAL CONVEYOR SECTION

Figure 65A (Cont'd)

USE OF STEAM IN DRUM BARKERS

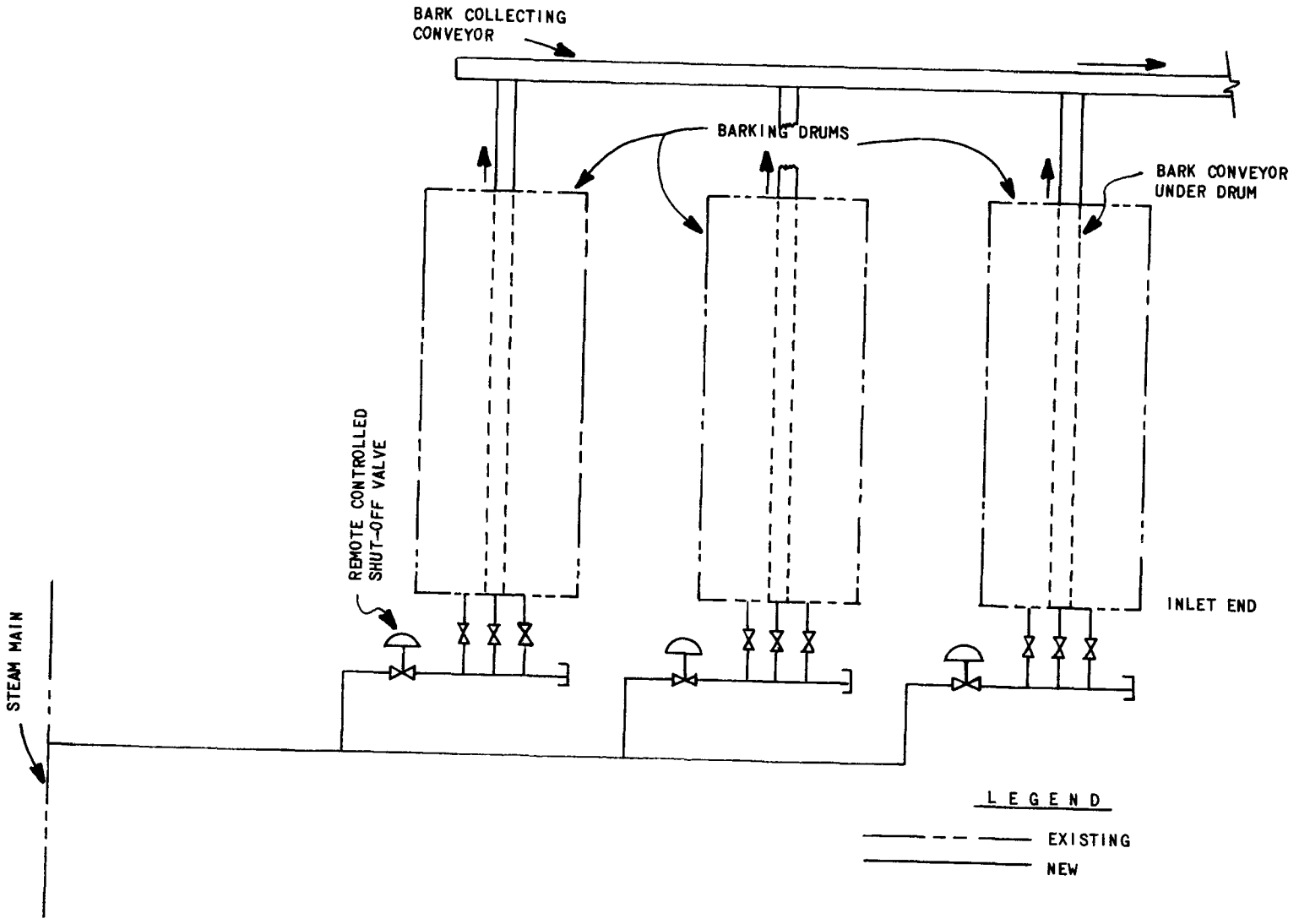
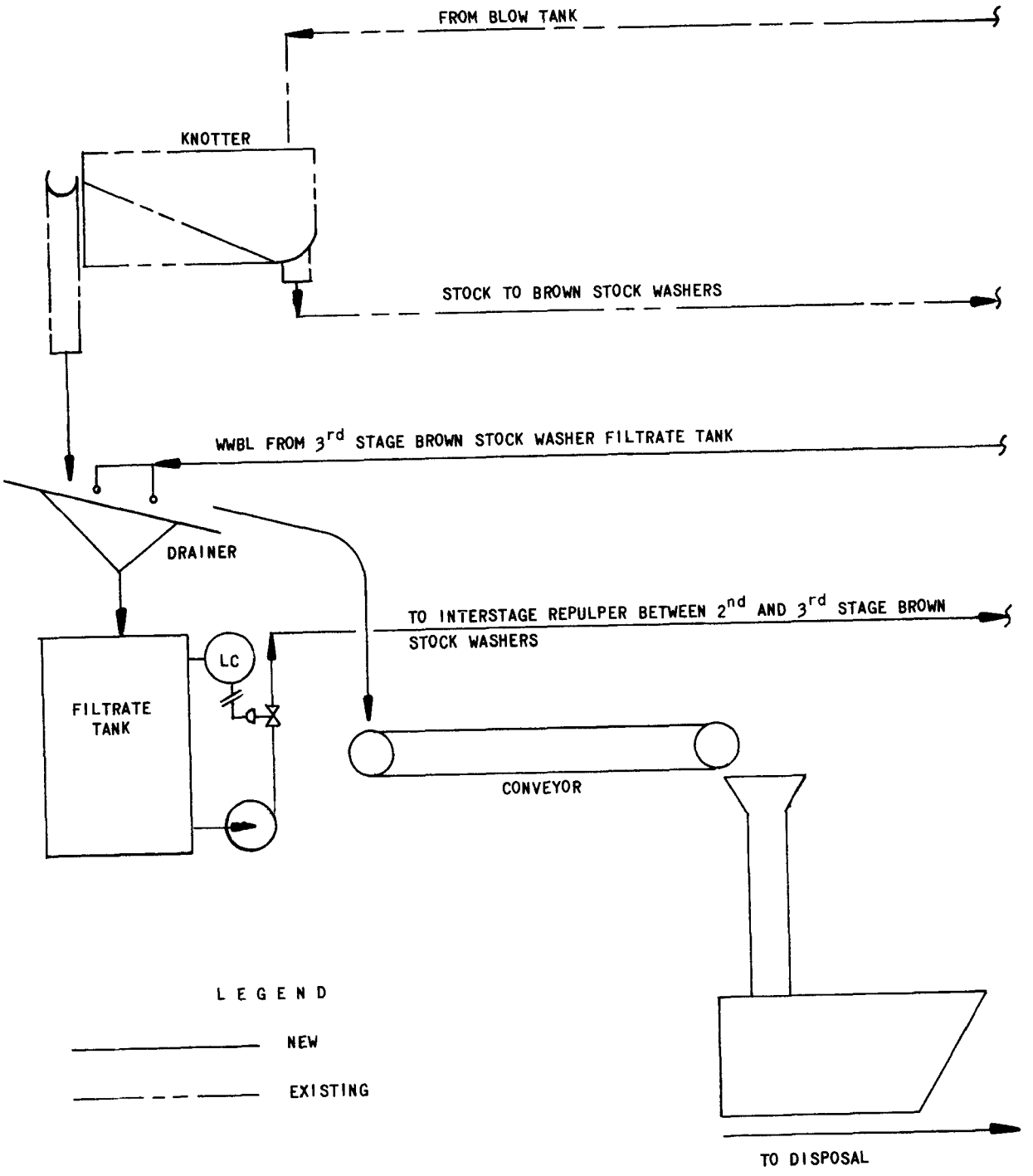


Figure 65A (Cont'd)

KNOTS COLLECTING AND DISPOSAL



tank and pump, hood extension and exhaust fan and stock conveyor to storage. It was assumed that there is space available on the existing washer operating floor for the new washer.

5. Decker Filtrate for Brown Stock Washer Showers

To recover a portion of the fiber and caustic in the decker filtrate which overflows to the sewer, a pump is added to the existing decker filtrate tank and used to pump decker filtrate to the brown stock washers. A new heat exchanger is included in the estimate.

6. Close-up Screen Room

It was assumed that the base mill sewered its secondary screen rejects and its secondary cleaner rejects.

In closing up the screen room, a third stage of cleaning was added and the existing atmospheric screens were replaced with pressure screens. The equipment required to refine the secondary screen rejects and return them to the secondary screen is included. The new screens are located on a new mezzanine inside the existing building. A new primary screens supply pump is included also.

7. Pulp Mill Spill Collection from Washers

The spill collection system collects any overflow that occurs at the brown stock washers, brown stock decker, or bleach plant washers and pipe the overflows to a central collection point. A pump is installed at the collection tank to return the spills at a controlled rate back into the system as shown on the flow diagram; one tank is used for the bleach washers and one for brown stock decker and washers. Two separate tanks are required as the spills from the bleach washers cannot be put back into the brown stock for fear of getting chlorides into the black liquor recovery system. The system is designed for a CEDED bleach sequence. Vat overflows are designed to handle 100% of production flows. The collection tanks are sized for 10 minute retention of production at 1% consistency.

8. Pulp Mill Spill Collection from Tanks, Equipment, and Drains

The spill collection system collects overflows from the washer seal tanks, digester area equipment and tanks, all of the floor drains in the pulp mill, and pipe them to a central collection area. Pumps at the collection tanks pump the spills back into the system at a controlled rate. Spills from the digester area are returned to the suction of the first stage washer recirculation pump as shown on the flow diagram. Spills collected from the floor drains are screened and piped to a dirty water tank which has fresh water made up for low level control. The solids go to a trash tank for hauling to landfill. Should a major stock spill occur, it is pumped to a spill collection tank.

Figure 65A (Cont'd)

DECKER FILTRATE FOR BROWN STOCK WASHERS SHOWERS

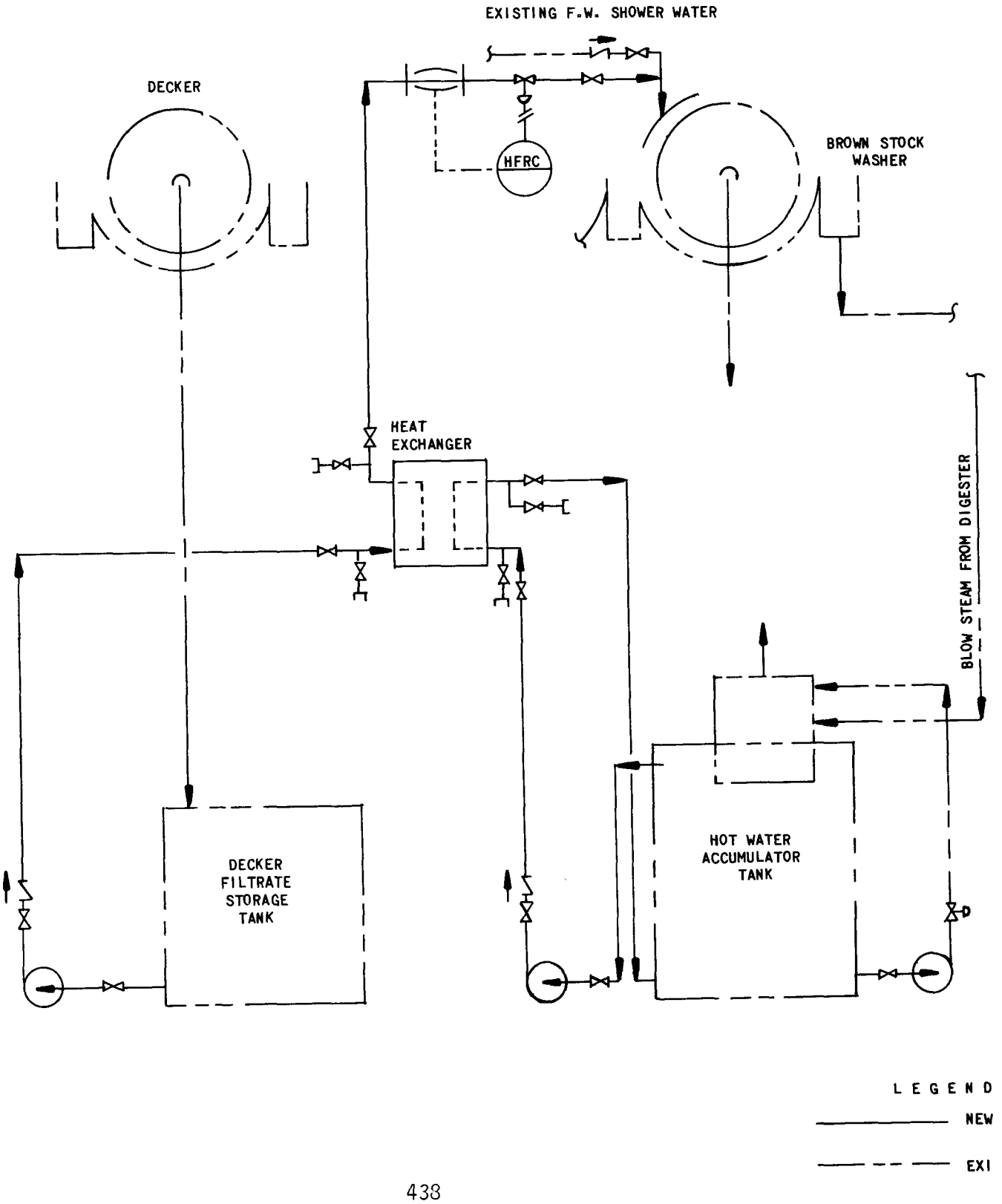


Figure 65A (Cont'd)

SCREEN ROOM CLOSE-UP

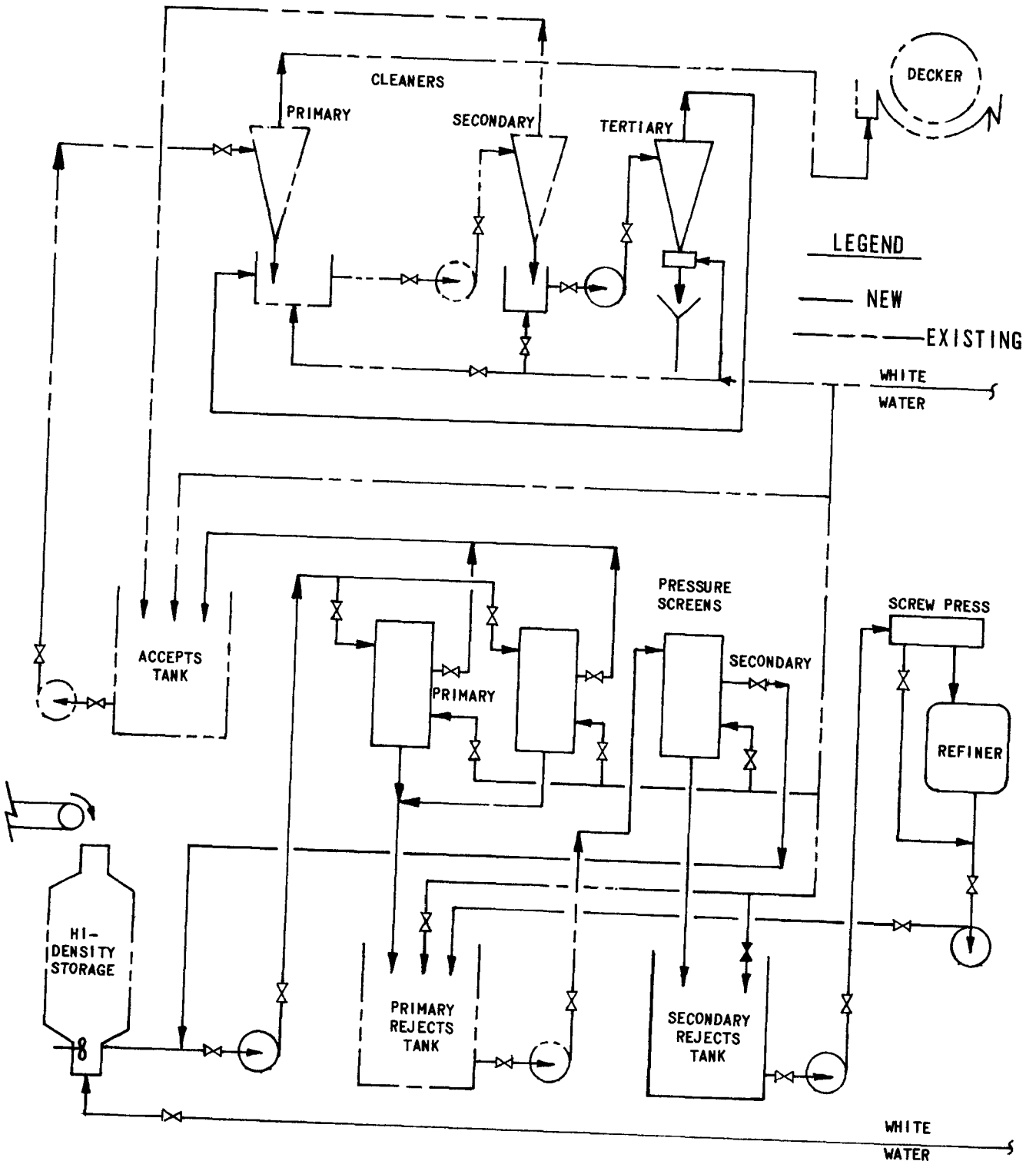


Figure 65A (Cort'd)

BLEACHED KRAFT MILL
SPILL COLLECTION AND REUSE

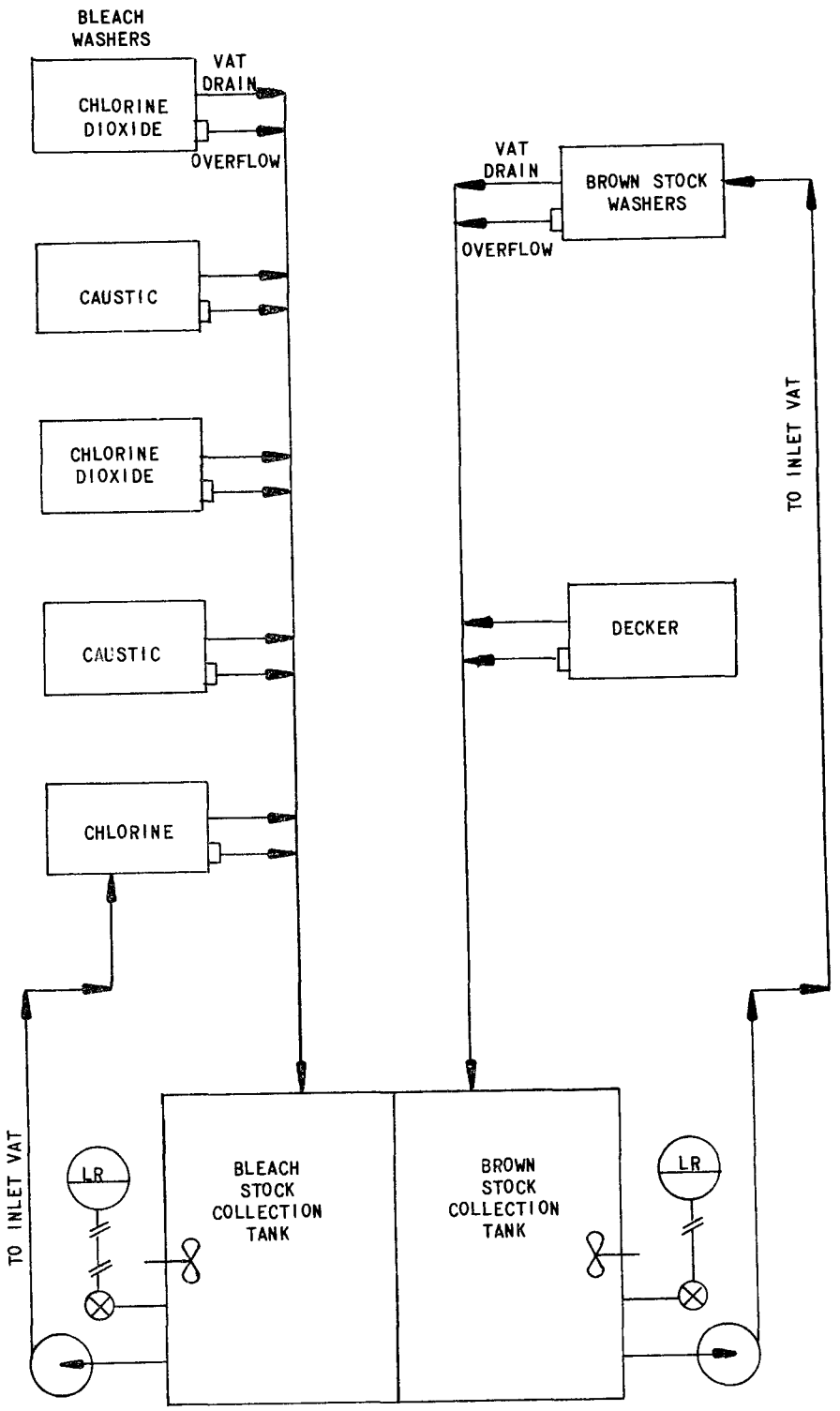


Figure 65A (Cont'd)

SULFITE PULP MILL SPILL
COLLECTION AND REUSE

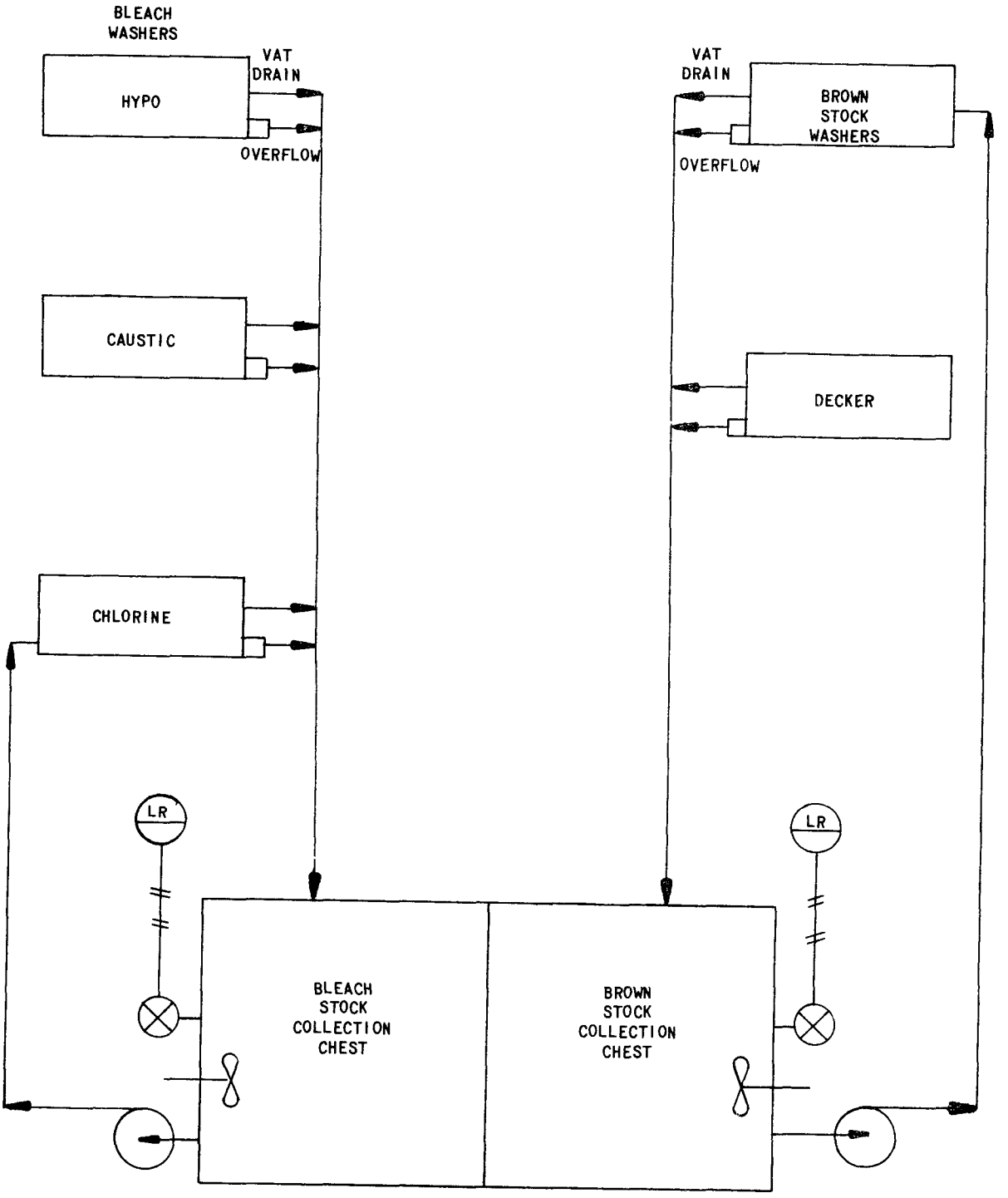


Figure 65A (Cont'd)

GROUNDWOOD PULP MILL SPILL
COLLECTION AND REUSE

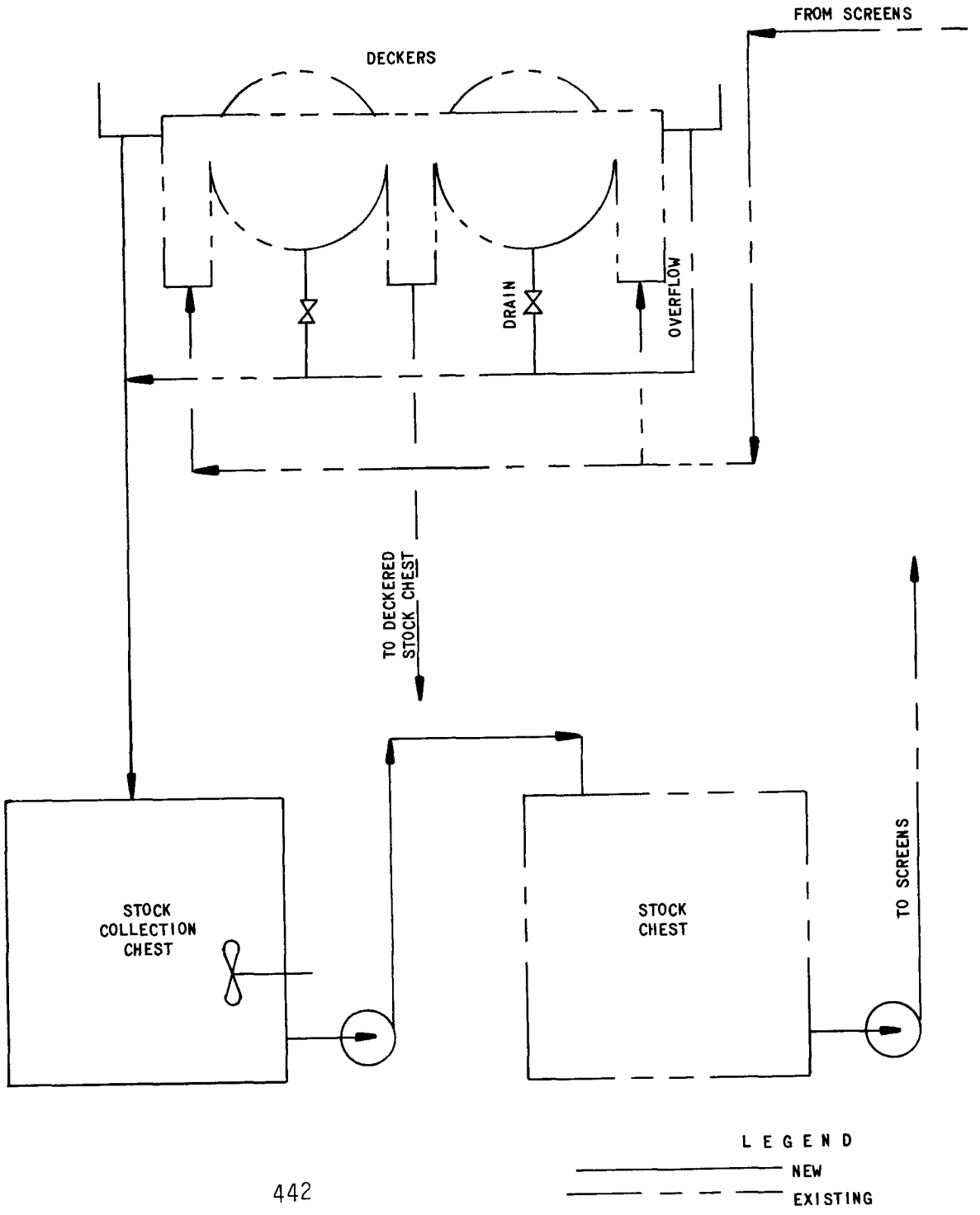
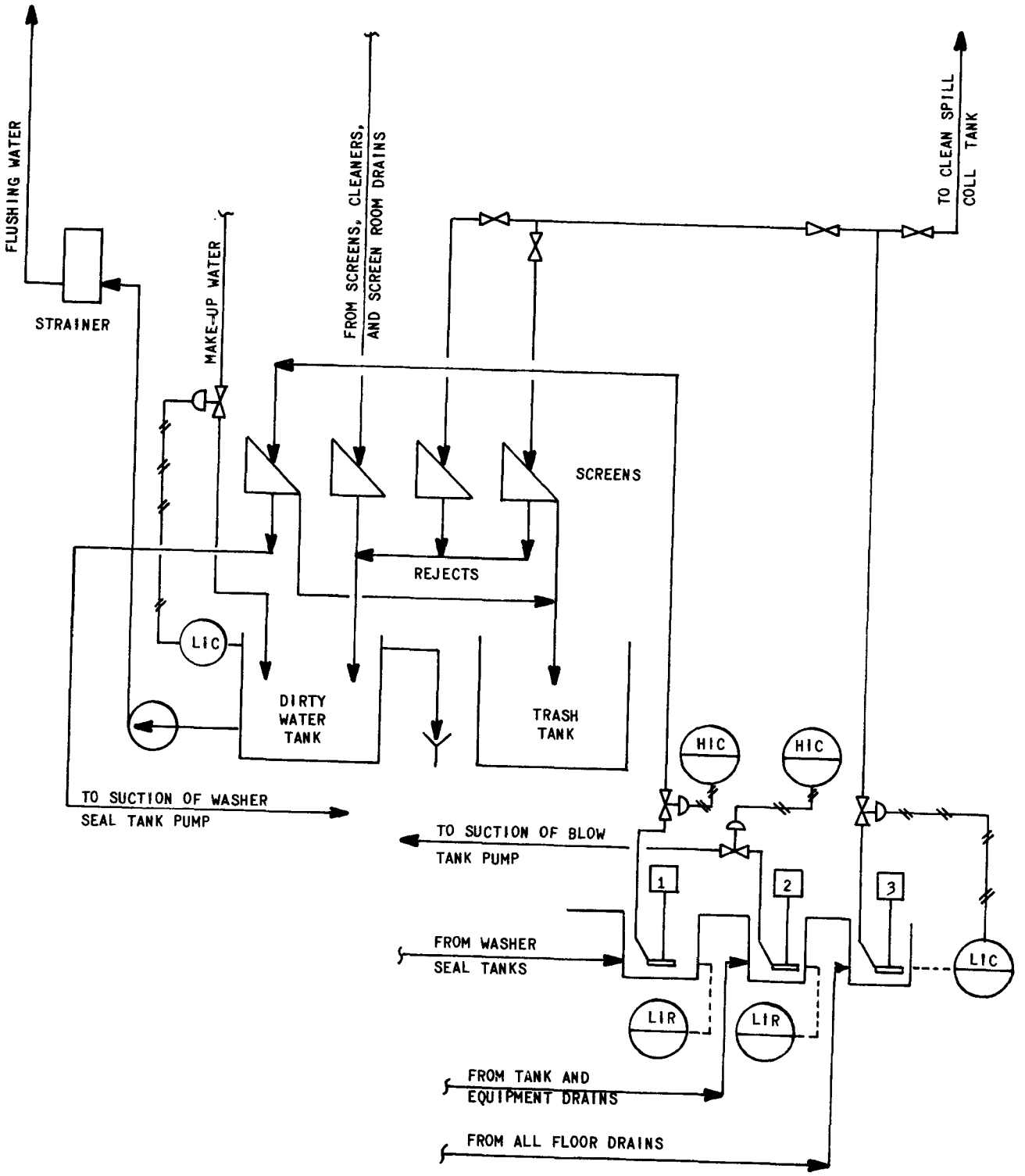


Figure 65A (Cont'd)

PULP MILL SPILL COLLECTION SYSTEMS



9. Jump Stage Countercurrent Washing--

A jump stage countercurrent washing system was estimated for reducing the effluent flow from the bleach plant. The basic mill bleaching sequence used for the kraft and soda subcategories was CEDED. The filtrate from the second chlorine dioxide washer is used on the showers for the first chlorine dioxide washer and the filtrate from the first chlorine dioxide washer is used on the showers for the chlorine washer. The filtrate from the second caustic washer is used on the first caustic washer. The overflow from the filtrate tanks are tied-in the same way, with only the first caustic and chlorination seal boxes overflowing to the sewer.

A displacement ratio of 1.2 to 1 is used on all washers and the consistency of the vat leaving the washers at 12%. The inlet washer vat consistency is 1%. Filtrate from chlorine washer is used for dilution after the brown stock decker.

10. Evaporator Surface Condenser--

In this installation, the existing barometric seal tank is reused as a surface condenser seal tank. The barometric air ejectors are retained as standby and for start-up of the system.

The new surface condenser and two-stage steam air ejector set with intercondenser are mounted on a steel structure, outdoors, adjacent to the evaporator building. The level at which the ejectors are located is enclosed and roofed over for weather protection.

A new cooling water pump will pump mill process water through the condenser and return it to the process water main. In summer, the cooling water may become too hot to return to process. The system is on temperature control to keep the process water main temperature within bounds by sewering all or part of the cooling water. Piping is provided to return the sewered water to a mill clean warm water outfall. A new condensate pump is used to pump condensate from the seal tank to the mill sewer.

11. Steam Stripping Condensates and Reuse--

The system estimated is designed to treat the digester contaminated condensates and half of the evaporators' combined condensate from the concentrated liquor end. The stripping column for a 400 TPD mill was estimated to be 5 foot diameter with 10 plates. A product cooler or condensate supply heater is included. The stripped gases are incinerated in the lime kiln, and the steam supply line is sized for an average of 10% steam requirement. The stripped condensate is pumped to storage. Use of the condensate is not included as part of this estimate.

12. Evaporators Boil Out Tank--

Figure 65A (cont'd)

JUMP STAGE COUNTERCURRENT
WASHING IN BLEACH PLANT

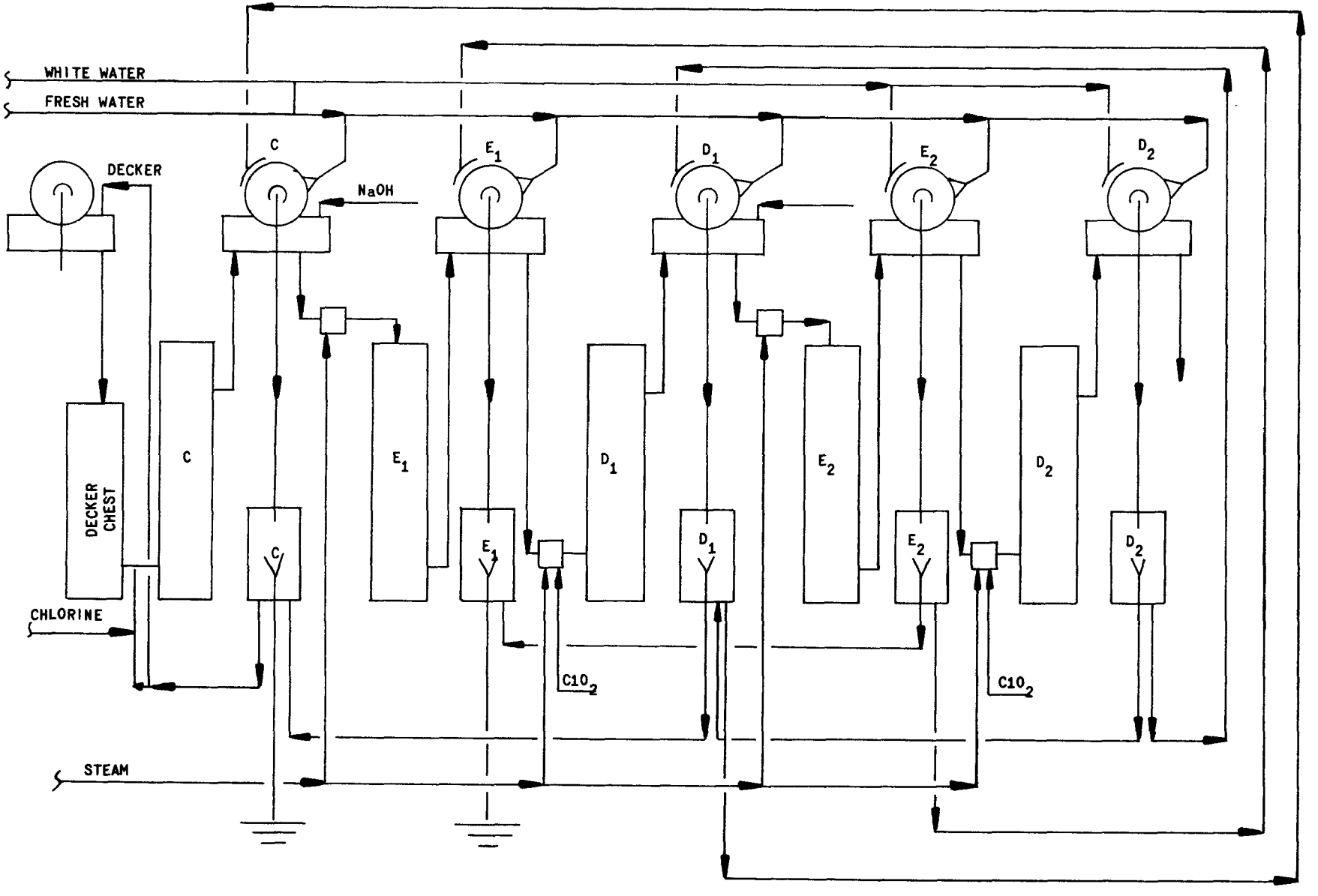


Figure 65A (Cont'd)

SURFACE CONDENSER

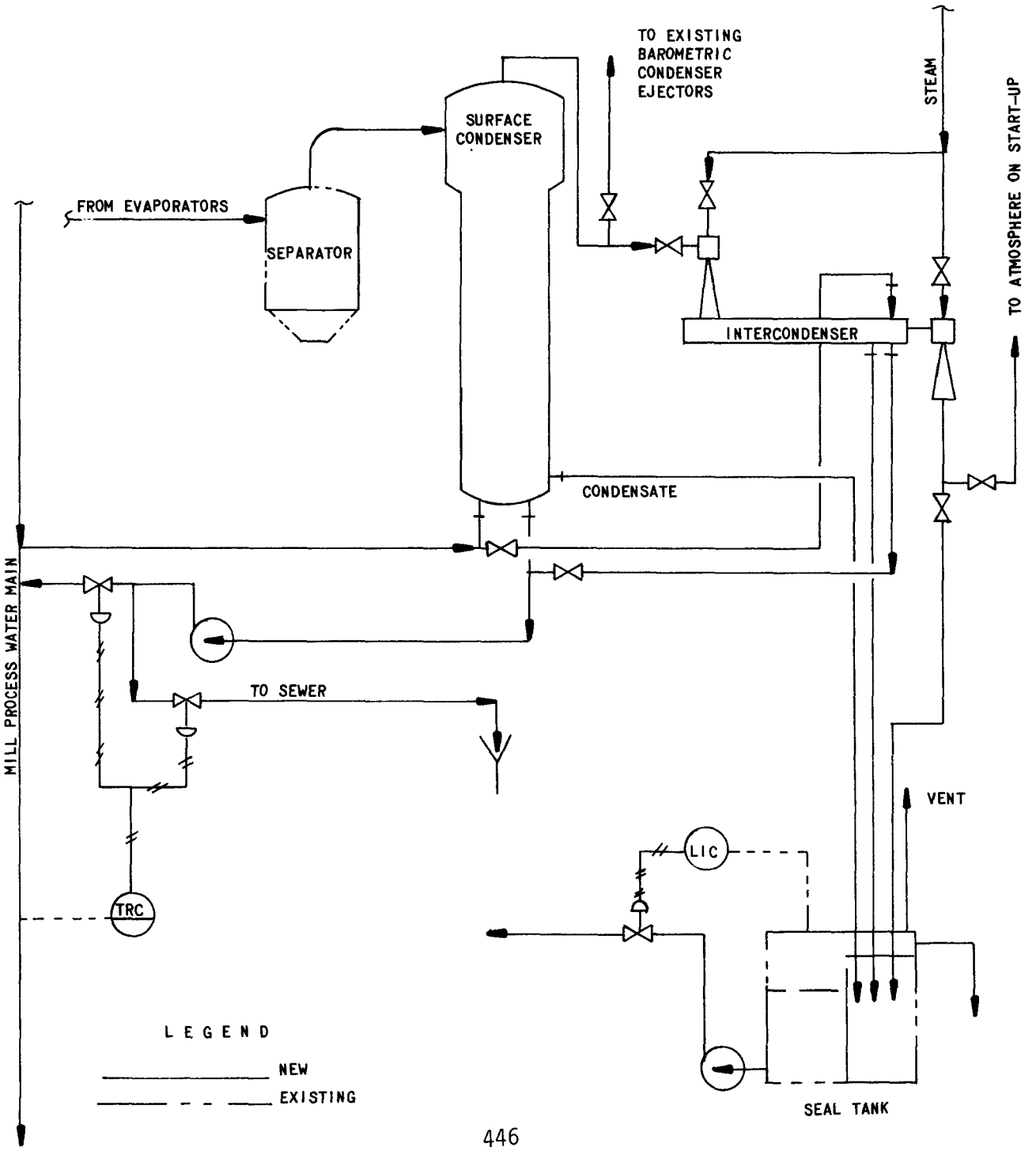
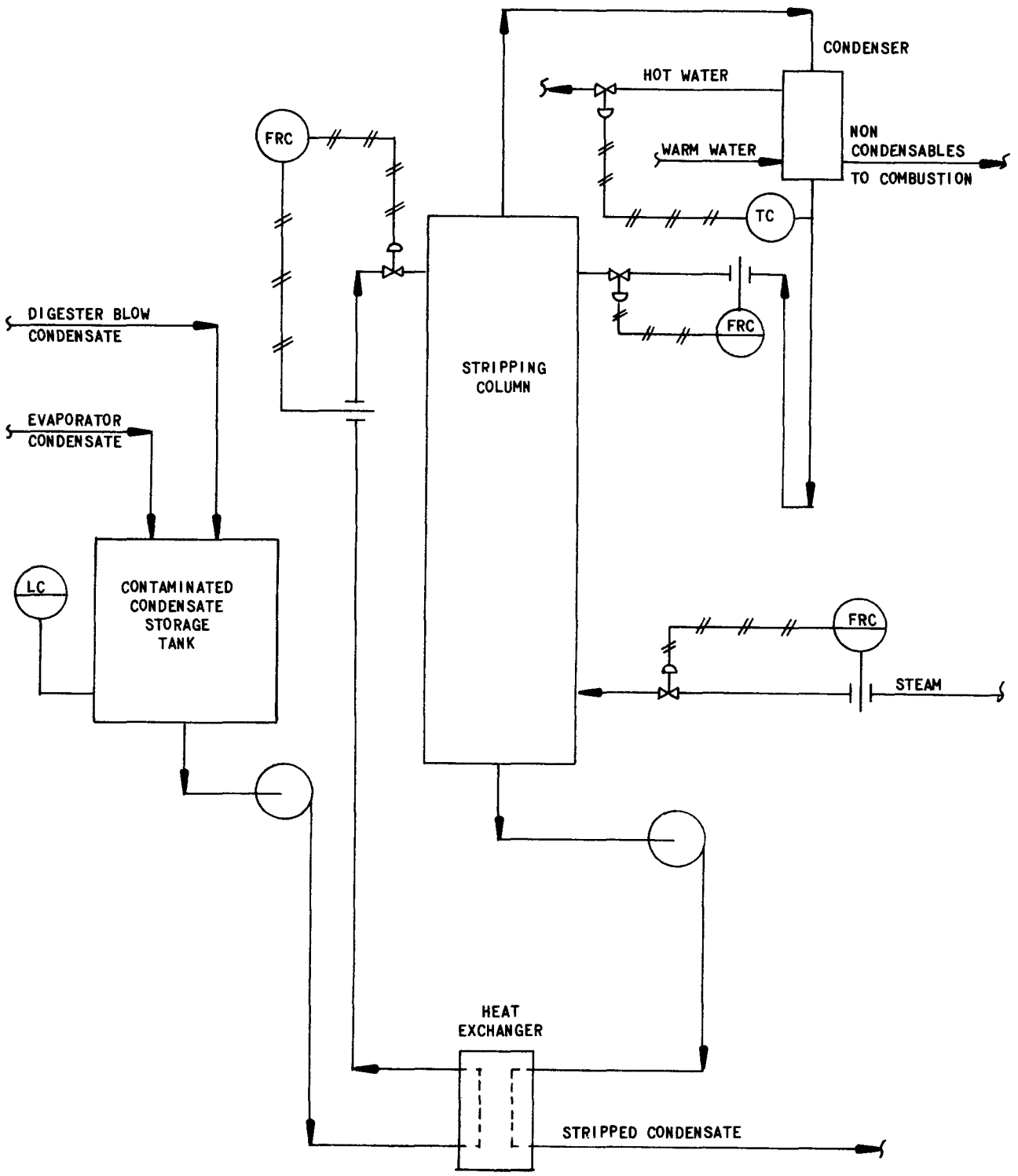


Figure 65A (Cont'd)

STEAM STRIPPING AND REUSE
OF BLOW STEAM AND
EVAPORATORS CONDENSATE



During evaporator boil out in the basic kraft and soda mills the liquor was returned to the weak black liquor storage tank until the concentration got down to about 8% or 1°Be, with the remaining liquor discharged to the sewer. This system was designed to collect the weak black liquor from about 10% down to approximately 2%, with the remainder below 2% going to sewer. During normal operation, the liquor is slowly metered back to the weak black liquor ahead of the evaporators.

13. Black Liquor Storage Tank Spill Collection

This system is to run all of the black liquor storage tank overflows to the evaporator bailout tank included in another estimate. The piping is arranged so that the weak liquor in the boilout tank would overflow to the sewer first.

14. Green Liquor Dregs Filtering

The basic mill takes the dregs from the green liquor clarifier, dilutes the dregs in a dregs mixer and reconcentrates the dregs in the dregs washer. The dregs from the washer are severed and the dilute liquor sent to weak wash storage. This system includes a vacuum dregs filter, with vacuum pump. The solids are collected in a container for disposal by land fill. The diluted green liquor goes to weak wash storage.

15. Causticizing Area Spill Collection System

The causticizing area liquor spill collection system includes a tank sized to hold the liquor from any clarifier or storage tank in the causticizing area. A transfer pump is used to pump to and from green liquor storage, white liquor storage, weak wash storage, green liquor clarifier, white liquor clarifier, and mud washer, as shown on the flow diagram.

16. Evaporator Condensate for Causticizing Makeup

Evaporator condensate from the second, third, and fourth effects are pumped to a holding tank for use in the causticizing and lime recovery area. Evaporator condensate is used at the kiln scrubber, lime mud dilution from storage, mud filter shower, dregs filter showers, and mud washer dilution. A conductivity probe is used to detect liquor carry over so that black liquor is kept out of the causticizing and lime recovery system. The holding tank uses fresh water for low level control.

17. Lime Mud Storage Pond

A concrete lime mud holding tank is located 800 feet from the lime kiln. The tank is 55' x 130' x 10' high for a bleached kraft pump mill producing 670 TPD. With a 12' free board, the tank holds 480,000 gallons.

Figure 65A (Cont'd)

EVAPORATORS BOIL OUT TANK

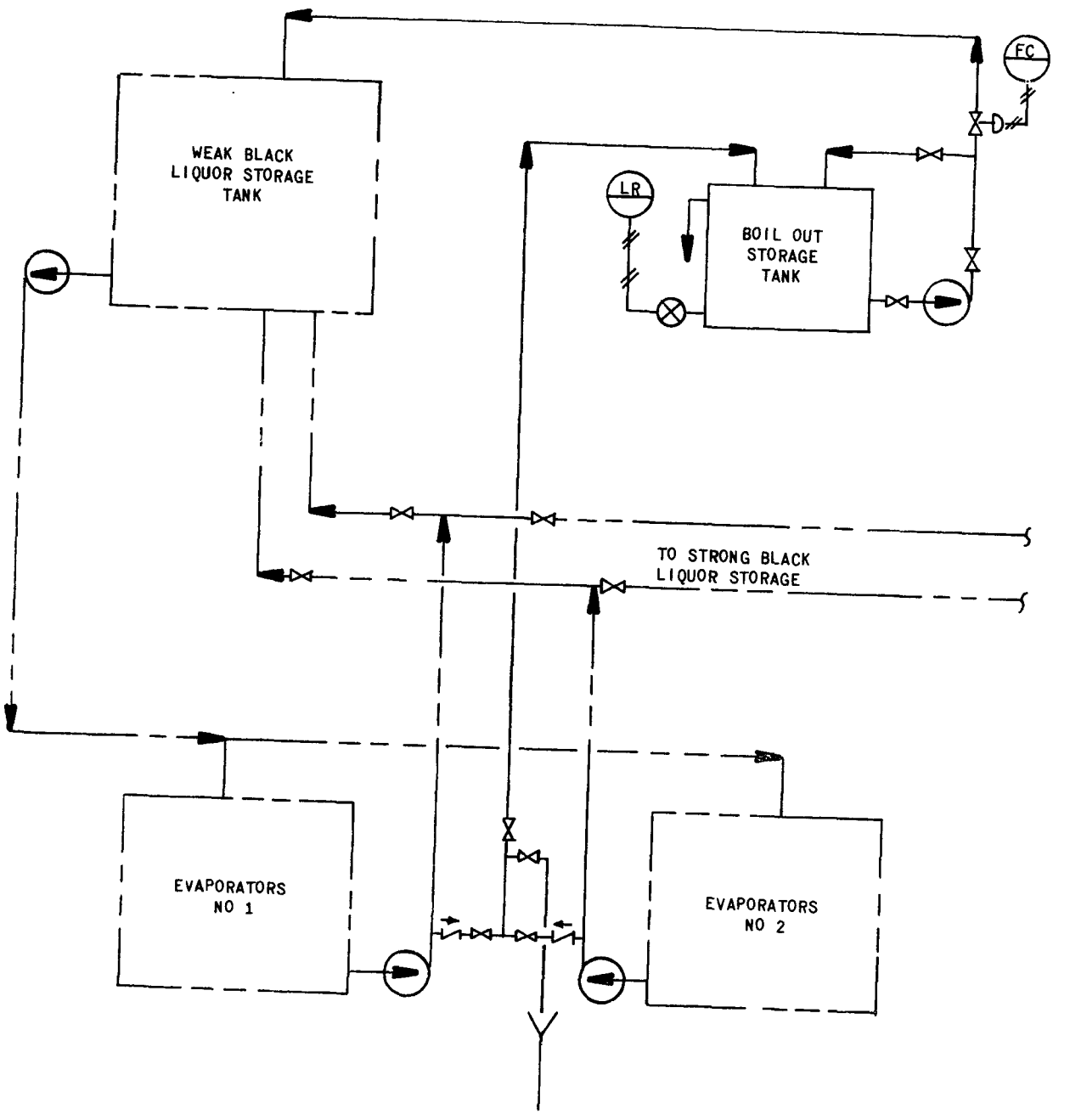


Figure 65A (Cont'd)

BLACK LIQUOR STORAGE TANK
SPILL COLLECTION AND REUSE

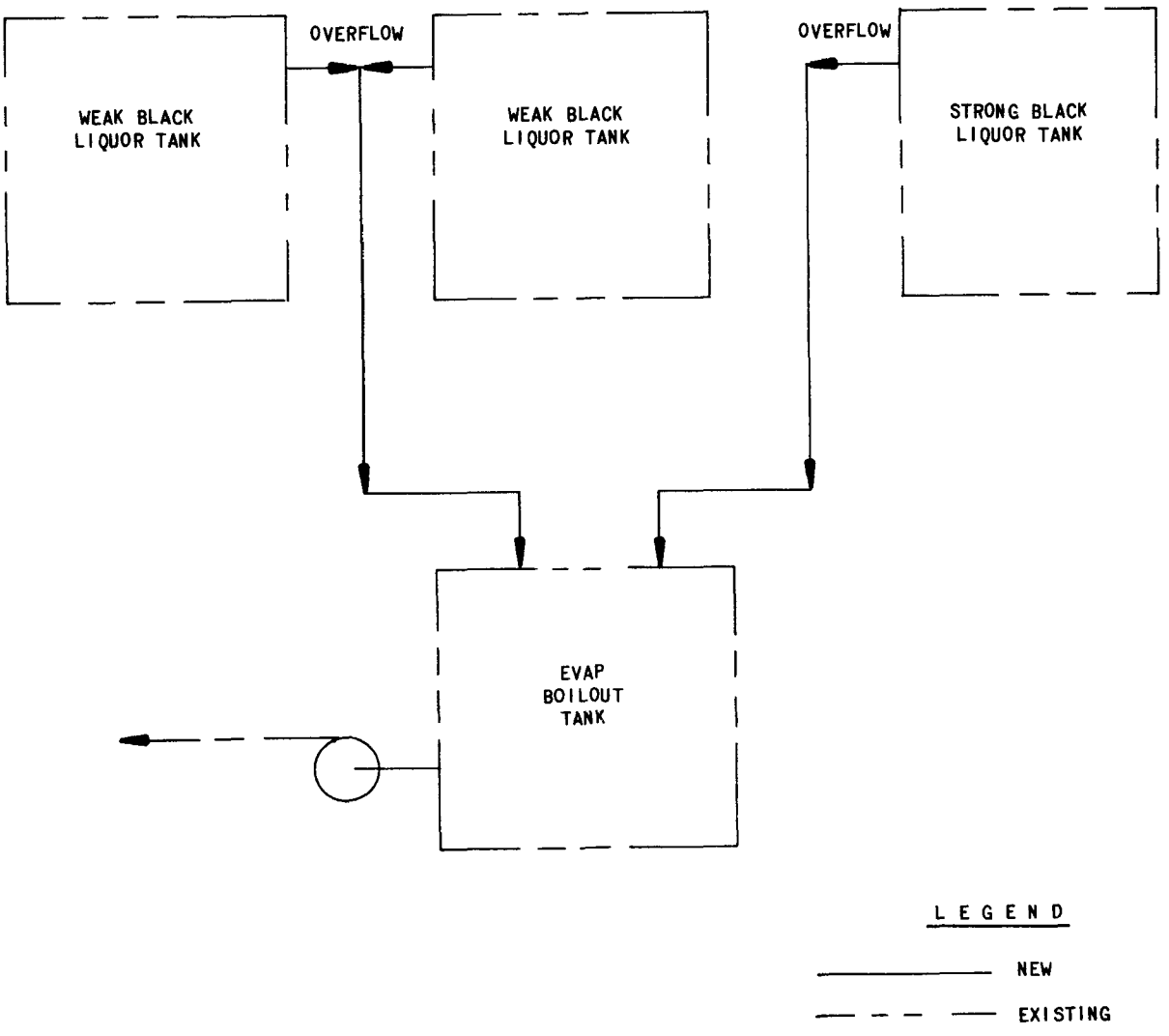


Figure 65A (Cont'd)

GREEN LIQUOR DREGS FILTER

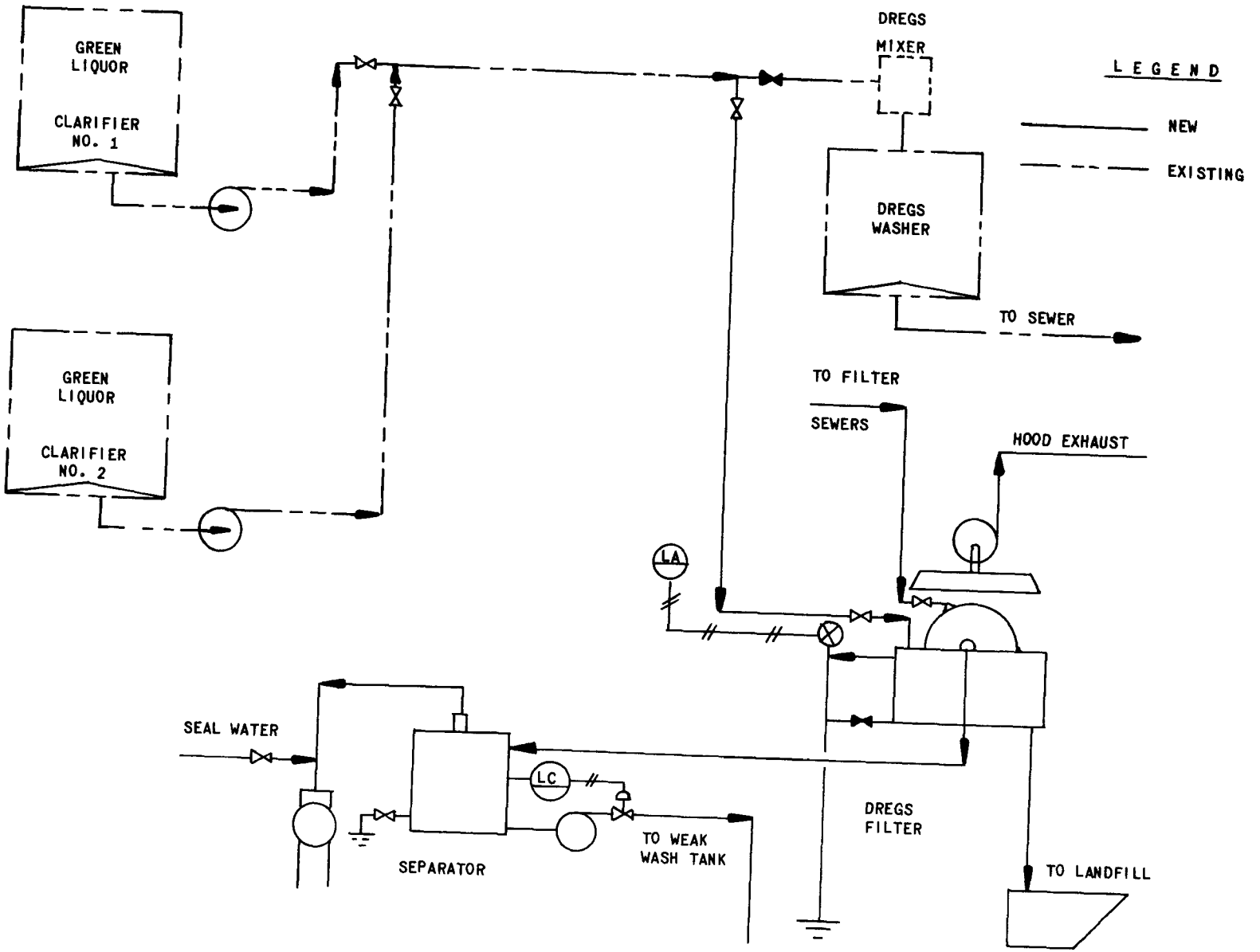


Figure 65A (Cont'd)

CAUSTICIZING AREA SPILL COLLECTION SYSTEM

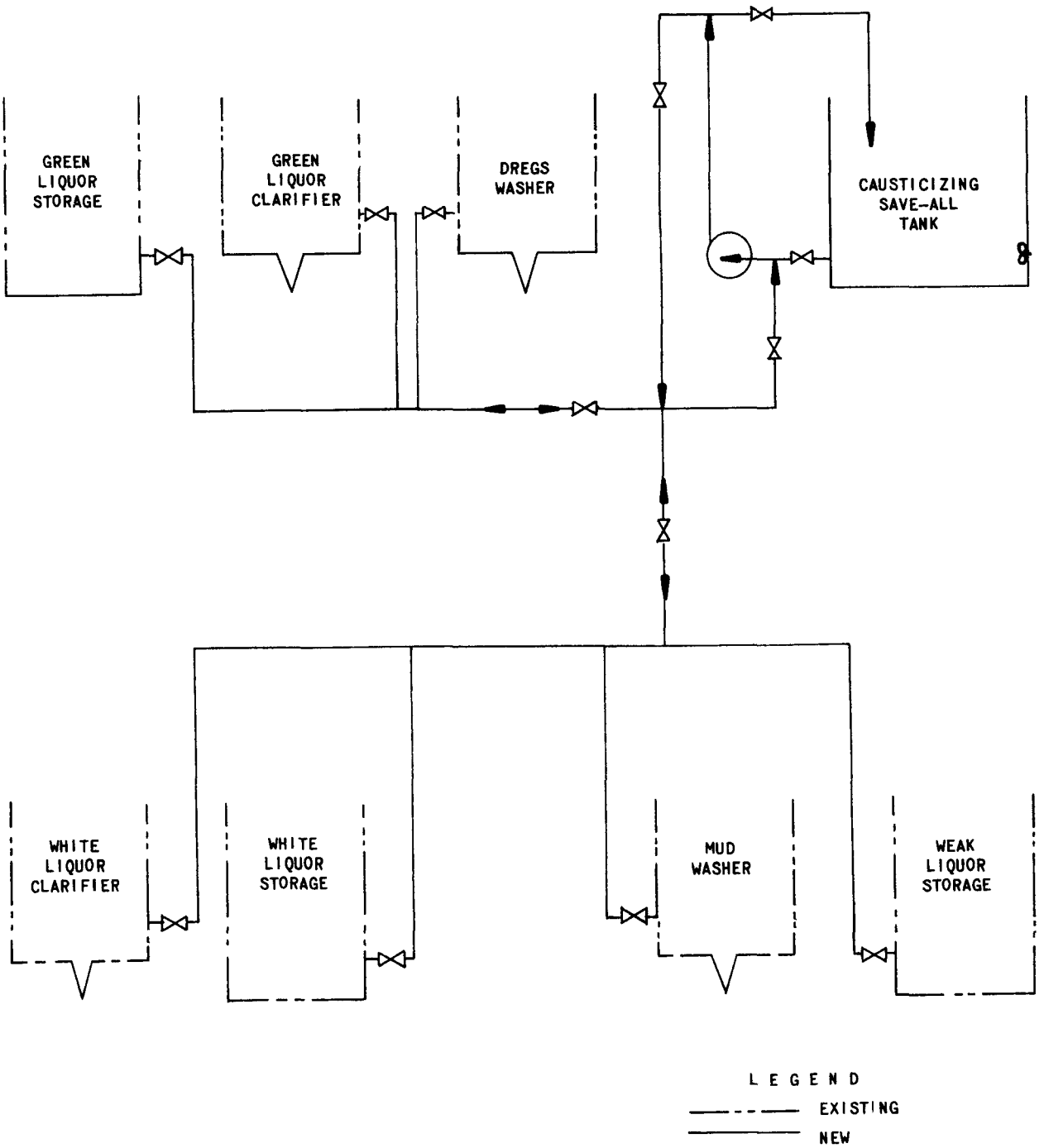
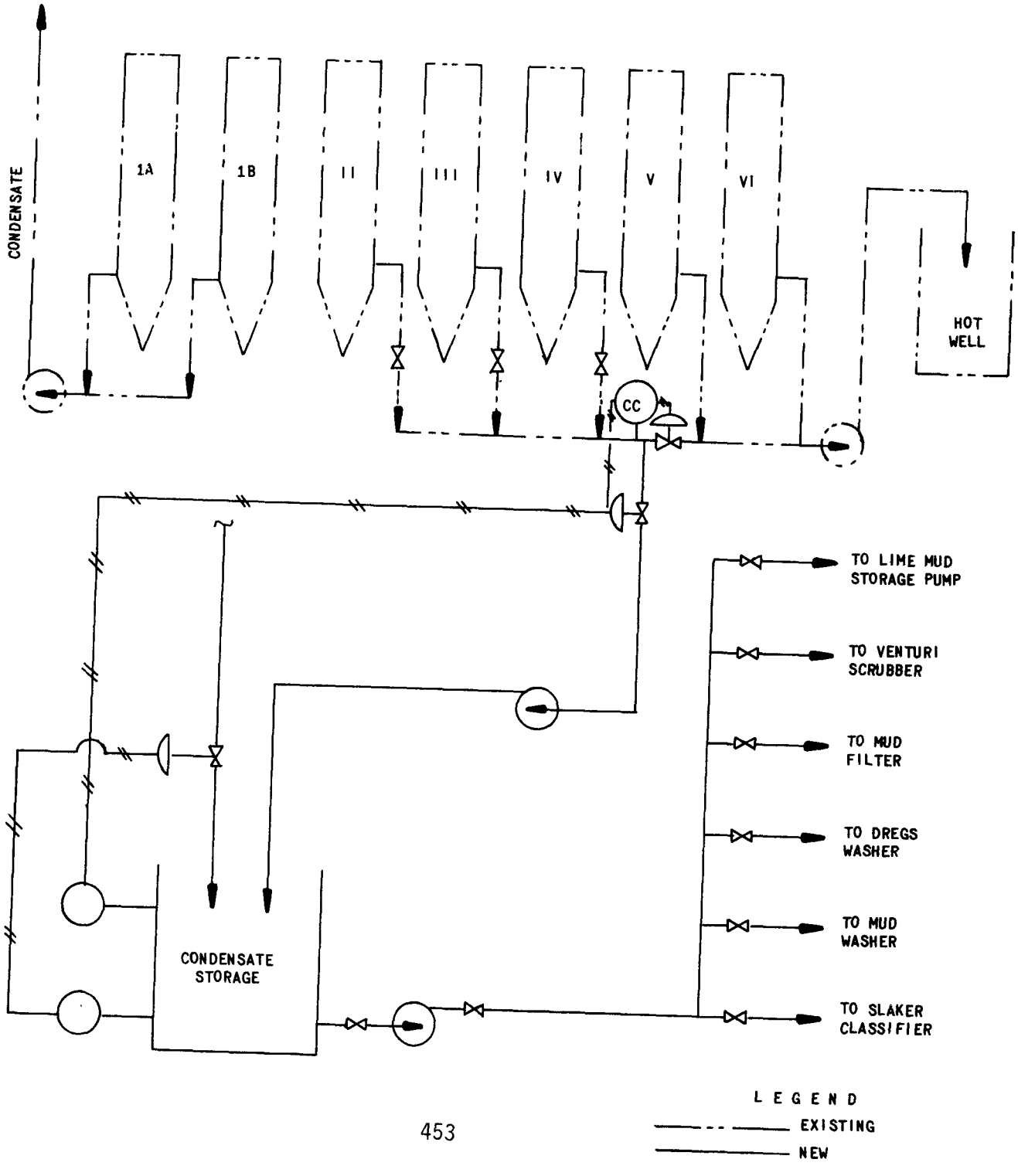


Figure 65A (Cont'd)

EVAPORATOR CONDENSATE USED FOR CAUSTICIZING MAKE-UP



The lime mud pond provides storage when the kiln is down and the mill continues to run on purchased lime. The mud is reclaimed with a floating "Mud-Cat".

18. Alarms for Chemical Tanks

High level alarms are installed on all pulp mill and paper mill chemical tanks so that the operator is alerted as soon as a tank is ready to overflow to the sewer, so that the duration of the spill is kept as short as possible. The small bleached kraft soda and sulfite mills required 20 alarms and each paper machine required three.

19. Prehydrolysate Disposal by Burning

Each system is unique and includes proprietary information. Therefore, the system used to arrive at the cost estimates will not be described.

20. Magnesium Bisulfite Liquor Recovery System

The magnesium bisulfite liquor recovery estimate includes brown stock drum washing, evaporators, incineration with chemical recovery and liquor reconstitution, to include make-up sulfur and magnesium oxide systems.

21. Paper Machine Vacuum Saveall

To properly cover all of the segments with some accuracy, estimates were prepared for the installation of vacuum disc filters on tissue machines, newsprint machines, and board machines. To establish an exponential factor to vary the cost from small to large machines, two tissue machine saveall estimates were prepared. Some of the smaller machines may install deckers since the cost would be considerably less and there may not be room for a vacuum saveall; however, all of the estimates are based on disc filters. It was also estimated that the smallest installation would cost in the range of $150,000.

22. Paper Machine Flotation Saveall

Most of the savealls being installed today are vacuum disc filters. It was noted that more than half of the savealls on fine paper machines in the mill surveyed were flotation savealls. At least a partial reuse of white water is practiced on most fine paper machines without savealls because of the relatively expensive additives and fillers used in the manufacture of many grades of fine papers. The cost of addition flotation savealls to fine paper machines was estimated on this basis.

23. Paper Machine High Pressure Showers

The fresh water used for headbox shower, fourdrinier section cleaning and sheet knock off, and in the press section can be significantly reduced by the installation of high pressure

Figure 65A (Cont'd)

LIME MUD STORAGE POND

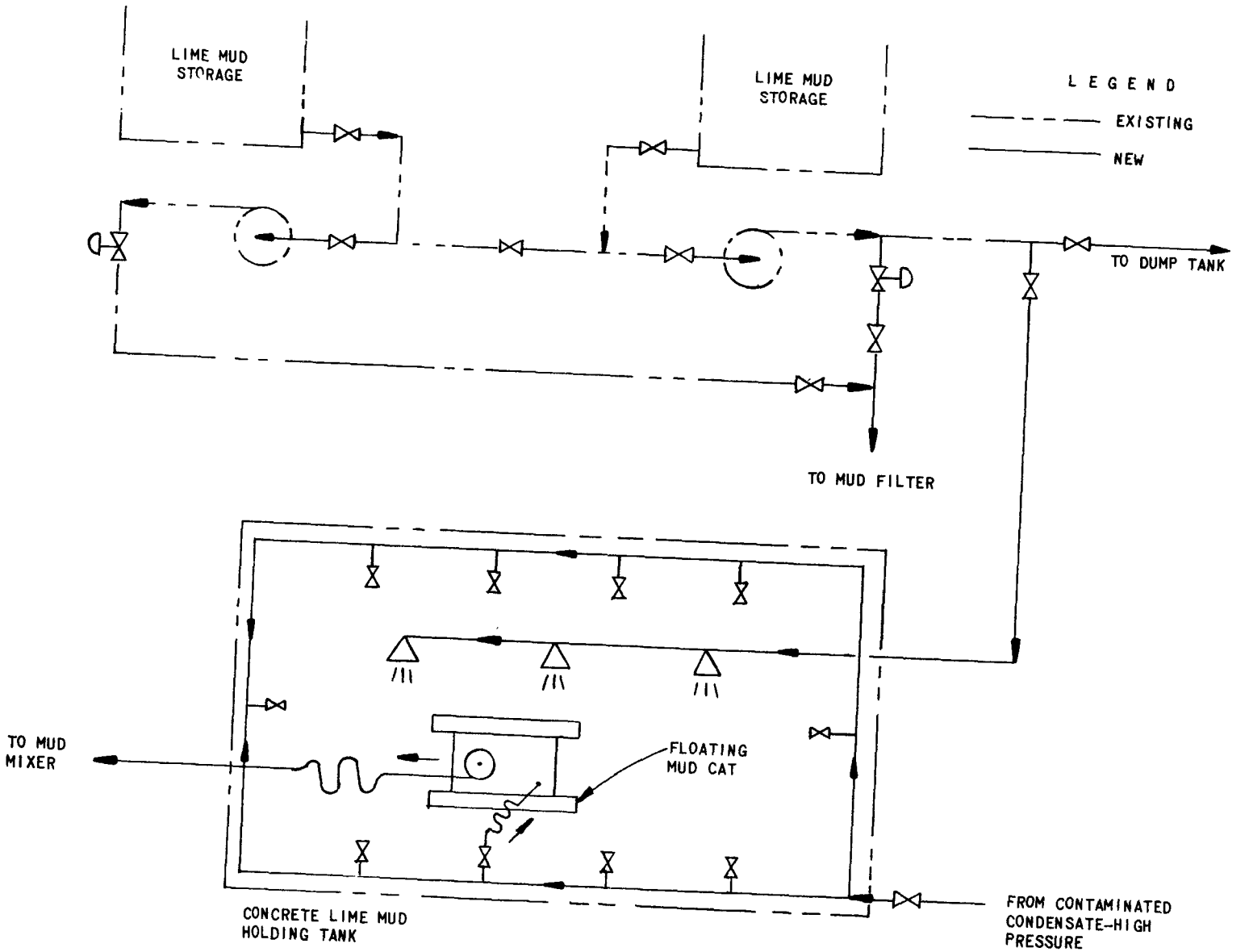


Figure 65A (Cont'd)

PAPER MACHINE
VACUUM SAVEALL
ALTERNATE I

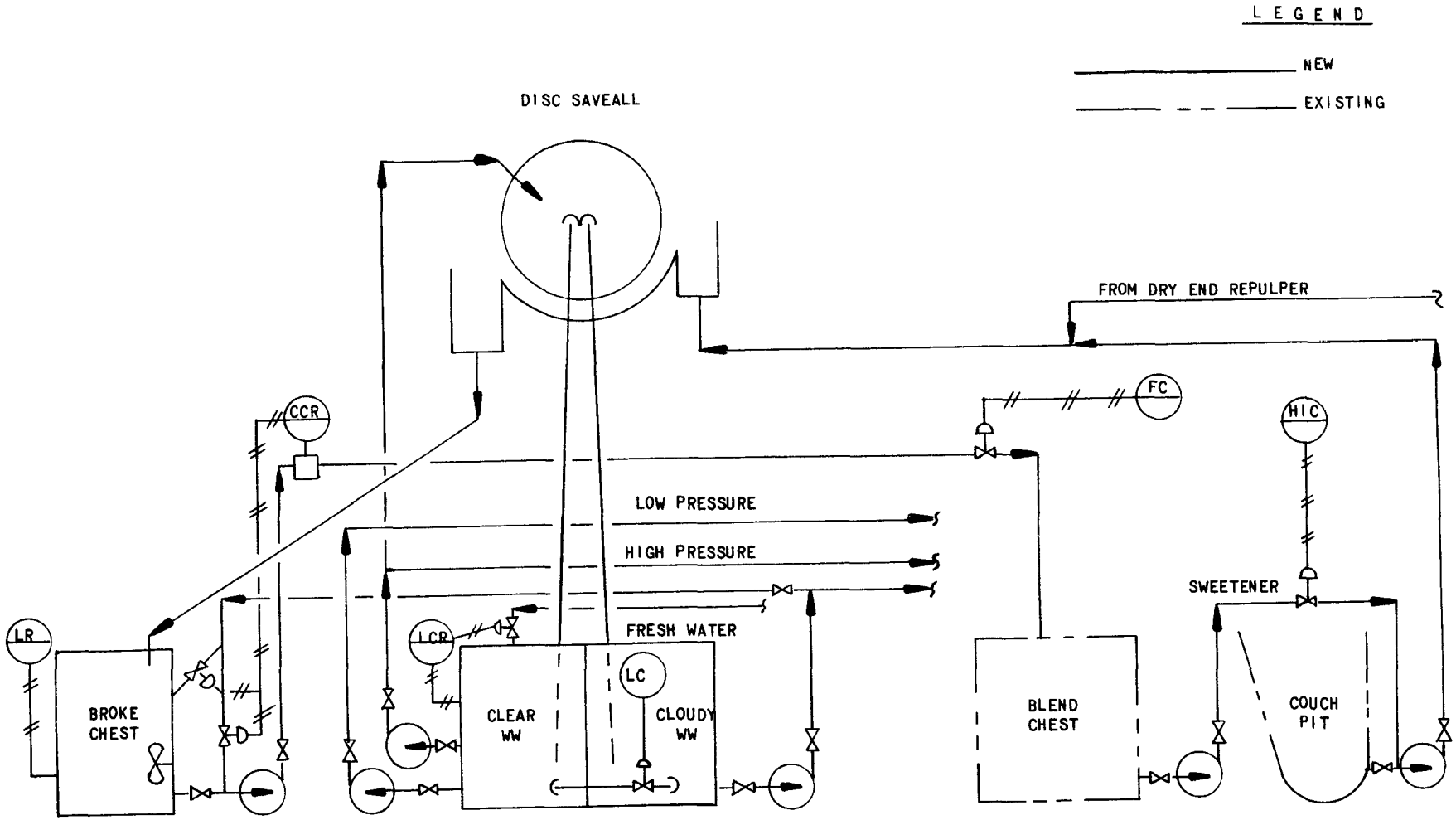


Figure 65A (Cont'd)

PAPER MACHINE
VACUUM SAVEALL
ALTERNATE II

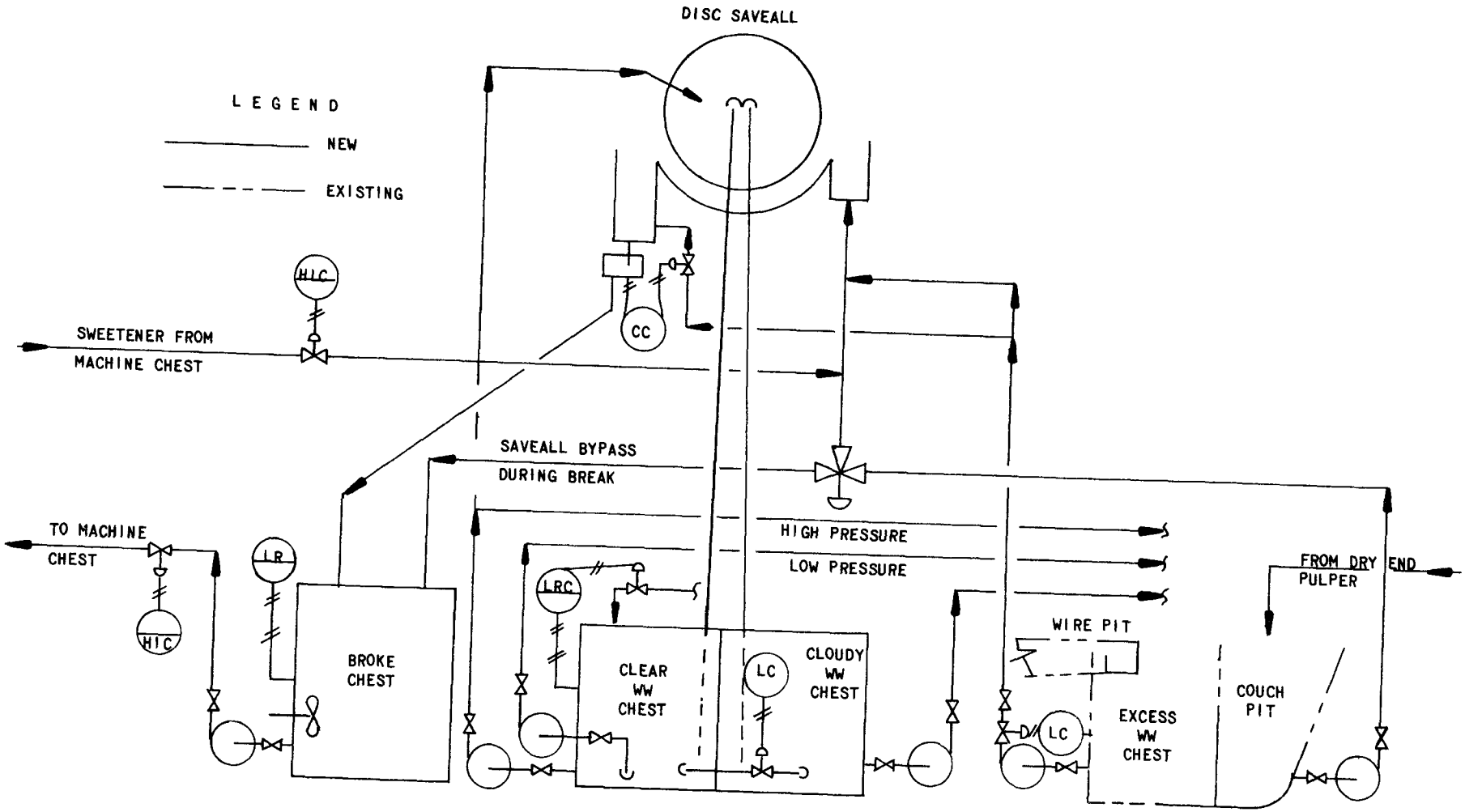


Figure 65A (Cont'd)

PAPER MACHINE
VACUUM SAVEALL
ALTERNATE III

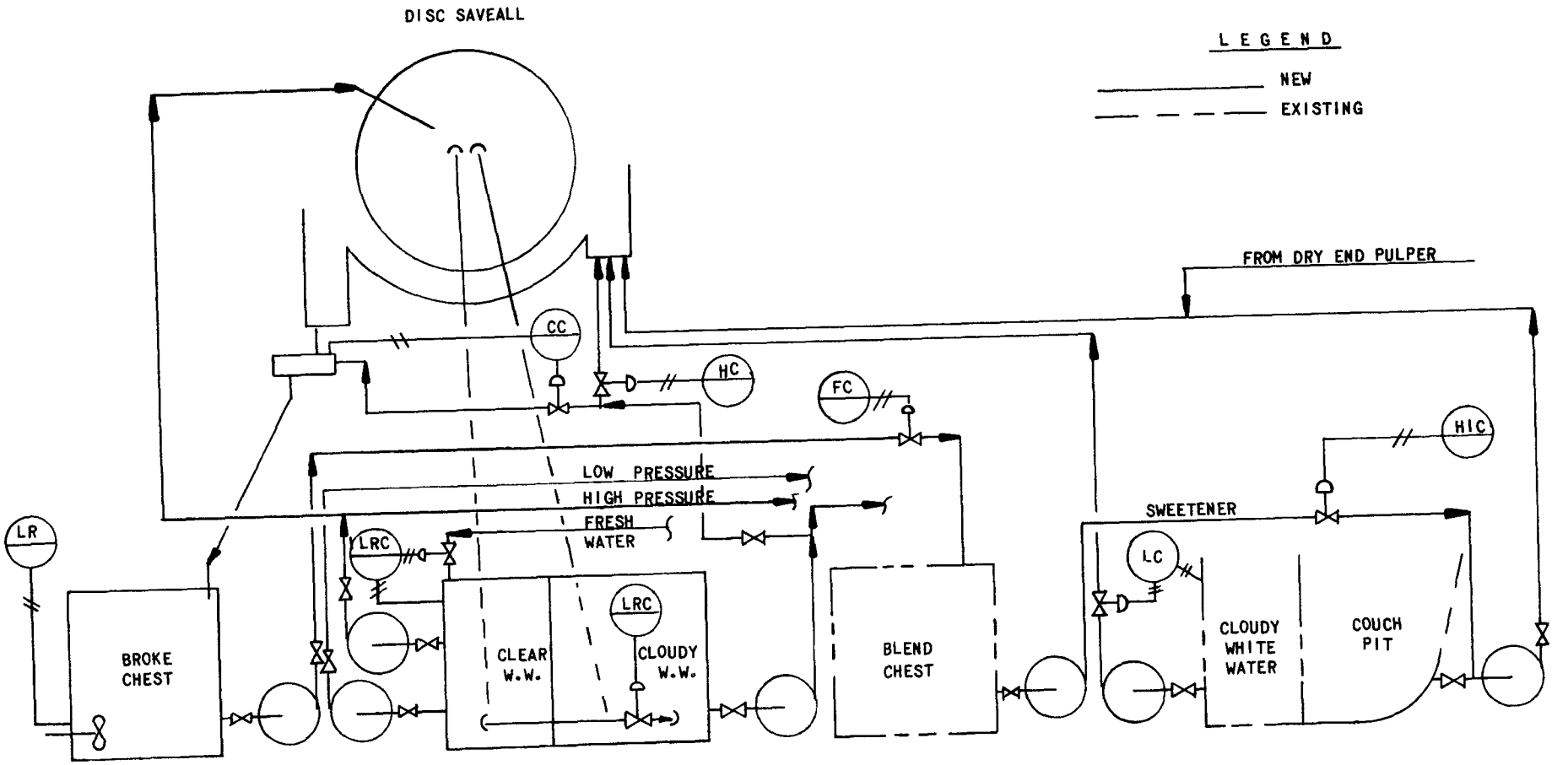
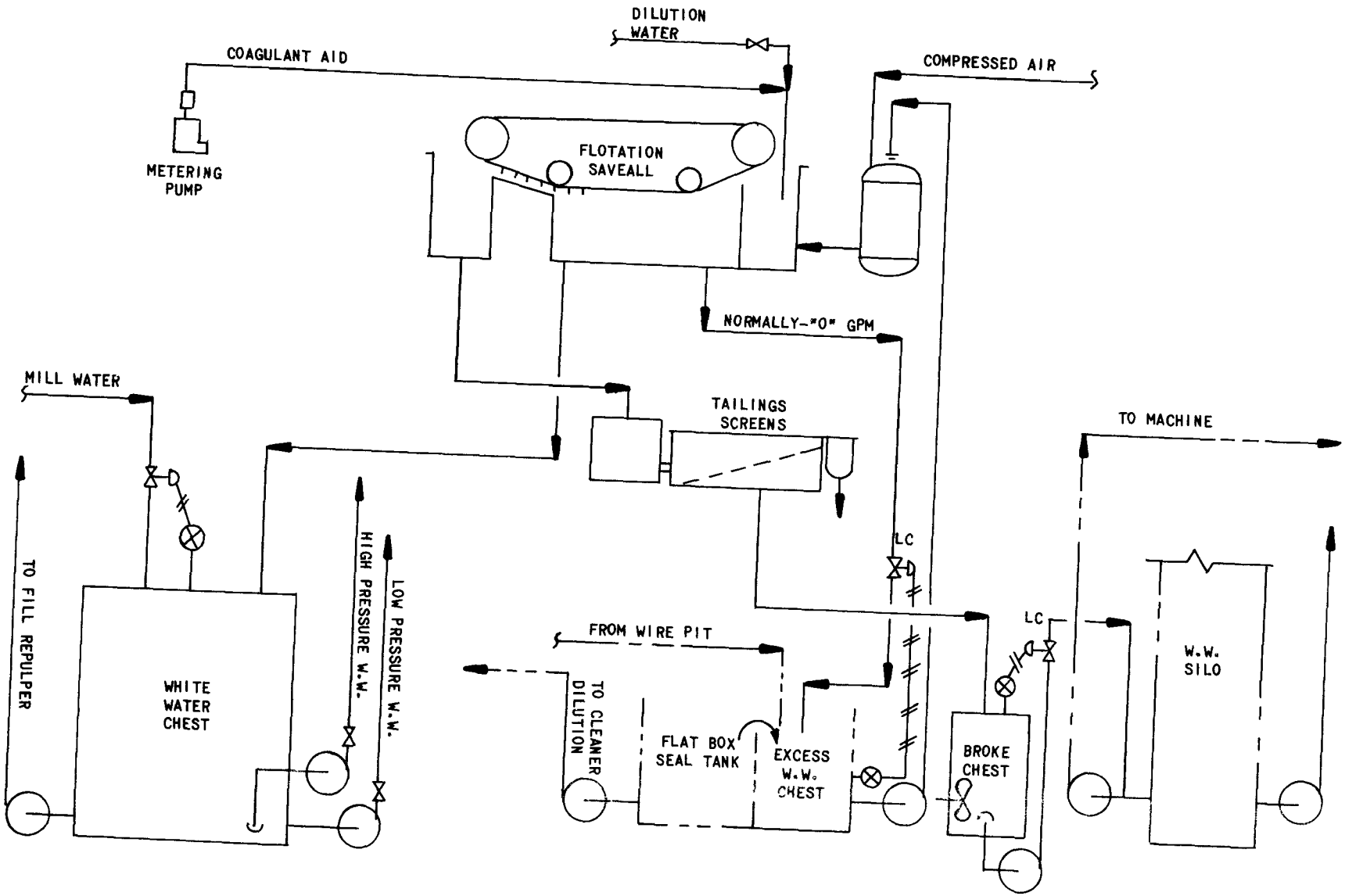


Figure 65A (Cont'd)

PAPER MACHINE FLOTATION SAVEALL



showers. The high pressure showers used on the fourdrinier are designed to operate at 300 psi and the showers on the felts at 500 psi. Each system includes a stand-by high pressure pump.

24. Paper Machine White Water Showers

When the paper machine white water does not contain many additives and fillers, self cleaning white water showers can be installed. On tissue machines, the higher shower water volume will help to work in new felts in a much shorter time, resulting in increased production. The system includes a single white water supply pump, with fresh water back-up on supply header low pressure control.

25. Cylinder Former White Wash Shower

Where a pulp dryer has a cylinder former in place of a fourdrinier section, the fresh water showers are replaced by filtered white water showers.

26. Cooling Water Segregation and Reuse

The indirect cooling water collected includes evaporator surface condenser, air compressor cooling, compressed air aftercooler, dryer drainage condensate cooling and blow through steam condenser, lube oil cooler, rewinder brake cooling, and stream chiller condensing water. The warm water is collected in a central tank, but is not reused in this estimate. The water could be used for high pressure showers, in the pulp mill, for pulper dilution, etc. Separate cost estimates for collecting the cooling water from bleached pulping operations and from non-integrated mills are included.

27. Felt Hair Removal.

There are certain operations that cannot tolerate the recycling of felt hairs to the stock furnish, such as on fine papers to be coated. This estimate includes the additional pump head required above the system included for vacuum pump seal water reuse, along with a sidehill strainer for removal of felt hairs so that the clean water can be recycled.

28. Vacuum Pumps Seal Water Reuse

Two estimates are included for reuse of vacuum pump seal water. For large integrated mills, the vacuum pumps are mounted side by side on an elevated foundation with a covered trench. The system includes cascading from the high vacuum pumps to the lower vacuum pumps, and then transfer to white water storage. For the small nonintegrated mill, the vacuum pumps are located all over the basement and individual sumps and pumps are included for each vacuum pump. The seal water is pumped to white water storage.

29. Paper Mill Stock Spill Collection System

Figure 65A (Cont'd)

HIGH PRESSURE FRESH WATER
CLEANING SHOWERS FOR PAPER MACHINES

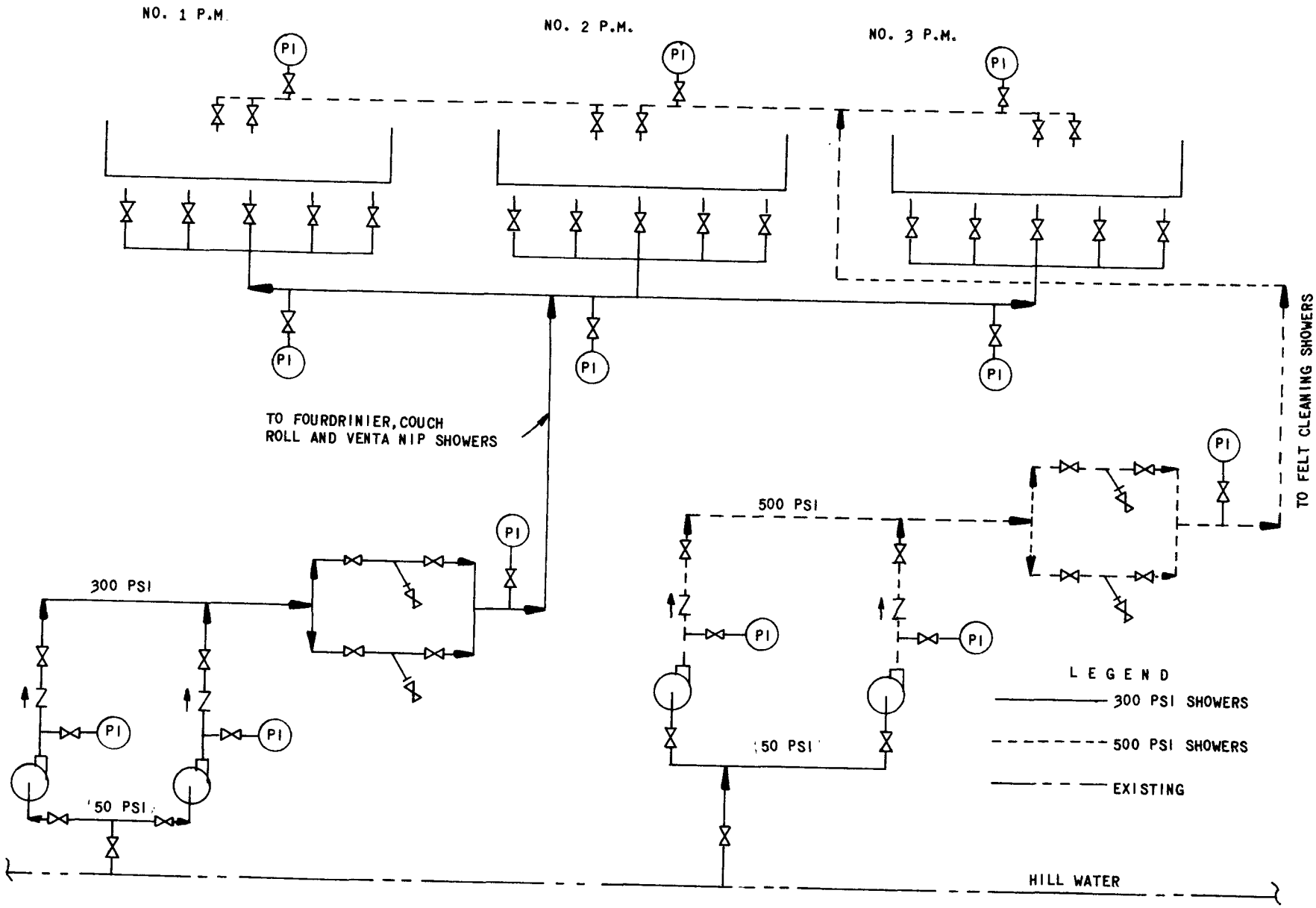


Figure 65A (Cont'd)

PAPER MACHINE WHITE WATER SHOWERS

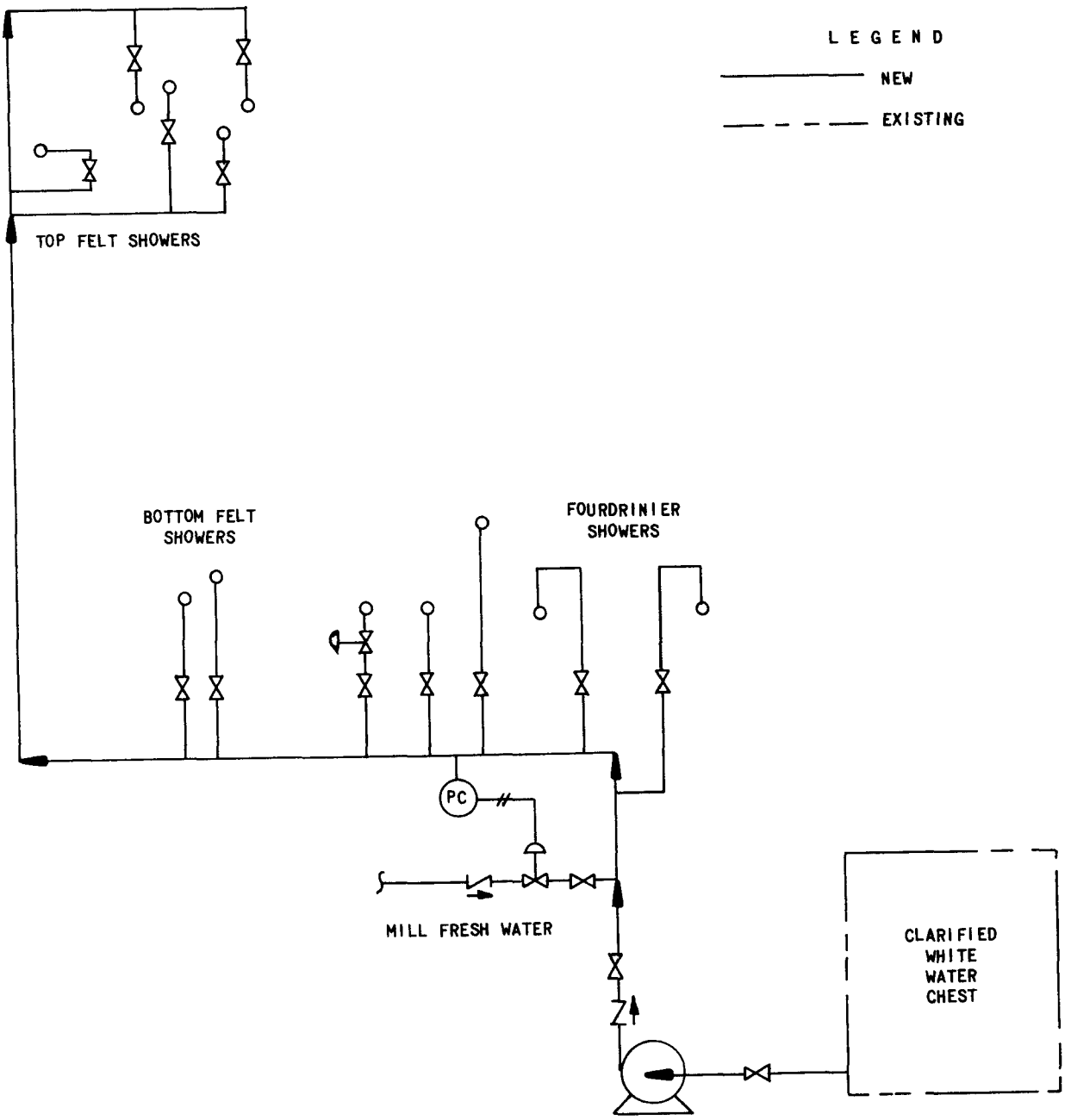


Figure 65A (Cont'd)

FELT HAIR REMOVAL FROM PRESS
SECTION VAC PUMP SEAL WATER

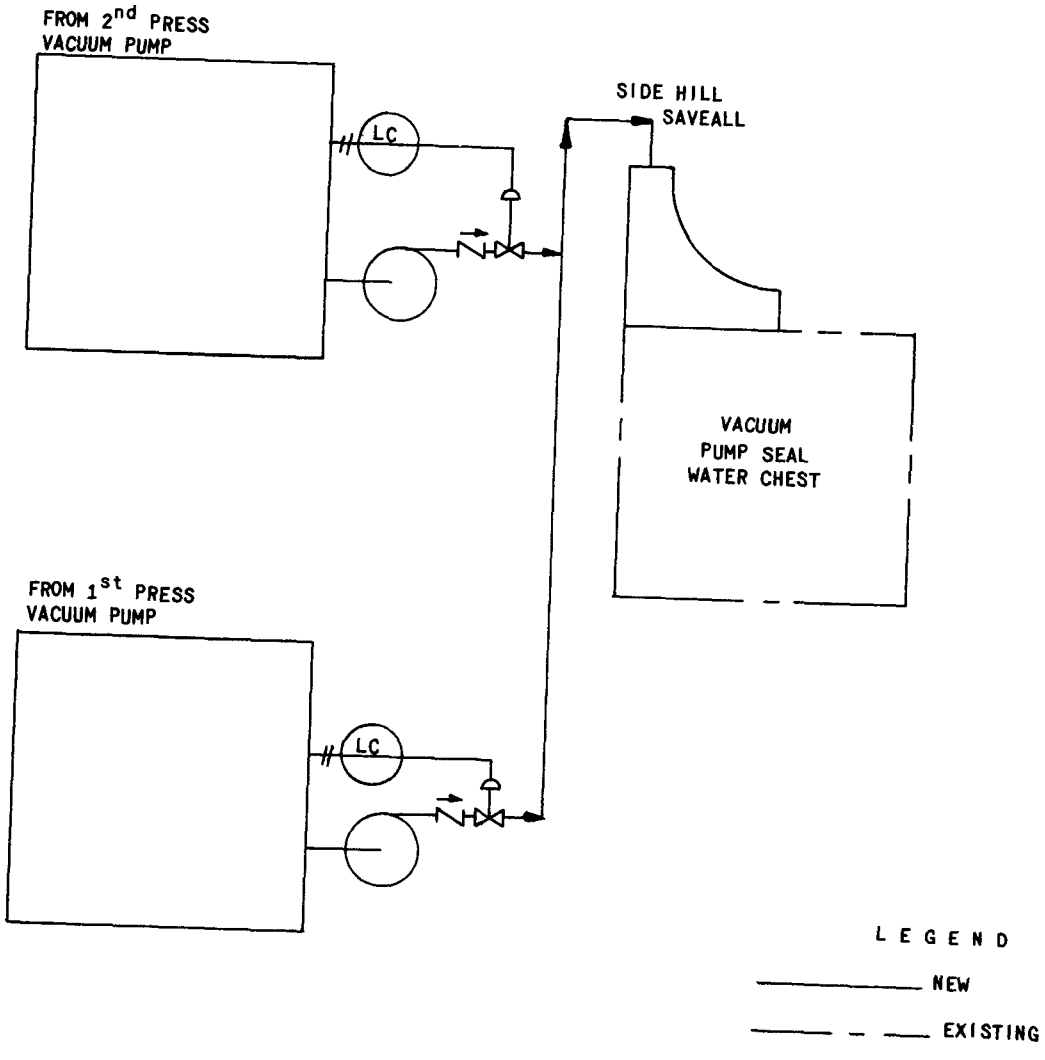
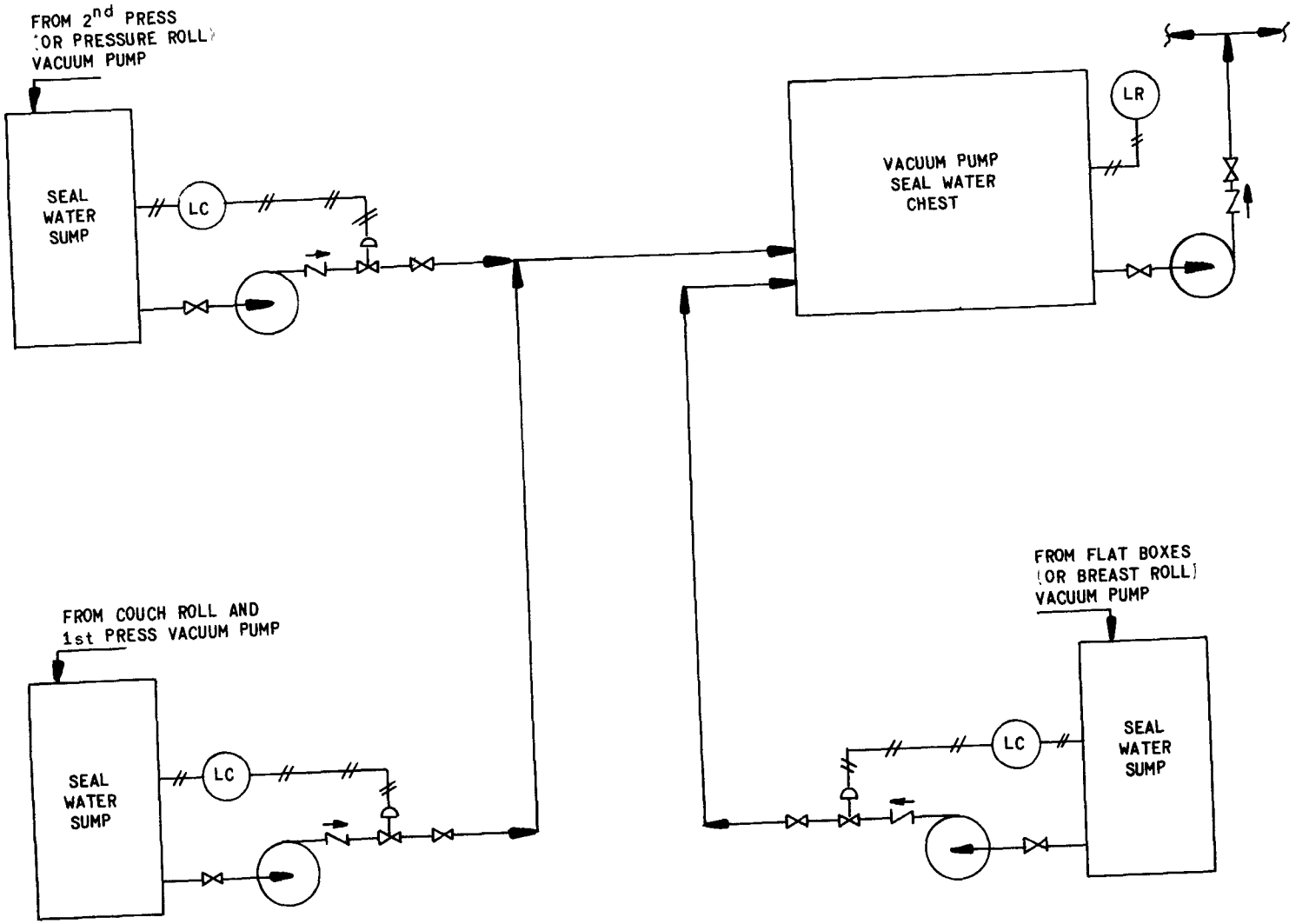


Figure 65A (Cont'd)

VACUUM PUMPS
SEAL WATER REUSE



The paper mill stock spill collection system picks up stock spills from the floor drains, which is not possible when producing quality paper. The stock is thickened for storage on static screens, which also separates some of the sand from the reclaimed pulp. The overflow from the stock chests are run to the spill collection chest. To bleach colors out of the stock such as stock dumps for grade changes, a hypochlorite solution line from the chemical preparation area is included.

EXTERNAL EFFLUENT TREATMENT

The following is a brief description of the external treatment systems used to prepare external construction costs, operation and maintenance costs, chemical costs, and power requirements. It should be remembered, however, that actual external treatment costs may vary significantly from mill to mill depending upon the climate, topography, soils conditions, unit locations, and the design and operation of the particular waste treatment facilitiy. Each production facility or waste treatment facility has some uniqueness which may be of importance in assessing the mill effluent treatment problems and the associated cost of waste treatment.

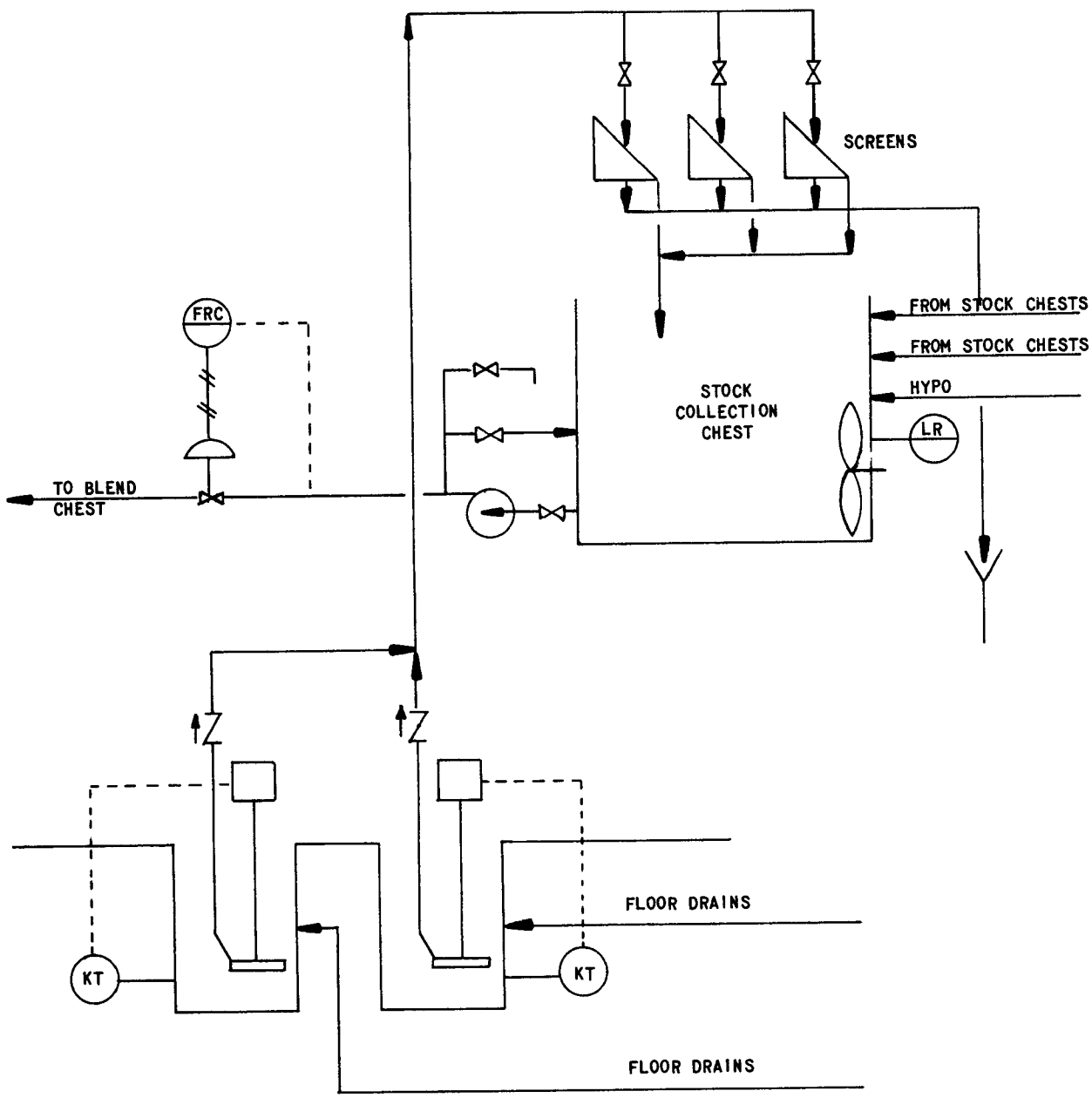
Raw and final waste characteristics associated with each technology level have been developed for each of the 15 subcategories. The data presented in this report represents approximate annual averages, and may not be relatable in every case to the limitations and standards shown in other sections because of the different methodologies utilized. In order to determine the impact of the limitations on the profitability of a mill's operation, "treatment trains" have been developed for each technology level.

Cost curves have been developed for each treatment technology outlined in this report. The cost curves and resultant unit costs are based on "model" effluent treatment facilities sized for several flow capacities. These "model" effluent treatment facilities are based on assumed unit processes, yard piping layouts, methods and materials of construction, site and soils characteristics, unit construction costs, and operational practices. Detailed design for each unit, process and mechanical layout, is beyond the scope and time limitations of this report.

The construction costs presented are those defined as the capital expenditures required to implement the control technology. Included in these costs are the traditional expenditures for such items as mechanical and electrical equipment, instrumentation, yard and process piping, earthwork, unit construction, site preparation and grading, equipment installation and testing, and engineering. Items such as electrical, instrumentation, process piping, site preparation, and engineering are included as a percentage of the base capital costs, which varies for each applicable control technology. A 15 percent contingency is also included with each control technology to cover miscellaneous work items not included in the estimates.

Figure 65A (Cont'd)

PAPER MILL STOCK SPILL COLLECTION SYSTEM



The annual operating costs presented in this report for the external effluent treatment facilties are subdivided into three categories, as follows:

1. Total Operating Costs
2. Depreciation and Interest
3. Operation and Maintenance

Depreciation costs reflect the accounting charges for replacement of the capital assets over a period of years. Straight line depreciation has been assumed in all annual cost calculations. Interest is the financial charges on the capital expenditures for the pollution control facilities. For purposes of this report, depreciation plus interest are assumed to be 15 percent of the initial capital expenditure.

The operation and maintenance costs are those costs expended for annual operation of the external waste treatment facility. These costs are subdivided as follows:

1. Operator Labor
2. Maintenance Labor
3. Energy Requirements
4. Chemicals

Operator labor costs are based on the annual manhours required to perform the tasks for proper operation, administration, quality control, monitoring, etc., for the "model" treatment facility. The maintenance costs are the annual manhours required for preventative maintenance tasks such as lubrication, equipment inspection, minor parts replacement, painting, etc. It was assumed that major equipment repair and/or replacement and miscellaneous yard work would be done by the existing mill personnel.

Chemical usage is based on estimated quantities required to meet effluent limitations, or as required for proper operation of the particular treatment technology. The energy requirements are based on the additional horsepower and operating times attributable to the effluent control technology.

The total annual operating costs presented in this report are the sum of the annual costs for operator labor, maintenance labor, energy requirements, and chemicals.

Ambient temperatures can have a significant impact on the performance of biological treatment facilities. In cold climates an aerated stabilization basin with long detention times will tend to approach ambient temperatures which can create operational and treatment problems. These problems can include freezing of basin surfaces, ice formation on equipment and structures, and a reduction in treatment efficiencies.

An activated sludge system is not affected to the same degree during cold weather operations as an ASB system. It may be

necessary, therefore, for certain northern mills to consider the use of an activated sludge system if they are to meet on a year round basis their effluent limitations. Based on the above comments, this report presents costs for both activated sludge and aerated stabilization systems to allow cost comparisons of each system. In addition to increased efficiencies during cold weather, it is anticipated that many mills may desire installation of an activated sludge system because of limited land availability for construction of an aerated stabilization basin.

Preliminary Treatment

Many foreign objects enter mill sewers, either through mill floor drains or process sewers. These objects, such as wood chips, bark, wet strength paper, etc., could interfere with the treatment processes or increase wear on the process equipment. Consequently, it is necessary that these objects be removed from the mill sewers prior to treatment. A mechanically cleaned bar screen is generally utilized by most pulp and paper mills for preliminary treatment. The high solids mill sewers flow into this facility, with the low solids sewers bypassing it. The bar screen used for purposes of this report is a mechanically operated, self-cleaning travelling bar screen with a bar spacing of 1-2 inches. A bypass channel and manual bar screen are incorporated into the facility to allow for screening during periods of maintenance on the mechanical bar screen. A "dumpster" unit is utilized for containment of the removed solids.

It is advantageous to monitor and sample the flow to the treatment process. Therefore, the preliminary treatment facility includes the necessary flumes and monitoring and sampling equipment for complete flow measurement and sampling. The capital costs prepared for the preliminary treatment facility include the necessary excavations, backfill, concrete, mechanical equipment, flow monitoring equipment (with necessary ancillary equipment), and the superstructure.

Mill Effluent Pumping

Normally, the topography of the effluent treatment site is not conducive to gravity flow through the entire treatment process. Consequently, it is necessary to construct an effluent pumping facility which is capable of pumping the maximum daily flow of the treatment facility. The pumping facility utilized for this report assumed a wet well and dry well. The mill effluent flows into the wet well (with detention time of five minutes at maximum daily flow), while the variable speed pumps are located in a dry well adjacent to the wet well. The construction costs prepared for the mill effluent pumping facility include excavation, backfill, concrete, pumps, variable speed controls, ancillary piping and equipment, and superstructure.

Primary Clarification

For purposes of this report, it has been assumed that internal fiber recovery is being accomplished to the degree of economic justification. Therefore, external fiber recovery for reuse has not been considered in the treatment process design. All mill sewers containing suspended solids are combined prior to primary clarification, with total removal being accomplished by mechanical clarification. Primary clarification removes 75-85 percent of the total suspended solids. The clarifier selected for this report is a heavy-duty thickener type with rotary sludge scraper, and scum removal facilities. The size of these units are based on an average design overflow rate of 600 gpd/ft 2. The rotary sludge scraper mechanism is sized for a torque rating of 15(D)2. For flows in excess of five (5) mgd, two parallel units, each capable of 50 percent of the daily flow, were assumed to be used. Waste solids are withdrawn by pumping from the primary clarifier at an anticipated solids content of 3-4 percent to either a sludge lagoon or a mechanical dewatering device. Scum collected in the clarifier discharges into a storage tank where it is then pumped for dewatering. The capital costs prepared for primary clarification include excavation, backfill, concrete, mechanical, electrical, and instrumentation equipment, scum facilities, waste sludge pumps, and yard piping related to unit construction.

Sludge Lagoon

Waste solids pumped from the mechanical clarifier can be dewatered in a lagoon. In a sludge lagoon the waste solids are allowed to settle, the decanted water recycled back to the waste treatment system. In addition, a sludge lagoon may serve as an emergency solids disposal area when the mechanical dewatering facilities are down due to mechanical malfunction. The lagoon costed in this report provides sufficient capacity for five years' detention of 20 percent solids. The capital cost includes the required earthwork to construct such a facility.

Aeration

BOD5 reduction in pulp and paper wastes is generally accomplished by biological treatment. Oxygen required for biological treatment may be supplied either by mechanical surface aerators or a diffused air system. The costs presented in this report are based on the use of mechanical surface aerators. The aeration equipment is sized to provide sufficient oxygen for BOD5 reduction and to ensure proper mixing. Depending on the particular biological treatment process selected, oxygenation requirements will differ.

One of the most utilized biological treatment processes by the pulp and paper industry is the Aerated Stabiliztion Basin (ASB). Standard design criteria for aeration of an ASB system suggests providng approximately 1.25# 02/#BOD5. For this report, it was assumed that the efficiency of the mechanical aerators under actual operating conditions is approximately 1.75 lbs 02/hp-hr. This varies depending on type of equipment and the

characteristics of the system (temperature, basin configuration, biological characteristics, alpha and beta).

The activated sludge system with its many process variations has had limited use by the pulp and paper industry. For cost analysis in this report, a high rate activated sludge system was considered. This system requires approximately one pound of oxygen per pound of BOD5 removed. Mechanical aerator performance for this system is assumed to be the same as that listed above for an ASB.

Aerated Stablization Basin

Biological treatment by aerated stabilzation basins has received wide acceptance by the pulp and paper industry. Aerated Stabilization Basins provide a high degree of BOD5 reduction with minimal decreases in efficiencies due to shock loadings. In general, however, pulp and paper wastes are deficient in the nutrients (nitrogen and phosphorus) required for optimum biological treatment. Consequently, it is necessary to add these nutrients, usually in the form of ammonia and phosphoric acid, to the biological treatment system. The nutrients are added in proportion to the organic (BOD5) loading of the facility. The ratio utilized for the cost analysis is 100:5:1, BOD:N:P.

The basins chosen for preparation of the cost curves is a single cell earthen-construction basin. In most instances the basins are constructed in areas where the soils are impervious, or can be made impervious by lining with an impervious soil. For cost purposes it is assumed that an impervious soil liner will be required to make the basin watertight. The cost of a synthetic liner is not included.

The sizing of the aerated stabilization basins were evaluated on both organic loading rate and detention time design criteria. The design detention time is 14 days, which assumed 13 days of aeration with one day of quiescent settling. The design organic loading is 50# BOD/Ac-Ft./ Day. The basin sizes obtained for the above cited detention time and organic loading were compared to determine which criteria was the governing value.

The capital costs prepared for the aerated stabilization basin include excavation, dike construction, impervious soil material, nutrient feed systems, yard piping, stone slope protection and the instrumentation and electrical costs associated with the basin size.

Activated Sludge Basin

The activated sludge process has numerous modifications in detention times, organic loadings, and oxygenation. The process selected for consideration in this report is commonly referred to as the conventional activated sludge process (6 to 8 hours detention time). The short detention time and variations in loadings (hydraulically and organically) make this process

susceptible to upsets due to shock loadings. It is recommended that an equalization basin be included with this system to even out hydraulic and organic loads to the system.

As stated previously, pulp and paper wastes are deficient in nutrients (nitrogen and phosphorus). The nutrients are added in proportion to the organic (BOD5) loading to the facility. A BOD:N:P ratio of 100:5:1 is utilized for cost analysis in this report.

Final clarifiers are required with the activated sludge basin to allow separation of the biological mass and treated stream. A large portion of these solids are recycled back to the activated sludge basin to maintain the biological mass in the aeration basin. This biological mass is necessary to achieve high removal efficiencies. The high rate activated sludge system also generates large quantities of biological solids which are not oxidized as in ASB systems. It is necessary, therefore, to continuously remove excess biological solids. These excess solids (waste activated sludge) can be extremely gelatinous with a solids concentration of approximately 0.5-1.0 percent. The methods for disposal of these excess solids are presented in a subsequent section of this report.

Since the activated sludge process has high horsepower requirements, an earthen basin would be susceptible to erosion. Consequently, the costs prepared for the activated sludge basin are based on a two-cell concrete tank. The cells would be operated in parallel to provide operational flexibility. The clarifiers associated with the activated sludge process are described in a subsequent process item.

As in the ASB system, sizing of the activated sludge system is based on both detention time and organic loading. The detention time is eight (8) hours (excluding recycle) while the organic loading rate is 50# BOD/1000 Cu.Ft. of aeration volume. The governing value was selected for cost analysis in this report.

The capital costs prepared for the activated sludge basins (presented as a function of the basin capacity) includes excavation, tank construction, concrete, nutrient feed systems, yard piping, electrical and instrumentation costs associated with the basin size.

Equalization Basin

An equalization basin is required quite often to minimize upsets due to fluctuation in pH valuations, and hydraulic and organic variations. This is particularly true of the activated sludge process. The equalization basin utlized for cost analysis provides a 12-hour detention time for equalization of process upsets and hydraulic peaks. The basin utlized is a concrete tank with control facilities to equalize the flow. The capital costs include excavation, tanks construction, concrete, backfill, and yard piping.

Vacuum Filtration

Various unit process are utilized by the pulp and paper industry for sludge dewatering (both primary and secondary solids). The method which has gained the widest acceptance in the industry is vacuum filtration. A vacuum filter consists of a rotary drum covered with a wire mesh on coil springs which is partially submerged in the waste solids. The rotary drum is divided into a series of compartments which are placed under a vacuum when submerged in the waste solids. The drum rotates so that when a compartment reaches the top of the circle the vacuum is released. A filter cake is built up on the filter media, and as it descends in rotation, this filter cake is removed from the filter media prior to re-submergence in the waste solids.

The efficiency of vacuum filtration operation is greatly affected by the consistency and properties of the waste solids being dewatered. The dewatering operation is more efficient and economical when the waste sludge solids to the filter are in a range of 3 to 5 percent. Consequently, often times it is advantageous to pre-thicken the waste sludge solids prior to vacuum filtration. This is particularly true when dewatering waste solids from a biological system.

The waste sludge (primary, excess biological solids, and solids from an ASB clari-flocculator) obtained from each treatment process is unique. The sludge obtained from each process requires detailed analyzation prior to actual design of dewatering facilties.

Waste sludge obtained from primary clarification usually has a solids content of 3 to 5 percent. These sludges normally contain fibrous material and wood particles which enhance its filterability. A filter rate of 6# Dry Solids/Sq.Ft. Filter Area/Hour is normally utilized for dewatering of primary waste solids. This filter loading rate for primary solids can oftentimes be achieved without the addition of chemicals; however, oftentimes, chemicals are required to obtain a filter cake of 20 to 30 percent solids.

As described previously, the waste biological solids obtained from an activated sludge system can be extremely gelatinous. This type of sludge is quite difficult to dewater because of its consistency and requires thickening prior to vacuum filtration. Once thickened, the waste biological solids can be combined with primary waste solids for vacuum filtration. When thickened waste biological solids are combined with primary solids, filter rates of 4#/Sq.Ft./Hour are normally obtained with the addition of chemicals to aid the vacuum filtration process.

Solids removal by clarification following an ASB is not a common practice in the pulp and paper industry. However, as solids removal becomes more important, industry will require such facilities. The solids in the effluent of an ASB are extremely difficult to settle and dewater. Consequently, it is anticipated

that a flocculant (such as alum) must be added at dosage rates of 100 to 300 mg/l in order to obtain efficient solids removal. Once withdrawn from the clarifier, the combined biological and chemical solids must be thickened prior to vacuum filtration. The thickened solids should then be combined with primary sludge for efficient vacuum filtration. By combining these solids in the above manner a filter rate of 3#/Sq.Ft./Hour was utilized for design. In addition, chemical conditioning will be required to efficiently dewater these solids by vacuum filtration.

In design of vacuum filtration facilities, there are numerous variables in design that must be considered, as outlined above. The hours per week which the vacuum filters are operating depend on the amount of solids dewatered each day and the filter loading rate.

The capital costs prepared for vacuum filtration of waste solids include: solids storage tank and pumping, building, mechanical equipment and appropriate ancillary equipment, process piping, electrical, instrumentation, and a standby vacuum filter unit. The operation and maintenance costs include disposal of the solids to a landfill site.

Sludge Press

Many times it is advantageous to provide additional solids dewatering after vacuum filtration prior to ultimate disposal, particularly if the solids are to be burned. This is normally achieved by use of a V-Press. A V-Press will normally raise the solids concentration to 35 to 40 percent solids. A screw conveyor feeds solids into a gap between two revolving press wheels. These wheels carry the solids around till a so-called "pinch point" is reached. At this point the maximum pressure is exerted on the solids. The pressed solids are then released as the wheels gradually diverge. A screw conveyor then discharges the solids into a receiving container. The filtrate from the pressing operation is then recycled back to the treatment system. The capital costs for pressing of waste solids following vacuum filtration include mechanical equipment and ancillary equipment, electrical and instrumentation, and building.

Flotation Thickening

As cited previously, waste biological and/or biological-chemical solids from the secondary clarification process require thickening before they can be efficiently dewatered. If these solids are not thickened prior to vacuum filtration, the capacity of the vacuum filter is greatly reduced. Air flotation was selected as the thickening process for this study. Air flotation requires addition of a flocculant such as a polymer to assist in the thickening process. The polymer is added to the waste solids prior to introduction into the flotation unit.

Air flotation requires the diffusion of air into the waste solids. This may be accomplished by a so-called "pressurization

system." Basically, three types of pressurization systems are available-total, partial, and recycle pressurization. In a total pressurization system, the entire waste solids stream is pressured in an air saturation tank. The partial pressurization system withdraws a portion of the influent waste solids flow to be pressurized and saturated with air. This pressurized flow is then discharged back to the influent line. In recycle pressurization, a portion of the effluent from the flotation unit is pressurized and saturated with air and recycled back to the influent.

The pressurized influent enters the flotation unit where the diffused air bubbles are allowed to surface. Diffusion of the air bubbles promotes coagulation and ultimate thickening of the waste solids. The coagulated solids (thickened sludge) are then removed for vacuum filtration. It is anticipated that air flotation will increase the secondary waste solids to 3 to 4 percent solids. The filtrate and scum from the air flotation is recycled back to the treatment process. As in vacuum filtration, there are numerous process variables that can be evaluated in sizing air flotation units. For this study it was assumed that the hours of operation of the flotation thickening equipment would vary depending on the solids loading. The following hours of application were assumed:

Secondary Solids - #/Day	Hours/Week
0-5,000	42
5,000-20,000	24
20,000-60,000	126

An air flotation loading rate of 2# Dry Solids/Sq.Ft./Hour was utilized in design of these facilities. The capital costs for air flotation thickening of waste biological and biological-chemical solids include building process equipment, chemical feed system, electrical, instrumentation, and ancillary equipment.

Secondary Clarification

Secondary clarification is required with an activiated sludge system to provide separation of the biological mass and treated stream. In addition, they are often required after an ASB system for supplemental solids removal. The clarifier most effective for secondary solids separation is the contact type. The effluent from the activated sludge basin or ASB system flows into a flocculation chamber in the clarifier. In this chamber flocculants such as alum and polymer are added to the wastewater stream. Low speed mixers disperse the flocculants throughout the chamber allowing for coagulation and floc formation. The wastewater stream then flows into the clarifier area for solids separation.

For flows in excess of five (5) mgd, two parallel units, each capable of 50 percent of the daily flow, were assumed to be used.

The design overflow rate for the clarifiers, excluding flocculation area, is 500 gpd/sq.ft. The drive mechanism would be rated for a torque of 10(D)2.

In a waste activated sludge system, most of the biological solids settled in the secondary clarifiers are recycled to the aeration basin to maintain an active biological mass in the aeration basin. Pumping capacity is provided for a maximum recycle rate of 75 percent of the average daily flow with an average recycle rate of 40 percent of the average daily flow.

The capital costs presented for secondary clarification include excavation, backfill, concrete, recycle pumps, mechanical equipment, electrical, instrumentation, yard piping, and ancillary equipment for proper operation.

Mixed Media Filtration

Mixed media filtration is presented in this report as a "polishing process" following secondary treatment for supplemental suspended solids removal. The units evaluated are single-stage, parallel pressure filters with provision for operation of two units in series for two stage filtration. A clear well for storage of the backwash water is provided for backwash of the captured solids. A surface wash is also provided for scouring the media and minimizing slime growth. The backwash water with its high solids concentration is pumped to a storage tank where the solids can settle, with the decanted water being conveyed back into the treatment system. The settled solids are transported to the solids dewatering equipment. The design rate for the filters is 5 gpm/sq.ft. A standby unit is provided for periods of breakdown or maintenance on one of the other filters.

The capital costs for mixed media filtration include building, process equipment, equalization basin, piping, electrical, instrumentation, and ancillary equipment.

Neutralization

Pulping processes significantly change the pH of a wastewater. Such variations in pH can affect the waste treatment process; therefore, it is necessary to add chemicals (acid and/or caustic) and flash mix the wastewater for neutralization.

The capital cost for pH adjustment includes excavation, backfill, concrete, mixer, chemical feed system, etc. The flash mix tank provides one minute detention time at peak flow with mixing capacity of 1 Hp/ 1000 gal. capacity of mix tank.

Flow Monitoring Structure

In order to monitor the unit processes and overall efficiency of the treatment process, it requires installation of flow monitoring structures throughout the process. The flow

monitoring structure considered in this study includes a Parshall flume and automatic sampling equipment.

Foam Control

In many installations, foam control is very critical. Included in this study, as required, is a foam tank with adequate capacity for storage of foam. As the foam builds up in the facility, it eventually settles because of its inability to support its own weight. The foam tank provides for a five-minute hydraulic capacity.

Outfall Sewer

The outfall sewer is defined as the sewers required to connect the mill to the treatment facility and the treatment facility to the diffuser. Thus, for this cost analysis, one (1) mile of outfall sewer is assumed to be required to make these connections.

Diffuser

Discharge from the outfall sewer is assumed to be through a multiplepart diffuser which will facilitate mixing of the treatment facility effluent with the receiving water. Such induced mixing will minimize any horizontal and vertical stratification of the effluent in the receiving waters. The costs presented in this report assume that the diffuser is of standard design and that moderate underwater conditions will be encountered. Standard design recommends 10 to 15 feet of diffuser/mgd; therefore, 12 feet/mgd was utilized. This can vary substantially depending on the desired and required diffusion characteristics. The capital costs include excavation backfill, laying and jointing of the diffuser pipe.

Minimum Lime Treatment

Where color removal technology has been required, treatment by minimum lime has been utilized in this report. The first caustic extraction stage effluent, approximately 20 percent of a mill's effluent, is mixed with 1500 to 3000 ppm of lime. Approximately 75 percent of the lime is recovered in a clarifier. The lime removed in the clarifier is then pumped to a lime mud mixer where it is combined with the kraft mill lime from the recausticized filter. The combined lime is then further thickened by filtration. The additional lime kiln capacity required to handle lime from a minimum lime system is approximately 15 percent. The mud drying and calcining capacity is increased through the addition of a flash drying system before the kiln. The capital costs presented for minimum lime treatment for color removal includes additional filters, kiln capacity, flash drying system, and a clarifier for settling of the lime.

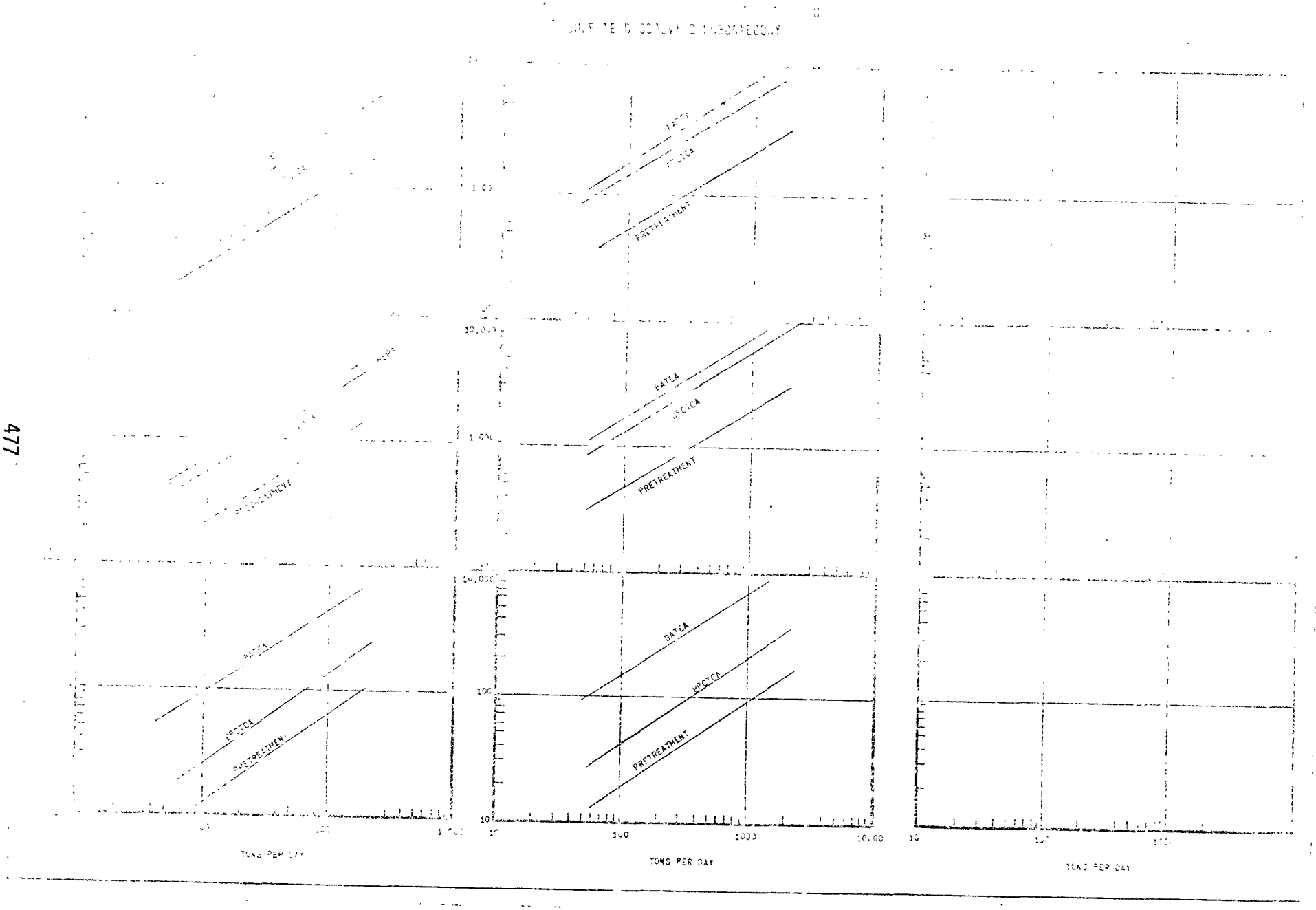
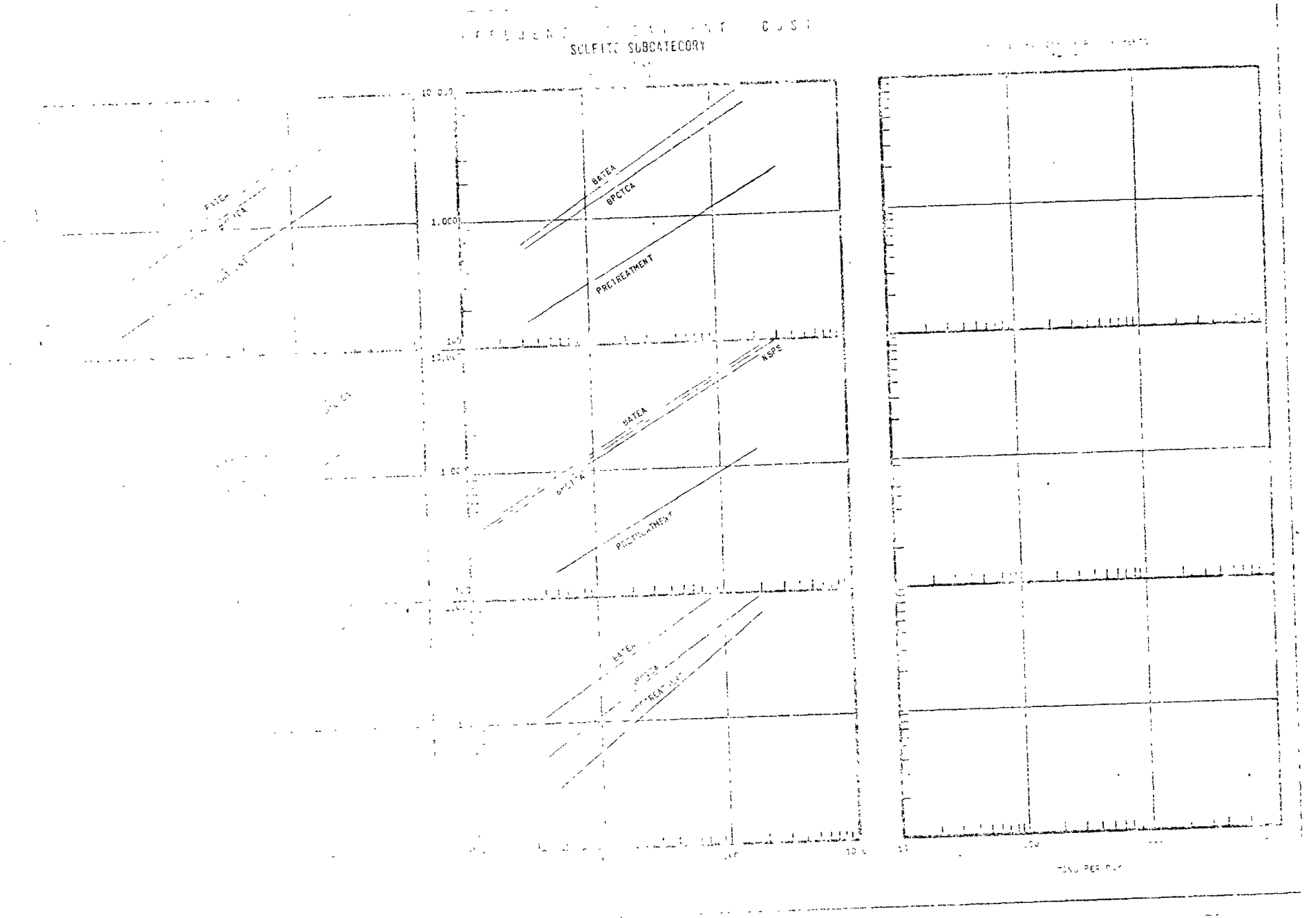


Figure 66


SULFITE SUBCATEGORY
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NSPS
BATEA
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PRETREATMENT
BATEA
BPCTCA
PRETREATMENT

Figure 67

BRICK
BLOCK
PRECIPITATION
BRICK
BLOCK
PRECIPITATION

Figure 68

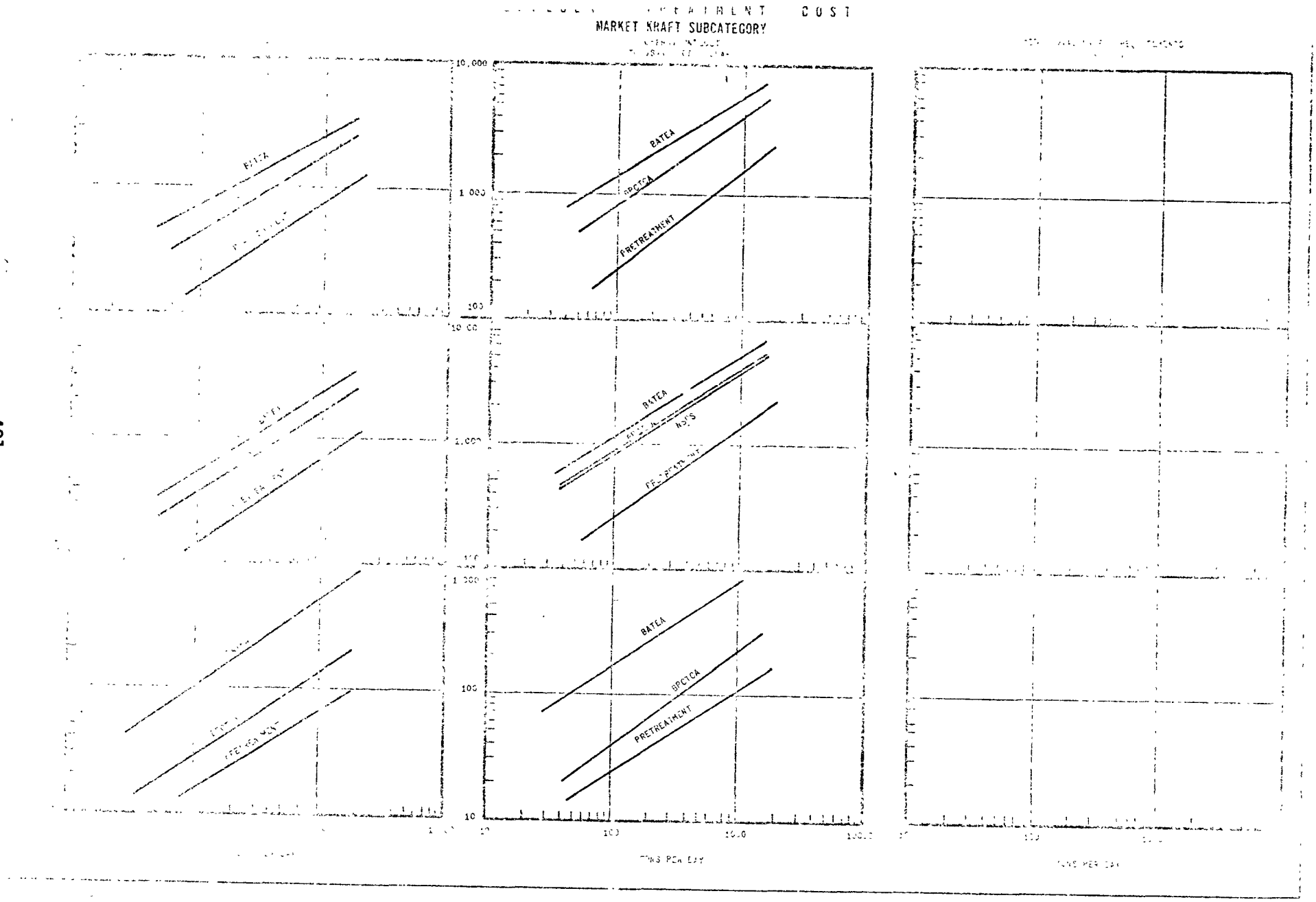
MARKET KRAFT SUBCATEGORY
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Figure 70

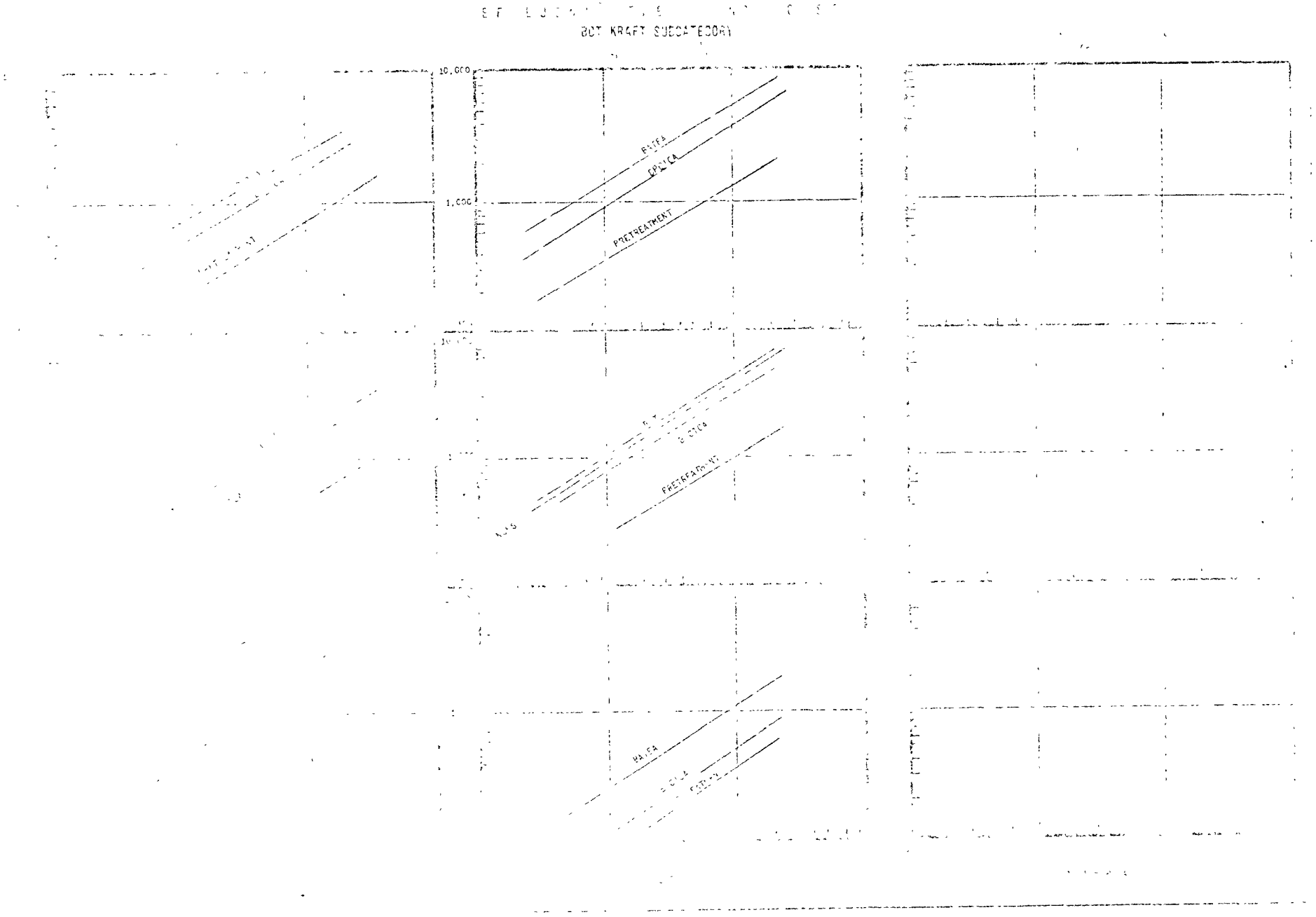

Figure 71

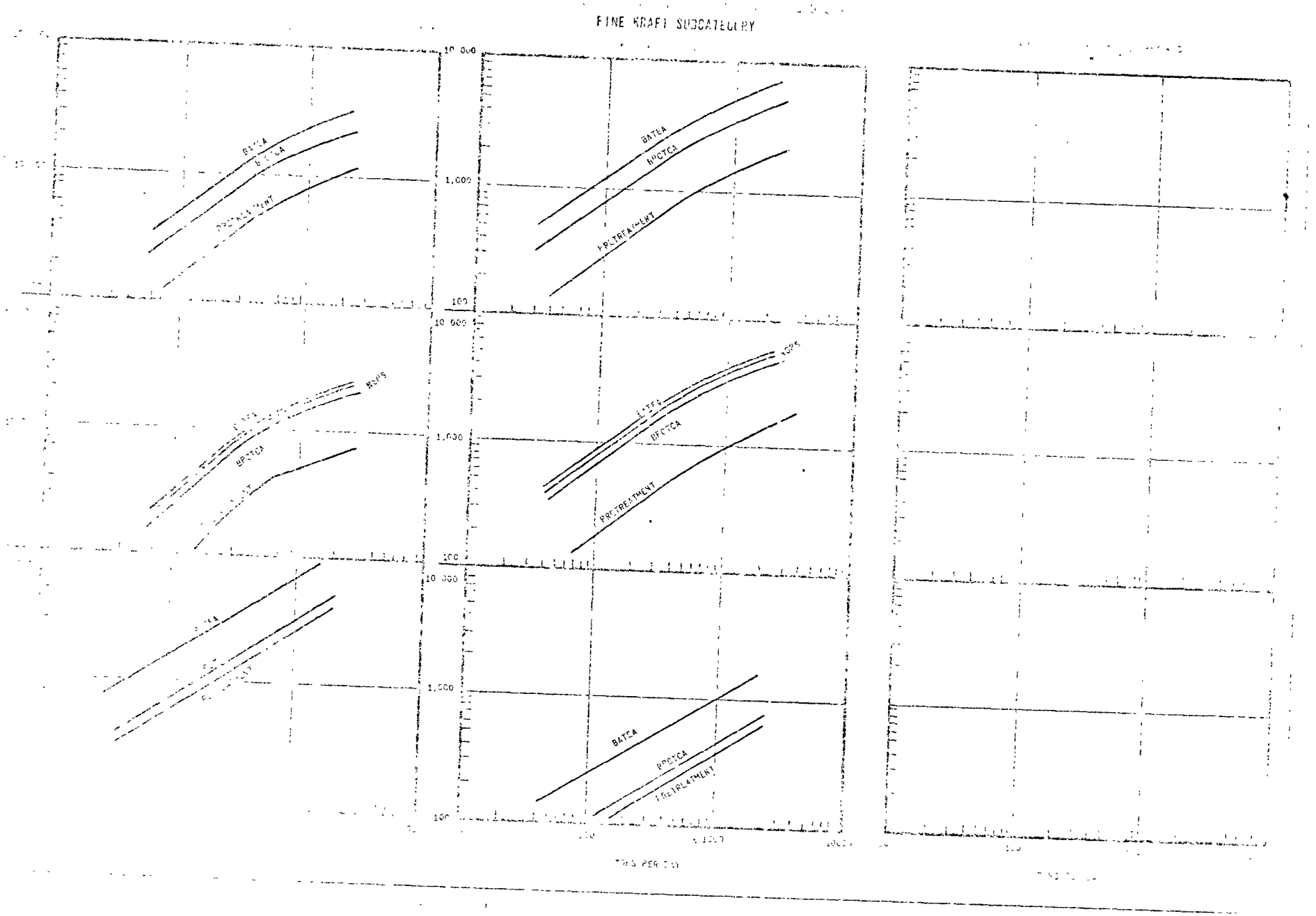
FINE KRAFT SUBCATEGORY
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Figure 72

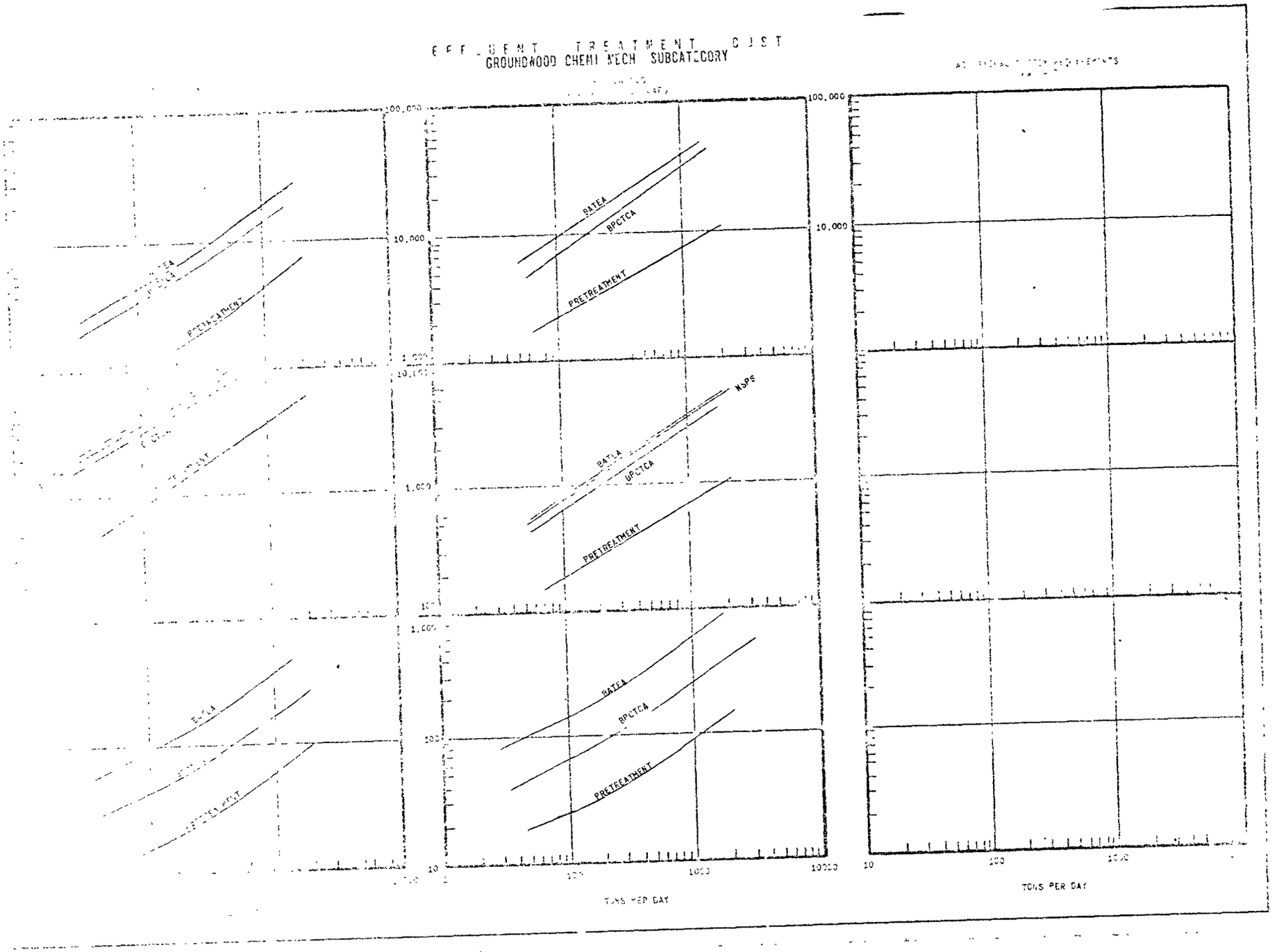

EFFLUENT TREATMENT COST
GROUNDWOOD CHEMI MECH SUBCATEGORY
BATEA
BPCTCA
PRETREATMENT
NSPS
100,000
10,000
1,000
100
10
1000
10000
TONS PER DAY

Figure 73

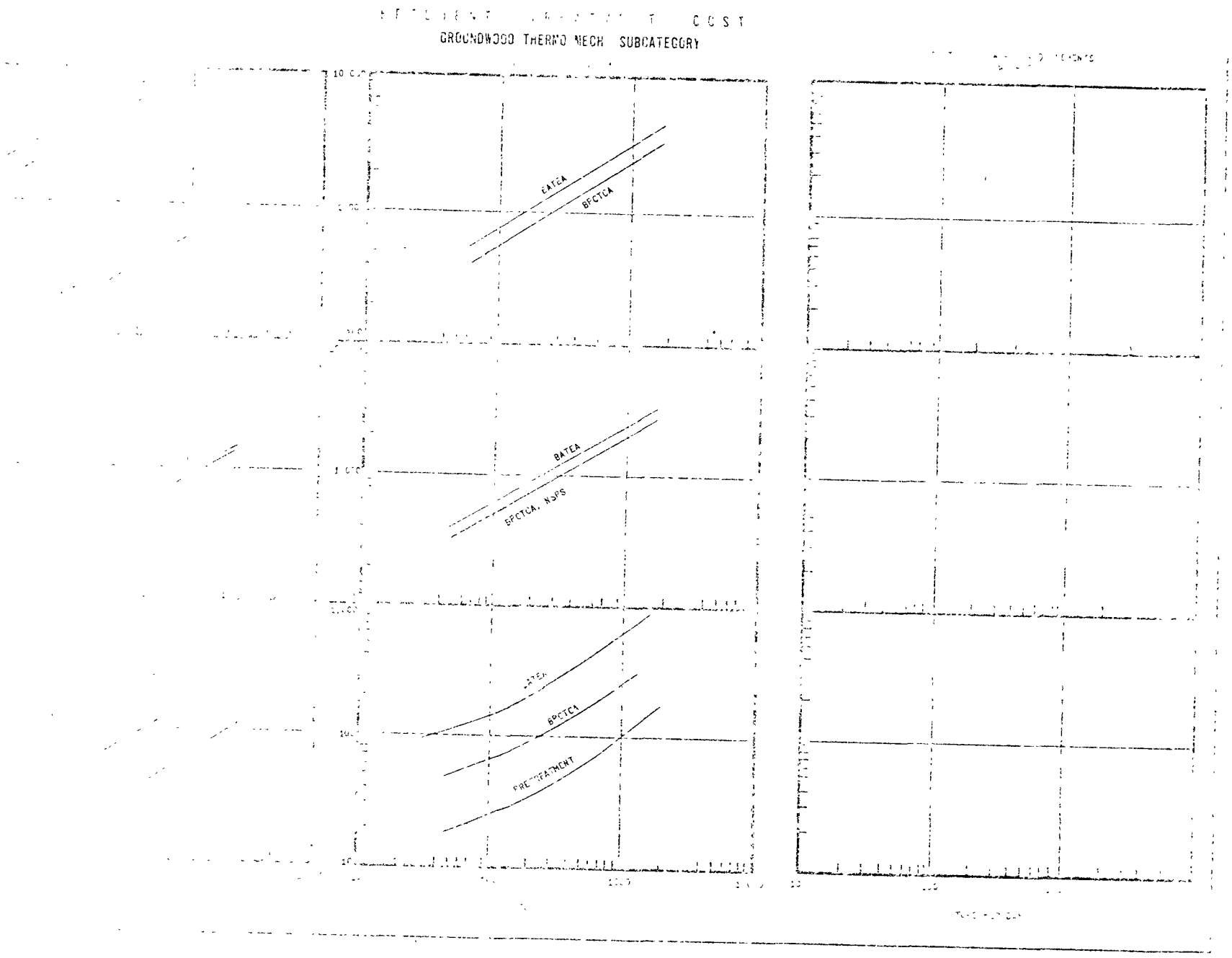

COST
GROUNDWOOD THERMO MECH SUBCATEGORY
BATEA
BPCTCA
BATEA
BPCTCA, NSPS
BATEA
BPCTCA
PRETREATMENT

Figure 74

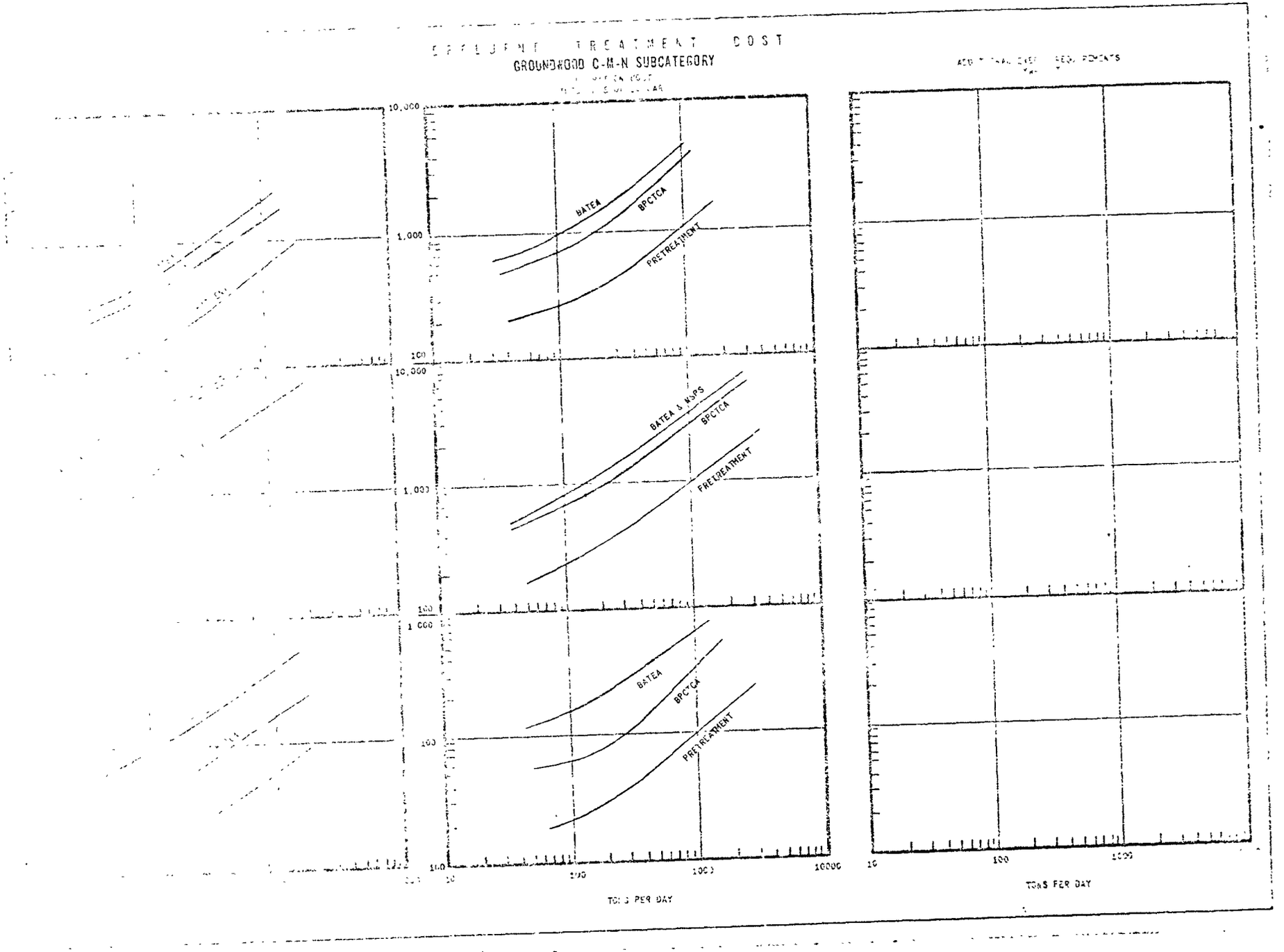

EFFLUENT TREATMENT COST
GROUNDWOOD C-M-N SUBCATEGORY
10,000
1,000
100
10,000
1,000
100
1,000
100
10.0
10
100
1000
10000
BATEA
BPCTCA
PRETREATMENT
BATEA & NSPS
BPCTCA
PRETREATMENT
BATEA
BPCTCA
PRETREATMENT
TONS PER DAY
10
100
1000
TONS PER DAY

Figure 75

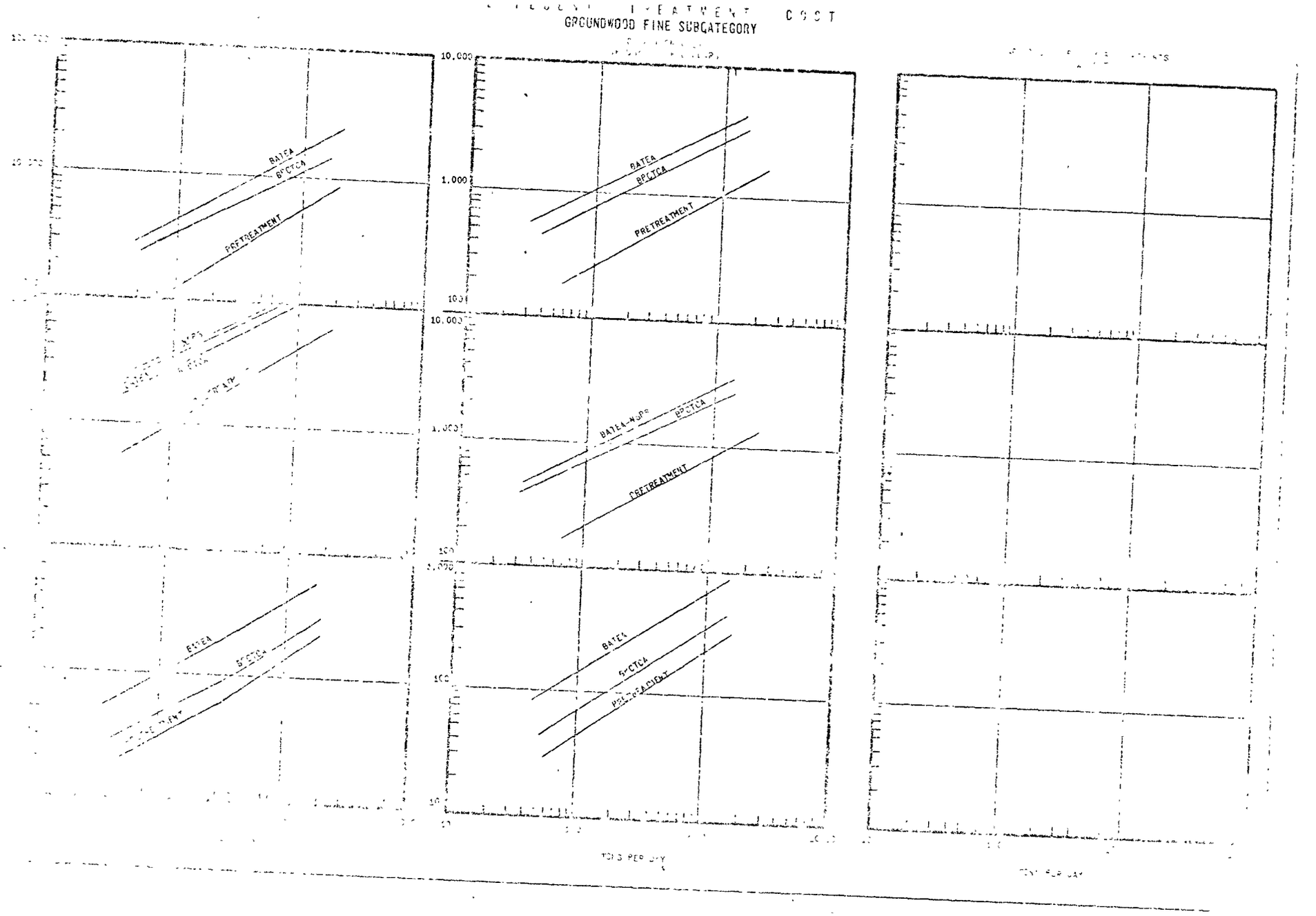

GROUNDWOOD FINE SUBCATEGORY
10,000
1,000
100
10,000
1,000
100
BATEA
BPCTCA
PRETREATMENT
BATEA-NLPS
BPCTCA
PRETREATMENT
BATEA
BPCTCA
PRETREATMENT
BATEA
BPCTCA
PRETREATMENT

Figure 76

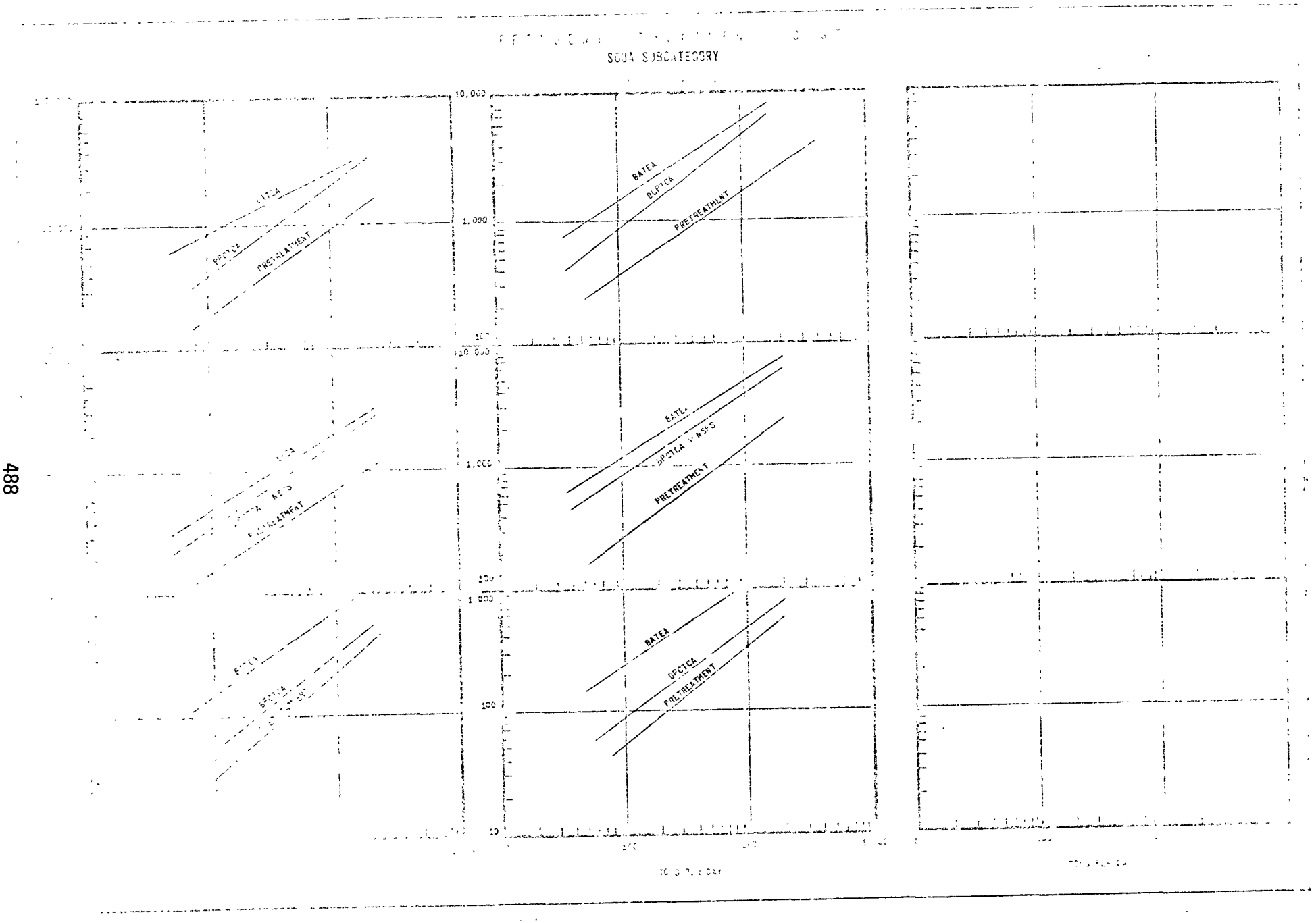

SODA SUBCATEGORY
10,000
1,000
100
10
BATEA
BPCTCA
PRETREATMENT
BATEA
BPCTCA
PRETREATMENT
BATEA
BPCTCA
PRETREATMENT

Figure 77

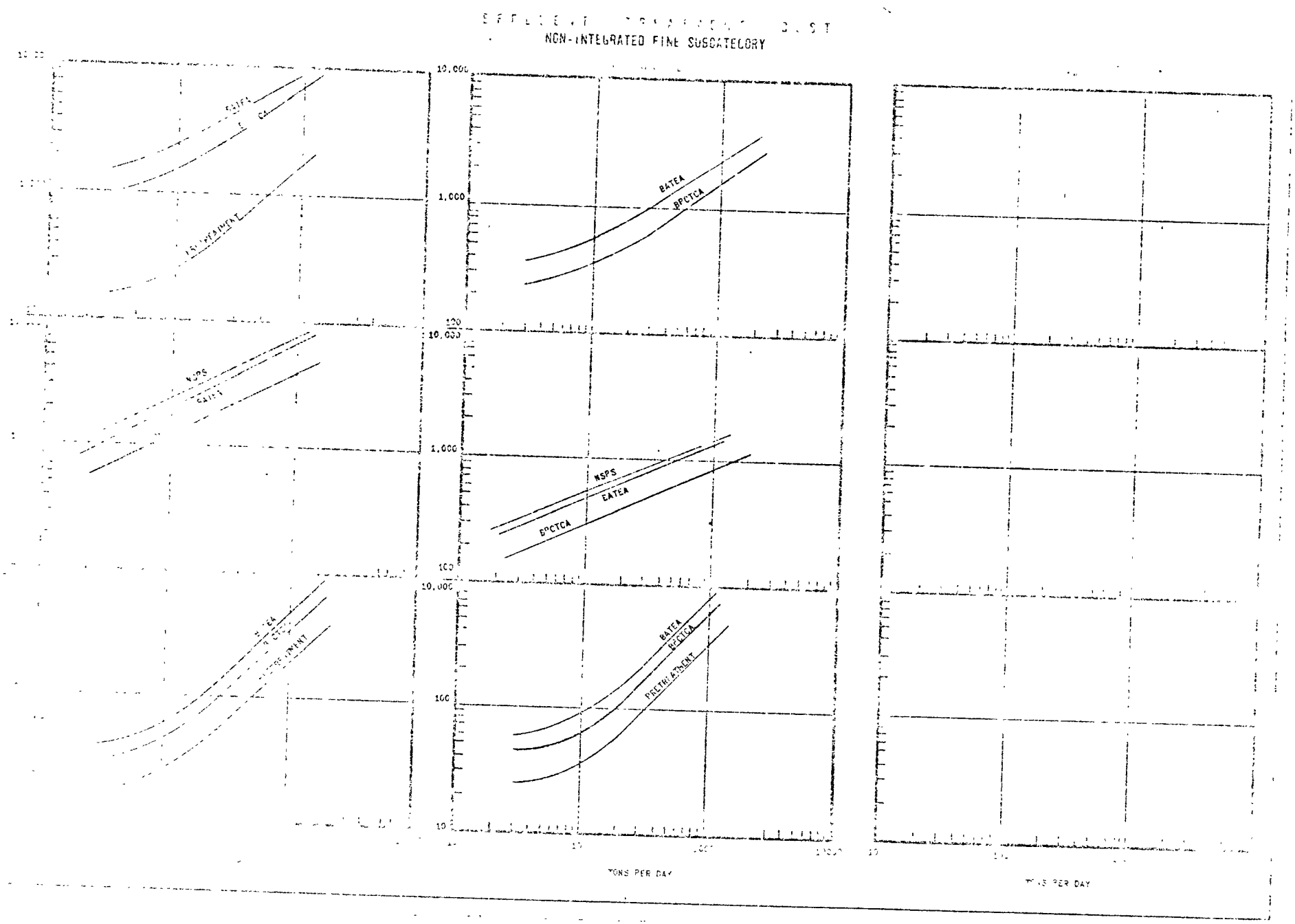

NON-INTEGRATED FINE SUBCATEGORY
10,000
1,000
100
10
BATEA
BPCTCA
NSPS
EATEA
PRETREATMENT
TONS PER DAY

Figure 78

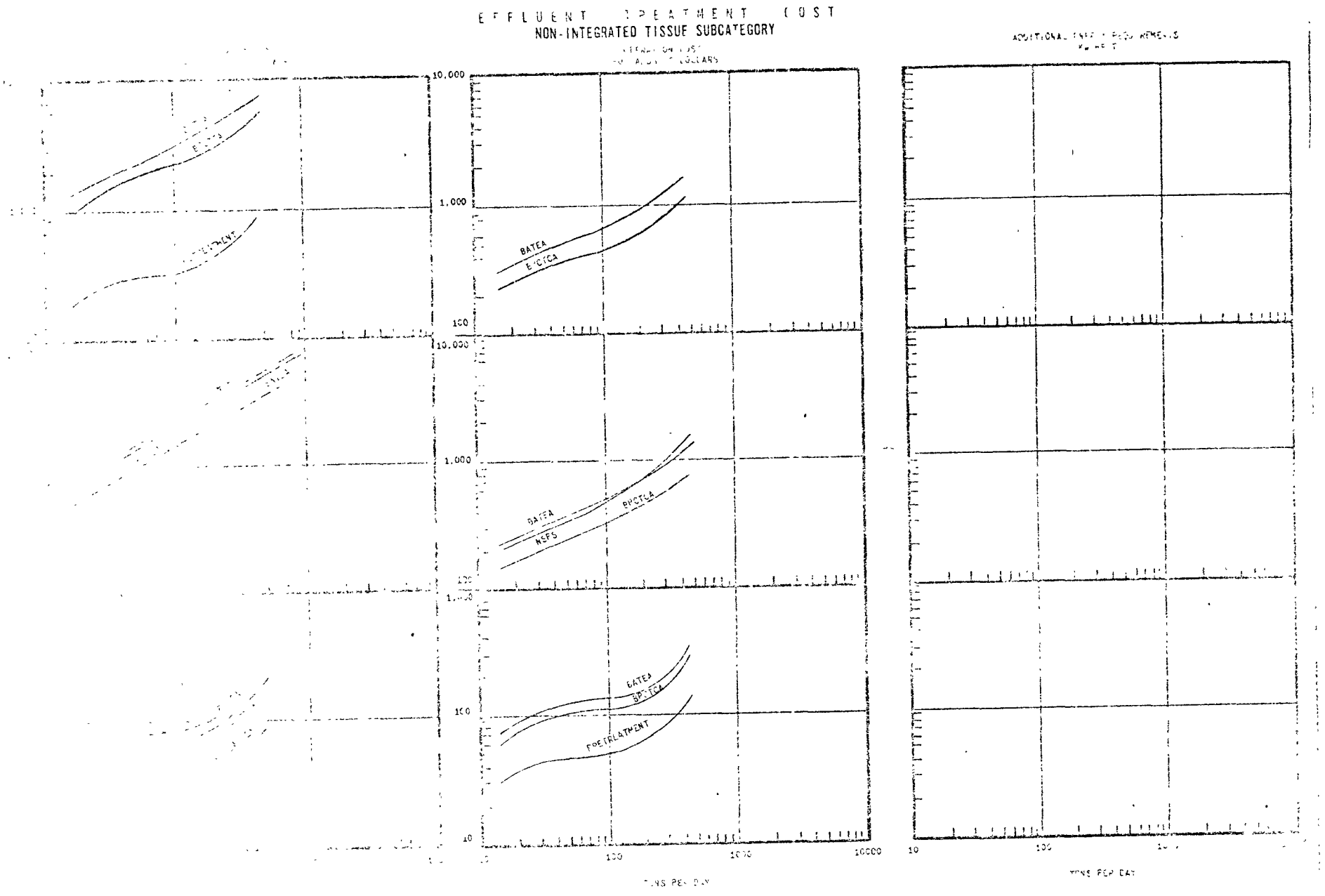

EFFLUENT TREATMENT COST
NON-INTEGRATED TISSUE SUBCATEGORY
10,000
1,000
100
10,000
1,000
100
10
BATEA
ELECTRA
BATEA
NSFS
BPCTCA
BATEA
BPCTCA
POSTTREATMENT
100
1000
10000
10
100

Figure 79

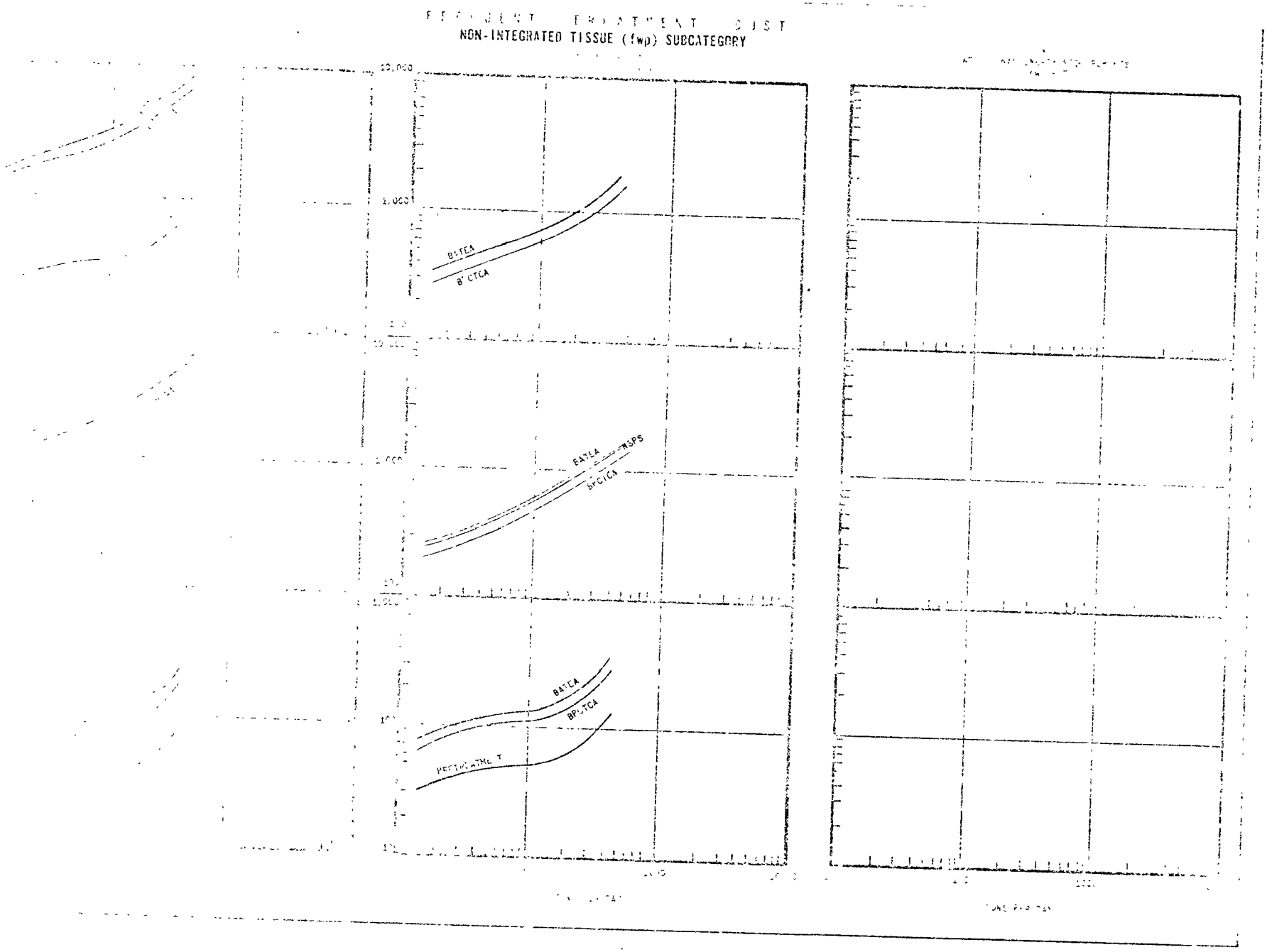

NON-INTEGRATED TISSUE (fwp) SUBCATEGORY
10,000
1,000
BATEA
BPCTCA
BATEA
BPCTCA
BATEA
BPCTCA

Figure 80

Retrofit Costs

The development of capital investment costs for mills that must upgrade their external wastewater treatment facilities in order to be in compliance with the effluent limitations was predicated on the following criteria.

1. "Retrofit costs" are determined using only mills with existing suspended solids removal and biological treatment facilities. This selection criteria is based on evaluation of all the pertinent data generated by this study which established that BPCTCA for all mills in each subcategory is primary and biological treatment. Mills in the tissue FWP (predominantly a waste paper furnish) subcategory require primary and biological treatment but mills using predominantly virgin pulp are an exception in that these mills require only primary treatment for BPCTCA. Therefore the mills in this subcategory that were selected to determine "retrofit costs" include mills with only primary treatment facilities.

2. A table listing all mills for each subcategory was prepared describing the mill size, production and reported treatment trains. Using the criteria described above, selection of all the mills in each subcategory or segment to be used for the determination of retrofit costs were made.

3. Retrofit costs are based on the difference between the annual average BOD and TSS actually achieved by each selected surveyed mill and the average of the annual averages achieved by the mills used to establish the effluent limitations for the subcategory. This difference represented the additional BOD and TSS removal required for each mill. The annual average wastewater volume and the additional BOD and TSS removal required for each mill was then developed. This information as well as mill size and treatment train is tabulated by the segment in Table 160.

Using the procedures and selection criteria described above the methodology for the determination of "retrofit costs" for each subcategory or segment was as follows:

Groundwood Segment

The groundwood segment includes the following subcategories: chemi-mechanical, thermo-mechanical, groundwood making fine paper and groundwood making coarse, news and molded paper products. There are a total of 19 mills that were surveyed and 20 mills that were not surveyed in this segment and only three mills qualified for determination of retrofit costs. The remaining mills either discharged to a municipal system, have no treatment facilities, have only primary treatment facilities or are in compliance with the effluent limitations. The design criteria on which "retrofit costs" are based are described in Table 161. "Retrofit costs" for the three mills selected are shown in Table 164.

TABLE 160

SURVEYED MILLS USED TO DETERMINE RETROFIT COSTS

Mill Code	Tons/ Day	Treatment Train	Flow M.G.D.	#/Day To Be Removed	
				BOD	TSS
		Groundwood			
003	542	C-TF-C	13.8	6,179	3,848
002A	217	C-A	4.9	586	1,259
004A	71	SB-SB-SB	2.1	277	I.C.
		Sulfite			
051	296	C-ASB	16.6	240	503
052	101	C-ASB	4.1	537	I.C.
		Soda			
150	300	C-TF	12.0	19,000	24,000
152	600	C-ASB	17.0	11,000	24,000
		Bleached Kraft			
140	320	SB-ASB	6.0	2,300	1,200
108	1000	C-ASB	55	6,800	4,000
120	1160	ASB	36.1	580	19,952
110A	1132	ASB	27.8	906	3,736
136	1650	ASB	47.4	3,300	83,655
134	945	ASB	21.0	8,978	37,044
104A	1342	A	70.2	13,554	27,511
116	1150	ASB	36.1	13,685	83,305
118	192	A	5.0	1,133	N.A.
132	417	*	8.1	3,294	I.C.
103	425	ASB	18.4	7,055	I.C.
107A	310	A	9.4	I.C.	3,689
112	640	ASB	16.9	I.C.	13,824
121A	1351	ASB	48.4	1,080	O.K.
138	986	ASB	33.0	1,578	4,733
113A	1177	ASB	39.8	2,589	N.A.
109A	1119	A	43.8	4,993	24,170
100	1027	ASB	37.1	21,362	I.C.
501	1385	ASB	66.1	21,745	26,315
122A	598	ASB	17.3	12,030	15,608
111A	772	ASB	25.0	I.C.	772
102A	1020	ASB	34.7	36,108	8,976

I.C. = In Compliance
N.A. = Not Applicable
* = Oxidation Lagoon

TABLE 160
(continued)

Mill Code	Tons/ Day	Treatment Train	Flow M.G.D.	#/Day To Be Removed BOD	#/Day To Be Removed TSS
			Deink		
210	320	SB-PS	6.2	6,003	I.C.
205A	100	C-ASB	1.9	245	N.A.
			Fine		
284	375	C-ASB-C	2.3	262	I.C.
257A	187	C-A	1.9	430	N.A.
			Tissue		
252	49	C-PS	0.6	54	I.C.
303	45	FI	2.8	239	N.A.
308A	160	C	4.4	560	304
318	125	C	4.2	188	438
333	163	C	5.2	652	N.A.
337	36	C	4.5	508	72
259A	194	C-FI	3.4	446	I.C.
312	15	C-ASB-PS	0.7	N.A.	590
313	37	C-PS	0.2	644	N.A.
330	20	C	0.4	352	N.A.
208A	104	C	1.5	707	62
302	226	C-PS	2.8	226	N.A.
329	74	C	2.7	488	96

I.C. = In Compliance
N.A. = Not Applicable

Sulfite Segment

The sulfite segment includes the sulfite and dissolving sulfite subcategories. There are 11 mills in this segment that were subject to detailed survey and 17 mills that were not. There were only two mills in the entire segment that qualified for determination of retrofit costs. The remaining mills discharged to a municipal sewer, have no treatment, have only primary treatment or are in compliance with the effluent limitations. The design criteria on which these costs are based is described in Table 161. "Retrofit costs" for the two mills shown in Table 164 represents the total costs for the entire sulfite segment.

Soda Subcategory

The two mills listed in Table 160 for the soda subcategory are the mills that qualify for development of "retrofit costs" for this subcategory. The costs to upgrade the wastewater treatment facilities for these two mills, i.e., "retrofit costs" are shown in Table 164. The design criteria on which these costs are based is described in Table 161.

Deink Subcategory

Four mills listed in Table 160 in this subcategory qualified for selection to determine retrofit costs. The remaining mills in this subcategory discharged to a municipal system, have no treatment, have primary treatment only, or are in compliance with the effluent limitations. The "retrofit costs" developed for these four mills therefore represent the costs for the entire subcategory which are shown in Table 164. The design criteria on which these costs are based is described in Table 161.

Fine Paper Subcategory (Non-Integrated)

The two mills shown in Table 160 provide the basis for determining "retrofit costs" for this subcategory. The other mills in this subcategory discharged to a municipal system, have no treatment, have primary treatment only, or are in compliance with the effluent limitations. The retrofit costs for this subcategory are shown in Table 166 and the design criteria on which they are based are shown in Table 161.

Bleached Kraft Segment

The bleached kraft market pulp, dissolving pulp, fine paper and BCT (board, coarse and tissue) subcategories are included in this segment. The twenty-two mills listed in Table 160 under the bleached kraft segment are those that require the determination of "retrofit costs." In addition to these mills there are ten more that were not surveyed, for which retrofit costs must be determined. There is insufficient data available for these unsurveyed mills to develop adequate design criteria on which to base "retrofit costs." Therefore those costs developed for the surveyed mills which are based on the design criteria shown in

TABLE 161

BASIS FOR RETROFIT COST DETERMINATION

The following list represents the additional removal requirements to be achieved by existing primary and secondary treatment facilities.

Tons/ Day	MGD	BOD #/Day	Added Treatment Required	TSS #/Day	Added Treatment Required
			Groundwood Segment		
560	13.0	6200	Aerators + 3 days retention	4000	Chemical feed only
220	5.0	600	Aerators only	in compliance	None
75	2.0	300	Aerators only	"	None
			Sulfite Segment		
300	17.0	300	Aerators only	500	none
100	4.0	600	Aerators only	In compliance	None
			Soda Segment		
600	17.0	11000	Aerators + 6 days retention	24000	Chemical feed + sludge handling
300	12.0	10000	Aerators + 8 days retention	24000	Chemical feed + sludge handling
			Deink Segment		
850	18.0	300	Aerators only	3000	Chemical feed only
400	7.0	8200	Aerators + 4 days retention	2700	Chemical feed only
320	6.0	6000	Aerators + 3 days retention	In compliance	None
200	3.0	1000	Aerators only	3000	Chemical feed
100	2.0	300	Aerators only	3000	Chemical feed
			Fine Segment		
375	2.5	270	Aerators only	In compliance	None
200	2.0	450	Aerators only	2000	Chemical feed

Table 162 approximate retrofit costs for the unsurveyed mills. The total retrofit costs for the entire bleached kraft segment were derived using the procedures described below.

Surveyed Mills

Two of the twenty-two bleached kraft mills listed in Table 160, required no additional capital costs to achieve compliance. Improved operation and additional chemical usage appeared to be the probable solution for these mills. The remaining twenty mills require various improvements in existing treatment facilities in order to achieve the additional BOD and TSS removals shown. The design criteria shown in Table 162 applies for from one to as many as four mills, all of which are included in the twenty surveyed mills. The costs to provide the additional treatment indicated are shown in Table 168 under the surveyed mills section. The retrofit costs used for the various treatment levels required are shown in Table 165.

Unsurveyed Mills

The ten mills that require additional treatment facilities are listed in Table 167, showing mill size and wastewater volume for each mill. The average mill size is 1092 kkg/day (1200 T/D) and volume is 113.4 MLD (30 MGD); therefore, the retrofit costs developed for the surveyed mills that averaged 910 kkg/day (1000 T/D) and 121 MLD (32 MGD) were used to determine retrofit costs for these unsurveyed mills. Using Table 162, it can be seen that there are ten surveyed mills requiring from two to ten days additional retention time in their aeration basin. The ten unsurveyed mills all utilize aeration basins and it was assumed that the amount of additional treatment known to be required by the surveyed mills could reasonably be expected to be required by the unsurveyed mills. Therefore the retrofit costs developed for the surveyed mills, increased by a factor of 1.2 to reflect the larger size of the unsurveyed mills was used to determine the retrofit cost for these mills. It was also assumed that the number of mills requiring the differing levels of treatment would be the same for the ten unsurveyed mills as was experienced by the ten surveyed mills. The results of these calculations are shown in Table 168. The total retrofit costs for the entire segment is also shown in this table.

Tissue Segment

The tissue segment includes the tissue made from virgin pulp and tissue (made from waste paper) subcategories. BPCTCA for the former subcategory is primary treatment and for the latter, primary treatment plus biological treatment. The thirteen mills listed in Table 160 are those surveyed mills that require the determination of retrofit costs. In addition, there are eleven mills that were not surveyed for which retrofit costs must be determined. There is insufficient data available for these unsurveyed mills to develop adequate design criteria on which to base retrofit costs. Therefore, those costs developed for the

TABLE 162

BASIS FOR RETROFIT COST DETERMINATION

The following list represents the additional removal requirements to be achieved by existing primary and secondary treatment facilities in the bleached kraft segment.

ALL ASB TREATMENT FACILITIES

# OF Mills	Tons/ Day	MGD	BOD #/Day	Added Treatment Required	TSS #/Day	Added Treatment Required
1	320	6.0	2400	Aerators only	1200	None
1	1000	55.0	6800	Aerators + 3 days retention	4000	Chemical feed only
4	1000	32.0	1000	Aerators only	7000	Chemical feed only
3	1000	32.0	3000	Aerators + 2 days retention	28000	Chemical feed + sludge hanc
2	1000	32.0	8000	Aerators + 4 days retention	19000	Chemical feed + sludge hanc
2	1000	32.0	13000	Aerators + 6 days retention	50000	Chemical feed + sludge hanc + Clarifier for 16 MGD
2	1000	32.0	22000	Aerators + 8 days retention	13000	Chemical feed + sludge hanc
1	1000	32.0	36000	Aerators +10 days retention	9000	Chemical feed + sludge hanc

ALL ACTIVATED SLUDGE TREATMENT FACILITIES

2	250	7.0	1000	Aeration	3000	Chemical feed
2	1230	57.0	10000	Provide Activated Sludge plant for 20 MGD	26000	Chemical feed for 57 MGD

NOTE: Added aerators, chemical feed, & sludge handling facilities are to be sized for pounds per day of additional removal required. Additional days retention are to be made for the MGD's shown.

TABLE 163

BASIS FOR RETROFIT COST DETERMINATION

The following list represents the additional removal requirements to be achieved by existing primary and secondary treatment facilities in the tissue segment.

TISSUE FROM 60% PURCHASED PULP OR MORE

AVG. T/D	# OF MILLS	AVG. MGD	BOD #/DAY	TSS #/DAY	ADDED TREATMENT REQUIRED
43	3	2.6	270	270	Chemical feed + full primary system for 1.3 MGD. Use clarifiers
160	4	4.3	460	500	Chemical feed + full primary system for 1.0 MGD. Use clarifiers
135	3	2.3	475	80	Chemical feed + full primary system for 0.6 MGD. Use clarifiers

TISSUE (fwp-90% WASTE PAPER OR MORE)

25	3	0.4	500	330	Aerators + 4 days retention for 0.4 MG + sludge handling facilities.

NOTE: Added aerators, chemical feed, & sludge handling facilities are to be sized for pounds per day of additional removal required. Additional days retention are to be made for the MGD's shown. Full primary system includes pumping and sludge handling facilities for flow and pounds per day removal requirements shown.

Table 164
RETROFIT
EFFLUENT TREATMENT COSTS

(All Costs In Thousands Of Dollars)

Mill Size				Retrofit Costs Additional Investment Cost	Additional Operating Cost	Depreciation & Interest	Operating & Maintenance
Tons/Day	MGD	BOD_r #/Day	TSS_r #/Day				
				Groundwood Segment			
560	13.0	6200	4000	1540	450	230	220
220	5.0	600	None	50	15	10	5
75	2.0	300	None	30	10	5	5
				Sulfite Segment			
300	17.0	300	500	25	10	5	5
100	4.0	600	None	45	10	5	5
				Soda Segment			
600	17.0	11,000	24,000	3870	1040	580	460
300	12.0	19,000	24,000	4430	1130	665	465
				Deink Segment			
400	7.0	8200	2700	1820	435	275	160
320	6.0	6000	None	1430	285	215	70
--	2.0	1000	3000	125	55	20	35

500

Table 165
RETROFIT
EFFLUENT TREATMENT COSTS

(All Costs In Thousands Of Dollars)

Mill Size				Retrofit Costs			
Tons/Day	MGD	BOD_r #/Day	TSS_r #/Day	Additional Investment Cost	Additional Operating Cost	Depreciation & Interest	Operating & Maintenance
				Bleached Kraft Segment			
320	6	2400	1200	150	40	25	15
1000	55	6800	4000	2980	1130	445	685
1000	32	1000	7000	125	345	20	325
1000	32	3000	2800	3115	1050	470	580
1000	32	8000	1900	3930	1170	590	580
1000	32	13,000	50,000	6570	1730	985	745
1000	32	22,000	13,000	5410	1470	810	660
1000	32	36,000	9000	6250	1630	940	740
				Bleached Kraft Segment Waste Activated Sludge			
250	7	1000	3000	110	95	20	75
1230	57	10,000	26,000	6885	2270	1035	1235

Table 166
RETROFIT
EFFLUENT TREATMENT COSTS

(All Costs In Thousands Of Dollars)

Mill Size				Retrofit Costs Additional Investment Cost	Additional Operating Cost	Depreciation & Interest	Operating & Maintenance
Tons/Day	MGD	BOD_r #/Day	TSS_r #/Day				
				Fine Segment			
375	2.5	270	None	25	10	5	5
200	2.0	450	2000	85	40	15	25
				Tissue Segments			
43	2.6	270	270	630	175	95	80
160	4.3	460	500	600	165	90	75
135	2.3	475	80	405	125	60	65
				Tissue (fwp)			
25	0.4	500	330	520	105	80	25

Table 167

UNSURVEYED MILLS -- REQUIRING RETROFIT
BLEACHED KRAFT SEGMENT

Code	T/D	MGD
179	1700	
173	1500	NA
149	1500	24.0
177	1500	42.0
167	1600	35.0
180	1300	38.0
171	920	20.0
161	725	30.0
174	720	36.0
187	640	29.0
		20.0
Average	1200	30.0

Table 168

RETROFIT COSTS FOR THE BLEACHED KRAFT SEGMENT

Surveyed Mills

Number of Mills	Cost Per Mill $,1000	Total Cost $1,000
1	150	150
1	2,980	2,980
4	125	500
3	3,115	9,345
2	3,930	7,860
2	6,570	13,140
2	5,410	10,820
2	6,250	6,250
1	110	220
2	6,885	13,770

Unsurveyed Mills

Number of Mills	Cost Per Mill $1,000	Size Factor	Total Cost $1,000
3	3,115	1.2	11,214
2	3,930	1.2	9,432
2	6,570	1.2	15,768
2	5,410	1.2	12,984
1	6,250	1.2	7,500
	TOTAL COST PER SEGMENT		121,933

Table 169

RETROFIT COSTS FOR THE TISSUE SEGMENT

Surveyed Mills

Number of Mills	Average T/D	Cost Per Mill $1,000	Factor	Total Cost $1,000
3	43	630	1	1,890
4	160	600	1	2,400
3	135	405	1	1,215
3	25	520	1	1,560

Unsurveyed Mills

Mill Code	Average T/D	Cost Per Mill $1,000	Factor	Total Cost $1,000
607	10	630	10/43	147
609	20	630	20/43	293
335	30	630	30/43	440
344	30	630	30/43	440
339	30	630	30/43	440
338	35	630	35/43	513
336	36	630	36/43	527
348	40	630	40/43	586
329	50	630	50/43	735
327	75	630	75/43	1,099
612	210	600	210/160	788
		TOTAL COST PER SEGMENT		13,073

surveyed mills which are based on the design criteria shown in Table 163 were utilized to determine approximate retrofit costs for the unsurveyed mills. The total retrofit costs for the entire tissue segment were derived using the procedures described below.

Surveyed Mills

The surveyed mills listed under the tissue segment in Table 160, require various improvements in existing treatment facilities in order to achieve the additional BOD and TSS removals shown. The design criteria shown in Table 163 were derived by grouping the mills by size and whether they used predominantly virgin pulp or waste paper. The first three treatment levels shown in Table 163 are for ten mills that require primary treatment only, i.e., tissue subcategory. The last treatment level is for three mills that require biological treatment, i.e., tissue (FWP) subcategory. The costs to achieve these various treatment levels are shown in Table 166. These costs are multiplied by the number of mills to which they apply and a total for each level of treatment is obtained for each of the four levels of treatment required. These final retrofit costs are shown in Table 169 under the surveyed mills section.

Unsurveyed Mills

The eleven unsurveyed mills that require additional treatment facilities are listed in Table 169. For purposes of developing retrofit costs for these mills, the cost developed for the surveyed mills for the group of mills that averaged 39.1 kkg/day (43 T/D) in size, see Table 166, was used for the first ten mills. To determine the cost for the eleventh unsurveyed mill, 191 kkg/day (210 T/D), the retrofit cost developed for the mills that averaged 146 kkg/day (160 T/D) was used, see Table 166. A correction factor was employed in each calculation to reflect the difference in size between the unsurveyed mill and the surveyed mill. The list of unsurveyed mills and the results of these calculations is shown in Table 169 under the unsurveyed mills section. The total retrofit costs for the entire tissue segment is also shown in this table.

Development of Costs

A sample calculation showing how the costs presented in Tables 129-158 for the BK:BCT subcategory were developed is shown in the following pages.

SAMPLE CALCULATION

FOR: BCT Kraft Subcategory
MILL SIZE: 670 Tons per day

A. Internal Costs (All Costs in $1,000)

		Capital Cost Subtotal	Capital Cost Total
1. To Achieve Pretreatment:			
90% of Item 3.	0.9 x 62		55.8
33% of Item 5.	0.33 x 103		34.3
75% of Item 9.	0.75 x 135		101.0
50% of Item 10.	0.5 x 530		265.0
33% of Item 12.	0.33 x 23.5		7.8
33% of Item 13.	0.33 x 11.7		3.9
33% of Item 14.	0.33 x 93		31.0
33% of Item 18.			
Pulp Mill		13.3	
Paper Mill (Three alarms per machine)		6.5	
	0.33 x 19.8		6.6
90% of Item 21. (All disc savealls)			
Two Board Machines, 220 TPD ea.		574.0	
Three tissue machines, 75 TPD ea.		780.0	
	0,9 x 1354		1219.0
20% of Item 23. (For Board Machines)			
	0.2 x 124		24.8
30% of Item 24. (For Tissue Machines)			
	0.2 x 108		21.6
33% of Item 28.	0.33 x 83		27.7
	TOTAL CAPITAL COST		$1,798,500
	INT. & DEP. AT 15%		$ 269,790

2. To achieve BPCTCA

Item	Cost	Item	Cost
3	62.0	14	93.0
5	103.0	18	19.8
9	135.0	21	1354.0
10	530.0	23	124.0
12	23.5	24	108.0
13	11.7	28	83.0
	TOTAL CAPITAL COST		$2,647,000
	INT. & DEP. AT 15%		$ 397,060

3. To achieve BATEA

Item	Cost	Item	Cost
2	145.0	15	147.0
4	560.0	16	95.0
6	730.0	17	237.0
7	288.0	26	430.0
8	245.0	29	193.0
	SUBTOTAL		$3,070,000
	PLUS BPCTCA		$2,647,000
	TOTAL CAPITAL COST		$5,717,000
	INT. & DEP. AT 15%		$ 857,560

4. For NSPS

Cost same as BATEA	
TOTAL CAPITAL COST	$5,717,000
INT. & DEP. AT 15%	$ 857,560

B. Internal Power Requirements

1. Power Required To Achieve Pretreatment

		KW-HR/T
90% of Item 3.		0.27
33% of Item 5.		0.50
75% of Item 9.		5.54
50% of Item 10.		0.06
33% of Item 12.		0.01
33% of Item 13.		0.00
33% of Item 14.		0.07
33% of Item 18.		0.00
90% of Item 21.		
$\frac{440}{665}$ x 21. (Board)	13.89	
$\frac{225}{665}$ x 56.2 (Tissue)	19.01	
0.9 x 32.9		29.61
20% of Item 23. (For Board Machines)		
$\frac{440}{665}$ x 15.2 = 10.1		
0.2 x 10.1		2.02
20% of Item 24 (For Tissue Machines)		
$\frac{225}{665}$ x 11.5 = 3.9		
0.2 x 3.9		0.78
33% of Item 28		0.76
TOTAL		39.62 KW-HR/TON

2. Power required to achieve BPCTCA

Item	KW-HR/T	Item	KW-HR/T
3	0.30	14	0.22
5	1.51	18	0.00
9	7.38	21	32.90
10	0.11	23	10.10
12	0.03	24	3.90
13	0.00	28	2.27
	TOTAL		58.72 KW-HR/T

3. Power required to achieve BATEA

Item	KW-HR/T	Item	KW-HR/T
2	- 1.30	15	1.73
4	10.80	16	0.57
6	56.50	17	3.70
7	2.43	26	17.16
8	2.34	29	2.20
	SUBTOTAL		96.13
	PLUS BPCTCA		58.72
	TOTAL		154.85 KW-HR/T

4. Power Required for NSPS

Requirements same as BATEA

TOTAL CONNECTED 154.85 KW-HR/T

C. External Cost

1. To Achieve the Pretreatment Level

Design Flow 50 K gal/T x 670 TPD x 1.5/1.3 = 38.7 MGD

Clarifier Flow 38.7 MGD x 47% = 18.2 MGD

Solids 48,819 #/D Dry Solids

53 Million Gal. @ 5 Years 20%

Black Liquor Spill Lagoon 2500 Gal. - D/T x 670 TPD = 1.67 MG

25% of the Cost

Unit Process:	Capital Cost ($1000)	Depreciation and Interest ($1000)	Operation and Maintenance ($1000)
Preliminary Treatment	170	25	12
Mill Effluent Pumping	850	127	70
Primary Clarification	1500	225	24
Sludge Lagoon	540	81	
Flow Monitoring	36	5	39
Outfall	504	76	
Diffuser	240	36	
Foam Control	85	13	
Black Liquor Spill Lagoon	25	4	—
TOTAL COST:	$3,950,000	$592,000	$145,000

2. To Achieve BPCTA Treatment Level

Design Flow 36.5 K gal/T x 670 TPD x 1.5/1.3 = 28.2 MGD

Solids 72% Removed x 103 #/T x 670 TPD x 92% of TSS to Clarifier = 45,712 # Dry Solid/D

BOD 8.4% Removed Through Primary Clarifier

BOD Influent to ASB 91.6% x 67 #/T x 670 TPD = 41,119 #/D

BOD Effluent 7.6 #/T x 670 TPD = 5902 #/D

= 35,217 #/D

BOD_r

ASB - Biological = $\frac{35,217\ \#/D}{50\ \#/Ac\text{-}ft./D}$ = 704 Ac-Ft. = 230 MG

ASB - Detention 28.2 MGD x 14 Days = 395 MG

Detention Controls

Aerators 1.25 $\#O_2/BOD_r$ x 35,217 $\#BOD_r/D$ x 1.6 = 70,434 $\#O_2/D$

= 2934 $\#O_2/Hr.$

H.P. Required = $\frac{2934\ \#O_2/Hr.}{1.75\ \#O_2/HP\text{-}Hr.}$ = 1676 H.P.

Black Liquor Spill Lagoon 75% of the Cost

Unit Process:	Capital Cost ($1000)	Depreciation and Interest ($1000)	Operation And Maintenance ($1000)
Aerators	1700	225	200
ASB	4000	600	151
Vacuum Filter	900	135	205
Press	200	30	28
Flow Monitoring	32	5	
Black Liquor Spill Lagoon	75	11	—
TOTAL COST:	$6,907,000	$1,036,000	$584,000

3. To Achieve BATEA Treatment Level

Design Flow 27 K gal/T x 670 TPD x 1.5/1.3 = 20.9 MGD

Caustic Flow 20.9 MGD (0.2) = 4.2 MGD

Unit Process:	Capital Cost ($1000)	Depreciation and Interest ($1000)	Operation And Maintenance ($1000)
Mixed Media Filtration	1700	255	300
Flow Monitoring	28	4	
Mini Lime	840	126	154
Mill Effluent Pumping	580	87	45
TOTAL COST:	$3,148,000	$472,000	$499,000

4. To Achieve NSPS Treatment Level:

The calculations for NSPS are the same as those for the previous treatment levels.

Unit Process:	Capital Cost ($1000)	Depreciation and Interest ($1000)	Operation And Maintenance ($1000)
Preliminary Treatment	130	20	8
Mill Effluent Pumping	580	87	45
Primary Clarification	1000	150	20
Sludge Lagoon	480	72	
Aerators	1400	210	155
ASB	3500	525	133
Vacuum Filtration	1500	225	244
Press	200	30	31
Flow Monitoring	28	4	35
Outfall	371	56	
Diffuser	100	15	
Foam Control	65	10	
Air Flotation	440	66	42
Secondary Clarification (With Recycle)	2700	405	290
Black Liquor Spill Lagoon	95	14	
TOTAL COST:	$12,589,000	$1,889,000	$1,003,000

D. External Power Requirements

1. Power Required for Systems Added to Achieve the Pretreatment Level.

Unit Process:	KW-Hr/Ton
Preliminary Treatment	0.20
Mill Effluent Pumping	10.42
Primary Clarification	0.61
TOTAL:	11.21 KW-Hr/Ton

2. Power Required for Systems Added to Achieve the BPCTCA Treatment Level.

Unit Process:	KW-Hr/Ton
Aerators	40.89
Vacuum Filtration	1.23
Press	0.41
SUBTOTAL:	42.53
Pretreatment	11.21
TOTAL:	53.74 KW-Hr/Ton

3. Power Required for Systems Added to Achieve the BATEA Treatment Level.

Unit Process:	KW-Hr/Ton:
Mill Effluent Pumping	5.72
Minimum Lime	10.22
SUBTOTAL:	15.94
To Achieve BPCTCA:	53.74
TOTAL:	69.68

4. Power Required for System to Achieve the NSPS Treatment Level.

Unit Process	KW-Hr/Ton
Preliminary Treatment	0.20
Mill Effluent Pumping	5.52

Primary Clarification	0.41
Aeration	31.69
Vacuum Filtration	1.23
Press	0.20
Air Flotation	0.41
Secondary Clarification	3.27
TOTAL:	42.93 KW-Hr/Ton

ENERGY REQUIREMENTS

The costs discussed above include energy costs. Costs for electrical energy are shown in Table 170 for secondary treatment with aerated stabilization basins and Table 171 for activated sludge in place of ASB. Such costs vary only slightly on a per-unit-of-production basis among mills of the same subcategory. Plant operation for 360 operating days per year have been assumed, and a unit cost of 2.0 cents per kwh was used. In cases where incineration of sludge is practiced, there may be a heat requirement or heat recapture, depending upon equipment employed, but no overall heat gain or loss from this cause is assumed on an industry-wide basis.

MgO liquor recovery is included with the base mill for the sulfite and dissolving sulfite subcategories.

Electrical energy projections at various levels of treatment are shown in Table 172, on a per-ton-of-production basis, using aerated stabilization basins, and Table 173 is for activated sludge in a place of ASB.

For approximate comparison purposes, total mill energy requirements per ton (excluding internal and external treatment) are shown in Table 174. Considerable caution should be exercised in utilizing these data, since significant variations in energy requirement within each subcategory occur depending on the particular process and equipment employed.

NON-WATER QUALITY ASPECTS OF CONTROL AND TREATMENT TECHNOLOGIES

Air Pollution Potential

There are several potential air pollution problems associated with the external treatment of effluents from mills in each of the subcategories.

When properly designed and operated, primary and biological treatment do not produce odors associated with anaerobic decomposition. However, biological treatment of the waste waters of these subcategories does result in very localized odors, especially when mechanical aeration is employed. The odor is characteristic of wood extractives.

Odors can also arise from improper land disposal of liquid sludges as a result of their anaerobic decomposition. These derive primarily from organic acids and hydrogen sulfide produced on reduction of sulfates dissolved in the water content of the sludges. Dewatering prior to disposal on the land inhibits such decomposition, thus reducing odors. The use of sanitary landfill practices will also mitigate odor problems.

Sludge lagooning usually takes place on large sites. The low level of odor produced is generally confined to company property.

Table 170
AERATED STABILIZATION BASIN
ELECTRIC POWER COST
$1000 Per Year

Subcategory	Mill Size Ton/Day	Pretreatment	BPCTCA	BATEA	NSPS
Sulfite	530	164	712	918	742
Dissolving Sulfite	55[illegible]	115	585	985	983
Deink	230	44	167	178	178
Dissolving Kraft	600	113	443	981	853
Market Kraft	7[illegible]0	129	424	1000	803
BCT Kraft	670	248	550	1098	1017
Fine Kraft	670	245	451	990	946
Groundwood Chem/Mech	300	35	188	353	346
Groundwood Thermo/Mech	300	23	140	302	298
Groundwood C-M-N	150	21	66	149	153
Groundwood Fine	300	49	128	293	293
Soda	300	95	237	477	441
Non-Integrated Fine	100	13	29	37	39
Non-Integrated Tissue	110	26	62	70	71
Non-Integrated Tissue (fwp)	110	25	75	80	80

Table 171
WASTE ACTIVATED SLUDGE
ELECTRIC POWER COST
$1000 Per Year

Subcategory	Mill Size Ton/Day	Pretreatment	BPCTCA	BATEA	NSPS
Sulfite	530	164	641	846	665
Dissolving Sulfite	550	115	520	919	808
Deink	230	44	174	185	173
Dissolving Kraft	600	113	448	986	806
Market Kraft	700	129	406	982	743
BCT Kraft	670	248	540	1088	992
Fine Kraft	670	245	458	996	907
Groundwood Chemi/Mech	300	35	184	350	329
Groundwood Thermo/Mech	300	23	139	301	297
Groundwood C-M-N	150	21	72	155	145
Groundwood Fine	300	49	129	294	281
Soda	300	95	235	475	419
Non-Integrated Fine	100	13	29	38	37
Non-Integrated Tissue	110	26	62	74	69
Non-Integrated Tissue (fwp)	110	25	78	83	76

Table 172
AERATED STABILIZATION BASIN
ELECTRICAL ENERGY REQUIREMENTS FOR TREATMENT

Subcategory	Mill Size Ton/Day	Pretreatment	BPCTCA	BATEA	NSPS
Sulfite	160	47.1	196.4	249.4	205.2
	530	42.4	184.0	237.2	191.7
Dissolving Sulfite	550	28.6	145.8	245.4	244.9
Deink	80	27.7	115.6	120.1	---
	230	26.2	99.4	105.8	105.9
	500	25.7	96.2	102.3	105.2
Dissolving Kraft	600	25.8	101.1	224.0	---
	1000	25.2	101.6	222.9	194.7
Market Kraft	350	25.6	83.4	198.0	---
	700	25.2	83.0	195.6	157.2
BCT Kraft	250	53.0	115.4	223.6	---
	670	50.8	112.4	224.3	208.0
	1300	49.7	112.4	221.6	204.6
Fine Kraft	250	50.6	92.5	204.0	---
	670	50.1	92.2	202.3	193.5
	1300	49.6	91.8	200.6	193.3
Groundwood Chemi/Mech	100	18.9	90.9	165.9	159.1
	300	16.2	85.9	161.4	157.8
	600	15.7	85.0	160.5	155.9
Groundwood Thermo/Mech	100	10.7	69.0	142.7	141.3
	300	10.7	64.0	138.1	136.3
	600	10.7	62.8	136.9	135.1
Groundwood C-M-N	75	21.6	64.4	140.4	145.9
	150	18.9	59.9	135.8	139.5
	500	17.0	58.1	133.7	134.4
Groundwood Fine	150	23.6	58.9	134.8	139.5
	300	22.2	58.5	134.0	134.0
	550	22.0	56.3	131.8	133.1
Soda	300	43.3	108.2	217.6	201.3
	700	42.2	107.7	215.8	197.5
Non-Integrated Fine	30	18.0	41.4	51.0	---
	100	18.0	40.2	50.6	52.8
	280	18.0	39.8	49.9	50.2
Non-Integrated Tissue	15	31.8	80.4	90.1	---
	35	31.8	78.5	87.9	---
	110	31.8	77.4	86.7	88.1
	450	31.8	76.7	85.9	85.1
Non-Integrated Tissue (fwp)	15	31.7	97.0	103.1	---
	35	31.7	94.3	100.3	---
	110	31.7	93.9	99.9	99.8
	450	31.7	92.8	98.6	97.9

Table 173

WASTE ACTIVATED SLUDGE
ELECTRICAL ENERGY REQUIREMENTS FOR TREATMENT
kwh/ton

Subcategory	Mill Size Ton/Day	Pretreatment	BPCTCA	BATEA	NSPS
Sulfite	160	47.1	175.0	228.1	179.1
	530	42.4	165.7	218.6	172.0
Dissolving Sulfite	550	28.6	129.4	228.9	201.3
Deink	80	27.7	107.1	111.6	---
	230	26.3	103.7	110.1	102.9
	500	25.7	101.4	107.5	100.3
Dissolving Kraft	600	25.8	102.2	225.1	---
	1000	25.1	97.0	218.3	184.0
Market Kraft	350	25.7	82.4	196.9	---
	700	25.3	79.5	192.1	145.4
BCT Kraft	250	53.0	115.4	223.7	---
	670	50.8	110.4	229.5	202.9
	1300	49.7	109.3	218.6	199.5
Fine Kraft	250	50.6	97.4	208.9	---
	670	50.1	93.6	203.7	185.5
	1300	49.6	93.2	202.0	182.8
Groundwood Chemi/Mech	100	18.9	92.3	167.3	153.6
	300	16.2	84.1	159.6	150.4
	600	15.7	82.2	157.7	148.8
Groundwood Thermo/Mech	100	10.7	71.8	145.5	144.1
	300	10.7	63.5	137.6	135.8
	600	10.7	62.6	136.7	134.9
Groundwood C-M-N	75	21.6	73.5	149.5	140.4
	150	18.9	65.3	141.7	132.1
	500	17.0	59.9	135.5	127.1
Groundwood Fine	150	23.6	61.7	137.6	131.2
	300	22.2	58.9	134.4	128.5
	550	22.0	57.3	132.8	127.1
Soda	300	43.3	107.3	216.7	191.2
	700	42.2	104.6	212.7	185.4
Non-Integrated Fine	30	18.0	41.4	59.2	---
	100	18.0	40.2	55.0	50.8
	280	18.0	39.8	52.2	48.1
Non-Integrated Tissue	15	31.8	80.4	92.3	---
	35	31.8	78.5	96.4	---
	110	31.8	77.4	91.9	85.6
	450	31.8	76.7	89.2	82.9
Non-Integrated Tissue (fwp)	15	31.7	107.9	114.0	---
	35	31.7	101.6	107.5	---
	110	31.7	97.1	103.1	94.5
	450	31.7	93.4	99.2	93.6

Table 174

Total Mill Energy Requirements*

Subcategory	Steam Mil. BTU/ton	Elect. KWH/ton	Total KWH/ton	Pre	Additional KWH/T at BPCTCA	BATEA	NSPS
Papergrade Sulfite	23	1250	7985	42	184	237	192
Dissolving Sulfite	23	1600	7735	29	146	245	245
Deink	11	500	3720	26	99	106	106
Dissolving Kraft	24	1050	8075	26	101	224	195
Market Kraft	23	1000	7735	25	83	196	157
BCT Kraft	24	1300	8325	51	112	225	208
Fine Kraft	24	1400	8425	50	92	202	194
Groundwood Chemi-Mech.	17	1700	6680	16	86	161	158
Groundwood Thermo-Mech.	16	1800	6485	11	64	138	136
Groundwood CMN	15	1800	6190	19	60	136	140
Groundwood Fine	15	1900	6290	22	59	134	134
Soda	24	1300	8325	43	108	218	201
Non-Integrated Fine	9	700	3335	18	40	51	53
Non-Integrated Tissue	7	425	2475	32	77	82	88
Non-Integrated Tissue (FWP)	8	425	2765	32	77	86	85

* Cumulative energy requirements

The practice of decanting free water from lagoons and returning it to the treatment system has noticeably reduced the odor level in their immediate environs.

Incineration of sludges produced in the effluent treatment processes can, without appropriate control equipment, result in the discharge of particulates to the atmosphere. However, emission control devices are available to meet state regulatory requirements in most instances. Incinerators are either sold with integral emission control appliances or are equipped with them on installation. Gaseous pollutant emissions from such incinerators are negligible.

In-mill controls which effect a reduction in fiber and additive losses, such as savealls, recycling of process waters, and removal of dregs and grits in the kraft recovery process, are not producers of air pollution. On the other hand, recovery of cooking chemicals in the kraft process, which, in addition to its principal function of conserving expensive raw materials and heat, also serves to reduce chemical waste load, produces odorous sulfur compounds. When these escape the recovery furnace to the atmosphere, they become the major air pollution problems of the mill. These emissions and measures to control them are described in a report prepared for an EPA predecessor agency entitled "Control of Atmospheric Emissions in the Wood Pulping Industry" (125).

Noise Potential

There are no official records of public noise problems arising from the operation of effluent treatment works by the subject subcategories of mills. However, on the basis of many year's of observation of industry operations, it can be stated that public complaints engendered by such noise are very infrequent. This is due in all probability to the remote location of most large treatment works or to their confinement, in some instances, to manufacturing or utility areas. Also, the noise level of most of the devices employed for treatment is generally lower than that of some manufacturing machinery.

The sources of noise are for the most part air compressors or mechanical surface aerators supplying air to treatment processes, vacuum pumps and centrifuges involved in sludge dewatering, and fans serving sludge incinerators. With the exception of surface aerators, these devices are most frequently operated in buildings which serve to muffle their noise.

Small surface aerators are generally found in small mills which are more likely to be located closer to habitation. Units of this size, particularly those not driven through gear boxes, produce little noise. The problem of noise emanating from gear boxes is the subject of an extensive investigation by the Philadelphia Gear Company which manufactures many of these units. It is anticipated that this study will lead to a reduction in

noise from these sources. Noise produced by the large aerator units which are usually operated away from populated areas is usually neither high-level nor far-carrying.

A new "noiseless" aeration system has been installed in a 32.7-acre reservoir to reaerate 24.5 MGD of waste water from a kraft mill located near an urban area. The system consists of 465 vertical plastic subsurface air pipes supplemented by 195 "air pump" tubes. The only moving parts are blowers to force more than a ton of air per hour into the waste water (160).

It can be concluded that noise produced by equipment used for treating pulp and paper mill effluent is not a major public problem at present. Efforts underway to reduce the noise level of mechanical equipment in general stimulated by industrial health protection programs, will assist in preventing it from becoming one.

Solid Wastes and Their Disposal

Sludge cake resulting from the dewatering of sludge is, to the extent that it could be termed "solid," the only solid waste specifically attendant to the control and treatment technologies practiced by all of the subject subcategories. This subject is covered in Section VII and in a study on solid waste management practices in the pulp and paper industry for EPA's Office of Solid Waste Management Programs (303).

Solid wastes in terms of process residues which require disposal are declining in quantity in some areas of the mills due to more modern practices. The disposal of bark will become less and less a pulp mill disposal problem as the trend to the use of delivered chips, sawdust, etc., intensifies. Where barking is still practiced on a mill's premises, silt is produced in amounts which vary with wet/dry weather, etc., in addition to bark. The bark is most likely to be incinerated in especially designed units by mills in all pulping subcategories except the large bleached kraft mills, or complex mills, which produce sufficient bark to fire a boiler for steam generation. Long washing overflow containing silt and fine bark particles generally joins the steam carrying ash from the mill which is discussed below.

In line with the economic trend of salvaging usable fiber, rejects and screenings are to a greater extent re-refined (groundwood), re-cooked in the chemical pulping processes, or sold. Otherwise, they are incinerated, burned in a bark-fired boiler, or disposed of by landfill. This is also true of broke and trimmings in a paper mill -- they are returned to the process or burned.

Particulate emissions from incineration of bark and other solid wastes must be controlled by effective devices such as bag filters or scrubbers.

Grits and dregs from the causticizing system of kraft and soda recovery plants, inorganic solids, are generally water-carried to a land disposal site.

Intermittent washing of the reaction towers in calcium base sulfite mills (every two months or so) produces a small amount of grits. These are easily dewatered for land disposal or can be sent to ash ponds.

Deinking mills do not produce the large quantities of trash generated in waste paperboard mills because of better quality raw materials. In 1971, deinking accounted for only one percent of the industry's solid wastes while the use of waste paper in other processes contributed nine percent (303).

Ash from bark- and coal-fired boilers, screening rejects, in some cases, and other materials as noted above are as a rule discharged hydraulically to ash ponds. There the solids settle and compact and the clear supernatant water is discharged to the mill effluent system. In some instances, ash and rejects are hauled to a disposal area away from the mill site. Wet handling of these materials avoids their being blown into the atmosphere.

Waste paper, garbage, and trash attendant to production or accessory operations and activities are either incinerated on the site or hauled away for disposal by contractors engaged in this business.

Byproduct Recovery

Byproducts can be defined as those materials produced by wood pulping that can be removed from the pulping and/or chemical recovery process and sold. They do not include chemicals recovered and reused in the process such as sodium and sulfur compounds in a kraft operation which are employed in the preparation of fresh cooking liquor.

For the most part, the pulp mill sells the basic material used in marketable byproducts to chemical plants which manufacture the final products. These are produced either through purification of the raw materials or by chemical reaction and separation. If preparation of the raw materials for shipment from the pulp mill is required, this operation may contribute a portion of the pulp mill waste load unless the effluent can be absorbed by the recovery plant for its chemical or heat value.

By-Products of Kraft Pulping

Many kraft mills recover two byproducts from the pulping process other than chemicals that are reused -- tall oil and crude turpentine (60). These materials are present to the greatest degree in pine species, particularly those common to the south. They are not usually recovered in mills where other woods low in these substances are pulped.

Tall oil is a mixture of the resin and fatty acids present in wood which are saponified during the pulping process and separate from the black liquor during concentration or cooling (162). Southern pine species contain approximately 90 to 150 kg (180 to 300 lb) of this material per kkg (ton) of air dried pulp produced (60). It is skimmed from concentrated black liquor storage tanks in the form of sodium soap (163). Some mills convey the soap directly to tank cars in which it is shipped to chemical plants for use in manufacturing a number of marketable products including detergents, adhesives, paints, disinfectants, special oils, soaps, and plasticizers (164) (163). Other mills acidulate the soap to produce the oil prior to shipping. This is generally accomplished by adding 30 to 50 percent sulfuric acid to the soap and separating the oil from the dregs by decantation or centrifuging. Some acidulation plants operate on a batch and others on a continuous basis (60). BOD_5 and COD values for tall oil are 0.72 and 1.25 kg (1.58 and 2.76 lb) per kb (lb) of tall oil respectively. The process produces dregs which consist of a strong solution of sodium sulfate together with precipitated lignins and other residues of black liquor origin. These are returned to the pulp mill recovery system in order to reclaim the chemical and heat values contained therein (165). Thus, the wastes from tall oil collection, processing, and shipping are minor in quantity. They consist of wash water from cleaning floors, equipment, and loading platforms and are, for the most part, intermittent in nature.

Pine woods contain from 6 to 18 l of turpentine (1.5 to 4.3 gal.) per kkg (ton) of air dried pulp. The quantity depends upon the specific wood species pulped, tree age, soil conditions, seasonal changes, and climatic conditions as well as the type and length of time of storage (60) (166).

Most of the substance appears in the digester relief condensate from which it is recovered. The gases leaving the digester are passed through a cyclone in which black liquor is separated out for entry into the recovery system. The steam-turpentine mixture then goes to a surface condenser, the condensate from which is sent to a storage tank. There the water and turpentine separate by gravity and the turpentine is decanted off for storage or shipping (167). The water fraction is sewered with the other condensates or, in some instances, disposed of on the land.

Crude turpentine is shipped to chemical plants for rectification after which it is sold for use as a solvent or fractionated to separate specific ingredients. Some of these are used as base compounds in the production of other chemicals (168), such as dimethyl sulfoxide, an excellent industrial solvent (169).

Some turpentine remains in the decanted water which joins the general condensate stream. In some mills anti-dispersants are used to enhance the separation and thus reduce the quantity of turpentine lost to the sewer.

Mill practices which will permit more complete recovery of turpentine and tall oil are forecast. For example, shorter storage of chips or precooking extraction would prevent the loss of turpentine and tall oil by oxygenation prior to pulping. Solvent extraction of the soap from black liquor could improve recovery efficiencies (168).

On the other hand there are factors which will inhibit recovery of these products. Increased use of continuous digesters will reduce the yield of turpentine thus creating a need for an economic method of turpentine recovery from the black liquor in continuous processes. Mixing pine and hardwood black liquors reduces the recovery of tall oil and separate liquor tanks will be required (170). Use of more hardwood, sawmill wastes, immature wood, and outside chip storage are other adverse factors (163).

Production of other byproducts, such as methanol, acetic acid, tars, etc., from kraft mills on a commercial scale is not yet economically feasible. Effluent limitations and standards are expected to stimulate increased research on byproduct recovery in the next decade.

By-Products of Sulfite Pulping

While in recent years the number of sulfite mills producing and marketing byproducts has not increased, eight mills continue such production and, in some instances, enjoy a concomitant decrease in waste load (52) (171). Presently about 10 percent of the spent sulfite liquor produced in this country is utilized and there is little indication that this quantity will increase (172) (173) (174). Sulfite mills marketing byproducts are shown in Table 175.

These byproducts derive from the spent pulping liquor and digester and evaporator condensates. The liquor products include 1) those which use the whole liquor itself; 2) products made from the liquor sulfonate fraction, 3) and those obtained by fermentation of the sugar fraction. Cymine is separated from the condensates removed from the digester relief system (3) and formic acid, acetic acid and furfural are components of the evaporator condensate (179).

The first class of liquor products is made by treating the raw liquor or evaporating it and bleeding off the concentrate at various consistencies (40-65 percent) for sale. The concentrated liquor of ammonia base sulfite mills can be used directly in tanning (3). Sulfite spent liquor is also sprayed on gravel roads (road binder) to reduce dusting (2) (3).

The lignosulfonates are precipitated from raw liquor by the Howard process (17). These materials can be used as oil well drilling mud, tanning agents, dispersants, and soil improvers. The precipitates can be reacted with other chemicals to produce

Table 175

MILLS MANUFACTURING SPENT SULFITE LIQUOR BYPRODUCTS

Mill Code	Products
070	Ethanol Lignin Products
051	Torula Yeast
061	Lignin Products
402	Lignin Products
063	Evaporate
052	Lignin Products
056	Evaporate
066	Evaporate

vanillin and other saleable materials (175) (172) such as dispersing and emulsifying agents, some of which are used in dyeing.

Fermentation products include ethanol and torula yeast which is used as an animal and human food supplement (174). They are produced from the raw liquor after the free sulfur dioxide has been steam stripped and returned to the acid plant.

The only major waste produced in the manufacture of spent sulfite liquor evaporate are the condensates which amount to about 6260 l (1500 gals.) for the liquor equivalent of one kkg (ton) of AD pulp (46). The combined condensates are acid, free of suspended matter, and, if no appreciable carry-over occurs in the evaporators, low in color. They contain considerable BOD_5 due to the presence of formic and acetic acids, alcohols, and aldehydes (46). Preneutralization of the liquor effectively reduces the BOD_5 range from 43 to 75 kg (85 to 150 lb) per kkg (ton) of AD pulp to 30 to 35 kg (60 to 70 lb) (46) (44). It has been shown that removal of the volatile materials from these condensates by steam stripping, chemical reaction in the vapor phase, or by activated carbon can reduce the COD about 75 to 80 percent (49). If the condensate is free of carry-over, a corresponding reduction in BOD5 will occur. However, insufficient markets are available for the formic and acetic acids that would be produced at the present time.

The lignosulfonates are separated from raw or concentrated liquor of the following composition:

	Percent of Dry Solids
Lignosulfonic Acid	45-50
Reducing Sugars -	
Hexoses	15
Pentosos	12
Other Carbohydrates	15
Inorganics	5

This separation is made by lime precipitation (176) from the raw liquor or by chemical treatment of evaporate (178). Effluents from precipitation processes contain the wood sugars and other carbohydrates responsible for a large portion of the BOD_5 of the liquor, and for this reason such separations reduce the BOD_5 waste load only about 20 percent. However, since the precipitate contains most of the color bodies, the process removes over 80 percent of this parameter.

There is little data available on specific pollutional values of the effluents from production of marketable products from precipitates. This is because such effluents are not generally

segregated and are difficult to relate to production. However, it has been observed that effluent from the manufacture of vanillin is very high in color and susceptible to foaming (172).

Only one mill in the U.S. presently produces ethanol and of the three that once produced torula yeast only two are in operation. After fermentation the spent beer from both processes can be evaporated to produce a substantially sugar-free lignosulfonate solution from which other products can be made. The condensates produced are lower in BOD_5 than those obtained from raw liquor, ranging from 20 to 25 kg (40 to 50 lb) per kkg (ton) of AD pulp. Since ethanol production utilizes only the hexose sugars, it results in a BOD_5 reduction of less than 25 percent. This reduction is closer to 50 percent in torula yeast production which utilizes both hexose and pentose sugars. Yeast plant effluent ranges from 12,519 to 28,865 l (3000 to 5000 gal.) for the liquor equivalents of yeast cells. Generally such effluents contain from 1500 to 3500 mg/l of BOD_5 and from 250 to 600 mg/l of total suspended solids.

IMPLEMENTATION REQUIREMENTS

Availability of Equipment

Since 1966, when Federal water pollution control expenditures began, various Federal and private organizations have analyzed the projected levels of water pollution control activity and their economic impact on the construction and equipment industries. As a result, a plethora of studies has been developed which is related to the levels of municipal and industrial water pollution control construction and the respective markets for waste water treatment equipment. Less information is available concerning the actual and anticipated levels of expenditure by any specific industry.

In recent years, the trend in the waste water equipment industry has seen the larger firms acquiring smaller companies in order to broaden their market coverage.

Figure 66 shows graphically past expenditures and projected future outlays for the construction of industrial waste water treatment facilities, as well as total water pollution control expenditures. Obviously, the level of expenditures by industry is related to the Federal compliance schedule. This will increase until industry is in compliance with Federal standards. Once that occurs, the level of spending will return to a level commensurate with the construction of new facilities, replacement of existing facilities, and the construction of advanced waste treatment facilities.

Figure 67 shows past expenditures for and projected future trends in total sales of waste water treatment equipment and the dollar amounts attributable to industrial and municipal sales. This curve closely follows the trend shown in Figure 66.

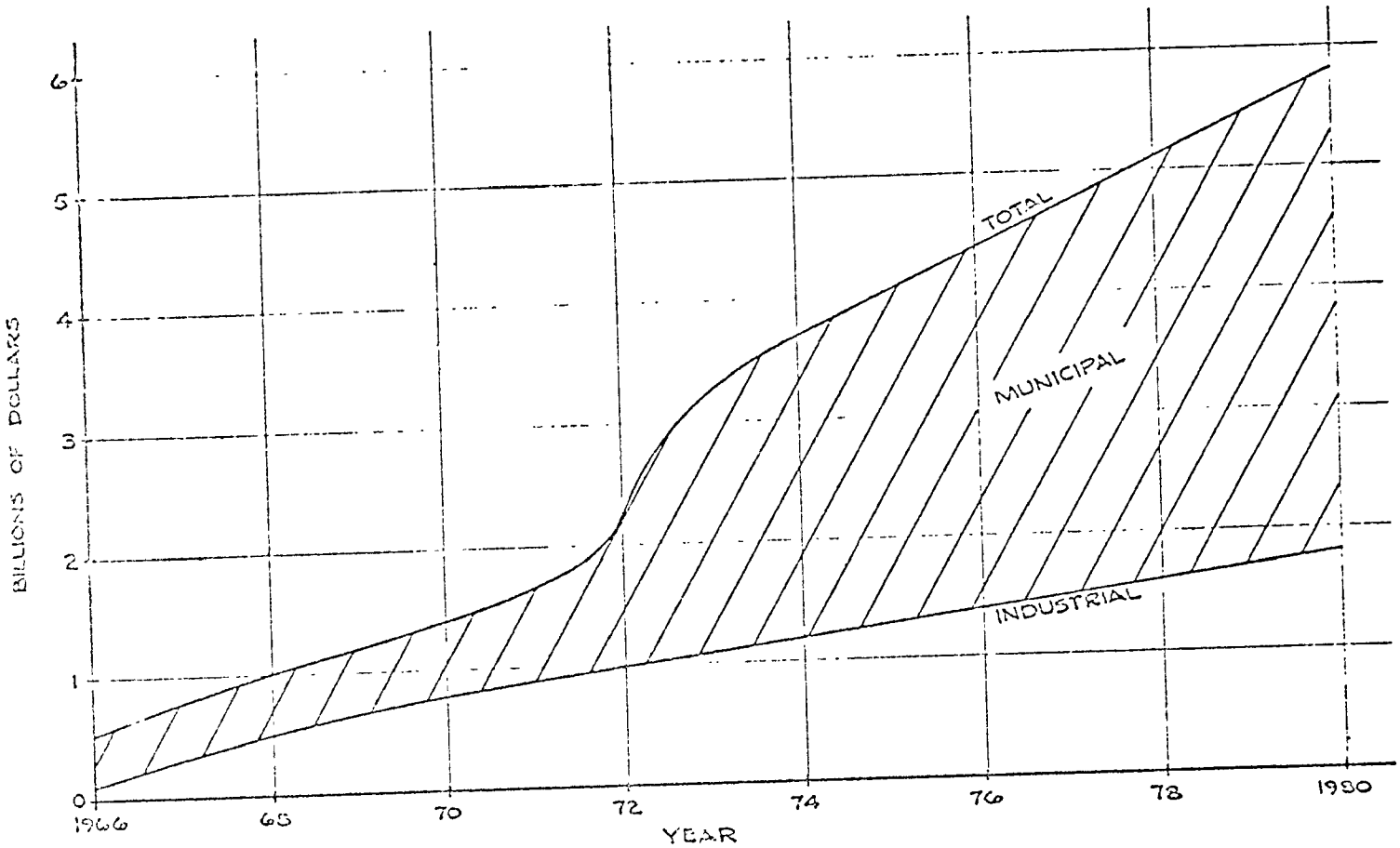


Figure 81

Total Water Pollution Control Expenditures

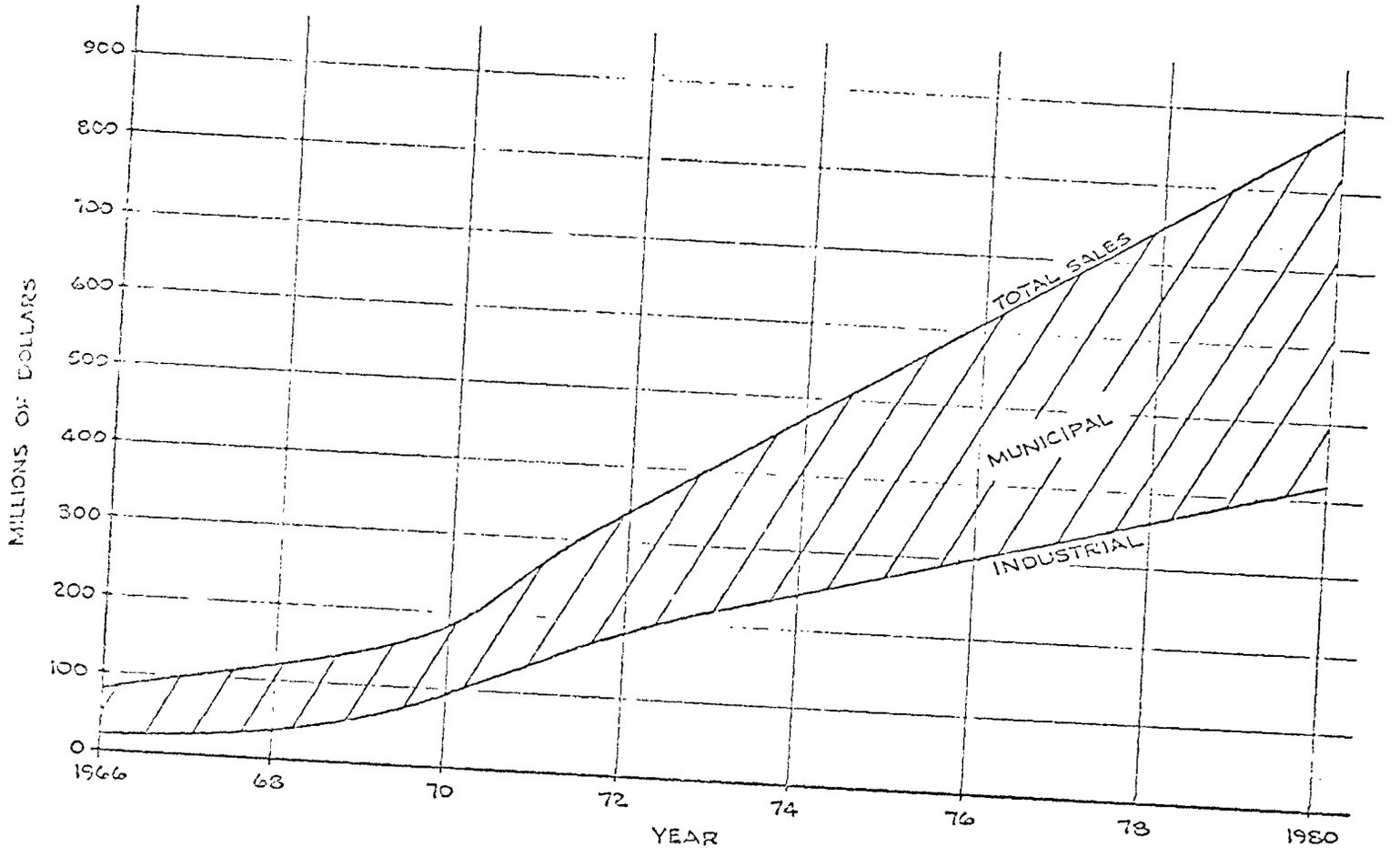


Figure 82

Waste Water Treatment Equipment Sales

The data in Figures 66 and 67 related to industrial water pollution expenditures include only those costs external to the industrial activity. Internal process changes made to accomplish water pollution control are not included.

Recent market studies have projected the total available production capacity for water and waste water treatment equipment. Most of them have indicated that the level of sales is currently only 30-40 percent of the total available plant capacity. Several major manufacturers were contacted to verify these figures and indications are that they are still accurate. A partial reason for this overcapacity is that the demand for equipment has been lower than anticipated. Production capacity has increased assuming Federal expenditures in accord with funds authorized by Congress and conformance to compliance schedules.

For the immediate future, increased demands for waste water treatment equipment can be absorbed by the existing overcapacity. Long term requirements will probably necessitate expansion of production capacity in various product lines where the demand is expected to increase dramatically -- specifically, advanced treatment systems and waste solids handling equipment.

It should also be noted that the capacity to produce waste water treatment equipment could be expanded significantly through the use of independent metal fabricators as subcontractors. Even at the present time independent fabricators are used by some equipment manufacturers when work loads are heavy and excessive shipping costs make it desirable to use a fabricator close to the delivery site.

There appear to be no substantial geographical limitations to the distribution of waste water treatment equipment to industry. In various areas, certain suppliers may be more successful than others; however, this seems to be related more to the effectiveness of the sales activities than to geographical limitation. The use of independent metal fabricators as subcontractors to manufacture certain pieces of equipment further reduced geographical limitations.

Equipment delivery schedules may vary substantially depending upon the manufacturer, the current demand, and the specific equipment in question. Obviously, the greater the demand or the more specialized the equipment, the greater the delivery time.

Availability of Construction Manpower

After consultation with the Associated General Contractors of America and other industry groups, it is concluded that sufficient manpower exists to construct any required treatment facilities.

This conclusion has reportedly been substantiated by EPA in an independent study although there is still some concern about

localized problems. The Bureau of Labor Statistics has been requested to conduct another study.

Construction Cost Index

The most detailed study and careful analysis of cost trends in prior years still leave much to be desired in predicting construction costs through the next ten years.

During the years 1955 through 1965 there was a very consistent price rise. The Engineering News Record (ENR) Construction Cost Index in January 1955 was 644. With slight deviations from a straight line, costs rose at a steady rate to an index of 988 in December 1965. This represented an increased cost of 53.4 percent over an 11 year period of approximately five percent per year.

The first six months of 1966 saw an increase of 6.6 percent then leveled off abruptly only to rise sharply again in 1967 at a rate of 6.2 percent, then increasing to 9.4 percent in 1968.

The increase in costs continued to rise at about 10.5 percent per year through 1970. During 1971, construction costs rose at the unprecedented rate of 15.7 percent primarily due to larger increases in labor rates.

With the application of federal wage and price controls in 1972, the rate of increase dropped to 8.6 percent for the year and continued at the same rate during the first six months of 1973. The cost index curve began to level off during the latter part of 1973 resulting in an increase of 6.8 percent for the year.

Cost predictions for extension of ENR Cost Index are confused at this time. ENR in the 1974 first Quarterly Cost Roundup (March 21, 1974) stated, "Predicting cost trends is always difficult, but this year contractors face what is perhaps the most bewildering period in a quarter century."

The commentary continued with the statement "The industry is facing some of the sharpest escalations in costs in recent time -- material as well as labor".

With the termination of price controls, manufacturers are making substantial price boosts to cover proposed expansions for increased capacity as well as actual increased production costs.

These developments have caused ENR to revise its predictions for 1974 increase in Cost Index. In December the predicted increase 12/73 to 12/74 was +4.0% for the Building Cost Index and +5.0% for Construction Cost Index. In ENR, March 21, 1974 issue, the prediction was revised to an increase 12/73 to 12/74 of +6.8% for Building Cost Index and +7.5% for Construction Cost Index. ENR on June 20, 1974, further revised 1974 predicted Building Cost Index increase to 10.3% and Construction Cost Index to 10.0%.

The strong inflationary forces now facing the United States and the rest of the world are the worst hazard to cost predictions. With what has previously been considered a normal rate of inflation, it could be anticipated that expansion of industrial capacity would help to level off current sharp price increases.

In spite of the skyrocketing cost increases during the second quarter of 1974, the long range outlook for the Construction Cost Index would seem to be closer to an annual increase of 8 percent, the bases on which Figure 68 was drawn. Developments in the industry may require adjustments up or down from the projected cost index for current program costs in any particular year.

Land Requirements

Land requirements for a number of external treatment systems have been evaluated and are shown in Figure 69 for a range of plant sizes. Incineration or off-site disposal of dewatered sludge has been assumed. Should sludge lagoons be used on-site, additional land would be required.

Time Required to Construct Treatment Facilities

The time required to construct primary and secondary effluent treatment facilities has been estimated for a range of plant sizes and for two different project contract possibilities. The treatment plant sizes evaluated were under 5 MGD, 5 to 20 MGD, and over 50 MGD. The contract possibilities evaluated were for the engineering and construction to be separate or on a turnkey basis.

A small mill with relatively small effluent volume (see Figure 70) could have its primary and secondary treatment facilities in operation in 2.5 years if the contract was handled on a turnkey basis The majority of the effluent treatment facilities handled with separate engineering and construction contracts, plus the medium and large mills handled on a turnkey basis, would be completed in 2.5 to 4.5 years.

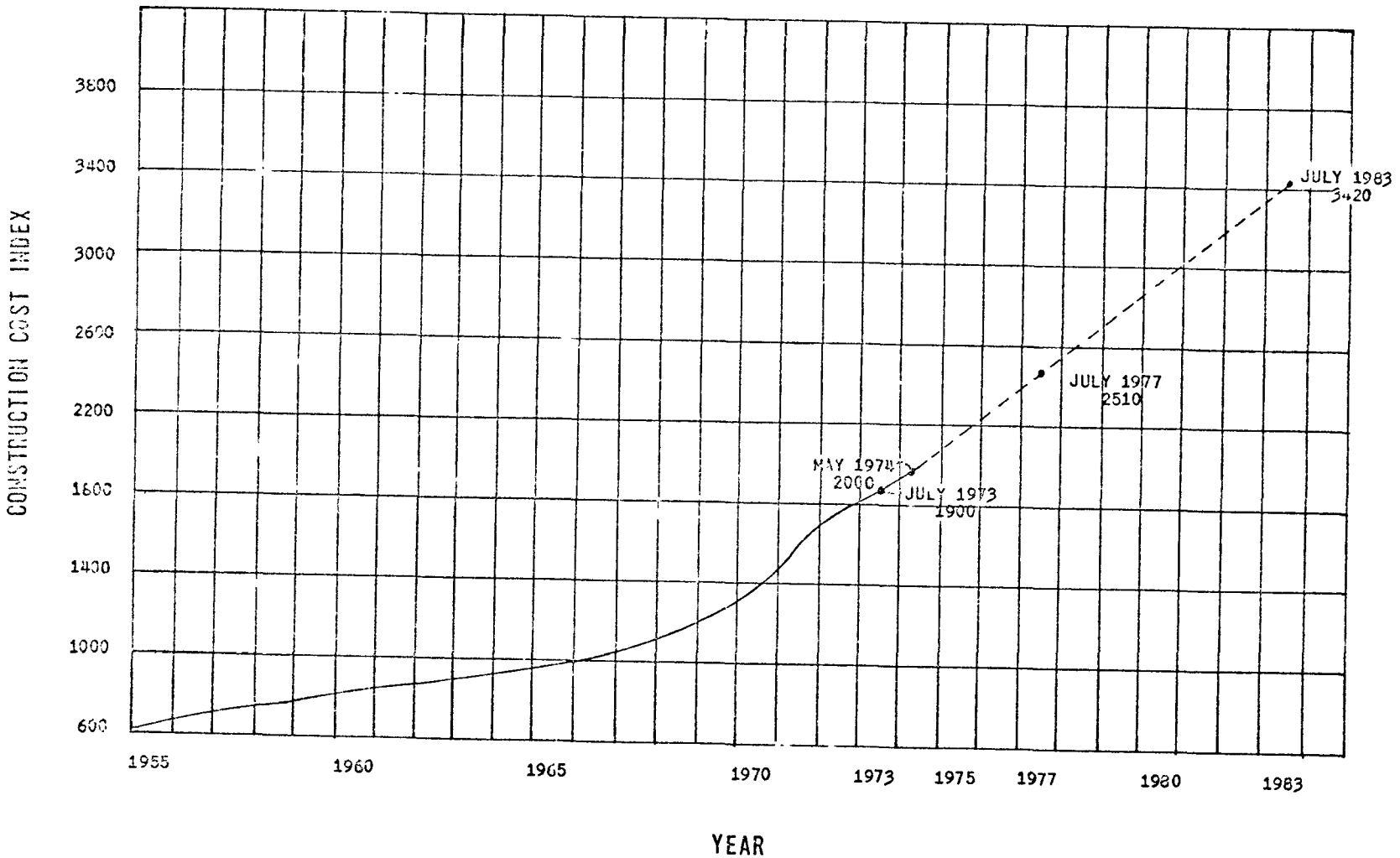


Figure 83

ENGINEERING NEWS RECORD

Figure 84

MINIMUM AREA REQUIRED FOR WASTEWATER TREATMENT

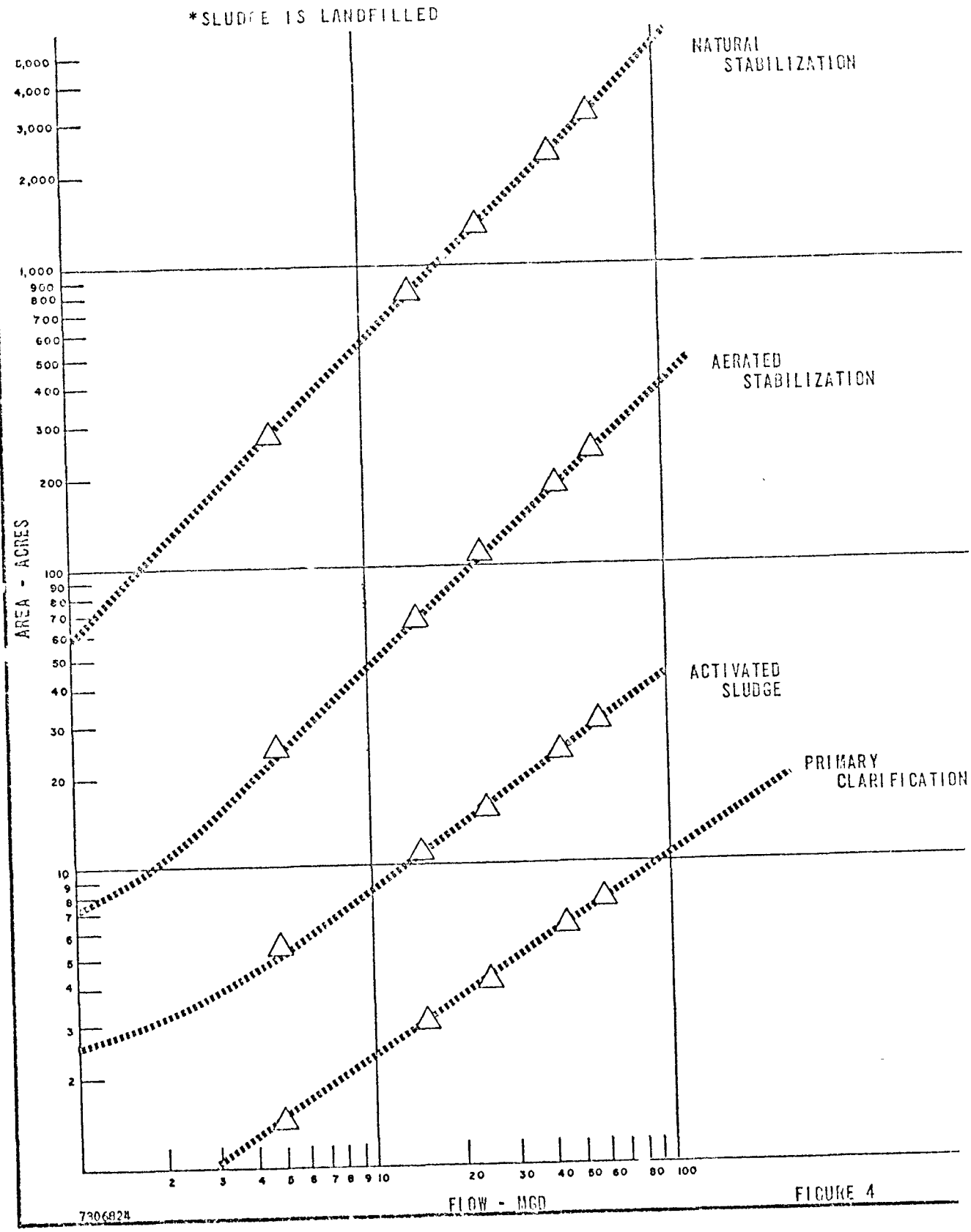


FIGURE 4

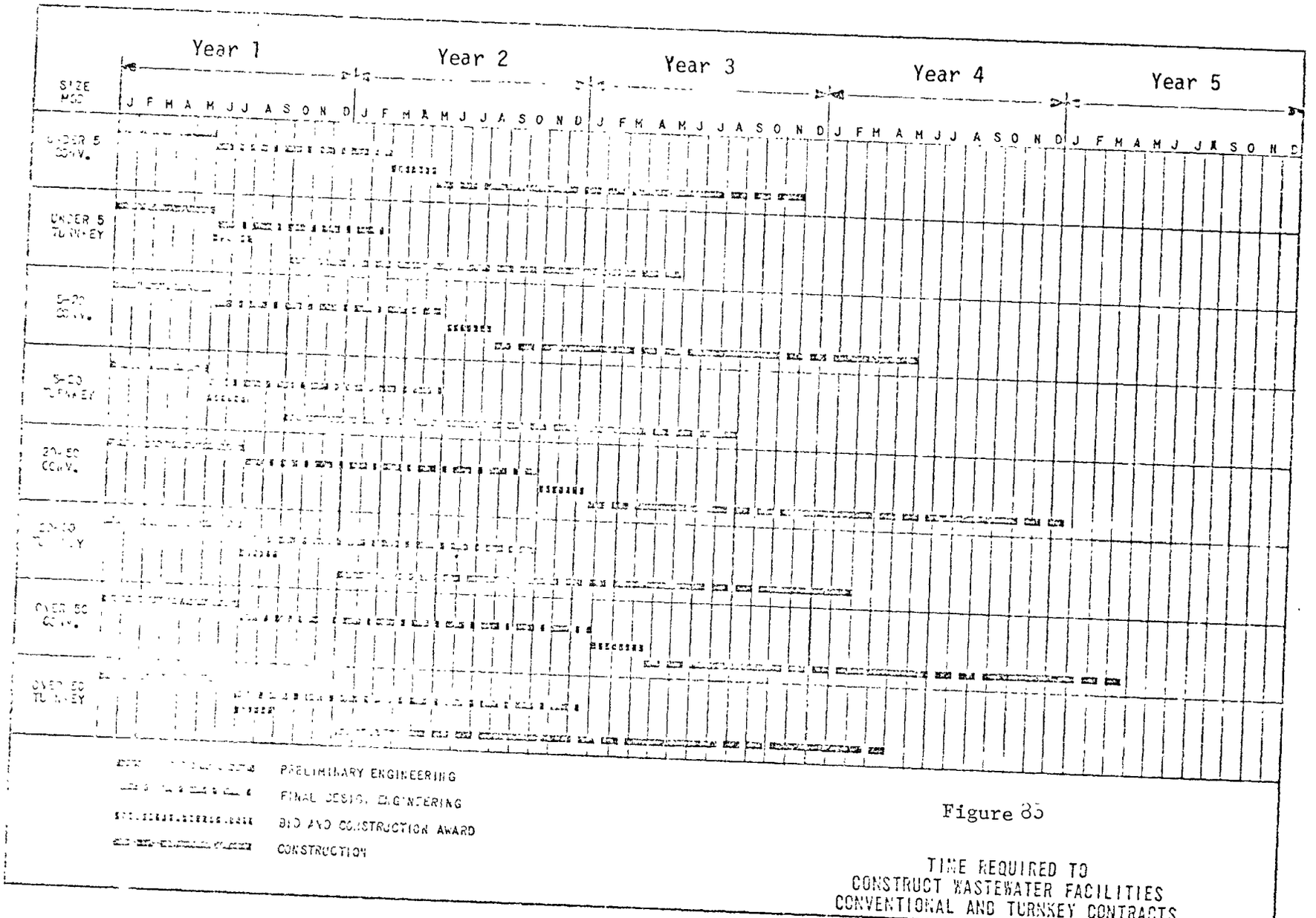


Figure 85

TIME REQUIRED TO
CONSTRUCT WASTEWATER FACILITIES
CONVENTIONAL AND TURNKEY CONTRACTS

SECTION IX

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE (BPCTCA)

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977, specify the degree of effluent reduction attainable through the application of the BPCTCA, which is generally based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within the industrial subcategory as discussed in detail below. In addition to the factors mentioned above, consideration was given to:

a. the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, including energy requirements.

b. the engineering aspects of the application of various types of control techniques;

c. process changes;

d. non-water quality environmental impact.

Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process, but includes the control technologies within the process itself when the latter are considered to be normal practice within an industry.

A further consideration is the degree of economic feasibility and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BPCTCA

Based upon the information available to the Agency, a determination has been made that the point source discharge limitations for each identified pollutant as shown in Table 176 can be attained through the application of the Best Practicable Pollution Control Technology Currently Available.

The average of daily values for any 30 consective days should not exceed the maximum 30 day average limitations shown. The value for one day should not exceed the daily maximum limitations shown in this table. The limitations shown are in kilograms of pollutant per metric ton of production (pounds of pollutant per

Table 176
BPCTCA
Effluent Limitations in kg/kkg(lbs/ton)

Subcategory	Maximum 30 Day Average BOD5	Maximum 30 Day Average TSS	Maximum Day BOD5	Maximum Day TSS
Dissolving Kraft	12.95(25.9)	15.55(31.1)	21.95(43.9)	34.05(68.1)
Market Kraft	7.1 (14.2)	10.3 (20.6)	12.05(24.1)	22.6 (45.2)
BCT Kraft	6.35(12.7)	10.3 (20.6)	10.75(21.5)	22.6 (45.2)
Fine Kraft	4.7 (9.4)	7.35(14.7)	7.9 (15.8)	16.05(32.1)
Papergrade Sulfite	15.2 (30.4)	21.15(42.3)	25.75(51.5)	46.4 (92.8)
Dissolving Sulfite	22.7 (45.4)	26.25(52.5)	38.5 (77.0)	57.55(115.1)
GW-Chemi-Mechanical	3.5 (7.0)	5.9 (11.8)	5.95(11.9)	12.9 (25.8)
GW-Thermo-Mechanical	2.6 (5.2)	4.45(8.9)	4.4 (8.8)	9.7 (19.4)
GW-CMN Papers	4.2 (8.4)	7.0 (14.0)	7.1 (14.2)	15.35(30.7)
GW-Fine Papers	3.75(7.5)	6.45(12.9)	6.35(12.7)	14.1 (28.2)
Soda	5.75(11.5)	8.3 (16.6)	9.75(19.5)	18.2 (36.4)
Deink	7.0 (14.0)	12.65(25.3)	11.9 (23.8)	27.7 (55.4)
NI Fine Papers	4.2 (8.4)	4.25(8.5)	7.1 (14.2)	9.35(18.7)
NI Tissue Papers	4.7 (9.4)	4.65(9.3)	7.9 (15.8)	10.25(20.5)
NI Tissue (FWP)	4.7 (9.4)	4.65(9.3)	7.9 (15.8)	10.25(20.5)

pH for all subcategories shall not exceed 6.0 to 9.0

	Zinc	
Subcategory	Maximum 30 Day Average kg/kkg(lbs/ton)	Maximum Day kg/kkg(lbs/ton)
GW:Chemi-mechanical	0.125 (0.25)	0.25 (0.50)
GW:Thermo-mechanical	0.095 (0.19)	0.19 (0.38)
GW:CMN Papers	0.150 (0.30)	0.30 (0.60)
GW:Fine Papers	0.135 (0.27)	0.27 (0.54)

ton of production). Effluents should always be within the pH range of 6.0 to 9.0.

Production in kkg (tons) is defined as annual tonnage produced from pulp dryers (in the case of market pulp) and paper machines (for paper/board) divided by the number of production days in the 12-month period. Pulp production is to be corrected, if necessary, to the "air dry" moisture basis. No such correction is necessary for paper/board production.

Allowance for Wet Woodyard Operations

Irrespective of the wood pulping subcategories the allowance for BOD5 and TSS shown below can be added to the above effluent limitations for mills with wet woodyard operations. Application of the additional allowance only shall be made for that portion of the total mills production attributable to the use of logs, specifically excluding any allowance for the portion of total production attributable to purchased chips, purchased pulp, or purchased waste paper.

The woodyard operations which qualify for this allowance are the following:

1. Log ponds used for defreezing logs prior to processing.
2. Log transport and defreeze flumes.
3. Log washing.
4. Wet debarking operations.

For mills using the above operations, the additional allowances for BOD5 and TSS are shown below:

	Max 30 day Average kg/kkg (lbs/ton)		Max daily Average kg/kkg (lbs/ton)	
BOD5	0.5	(1.0)	0.9	(1.8)
TSS	0.75	(1.5)	1.6	(3.2)

IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Best Practicable Control Technology Currently Available varies among the subcategories. Internal technologies are shown in Tables 112 through 126 of Section VIII, and the external technologies are shown in Table 127. The selected external technology suggested as BPCTCA and the internal technologies employed by the mills in each subcategory are discussed in detail in Section VII and VIII.

It is emphasized here that these technologies are not of themselves required. Due to economic, space, or other factors, many mills may choose to use alternative technologies. Conversely, some mills may choose technologies in addition to those shown. For example, biological treatment is not included for mills in the non-integrated tissue subcategory. The reason is that many of these mills with only primary treatment have achieved equal or better results than some others which also use biological treatment. A specific mill within these subcategories may, howeven, choose biological treatment as the most effective method of meeting the limitations.

RATIONALE FOR THE SELECTION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Age and Size of Equipment and Facilities

There is a wide range, in both size and age, among mills in the subcategories studied. However, internal operations of most older mills have been upgraded, and most of these mills currently operate very efficiently. The technology for upgrading of older mills is well known within a given subcategory. Studies have also shown that waste treatment plant performance does not relate to mill size. There is no significant variation in either the waste water characteristics or in the waste water loading rates, in kg/kkg (lb/ton), among mills of varying sizes.

Processes Employed

All mills within each subcategory studied utilize the same basic production processes. Although there are deviations in equipment and production procedures, these deviations do not significantly alter the characteristics of the wastewater generated. Treatability of all these wastes is similar.

Application of best practicable control technology currently available does not require major changes in existing industrial processes for the subcategories studied. Incorporation of additional systems, treatment processes, and control measures can be accomplished in most cases through changes in piping, and through modifications of existing equipment. Such alterations can be carried out at all mills within a given subcategory.

The technology to achieve these effluent limitations is practiced within the subcategories under study. The concepts are proven, available for implementation, and applicable to the wastes in question. The waste treatment techniques are also broadly applied within many other industries. The technology required will necessitate improved monitoring of waste discharges and of waste treatment components on the part of many mills, and may require more extensive training of personnel in the operation and maintenance of waste treatment facilities. However, these procedures are currently practiced in many mills and are common practice in many other industries.

Non-Water Quality Environmental Impact

The technology cited will not create any significant increase in odors, or in noise levels beyond those observed in well-designed municipal waste water treatment systems which currently are being approved by the federal government for construction in populated areas. Further, no hazardous chemicals are required as part of this technology.

Cost of Application in Relation to Effluent Reduction Benefits (Including Energy Requirements)

The total project costs of BPCTCA reflect an increase of production expenses as shown in Tables 129 through 158 of Section VIII. These increases reflect both all internal mill and external waste treatment improvements. They are based on 360 days of production per year. It should be emphasized, however, that most mills have already carried out many of these improvements. Consequently, their increased costs would be less than those shown. The energy requirements associated with the application of pollution control technologies are described in Section VIII.

RATIONALE FOR SELECTION OF EFFLUENT LIMITATIONS

The rationale used in developing the effluent limitations for BOD, TSS, zinc (groundwood subcategories only), and pH is discussed below for each of the subcategories. Specifically identified are the methods used to select the limitations for the maximum 30 consective day average and the daily maximum value for BOD and TSS. To the extent possible, the effluent limitations for both parameters are based on twelve months of data obtained from nearly 200 mills during this study. The procedure for selecting the mills in each subcategory whose external pollution control facilities demonstrate a high level of performance is also described in this section.

The development of the effluent limitations for each subcategory are discussed in detail in the following paragraphs. The basic approach used in determining the effluent limitations involved (1) the establishment of raw waste loads for each subcategory (see Section V), (2) determination of external treatment capabilities within each of the subcategories, and (3) establishment of the effluent limitations using the raw waste loads and external treatment capabilities. Specifically, the average effluent flow volume as determined for each subcategory in Section V was used with the average of the BOD5 and TSS concentrations presently being achieved by mills with well designed and operated secondary treatment systems. The effluent flow indicates the extent of inplant control measures in use at mills within the subcategories, and use of the average flow per subcategory in developing the effluent limitations inherently

reflects a level of in plant waste water management technologies which are commonly practiced. The use of the final effluent average BOD5 and TSS concentrations from mills with adquately designed and operated secondary treatment systems reflects basic sanitary engineering concepts. By using the average flow for each subcategory, mills using a normal level of in plant control measures and well designed and operated external treatment should be able to achieve the effluent limitations through use of BPCTCA external treatment. It should be pointed out that the BOD5 and TSS raw waste loads that were developed in Section V were used in the development of the costs in Section VIII along with the effluent flow values.

The selection of the BOD5 and TSS concentrations used in determining the effluent limitations involved thorough evaluations of the external treatment systems at mills within each of the subcategories. In several cases, mills achieved high quality BOD5 concentrations in their effluents while the TSS concentrations were very poor. In nearly every case, the poor performance on TSS can be related directly to poor design and operation of the facilities (i.e. the design was based solely on BOD5 removal without regard to TSS removal; for example, ASBs with short detention times and adequate aeration horsepower demonstrate low BOD5s and high TSS).

The effluent limitations were developed on an annual average basis and then multiplied by the variability factors developed in Section VII to determine the 30 consecutive day and maximum day limitations. The flow values developed in Section V were based upon 12 or more months of daily data when available. In addition, the final effluent concentrations represent averages of 12 months or more of daily data. It should again be emphasized that mill sampling, flow measurement, and laboratory analytical techniques were thoroughly evaluated to assure that the mill data used in the development of the effluent limitations was valid. Because of this, some mill data was eliminated from consideration due to various deficiencies. For instance, a number of mills measure TSS by non-standard methods using a paper filter rather than by the standard procedure of using a glass fiber filter. The two analytical procedures yield widely different results and no correlation exists between the two tests. TSS data as measured by non-standard methods was thereby not used in determining effluent limitations.

Bleached Kraft Segment

Extensive effluent data were available for 28 bleached kraft mills that have biological treatment facilities. Of the 28 mills with treatment, 20 were determined to have biological treatment systems capable of achieving high quality effluents. Three of the 20 mills, however, were not achieving high quality TSS levels due to apparent deficiencies in the design of their treatment systems.

The data for the 28 mills is summarized by subcategory in Table 177. The final effluent BOD_5 and TSS values are shown in both kg/kkg (lbs/ton) and concentrations. As discussed previously, TSS data measured by non-standard methods was excluded from the table. The most commonly practiced form of biological treatment practiced by these mills is aerated stabilization basins (ASB) which is used by eleven mills. ASBs followed by post storage (PS) ponds are used by eight mills. The activated sludge (A) treatment system is used by five mills, and four other mills use ASBs followed by clarification or A's followed by PS.

The final effluent BOD_5 concentrations for the 28 mills are arrayed in order of increasing concentrations in Table 178. Also, shown in the table are the mill subcategories, the treatment system, and the final effluent TSS concentration. Figure 71 presents a graphic display of the data presented in Table 177. The obvious break point is at 40 mg/l (mill 108) above which the slope of the curve increases sharply. As shown in the table, the average BOD_5 concentration for the top 20 mills is 24 mg/l whereas inclusion of the bottom eight increases the average to 39.5 mg/l. The average TSS concentration for the top 20 mills was 36 mg/l excluding mills using non-standard methods and mills 120, 136, and 109. The high TSS concentrations for mills 120, 136, and 109 are apparently due to deficiencies in the design of the treatment systems. For example, mill 109 is achieving 36 mg/l BOD_5 but discharging an average of 104 mg/l TSS. Examination of the mill's design parameters shows that the ASB has 1500 hp which is adequate for BOD_5 removal but only six days detention time. The adequate aeration capacity and the six days of detention allow oxidation of the soluble BOD_5, but the biological organisms are apparently still in the log growth phase rather than in the endogeneous respiration growth phase. Adequate designs of biological treatment systems include detention times into the endogenous respiration growth phase as this greatly reduces the TSS concentrations in the final effluent. Adequate detention times as shown in Section VII and VIII are approximately 14 days.

External treatment systems for mills with biological treatment are schematically shown in Figure 42A and the basic design parameters are included. Table 179 summarizes the basic design parameters for the bleached kraft mills with biological treatment.

Using the BOD_5 and TSS concentration data for the top 20 mills in Table 180, an analysis of the capabilities of the type of biological treatment system was made. The results of the analyses are presented in Table 181. The analyses compared the four basic forms of biological treatment used by the 20 bleached kraft mills with the final effluent BOD5 and TSS concentrations. Any conclusions resulting from the data presented in the table are limited by the size of the sample. It appears that ASB-PS systems achieve the best overall BOD_5 and TSS concentrations but both ASB and A systems can achieve similiar quality BOD_5 concentrations as indicated by the low end of the range. The TSS

Table 177
Bleached Kraft Segment
Final Effluent Characteristics

Mill	Size kkg/day (tons/day)		Flow kl/kkg (kgal/ton)		Treatment	FINAL EFFLUENT BOD kg/kkg (lbs/ton)		BOD mg/l	TSS kg/kkg (lbs/ton)		TSS mg/l
MARKET PULP											
114	668	(737)	172.6	(41.4)	C-ASB	2.9	(5.9)	17	3.7	(7.5)	22
130	366	(404)	256.4	(61.5)	SB-ASB	2.9	(5.8)	11	6.5	(13.0)	25
140	288	(318)	79.2	(19.0)	SB-ASB	7.8	(15.6)	98	8.1	(16.3)	103
BCT											
105	1017	(1121)	162.2	(38.9)	C-ASB-PS	2.5	(5.1)	16	-	(-)	-
109	1015	(1119)	163.0	(39.1)	C-ASB	5.9	(11.8)	36	17.0	(34)	104
111	700	(772)	134.7	(32.3)	C-ASB	2.8	(5.7)	21	6.7	(13.4)	50
121	1225	(1351)	149.3	(35.8)	C-ASB-PS	4.1	(8.2)	27	4.3	(8.7)	29
BCT & MARKET											
501	1256	(1385)	198.9	(47.7)	C-ASB	11.9	(23.8)	60	15.8	(31.7)	80
117	297	(327)	203.9	(48.9)	C-ASB	2.8	(5.6)	14	5.2	(10.4)	25
113	1068	(1177)	140.9	(33.8)	C-ASB	5.0	(10.0)	35	-	(-)	-
122	542	(598)	120.9	(29.0)	C-ASB-PS	14.0	(28.0)	116	19.3	(38.6)	160
100	931	(1027)	150.5	(36.1)	C-ASB	14.2	(28.4)	94	1.5	(3.0)	10
138	894	(986)	139.7	(33.5)	C-ASB	4.6	(9.2)	33	8.6	(17.3)	62
DISSOLVING PULP											
127	*	*	229.8	(55.1)	C-ASB	5.5	(11.1)	24	7.9	(15.9)	34
108	824	(908)	250.6	(60.1)	C-ASB	10.1	(20.2)	40	11.8	(23.6)	47

Table 177 cont'd
Bleached Kraft Segment
Final Effluent Characteristics
Continued

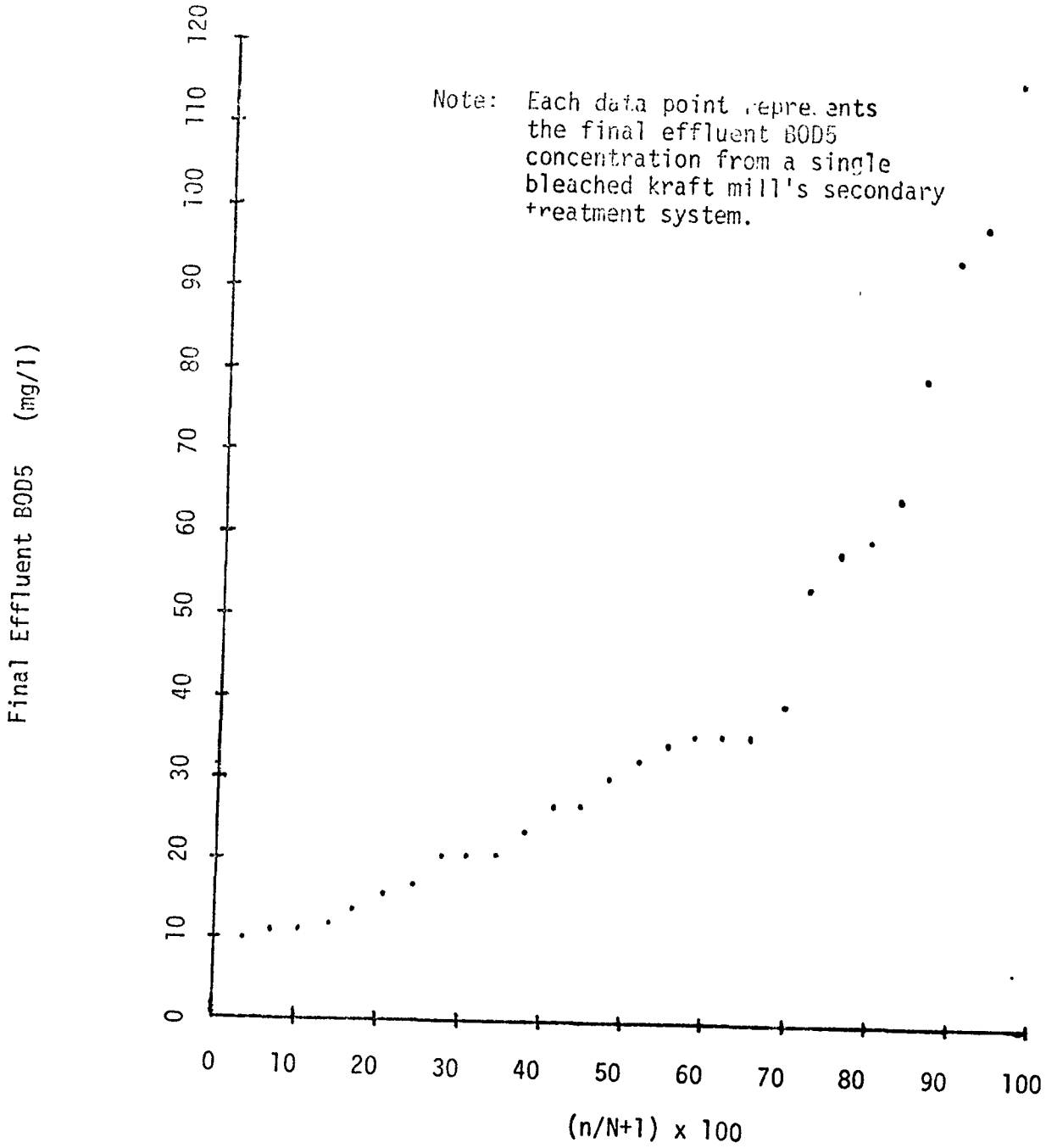
Mill	Size kkg/day (tons/day)		Flow kl/kkg (kgal/ton)		Treatment	FINAL EFFLUENT BOD5 kg/kkg (lbs/ton)		BOD5 mg/l	TSS kg/kkg (lbs/ton)		TSS mg/l
FINE PAPERS											
116	1043	(1150)	149.7	(35.9)	C-ASB	8.7	(17.5)	58	40.9	(81.8)	273
118	174	(192)	107.2	(25.7)	C-A	5.7	(11.5)	54	-	(-)	-
134	857	(945)	94.2	(22.6)	C-ASB-C	7.5	(15.1)	80	24.1	(48.3)	256
119	522	(575)	97.2	(23.3)	C-A	1.1	(2.2)	11	3.2	(6.5)	33
112	580	(640)	117.6	(28.2)	C-ASB-C	1.4	(2.9)	12	-	(-)	-
136	1497	(1650)	124.3	(29.8)	C-A	3.8	(7.6)	31	29.9	(59.8)	240
104	1217	(1342)	218.1	(52.3)	C-A	7.8	(15.7)	36	-	(-)	-
FINE & MARKET											
103	385	(425)	181.0	(43.4)	C-ASB-PS	11.7	(23.5)	65	4.7	(9.5)	26
106	473	(522)	161.4	(38.7)	C-ASB-PS	3.4	(6.9)	21	3.9	(7.8)	24
101	517	(570)	150.9	(36.2)	C-ASB-PS	1.5	(3.0)	10	22.5	(45)	15
107	281	(310)	126.4	(30.3)	C-A-PS	2.7	(5.4)	21	-	(-)	-
110	1027	(1132)	102.6	(24.6)	C-ASB-C	3.7	(7.4)	36	6.7	(13.5)	66
120	1052	(1160)	129.7	(31.1)	C-A	3.5	(7.1)	27	13.8	(27.6)	105

TABLE 178
BLEACHED KRAFT SEGMENT
FINAL EFFLUENT BOD5 & TSS CONCENTRATIONS

Mill	Subcategory	Treatment	BOD5 mg/l	TSS mg/l
101	Fine & Market	C-ASB-PS	10	15
130	Market	SB-ASB	11	25
119	Fine	C-A	11	33
112	Fine	C-ASB-C	12	-
117	BCT & Market	C-ASB	14	25
105	BCT	C-ASB-PS	16	-
114	Market	C-ASB	17	22
106	Fine & Market	C-ASB-PS	21	24
111	BCT	C-ASB	21	50
107	Fine & Market	C-A-PS	21	-
127	Dissolving	C-ASB	24	35
12[illegible]	BCT	C-ASB-PS	27	29
120	Fine & Market	C-A	27	106*
136	Fine	C-A	31	240*
138	BCT & Market	C-ASB	33	62
113	BCT & Market	C-ASB	35	-
109	BCT	C-ASB	36	104*
110	Fine & Market	C-ASB-C	36	66
104	Fine & Tissue	C-A	36	-
108	Dissolving	C-ASB	40	47
	Ave.		23.9	36.1
118	Fine	C-A	54	-
116	Fine	C-ASB	58	273
501	BCT & Market	C-ASB	60	80
103	Fine & Market	C-ASB-PS	65	26
134	Fine	C-ASB-C	80	256
100	BCT & Market	C-ASB-PS	94	-
140	Market	C-ASB	98	103
122	BCT & Market	C-ASB-PS	116	160
	Ave.(all mills)		39.5	84.8

*only included in average for all mills

Figure 86
BLEACHED KRAFT SEGMENT
SECONDARY TREATMENT EFFLUENT BOD5 CONCENTRATIONS



data is too limited to base any conclusions upon other than that high quality TSS concentrations can be achieved by ASB and A treatment systems.

The final effluent BOD_5 and TSS concentrations for the top 20 mills are separated into subcategories and presented in Table 180. The average concentrations are, in most cases, those used in developing the effluent limitations and are described below.

Dissolving Kraft

Table 176 presents the BOD_5 and TSS concentrations used with the subcategory average effluent flow to determine the effluent limitations on an annual average basis. As mentioned earilier in Section IX, these values were then multiplied by the variability factors developed in Section VII to determine the maximum 30 consecutive days and maximum day effluent limitations. The factors used are shown in Table 182 and were used for all subcategories.

As shown in Table 183, the BOD_5 and TSS concentrations used as the basis of the effluent limitations were 32 mg/l and 40 mg/l respectively, which were the averages of mill 127 and mill 108 (See Table 180).

Market Kraft

The average BOD_5 and TSS concentration for mills 114 and 130 were 14.0 mg/l and 23.5 mg/l respectively, as shown in Table 183. Since these average values were near the best achieved by all bleached kraft mills (See Table 180), the effluent limitations were based upon 24 mg/l and 36 mg/l which were the average BOD_5 and TSS concentrations, respectively, for the top 19 mills (excluding mill 112) in the bleached kraft segment.

BCT Papers

The average BOD_5 concentration used to determine the effluent limitations was 25 mg/l which is shown in Table 183 and developed in Table 180 from mills in the BCT Papers Subcategory. The TSS concentration used to determine the effluent limitations was 42 mg/l which is an average of mills 111, 121, 117, and 138, the latter two manufacturing both BCT papers and market pulp. Since TSS data was available for only two mills in the BCT Paper and the average TSS increased only slightly, the four mills were used as the basis.

Fine Papers

As shown in Table 183, the average BOD_5 and TSS concentrations used in determining the effluent limitations were 26 mg/l and 42 mg/l, respectively. The BOD_5 value of 26 mg/l was an average of three mills in the fine papers subcategory. It should be noted that the average for fine papers and fine and market subcategories was 24 mg/l. The TSS value of 42 mg/l is the same

Table 179
External Treatment Facilities
Bleached Kraft Segment

Mill	C klpd/m2(gpd/ft2)	A hrs	A hp	ASB days	ASB hp	C klpd/m2(gpd/ft2)	PS days
100	27.70 (680)	-	-	4	1185	- -	7
101	14.26 (350)	-	-	20	850	- -	15
102	10.96 (269)	-	-	4	750	- -	16.5
103	18.33 (450)	-	-	20	300	- -	12.5
104	32.39 (795)	5	1785	-	-	48.89 (1200)	-
105	16.30 (400)	-	-	14	750	- -	10-12
106	37.89 (930)	-	-	10	400	- -	58
107	24.44 (600)	3	440	5.5	60	16.30 (400)	-
108	15.15 (372)	-	-	16	3225	- -	-
109	25.34 (622)	-	-	6	1500	- -	-
110	19.15 (470)	-	-	13	1020	19.96 (490)	-
111	10.72 (263)	-	-	8	1650	- -	-
112	NA (NA)	-	-	3.75	600	25.99 (638)	-
113	19.64 (482)	-	-	15	1990	- -	-
114	14.26 (350)	-	-	10,5	1400	- -	9
116	87.80 (2155)	-	-	2	1170	- -	-
117	20.37 (500)	-	-	14	480	- -	-

Table 179 cont'd
External Treatment Facilities
Bleached Kraft Segment
Continued

Mill	C klpd/m2(gpd/ft2)		A hrs	A hp	ASB days	ASB hp	C klpd/m2(gpd/ft2)		PS days
118	NA	(NA)	4.6	NA	-	-	-	-	-
119	31.00	(751)	7	NA	-	-	19.31	(474)	-
120	28.52	(700)	NA	2000	-	-	NA	(NA)	-
121	21.59	(530)	-	-	3.6	1660	-	-	7
122	24.44	(600)	-	-	12	900	-	-	197
125	24.44	(600)	-	-	10	1300	-	-	24.5
127	9.94	(244)	-	-	8.5	1920	-	-	-
130	NA	(NA)	-	-	7	1030	-	-	-
131	39.07	(959)	-	-	6.5	1250	-	-	-
136	25.56	(652)	6.6	2500	-	-	31.78	(780)	-
138	18.62	(457)	-	-	14.5	1950	-	-	-
501	6.51	(162)	-	-	6	1700	-	-	-

TABLE 180
BLEACHED KRAFT SEGMENT
BEST MILLS: FINAL EFFLUENT BOD5 & TSS

Mill	Treatment	BOD5 mg/l	TSS mg/l
Market Pulp			
114	C-ASB	17	22
130	SB-ASB	11	25
Ave.		14	23.5
BCT Papers			
105	C-ASB-PS	16	-
109	C-ASB	36	104*
111	C-ASB	21	50
121	C-ASB-PS	27	29
Ave.		25	39.5
BCT & Market			
117	C-ASB	14	25
113	C-ASB	35	-
138	C-ASB	33	62
Ave.		27	43.5
Ave. (BCT, BCT & MKT)		26	41.5
Dissolving Pulp			
127	C-ASB	24	34
108	C-ASB	40	47
Ave.		32	40.5
Fine Papers			
119	C-A	11	33
136	C-A	31	240*
104	C-A	36	-
Ave.		26	33
Fine & Market			
106	C-ASB-PS	21	24
101	C-ASB-PS	10	15
107	C-A-PS	21	-
110	C-ASB-C	36	66
120	C-A	27	106*
Ave.		23	35
Ave. (Fine, Fine & Market)		24	34.5

*Not included in averages (see text)

TABLE 181

BLEACHED KRAFT SEGMENT
TYPE TREATMENT VS BOD5 & TSS

Treatment	BOD5(mg/l) # Mills	Ave	Range	TSS(mg/l) # Mills	Ave	Range
ASB	9	26	11-40	7	38	22-62
ASB-PS	4	19	10-27	3	23	15-29
A	4	26	11-36	1	33	33
ASB-C, A-PS	3	23	12-36	1	66	66

Table 182
BPCTCA Variability Factors

Parameter	Maximum Month	Maximum Day
BOD_5	1.67	2.83
TSS	1.61	3.53

Table 183
Basis for BPCTCA Effluent Limitations
Summary

Subcategory	Flow kl/kkg (kgal/ton)		BOD5 mg/l	TSS mg/l	Annual Average BOD5 kg/kkg (lbs/ton)		Annual Average TSS kg/kkg (lbs/ton)	
BK: Dissolving Kraft	241.9	(58.0)	32	40	7.75	(15.5)	9.65	(19.3)
BK: Market Kraft	177.2	(42.5)	24	36	4.25	(8.5)	6.4	(12.8)
BK: BCT Papers	152.2	(36.5)	25	42	3.8	(7.6)	6.4	(12.8)
BK: Fine Papers	108.4	(26.0)	26	42	2.8	(5.6)	4.55	(9.1)
Soda	123.0	(29.5)	28	42	3.45	(6.9)	5.15	(10.3)
GW: Chemi-Mechanical	83.4	(20.0)	25	44	2.1	(4.2)	3.65	(7.3)
GW: Thermo-Mechanical	62.6	(15.0)	25	44	1.55	(3.1)	2.75	(5.5)
GW: Fine Papers	90.9	(21.8)	25	44	2.25	(4.5)	4.0	(8.0)
GW: CMN Papers	99.2	(23.8)	25	44	2.5	(5.0)	4.35	(8.7)
Papergrade Sulfite	208.5	(50.0)	40	58	9.1	(18.2)	13.15	(26.3)
Dissolving Sulfite	271.9	(65.2)	50	60	13.6	(27.2)	16.3	(32.6)
Deink	94.2	(22.6)	41	77	4.2	(8.4)	7.85	(15.7)
NI Fine Papers	62.6	(15.0)	40	42	2.5	(5.0)	2.65	(5.3)
NI Tissue Papers	95.9	(23.0)	29	30	2.8	(5.6)	2.9	(5.8)
NI Tissue Papers (FWP)	95.9	(23.0)	29	30	2.8	(5.6)	2.9	(5.8)

as in the BCT papers subcategory. TSS data were available for only one mill in the fine paper subcategory with three additional mills having data in the fine and market subcategory. Three of the four mills used ASB-PS for their treatment and as indicated in Table 180 achieved TSS effluent qualities slightly better than the other systems. Thus, being conservative, the same TSS concentration of 42 mg/l was used for fine papers.

Groundwood Segment

Effluent data for groundwood mills which have biological treatment facilities are summarized in Table 184. Schematics of the mills external treatment facilities and the basic design parameters are shown in Figure 42A. The design parameters are summarized in Table 185.

As shown in Table 184, effluent data was available for the four groundwood mills with biological treatment facilities. The type of treatment systems used at these groundwood mills include aerated stabilization basins, activated sludge, and one mill employs trickling filters. The average BOD_5 and TSS concentrations in the final effluents are 25 mg/l and 44 mg/l (excluding mill 003), respectively. The trickling filter system utilized by mill 003 does not achieve high quality BOD_5 concentrations and thereby is not considered as adequate treatment.

Table 183 presents the effluent parameters used as a basis for the effluent limitations. The flows are the average subcategory flows as developed in Section V and the BOD_5 and TSS concentrations represent the average of the best biological treatment systems used at groundwood mills. The maximum 30 consecutive days and maximum day effluent limitations were determined by multiplying the annual average BOD_5 and TSS values by the variability factors shown in Table 182.

The use of zinc hydrosulfide by groundwood mills as a bleaching agent generally results in relatively high zinc levels in the process wastewaters. Available data resulting from the mill surveys are shown below:

Mill	Bleaching Agent	Production kkg (tons) day	Flow kl/kkg (kgal/ton)	Zinc mg/L	Zinc kg/kkg (lbs/to
002	Na	197 (217)	95.1 (22.8	0.097	0.009 (0.018)
003	Zn	492 (542)	106 (25.5)	4.170	0.444 (0.887)
005	Zn	505 (557)	94.7 (22.7)	0.390	0.037 (0.074)
013	Na	461 (508)	85.5 (20.5)	0.118	0.010 (0.020)
008	Zn	380 (419)	112 (26.8)	0.880	0.099 (0.197)
010	None	904 (997)	179 (42.9)	0.088	0.016 (0.032)
014	Na	93 (102)	97.6 (23.4)	0.350	0.034 (0.068)
011	Na	101 (111)	48.8 (11.7)	0.196	0.010 (0.019)

Three mills for which data were available used zinc hydrosulfite for brightening the pulp, mills 003, 005, and 008. These mills

Table 184

GROUNDWOOD SEGMENT
FINAL EFFLUENT CHARACTERISTICS

Mill	Size kkg/day (tons/day)	Flow kl/kkg (kgal/ton)	Treatment	BOD_5 kg/kkg (lbs/ton)	BOD_5 mg/l	TSS kg/kkg (lbs/ton)	TSS mg/l
001	85 (94)	91.8 (22.0)	SB-ASB-C	2.1 (4.1)	22	3.2 (6.4)	35
003	492 (542)	106.3 (25.5)	C-TF-C	8.0 (15.9)	75	7.9 (15.7)	74
005	505 (557)	98.0 (23.5)	SB-ASB	2.1 (4.1)	21	2.2 (4.4)	22
002	194 (214)	97.2 (23.3)	C-A	3.3 (6.5)	33	7.3 (14.6)	75

Table 185
External Treatment Facilities
Groundwood Segment

Mill	C klpd/m2(gpd/ft2)		A hrs	A hp	ASB days	ASB hp	C klpd/m2(gpd/ft2)		PS days
001	NA	(NA)	-	-	8	320	-	-	NA
002	18.09	(444)	12	240	-	-	18.09	444	-
003	37.81	(928)	-	-	TF	-	28.40	697	-
005	NA	(NA)	-	-	8	600	-	-	-

show distinctly higher levels of zinc in the effluent values. The effluent limitation was based upon mill 008 which had a concentration of 0.88 mg/l. The limitation was thus based upon 1 mg/l and the subcategory flow values. The maximum 30 consecutive days and maximum day limitations were determined by using variability factors of 1.5 and 3.0, respectively, which reflect raw waste load variability and not the variability of biological treatment systems.

Sulfite Segment

Effluent data for the six mills in the Sulfite Segment that have biological treatment systems are presented in Table 186. As noted on the table, several items should be noted when evaluating the raw waste and final effluent data from these mills. Mill 006 and 007 have significant groundwood pulping operations on-site and the waste water from both the sulfite and groundwood pulping operations are combined and discharged to the biological treatment system. These mills are included in the sulfite table since the raw waste load is much more significantly affected by the sulfite operation than the groundwood operation. Mill 52 produces papergrade high yield unbleached products and thus is not necessarily representative of papergrade sulfite mills. Mill 053 is a relatively new papergrade sulfite mill and as such has separate treatment systems for the pulp mill wastes and the paper mill wastes. Mill 501 is a dissolving sulfite mill that only treats a portion of the waste waters. Mill 051, shown in Table 185, is a papergrade sulfite mill producing fine papers, and the mill waste waters are the most representative for mills using BPCTCA internal controls in the papergrade sulfite subcategory.

The treatment systems in use by the sulfite mills in Table 185 primarily include aerated stabilization basins. As described on the table, mill 053 uses the activated sludge process. Schematics of the mill external treatment systems are presented in Figure 42A and the design parameters are summarized in Table 187. The final effluent BOD_5 and TSS concentrations are shown in Table 186 and as shown, none of the mills are achieving high quality effluents. The BOD_5 concentration of 24 mg/l shown for mill 053 is an average of the activated sludge system effluent and the DAF unit effluent. The activated sludge system effluent averaged 62 mg/l. The average BOD_5 concentration for the mills in Table 186 was 70 mg/l (using 62 mg/l for mill 053) which is much worse than that normally considered as high quality effluents and is an indication that the designs or operations of the treatment facilities were deficient in some aspect. Evaluation of each mill's treatment system generally shows that the systems were under designed, especially in detention times. For example, Mill 051 which (discussed previously and in Section V) has the most representative flow and BOD_5 raw waste load is presently achieving final effluent BOD_5 and TSS qualities of 68 mg/l and 44 mg/l, respectively. Examination of some of the design parameters of the aerated stabilization basin at mill 051 show that the aeration capacity is adequate (1600 hp), but the detention time of 7.5 days is much less than that considered as

Table 186

SULFITE SEGMENT
FINAL EFFLUENT CHARACTERISTICS

Mill	Size kkg/day (tons/day)		Flow kl/kkg (kgal/ton)		Treatment	BOD5 kg/kkg (lbs/ton)		mg/l	TSS kg/kkg (lbs/ton)		mg/l
006*	463	(510)	79.6	(19.1)	C-ASB	4.6	(9.1)	57	-	(-)	-
007*	517	(570)	95.9	(23.0)	C-ASB	5.0	(9.9)	51	-	(-)	-
051	281	(310)	193	(46.2)	C-ASB	13.2	(26.4)	68	8.6	(17.1)	44
052	92	(101)	169	(40.6)	C-ASB	16.3	(32.5)	96	-	(-)	-
053***	**		121	(29.0)	C-A, DAF	2.9	(5.8)	24	7.5	(15.0)	61
501****	-	-	-	(-)	ASB-C	-	(-)	83	-	(-)	-

* includes groundwood pulping effluents
** Trade secret
*** Mill 053 values were calculated by averaging the results from the final effluents from the activated sludge system and the DAF system
**** Mill treats only portion of total waste water; influent to treatment system is 3530mg/l at 83 million liters (2.2 mgj/day.

Table 187
External Treatment Facilities
Sulfite Segment

Mill	C klpd/m2(gpd/ft2)		A hrs	A hp	ASB days	ASB hp	C klpd/m2(gpd/ft2)		PS days
51	20.78	(510)	-	-	7.5	1600	-	-	-
52	NA	(NA)	-	-	10	374	-	-	-
53	NA	(NA)	24	NA	-	-	19.56	480	-
006	17.52	(430)	-	-	12.6	1200	-	-	-
007	22.33	(548)	-	-	6	1100	-		-
401	-	-	-	-	7-8	3200	-	-	-

adequate design (i.e. 14 days, see Section VIII). In addition, operation of the treatment system has an effect upon effluent qualities. The relatively high BOD_5 concentrations being discharged by mill 051 can be attributed to both design and operation, as two or three aerators are shut down during winter months. This certainly has an effect upon the treatment effectiveness.

As discussed above, the treatment systems in use by sulfite mills have not demonstrated high quality effluents representative of BPCTCA primarily because of the design and operation of the treatment systems. High quality effluents are presently being achieved in the bleached kraft segment of the pulp and paper industry by 20 mills for which effluent data from their biological treatment systems were available. As graphically displayed in Figure 75, BOD_5 concentrations from bleached kraft mill treatment systems vary from 10 mg/l to 116 mg/l with a definite "break-point" at 40 mg/l. Examination of the effluent data and the treatment system design and operating parameters show deficiencies in the mill treatment systems which achieve above 40 mg/l BOD5. The range of high quality effluents was thereby 10-40 mg/l with an average of 24 mg/l BOD_5 and a TSS average of 36 mg/l. Because the treatment systems in use by sulfite mills are generally not representative of BPCTCA, the effluent limitations were based upon adequate design and operation of treatment facilities as demonstrated by bleached kraft mills. Adequate design and operation of the sulfite mill treatment facilities should result in at least a final effluent BOD_5 concentration of 40 mg/l (top end of bleached kraft range), and the effluent limitations for papergrade sulfite were thereby based upon 40 mg/l and the average subcategory flow of 208.5 kl/kkg (50.0 kgal/ton). The dissolving sulfite effluent limitations were based upon 50 mg/l which is conservative since only one dissolving sulfite mill has any experience with biological treatment and since the dissolving sulfite flow and BOD_5 raw waste loads are higher than the papergrade sulfite subcategory. The TSS effluent limitations were based upon 58 mg/l for the papergrade sulfite subcategory and 60 mg/l for the dissolving sulfite subcategory. The average TSS concentration presently achieved by mill 051 is 44 mg/l which is relatively close to the bleached kraft TSS average of 36 mg/l. However, mill 051 is not achieving high quality BOD_5 concentrations and the additional treatment required to achieve 40 mg/l may generate additional TSS in the form of biological organisms. Assuming that very few of the additional biological organisms are removed in the treatment process (a very conservative assumption) and applying the general rule-of-thumb of 0.227 kg (0.5 lbs) of TSS created per 0.454 kg (1.0 lbs) of BOD_5 destroyed yields an additional 14 mg/l of TSS in the final effluent above the present level of 44 mg/l. Thus, the papergrade sulfite effluent limitations were based upon 58 mg/l. The dissolving sulfite effluent limitations were based upon a conservative 60 mg/l because of the similarity in waste water characteristics and lack of operating data from dissolving sulfite mills operating systems representative of BPCTCA. The basis for the effluent limitations

for the sulfite subcategories are summarized in Table 183. The maximum 30 consecutive days and maximum day limitations were determined using the variability factors in Table 182 which were developed in Section VII.

Soda Segment

Two of the three mills in the soda subcategory have biological treatment facilities and the effluent data is summarized for these mills in Table 188. Schematics of the treatment facilities at these mills are shown in Figure 42A and the design parameters are summarized in Table 189.

Mill 150 uses a trickling filter system and does not achieve comparable effluent BOD_5 qualities with mills using aerated stabilization basins, such as mill 152. Mill 150's BOD_5 and TSS concentrations were 222 mg/l and 150 mg/l, respectively, whereas mill 152 achieved 28 mg/l BOD_5 and 107 mg/l, respectively. The treatment facilities utilized by mills 150 and 152 are not considered to be representative of BPCTCA as indicated by the effluent BOD_5 and TSS concentrations. The BOD_5 concentrations of mill 152 are high quality; however, the TSS concentrations indicate a deficiency in design and/or operation of the treatment facilities. The mill treatment system as displayed in Figure 42A consists of a clarifier followed by a six days detention time ASB. The ASB appears to have adequate aeration capacity for reduction of BOD_5 but the detention time is much less than normal design which can have significant impact upon TSS concentrations in the final effluent. In addition, the primary clarifier overflow rate of 38.7 klpd/m^2 (950 gpd/ft^2) is nearly 50% higher than design flow rates considered to be representative of BPCTCA (See Section VIII). This could certainly have an effect upon the level of TSS in the final effluent.

The effluent limitations were based upon 28 mg/l BOD_5 and 42 mg/l TSS. Mill 152 is presently achieving 28 mg/l BOD_5 which is nearly equal to the effluent qualities achieved by the bleached kraft segment. The soda manufacturing process is very similar to the bleached kraft manufacturing process (See Section III) and thereby the raw waste characteristics and treatability are similar. Because of the similiarities in waste waters and treatability and since the treatment facilities at mill 152 are not representative of BPCTCA, the TSS effluent limitations were based upon 42 mg/l which was the basis for the bleached kraft fine papers and BCT papers subcategories. The basis for the effluent limitations for the soda subcategory are summarized in Table 183.

The maximum 30 consecutive days and maximum day limitations were determined by multiplying the annual average values by the variability factors in Table 182.

Deink Segment

Table 188

SODA SUBCATEGORY
FINAL EFFLUENT CHARACTERISTICS

Mill	Size kkg/day (tons/day)		Flow kl/kkg (kgal/ton)		Treatment	BOD_5 kg/kkg (lbs/ton)		mg/l	TSS kg/kkg (lbs/ton)		mg/l
150	262	(289)	158	(37.9)	C-TF-C	35.2	(70.3)	222	23.7	(47.3)	150
152	548	(604)	110	(26.3)	C-ASB	3.1	(6.1)	28	11.7	(23.4)	107

Table 139
External Treatment Facilities
Soda Segment

Mill	C	A		ASB		C		PS
	klpd/m2(gpd/ft2)	hrs	hp	days	hp	klpd/m2(gpd/ft2)		days
152	38.70 (950)	-	-	6.5	600	-	-	-
150	43.23 (1061)	-	-	TF	-	35.44	870	-

Effluent data for the five deink mills with biological treatment facilities are shown in Table 190. Schematics of the external treatment facilities at these mills are presented in Figure 42A and the design parameters are shown in Table 191. The treatment systems used by these mills involve aerated stabilization basins, activated sludge, and a modified activated sludge - aerated stabilization basin system. Mill 300 is located in the Southwest and uses an ASB followed by filtration to achieve total recycle of waste waters. Mill 204 uses an ASB with only 1.4 days detention time and 180 horsepower. The final effluent BOD_5 concentration from mill 204 was 108 mg/l which is much better than mill 203 which achieved only 197 mg/l BOD_5 by 7.2 days detention time and 735 horsepower. Mill 205 used an ASB with six days detention time and 180 horsepower to achieve 67 mg/l BOD_5. As indicated by their final effluent concentrations, these mill treatment systems do not represent BPCTCA as the detention times are less than that considered as representative of BPCTCA (See Section VIII). The effluent qualities from mills 206 and 216 are significantly better than all of the other mills. Evaluation of the mill treatment system design parameters shows that the treatment systems at mills 206 and 216 are of relatively adequate design. The BOD_5 concentrations in the final effluent at mills 206 and 216 were 31 mg/l and 52 mg/l, with an average of 41.5 mg/l respectively. The TSS concentrations were 110 mg/l and 45 mg/l, respectively. The effluent limitations were based upon mills 216 and 206 even though the level of TSS in the final effluent (110 mg/l) from mill 206 exceeds that normally achieved by biological treatment. This possibly is due to the nature of the manufacturing process which is to remove the impurities from the waste paper in order to produce a clean product. This process can create high raw waste loads and have an effect upon final effluent qualities depending upon the types of waste paper utilized.

The effluent limitations were based upon the subcategory flow (at 100% deink) and the averages of BOD_5 and TSS concentrations from mills 206 and 216. The basis for the limitations is shown in Table 183.

The maximum 30 consecutive days and maximum day effluent limitations were determined by multiplying the annual average values by the variability factors shown in Table 182.

Non-Integrated Papers Mills Segment

Non-Integrated Fine Papers Subcategory

Effluent data for non-integrated fine paper mills is summarized in Table 192 for those mills with primary and/or secondary treatment systems. Schematics are presented for non-integrated fine paper mills with biological treatment facilities in Figure 42A and the design parameters are summarized in Table 193. Only two mills, 257 and 284, utilize biological treatment systems for which data was available. The final effluent BOD_5 concentrations

Table 190

DEINK SUBCATEGORY
FINAL EFFLUENT CHARACTERISTICS

Mill	Size kkg/day (tons/day)		Flow kl/kkg (kgal/ton)		Treatment	BOD_5 kg/kkg (lbs/ton)		mg/l	TSS kg/kkg (lbs/ton)		mg/
203	349	(385)	75.1	(18.0)	C-ASB	14.8	(29.6)	197	10.6	(21.2)	141
204	181	(200)	55.5	(13.3)	C-ASB	6.0	(11.9)	108	-	(-)	-
206	673	(743)	102.2	(24.5)	C-ASB-C	3.2	(6.3)	31	11.3	(22.5)	110
205	89	(98)	80.9	(19.4)	C-ASB	5.4	(10.8)	67	-	(-)	-
216	72	(79)	79.2	(19.0)	C-A	4.2	(8.3)	52	3.6	(7.2)	45

Table 191
External Treatment Facilities
Deink Segment

Mill	C klpd/m2(gpd/ft2)	A hr	A hp	ASB days	ASB hp	C klpd/m2(gpd/ft2)	PS days
203	30.56 (750)	-	-	7.2	735	- -	-
204	9.98 (245)	-	-	1.4	180	- -	-
205	13.85 (340)	-	-	6	180	- -	-
206	11.41 (280)	-	-	5	1400	19.31 (474)	-
216	21.35 (524)	5.3	NA	-	-	41.80 (1026)	-

for mills 257 and 284 were 86 mg/l and 110 mg/l, respectively. In addition, the TSS concentration for mill 284 was 102 mg/l. The average BOD_5 concentration for all the mills in Table 192 that have primary treatment facilities was 86 mg/l (excluding mill 279) indicating that primary treatment is not adequate to achieve high quality effluents. The secondary treatment systems in use by mills 257 and 284 were only achieving an average BOD_5 concentration of 98 mg/l which is also not a high quality effluent indicating that the biological treatment systems in use by the two mills are not representative of BPCTCA.

Because no mills were demonstrating treatment systems representative of BPCTCA, the effluent limitations were based upon a BOD_5 level of 40 mg/l and a TSS level of 42 mg/l. The bleached kraft segment achieved high quality effluents ranging from 10 - 40 mg/l and since non-integrated paper mills are relatively small mills and have little experience in achieving high quality levels of BOD_5 by biological treatment, 40 mg/l was used as the basis of the BOD_5 effluent limitations. A level of 42 mg/l was used for the TSS limitations which is the same level as the bleached kraft fine paper subcategory. It should be pointed out that several mills achieve or nearly so the effluent limitations using only primary treatment. The flow basis for the effluent limitations was 62.5 kl/kkg (15.0 kgal/ton) as developed in Section V. The maximum 30 consecutive days and maximum day effluent limitations were determined by multiplying the annual average values by the variability factors in Table 182.

Non-Integrated Tissue Papers Subcategories

Table 194 shows effluent data for non-integrated tissue mills and is divided into the following three groups: Group 1: 100% purchased pulp, Group 2: Purchased Pulp and Waste Paper, Group 3: 100% Waste paper. BPCTCA for the non-integrated tissue subcategory includes only primary treatment as most of the BOD_5 in the raw waste waters is associated with the fibrous materials (TSS) in the mill waste waters. In these cases, removal of the TSS also removes a large amount of the raw waste BOD_5. Three forms of primary treatment are used by NI tissue mills: (1) Clarifiers, (2) Dissolved air flotation, and (3) Settling basins. Each of these is capable of achieving high quality levels of BOD_5 and TSS in effluents from NI tissue mills. At times, chemical are added as a coagulant to aid in BOD_5 and TSS removal. Examination of the BOD_5 and TSS levels achieved by mills in each of the three groups results in the following conclusions:

(1) High quality effluents can be achieved with primary treatment by mills using 100% purchased pulp or by mills using varying proportions of waste paper and purchased pulp.

(2) Mills using 100% waste paper and primary treatment cannot achieve similar quality effluents as mills using purchased pulp with similar treatment systems. This is

Table 192

NI FINE PAPERS SUBCATEGORY
FINAL EFFLUENT CHARACTERISTICS

Mill	Size kkg/day	(tons/day)	Flow kl/kkg	(kgal/ton)	Treatment	BOD5 kg/kkg	(lbs/ton)	mg/l	TSS kg/kkg	(lbs/ton)	mg/
266	217	(239)	49.2	(11.8)	C	4.4	(8.7)	88	1.3	(2.6)	26
261	100	(110)	26.3	(6.3)	C	1.7	(3.3)	63	-	(-)	-
257	180	(199)	40.0	(9.6)	C-A	3.5	(6.9)	86	-	(-)	-
255	57	(63)	37.9	(9.1)	C	-	(-)	-	6.3	(12.5)	165
250	84	(93)	53.8	(12.9)	SB	4.8	(9.7)	90	0.8	(1.5)	14
281	330	(364)	73.0	(17.5)	SB	2.6	(5.2)	36	1.7	(3.4)	23
275*	373	(411)	90.5	(21.7)	C	14.7	(29.3)	162	11.7	(23.4)	129
265	415	(458)	69.2	(16.6)	C	5.6	(11.2)	81	-	(-)	-
284	339	(374)	25.8	(6.2)	C-ASB-C	2.9	(5.7)	110	2.7	(5.3)	102
277	573	(632)	80.5	(19.3)	C	10.6	(21.1)	131	-	(-)	-
279	561	(618)	37.5	(9.0)	SB	8.7	(17.3)	230	7.4	(14.7)	196
274	18	(20)	138	(33.0)	SB	4.6	(9.1)	33	2.0	(4.0)	14

* 20% Deink

Table 193
External Treatment Facilities
Non-Integrated Fine Segment

Mill	C klpd/m2(gpd/ft2)		A hrs	A hp	ASB days	ASB hp	C klpd/m2(gpd/ft2)		PS days
250	8.80	(216)	-	-	9	NA	-	-	-
251	-	(-)	-	-	90	30	-	-	-
257	32.63	(801)	22	150	-	-	32.63	801	-
263	10.06	(247)	-	-	3.5	60	-	-	-

TABLE 194
NI TISSUE SEGMENT
FINAL EFFLUENT CHARACTERISTICS

Mill	Size kkg/day(tons/day)	FLOW kl/kkg(kgal/ton)	Treatment	BOD5 kg/kkg(lbs/ton)	BOD5 mg/L	TSS kg/kkg(lbs/ton)	TSS mg/L
Group 1*							
308	141.5 (156)	115.5 (27.7)	C	4.5 (9.1)	39	3.8 (7.7)	33
325	110.7 (122)	130.9 (31.4)	DAF	17.5 (35.1)	134**	- (-)	-
318	113.4 (125)	140.5 (33.7)	C	3.5 (7.1)	25	4.6 (9.3)	33
315	926.0 (1021)	66.3 (15.9)	DAF	4.4 (8.9)	67	- (-)	-
306	85.3 (94)	43.4 (10.4)	DAF	1.0 (2.0)	23	- (-)	-
252	44.4 (49)	48.0 (11.5)	C-PS	3.4 (6.9)	72	1.1 (2.2)	23
319	20.0 (22)	120.1 (28.8)	SB	2.5 (5.0)	21	- (-)	-
	Average (Group 1)			3.3 (6.5)	41	3.2 (6.4)	30
Group 2*							
208	94.3 (104)	61.3 (14.7)	C	6.2 (12.4)	101	3.2 (6.4)	52
329	67.1 (74)	153.9 (36.9)	C	6.1 (12.2)	40	3.5 (7.1)	23
302	205.0 (226)	50.9 (12.2)	C-PS	3.3 (6.6)	65	- (-)	-
310	41.7 (46)	96.7 (23.2)	C	2.7 (5.5)	28	3.0 (6.0)	31
334	229.5 (253)	94.7 (22.7)	SB	1.4 (2.8)	15	1.5 (3.0)	16
309	18.1 (20)	69.6 (16.7)	C	1.9 (3.8)	27	- (-)	-
333	147.8 (163)	133.4 (32.0)	C	4.8 (9.6)	36	- (-)	-
259	176.0 (194)	73.8 (17.7)	C, DAF	3.9 (7.9)	54	1.9 (3.9)	26
326	59.0 (65)	72.6 (17.4)	C	2.4 (4.9)	34	- (-)	-
	Average (Group 2)			3.6 (7.3)	44	2.6 (5.3)	30
	Average (Group 1 & 2)			3.5 (7.0)	43	2.8 (5.7)	30
Group 3*							
330	18.1 (20)	79.2 (19.0)	C	11.6 (23.2)	146	- (-)	-
313	33.6 (37)	27.9 (6.7)	C-PS	11.5 (23.0)	411	- (-)	-
	Average (Group 3)	53.4 (12.8)		11.5 (23.1)	278	- (-)	-

*Group 1 mills use 100% purchased pulp;
Group 2 mills use purchased pulp and waste paper in varying proportions;
Group 3 mills use 100% waste paper.

**Not included in averages.

due to higher levels of soluble BOD5 in the waste waters of mills using 100% waste paper.

(3) Biological treatment is necessary for mills using 100% waste paper to achieve high quality effluents.

The final effluent BOD5 data presented for Group 1 and Group 2 in Table 194 was arranged in ascending order of BOD5 concentrations and is shown below:

Mill	BOD5 mg/l	TSS mg/l
334	15	16
319	21	-
306	23	-
318	25	33
309	27	-
310	28	31
326	34	-
333	36	-
308	39	33
329	40	23
259	54	26
302	65	-
315	67	-
252	72	23
208	101	52
325	134	-

The average BOD5 concentration for the top 10 mills was 29 mg/l with a range from 15 - 40 mg/l. The BOD5 average for all 16 mills was 49 mg/l. The TSS average for all mills was 30 mg/l. The basis for the effluent limitations was thereby 29 mg/l for BOD5 and 30 mg/l for TSS with a flow of 95.9 kl/kkg (23.0 kgal/ton) (See Section V). The maximum 30 consecutive days and maximum day limitations were determined by multiplying the annual average values by the variability factors in Table 182. It should be pointed out that the effluent limitations for mills in either the NI Tissue Papers or the NI tissue papers (fwp) subcategory are identical. The differences is in the treatment facilities included in BPCTCA, primary vs. secondary, respectively.

SECTION X

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE (BATEA)

INTRODUCTION

The effluent limitations predicated on the application of the Best Available Technology Economically Achievable (BATEA) are to be achieved not later than July 1, 1983. These are not based upon an average of the best performance within a given subcategory under study, but have been determined by identifying the best control and treatment technology employed by a specific point source within a given subcategory, and by applying technologies utilized by other industries or demonstrated by pilot plant performance on waste waters generated by mills in the Pulp and Paper Industry.

Consideration was also given to:

a. the age of equipment and facilities involved;

b. the process employed;

c. the engineering aspects of the application of control technologies;

d. the cost of application in relation to reduction benefits (including energy requirements);

e. the non-water quality environmental impact.

This level of technology emphasizes both internal process improvements and external treatment of waste waters. It will require existing mills to implement programs designed to achieve:

1. Significant restrictions in the volume of waste water generated thereby effecting attendant reductions in BOD and TSS raw waste load which accompany water reuse practices;

2. Improvement and modernization of the chemical handling, recovery, and recycle systems employed.

In addition the application of more advanced water treatment processes will be required to meet the BATEA limitations.

EFFLUENT REDUCTION ATTAINABLE THROUGH APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Based upon the information available to the Agency, the point source discharge limitations for each identified pollutant are

Table 195
BATEA
Effluent Limitations in kg/kkg(lbs/ton)

Subcategory	Maximum 30 Day Average BOD5	Maximum 30 Day Average TSS	Maximum Day BOD5	Maximum Day TSS
Dissolving Kraft	5.45(10.9)	3.45(6.9)	11.25(22.5)	7.6 (15.2)
Market Kraft	3.35(6.7)	2.25(4.5)	6.9 (13.8)	4.95(9.9)
BCT Kraft	2.85(5.7)	1.85(3.7)	5.9 (11.8)	4.05(8.1)
Fine Kraft	1.9 (3.8)	1.55(3.1)	4.0 (8.0)	3.35(6.7)
Papergrade Sulfite	6.45(12.9)	3.15(6.3)	13.3 (26.6)	6.9 (13.8)
Dissolving Sulfite	8.35(16.7)	4.05(8.1)	17.3 (34.6)	8.85(17.7)
GW-Chemi-Mechanical	1.25(2.5)	1.2 (2.4)	2.6 (5.2)	2.65(5.3)
GW-Thermo-Mechanical	1.1 (2.2)	0.65(1.3)	2.25(4.5)	1.4 (2.8)
GW-CMN Papers	1.75(3.5)	1.3 (2.6)	3.65(7.3)	2.8 (5.6)
GW-Fine Papers	1.65(3.3)	1.2 (2.4)	3.45(6.9)	1.0 (2.0)
Soda	2.4 (4.8)	1.55(3.1)	5.0 (10.0)	3.35(6.7)
Deink	2.5 (5.0)	2.4 (4.8)	5.2 (10.4)	5.3 (10.6)
NI Fine Papers	1.25(2.5)	0.65(1.3)	2.6 (5.2)	1.4 (2.8)
NI Tissue Papers	2.0 (4.0)	0.95(1.9)	4.15(8.3)	2.1 (4.2)
NI Tissue (FWP)	2.0 (4.0)	0.95(1.9)	4..5(8.3)	2.1 (4.2)

pH for all subcategories shall not exceed 6.0 to 9.0

Color

Subcategory	Maximum 30 Day Average kg/kkg(lbs/ton)	Maximum Day kg/kkg(lbs/ton)
Dissolving Kraft	125 (250)	250 (500)
Market Kraft	95.0 (190)	190 (380)
BCT Kraft	65.0 (130)	130 (260)
Fine Kraft	65.0 (130)	130 (260)
Soda	65.0 (130)	130 (260)

Zinc

Subcategory	Maximum 30 Day Average kg/kkg(lbs/ton)	Maximum Day kg/kkg(lbs/ton)
GW:Chemi-mechanical	0.115 (0.23)	0.23 (0.46)
GW:Thermo-mechanical	0.065 (0.13)	0.13 (0.26)
GW:CMN Papers	0.120 (0.24)	0.24 (0.48)
GW:Fine Papers	0.115 (0.23)	0.23 (0.46)

shown in Table 195 and may be attained through the application of Best Available Technology Economically Achievable.

The average of daily values for any 30 consecutive days should not exceed the maximum 30 day average limitations shown in Table 195. The value for any one day should not exceed the daily maximum limitations shown in this table. The limitations shown are in kilograms of pollutant per metric ton of production (pounds of pollutant per ton of production). Effluents should always be within the pH range of 6.0 to 9.0.

Production in kkg(tons) is defined as annual tonnage produced from pulp dryers (in this case of market pulp) and paper machines (for paper/ board) divided by the number of production days in the 12-month period. Pulp production is to be corrected, if necessary, to the "air dry" moisture basis. No such correction is necessary for paper/board production.

Effluent limitations will be established at a later date for ammonia nitrogen for mills in the sulfite and dissolving sulfite subcategories using an ammonia base. No specific limitation has been developed because of the limited availability at this time of meaningful data. Indications are that discharges in the range of 1.0-3.0 kg/kkg (2-6 lb/ton) can occur. No technology for the removal of nitrogen has been applied within the pulp and paper industry, and only very limited technology has been applied in other industries. Effluent limitations have not been established for ammonia nitrogen as it is not considered to be economically achievable at this time for these two subcategories. Extensive studies on effective methods for the removal of nitrogen must be undertaken in order to provide a basis for an effluent limitation for this parameter.

Effluent limitations for color will be developed for all sulfite and dissolving sulfite mills at a later date. Sparse data indicate that color discharges from these mills contain 200 to 250 kg/kkg (400 to 500 lb/ton). No technology for removing color from these effluents is presently available or in a stage of development which is foreseen to be available by 1983. Thus, limitations for color have not been established as it is not considered to be economically achievable for these two subcategories at this time.

IDENTIFICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The Best Available Technology Economically Achievable consists of the Best Practicable Control Technology Currently Available as defined in Section IX and discussed in Sections VII and VIII of this report. It also includes the additional internal mill improvements and external advanced waste water treatment practices as discussed in detail in Section VII and VIII.

It is emphasized here that these technologies are not of themselves required. Due to economic, space, or other factors, many mills may choose to use alternative technologies. Conversely, some mills may choose technologies other than those indicated above.

RATIONALE FOR THE SELECTION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Age and Size of Equipment and Facilities

There is a wide range, in both size and age, among mills in the subcategories studies. However, internal operations of most older mills have been upgraded, and most of these mills currently operate very efficiently. The technology for updating of older mills is well established, and does not vary significantly from mill to mill within a given subcategory. As discussed in some detail in Sections IV and V, there is little or no basis for quantifying the effect of age, size, or geographical location, on the quantity or quality of the waste water generated by mills within a subcategory.

Processes Employed

All mills within each subcategory studied utilize the same basic production processes. Although there are deviations in equipment and production procedures, these deviations do not significantly alter the characteristics of the waste water generated. The treatability of these wastes, is similar.

Application of BATEA may require major changes in existing industrial processes for the subcategories studied. Incorporation of additional systems, treatment processes, and control measures can be accomplished in most cases through changes in piping, and through design modifications to existing equipment. Such alterations can be carried out by mills within a given subcategory.

Engineering Aspects of the Application of Control Technologies

Much of the technology to achieve these effluent limitations is practiced within the pulp and paper industry by outstanding mills in a given subcategory. Sufficient research and pilot work has been carried out on color Removal to demonstrate the feasibility of achieving the recommended effluent limitations after completion of additional demonstration studies. The technology required for all best available treatment and control systems will necessitate sophisticated monitoring, sampling, and control programs, as well as properly trained personnel.

Cost of Application in Relation to Effluent Reduction Benefits (Including Energy Requirements)

The total projected costs of BATEA reflect an increase of production expenses as shown in Tables 129 through 158 of Section VIII. These increases include both internal control and external waste improvements and they are based on 360 days of production per year. It should be emphasized however, that some mills have carried out many of these improvements and, consequently, their increased costs would be less than those shown.

The energy requirements associated with the application of pollution control technologies are developed in Section VIII and shown in Table 174.

Non-Water Quality Environmental Impact

The technology cited will not create any significant increase in odors, or in noise levels beyond those observed in well-designed municipal waste water treatment systems which currently are being approved by the federal government for construction in populated areas. Further, no hazardous chemicals are required as part of this technology.

RATIONALE FOR SELECTION OF EFFLUENT LIMITATIONS

The rationale used in developing the effluent limitations for BOD, and TSS, is discussed below for each of the subcategories as is the rationale for the color limitations for the bleached kraft and soda subcategories. Specifically identified are the methods used to establish the limitations for the maximum 30 day average and the daily maximum value for BOD, TSS, and color.

The BATEA effluent limitations were based upon the capabilities of the internal and external pollution control technologies identified in Section VIII.

The general approach in determining the effluent limitations is given below:

1. The best mill or mills within each subcategory were identified from a standpoint of raw waste loads.

2. The extent of internal controls at the best mill(s) was then thoroughly evaluated to determine the general relationships between raw waste load and internal controls.

3. Estimates of possible raw waste load reductions, if any, were made for the mills which would be a result of installation of additional internal controls identified as BATEA in Section VIII that were not in use by the best mills.

4. The raw waste load achievable by the best mill or mills in each subcategory by the use of BATEA was thus established.

5. The effluent reduction capabilities of the identified external treatment systems were than used in conjunction with the established raw waste load per subcategory to determine the effluent limitations.

The maximum 30 consecutive days and maximum day limitations were determined by multiplying the annual average values by the variability factors shown in Table 196. The development of the variability factors is discussed in Section VII. It should be pointed out that the variability factors used for the BATEA limitations are the same or slightly higher than those used for the BPCTCA limitations.

Table 197 summarizes the BATEA raw waste loads and BOD5 and TSS concentrations for each subcategory used as the basis for the BATEA limitations.

Bleached Kraft Segment

Dissolving Kraft Subcategory

The dissolving kraft raw waste load was based upon mill 127 which had the following flow, BOD5, and TSS raw waste loads:

Flow:	229.3 kl/kkg (55.0 kgal/ton)
BOD5:	40 kl/kkg (80 lbs/ton)
TSS:	87.5 kl/kkg (175 lbs/ton)

Evaluation of the in plant controls presently in use at mill 127 and the additional controls identified as BATEA in Section VIII resulted in the following estimates of RWL reduction:

Flow:	12.5 kl/kkg (3.0 kgal/ton)
BOD5:	2.5 kg/kkg (5.0 lbs/ton)
TSS:	2.5 kg/kkg (5.0 lbs/ton)

Thus, the BATEA RWL for the dissolving kraft subcategory were the following:

Flow:	216.8 kl/kkg (52.0 kgal/ton)
BOD5:	37.5 kg/kkg (75.0 lbs/ton)
TSS:	85.0 kg/kkg (170.0 lbs/ton)

Mill 127 presently achieves 24 mg/l BOD5 in the final effluent from the aerated stabilization basin which is the best quality effluent of the two mills in the dissolving kraft subcategory that have biological treatment facilities. This level of BOD5 is, however, higher than that achieved by many other mills in the bleached kraft segment. Table 198 presents BOD5 and TSS concentration for the top seven bleached kraft mills which were derived from Table 180 in Section IX. As shown, the averages for

Table 196
BATEA Variability Factors

Parameter	Maximum Month	Maximum Day
BOD_5	1.67	3.36
TSS	1.61	3.53

Table 197
Basis for BATEA Effluent Limitations

Subcategory	Flow kl/kkg(kgal/ton)	BOD5 mg/l	TSS mg/l	Annual Averages BOD5 kg/kkg(lbs/ton)	Annual Averages TSS kg/kkg(lbs/ton)
BK: Dissolving Kraft	216.3 (52.0)	15	10	3.25 (6.5)	2.15 (4.3)
BK: Market Kraft	141.4 (34.0)	14	10	2.0 (4.0)	1.4 (2.8)
BK: BCT Papers	112.3 (27.0)	15	10	1.7 (3.4)	1.15 (2.3)
BK: Fine Papers	95.7 (23.0)	15	10	1.15 (2.3)	0.95 (1.9)
Soda	95.7 (23.0)	15	10	1.45 (2.4)	0.95 (1.9)
GW: Chemi-Mechanical	74.9 (18.0)	10	10	0.75 (1.5)	0.75 (1.5)
GW: Thermo-Mechanical	41.7 (10.0)	15	10	0.65 (1.3)	0.4 (0.8)
GW: Fine Papers	74.9 (18.0)	13	10	1.0 (2.0)	0.75 (1.5)
GW: CWW Papers	79.0 (19.0)	13	10	1.05 (2.1)	0.8 (1.6)
Papergrade Sulfite	176.8 (42.5)	20	10	3.85 (7.7)	1.95 (3.9)
Dissolving Sulfite	249.6 (60.0)	20	10	5.0 (10.0)	1.5 (3.0)
Deink	74.9 (18.0)	20	20	1.5 (3.0)	1.5 (3.0)
NI Fine Papers	38.4 (9.2)	20	10	0.75 (1.5)	0.4 (0.8)
NI Tissue Papers	60.5 (14.5)	20	10	1.2 (2.4)	1.2 (2.4)
NI Tissue Papers (FWP)	60.5 (14.5)	20	10	1.2 (2.4)	1.2 (2.4)

Table 198
Bleached Kraft Segment
Best Final Effluent BOD_5 & TSS Concentration

Mill	Subcategory	Treatment	BOD_5 mg/l	TSS mg/l
101	Fine & Market	C-ASB-PS	10	15
130	Market	SB-ASB	11	25
119	Fine	C-A	11	33
112	Fine	C-ASB-C	12	-
117	BCT & Market	C-ASB	14	25
105	BCT	C-ASB-PS	16	-
114	Market	C-ASB	17	22
Average			13	24

BOD5 and TSS for the "best of the best" external treatment systems are 13 mg/l and 24 mg/l, respectively. The range for BOD5 is from 10 to 17 mg/l. Improved operation of the external treatment system and the addition of effluent coagulation and filtration as identified as BATEA in Section VIII should allow mill 127 to achieve an average BOD5 concentration of 15 mg/l (as demonstrated by the mills in Table 198 which do not even use filtration). Filtration of biological treatment effluents reduces TSS to levels between 5 to 10 mg/l as discussed in Section VII. In addition to TSS reduction, approximately 20% of the BOD5 is removed by filtration. The effluent limitations were thereby based upon 15 mg/l BOD5 and 10 mg/l TSS.

Market Kraft Subcategory

The market kraft subcategory raw waste load was essentially based upon three mills, 130, 114, and 140. Mills 140 and 139 are relatively newer mills and have flow volumes of 79.2 kl/kkg (19.0 kgal/ton) and 85.1 kl/kkg (20.4 kgal/ton), respectively. The older market kraft mills cannot necessarily be expected to achieve these flow values and thereby the flows used for BATEA limitations were based upon mill 114 which had a flow of 172.6 kl/kkg (41.4 kgal/ton). Evaluation of the internal, controls in use by mill 114 resulted in estimates of flow reductions of about 29.2 kl/kkg (7.0 kgal/ton). The BOD5 raw waste load which was used primarily in developing the costs of the treatment system required to achieve the BATEA limitations was based on mills 130 and 140. Evaluation of the in plant controls in use at mills 114, 130, and 140 resulted in estimates that BOD5 reductions of 5.0 kg/kkg (10.0 lbs/ton) could be achieved by BATEA internal controls not yet in use by mill 130 and that the BOD5 levels were achievable as demonstrated by mill 140. The estimated raw waste loads for BATEA were the following:

Flow:	141.8 kl/kkg (34.0 kgal/ton)
BOD5:	26.5 kg/kkg (53.0 lbs/ton)
TSS:	65.0 kg/kkg (130 lbs/ton)

The effluent limitations for BATEA were based upon 10 mg/l TSS and 14 mg/l BOD5 in conjuction with 141.8 kl/kkg (34.0 kgal/ton). As discussed previously, the capabilities of the coagulation and filtration systems results in levels of TSS in effluents of 5 - 10 mg/l TSS. The BOD5 level of 14 mg/l is an average of mills 130 and 114 which are presently being achieved by aerated stabilization basins without any coagulation or filtration systems of the biological treatment effluents.

Bleached Kraft - BCT Papers Subcategory

The BCT Papers Subcategory raw waste load was based upon mill 111 which had the following flow, BOD5, and TSS raw waste loads:

Flow:	134.7 kl/kkg (32.3 kgal/ton)
BOD5:	30.8 kg/kkg (61.6 lbs/ton)
TSS:	51.5 kg/kkg (103 lbs/ton)

Evaluation of the internal controls in use by mill 111 and estimating the possible raw waste load reductions possible by installation of the BATEA internal technologies not used by mill 111 resulted in the following estimates of RWL reductions for mill 111.

Flow:	20.9 kl/kkg (5.0 kgal/ton)
BOD5:	5.0 kg/kkg (10.0 lbs/ton)
TSS:	5.0 kg/kkg (10.0 lbs/ton)

Thus, the RWL for the BCT Papers Subcategory used in developing the BATEA effluent limitations and the costs of achieving the limitations are the following:

Flow:	112.6 kl/kkg (27.0 kgal/ton)
BOD5:	26.0 kg/kkg (52.0 lbs/ton)
TSS:	46.5 kg/kkg (93.0 lbs/ton)

The BATEA effluent limitations were based upon 10 mg/l TSS, 15 mg/l BOD5, and 112.6 kl/kkg (27.0 kgal/ton) as shown in Table 197. Use of coagulation and filtration systems treating the biological treatment effluent will achieve at least 10 mg/l TSS as discussed in Section VII. Mills 117 and 105 are presently achieving BOD5 effluent levels of 16 mg/l and 14 mg/l, respectively, as shown in Table 178. The BOD5 on which the effluent limitations were based is thereby an average of the final effluent BOD5 concentrations from mills 105 and 117.

Bleached Kraft - Fine Papers Subcategory

The bleached kraft fine papers subcategory raw waste loads which were used in determining the BATEA effluent limitations and the costs of achieving the limitations were based upon mill 119 which had the following RWL:

Flow:	97.2 kl/kkg (23.3 kgal/ton)
BOD5:	23.4 kg/kkg (46.7 lbs/ton)
TSS:	46.5 kg/kkg (92.9 lbs/ton)

Evaluation of the internal controls identified in Section VIII as BATEA and those presently in use by the mill showed that the mill was already achieving effluent raw waste loads representative of the BATEA. Thus, the BATEA effluent limitations were based upon mill 119 and, the mills RWL were rounded to the following:

Flow:	95.9 kg/kkg (23.0 kgal/ton)
BOD5:	23.5 kg/kkg (47.0 lbs/ton)
TSS:	46.5 kg/kkg (93.0 lbs/ton)

The BOD5 and TSS concentrations on which the BATEA effluent limitations were based were 12 mg/l and 10 mg/l, respectively. The TSS level of 10 mg/l has been discussed previously. Mills 119 and 112 were achieving BOD5 levels of 11 mg/l and 12 mg/l, respectively, by the activated sludge process and a modified

activated sludge - aerated stabilization basin treatment process. The effluent limitation was thereby based upon 12 mg/l.

Color Limitations

The color effluent limitations were based upon the color data presented in Table 37 in Section V. Analysis of the data in the table shows four significant levels of color: (1) Dissolving kraft, (2) Market kraft, (3) BCT Papers, and (4) Fine Papers. The raw waste color loads for the above subcategories are the following: 415 kg/kkg (830 lbs/ton), 310 kg/kkg (620 lbs/ton), 225 kg/kkg (450 lbs/ton), and 150 kg/kkg (300 lbs/ton), respectively. It should be pointed out that the data used in determining these color RWL is the highest of stream 09 or stream 79 data per mill in Table 37. The dissolving kraft and market kraft RWL were based upon mills 127 and 114, respectively, whereas the BCT RWL was based upon mills 105, 125, and 117. Mills 101, 110, 106, 116, and 119 were used as the basis for the fine RWL.

As identified in Section VIII, the "minimum lime" process for color removal was suggested for application to the caustic extraction effluent and a portion of the decker effluent. Color data obtained from surveyed mills were insufficient to establish reliable color values for those streams. As discussed in Section VII, however, the minimum lime process can attain a 90 to 94 percent color reduction (260) (261). Comparable streams treated by the massive lime process can achieve similar results (247).

At these levels of color reductions in the extraction and decker effluents, total mill raw waste color is reduced approximately 72% (232). By BATEA internal controls such as extensive spill control and more efficient liquor recovery, it is estimated that at least 10% additional color reduction will occur. Thus, minimum lime and BATEA controls should reduce raw waste color loads by over 80%. Applying 80% reduction to the subcategory RWL given above resulted in the color values based upon annual averages. Applying variability factors of 1.5 and 3.0 for maximum 30 consecutive days and maximum day to annual average, respectively, resulted in the effluent limitations. The RWL used in calculating the limitations for BCT and Fine subcategories was based upon 212.5 kg/kkg (425 lbs/ton) which was an average of six mills manufacturing various proportions of BCT papers, fine papers, and market pulp. This RWL was used because of the relatively large range of color RWL for mills producing varying proportions of fine papers and market pulp.

Soda Segment

The soda subcategory raw waste load used in developing costs and in determining the BATEA effluent limitations was based upon mills 151 and 152. The average flow and BOD_5 RWL for mills 151 and 152 are shown below:

FLOW: 105.9 kl/kkg (25.4 kgal/ton)

BOD5: 35.7 kg/kkg (71.4 lbs/ton)

Evaluation of the internal controls used at these mills and those additional internal controls identified in Section VIII as BATEA resulted in the following estimates of flow and BOD5 reductions:

Flow: 10.4 kl/kkg (2.5 kgal/ton)
BOD5: 5.5 kg/kkg (11.0 lbs/ton)

The TSS RWL demonstrated by mill 150 was used as the basis for the TSS RWL as TSS data was unavailable for mill 151 and mill 152 had very high TSS losses. The resulting RWL used in determining the BATEA effluent limitations and costs are given below:

Flow: 95.9 kl/kkg (23.0 kgal/ton)
BOD5: 30.0 kg/kkg (60.0 lbs/ton)
TSS: 65.0 kg/kkg (130 lbs/ton)

Mill 152 presently achieves 28 mg/l BOD5 with an aerated stabilization basin of six days detention time. Increasing the extent of the biological treatment will probably be necessary for mill 152 to achieve BPCTCA TSS limitations and in so doing improved BOD5 reduction should occur. The BATEA limitations are based upon BOD5 levels of 15 mg/l as demonstrated by bleached kraft mills. The level of 15 mg/l was selected as a conservative estimate of the capabilities of the BATEA external technologies including biological treatment and coagulation and filtration. It should be pointed out that the average of the top seven bleached kraft mills was 15 mg/l as shown in Table 198 and 13 mg/l is thus demonstrated and achievable. The TSS effluent limitations were based upon 10 mg/l as discussed previously.

The color limitations for the soda subcategory were the same as the BK: BCT and BK: fine papers subcategories as the soda manufacturing process is similiar to these two subcategories.

Groundwood Segment

GW: Chemi-Mechanical Subcategory

The raw waste load for the chemi-mechanical subcategory used in determining the BATEA effluent limitations and the costs were based upon mill 001 which had the following RWL:

Flow: 84.7 kl/kkg (20.3 kgal/ton)
BOD5: 48.5 kg/kkg (97.0 lbs/ton)
TSS: 23.3 kg/kkg (46.6 lbs/ton)

More recent data for mill 001 has shown significant decreases in flow accomplished by in plant control measures and was used as the basis for the BATEA RWL. BOD5 data was unavailable for the most recent period but it is estimated that BOD5 would be reduced by the additional BATEA internals by 3.5 kg/kkg (7.0 lbs/ton). The RWL used as a basis for the BATEA limitations is given below:

Flow:	75.1 kl/kkg	(18.0 kgal/ton)
BOD_5:	45.0 kg/kkg	(90.0 lbs/ton)
TSS:	22.5 kg/kkg	(45.0 lbs/ton)

During the most recent data period, mill 001 has achieved an average of 10 mg/l BOD_5 and 20 mg/l TSS with a treatment system consisting of an aerated stabilization basin followed by a clarifloculator. The BATEA effluent limitations was thereby based upon 10 mg/l BOD_5 and 10 mg/l TSS. Addition of a filtration system should allow the mill to attain 5 to 10 mg/l TSS.

GW: Thermo-mechanical Subcategory

The thermo-mechanical subcategory raw waste load was based upon estimates of flow and BOD_5 loads for companies starting new mills and waste water data developed from thermo-mechanical mills in Sweden. Data for a thermo-mechanical mill in Sweden showed flows and BOD_5 loads of 17.1 to 27.2 kl/kkg (4.1 to 6.6 kgal/ton) and 21.3 kg/kkg (42.5 lbs/ton) were reported. The following RWL values were therefore selected as conservative estimates of the thermo-mechanical subcategory RWL:

Flow:	41.7 kl/kkg	(10.0 kgal/ton)
BOD_5:	26.5 kg/kkg	(53.0 lbs/ton)
TSS:	25.0 kg/kkg	(50.0 lbs/ton)

There are very few mills in this country presently using the thermo-mechanical pulping process and effluent data is not available from any mill operating biological treatment facilities which has a significant portion of the total pulp production produced by the thermo-mechanical process. As demonstrated by mill 001 in the chemi-mechanical subcategory and several mills in the bleached kraft subcategories, effluent BOD_5 qualities of 10 -17 mg/l are achievable with biological treatment and thereby the BOD_5 BATEA effluent limitations were based upon 15 mg/l. The TSS limitations were based upon 10 mg/l as discussed previously.

GW: Fine Papers Subcategory

The groundwood: fine papers subcategory raw waste load was based upon mill 13 which had a flow of 83.0 kl/kkg (19.9 kgal/ton) and a raw waste BOD_5 of 13.5 kg/kkg (27.0 lbs/ton). Two mills, 19 and 21, had flows less than mill 13 but the C & F content of their final product was 35% and 20%, respectively, which could have the effect of lowering their water use per kkg (ton) of product. Thus, the BATEA flow rate was based upon mill 13. Evaluation of the in plant controls utilized by mill 13 and those additional controls identified as BATEA in Section VIII result in estimating that 74.9 kl/kkg (18.0 kgal/ton) was achievable. Because mill 13's BOD_5 of 13.5 kg/kkg (27.0 lbs/ton) was significantly lower than the other mills with 10-15% C & F, the BATEA raw waste BOD_5 and TSS were estimated by the internal controls used by mill 005 which used 10% C & F were evaluated. It was estimated that the additional BATEA controls identified in

Section VIII would reduce the average BOD_5 to 16.0 kg/kkg (32.0 lbs/ton). The TSS raw waste load was based on an estimate involving the TSS reduction capabilities of the BATEA internal controls upon the average BPCTCA raw waste load. It was estimated that the added controls could achieve at least 45.0 kg/kkg (90.0 lbs/ton). It should be noted that the BOD_5 and TSS BATEA raw waste loads were used primarily in the development of the costs presented in Section VIII.

Data for mill 005A shows that 13 mg/l BOD_5 and 21 mg/l TSS are presently being achieved by the mill's aerated stabilization basin. Addition of filtration systems will further decrease these levels. The BATEA effluent limitations were thereby based upon 13 mg/l BOD_5 and 10 mg/l TSS.

GW: CMN Papers Subcategory

The groundwood: CMN papers subcategory was based upon an average of mills 009 and 014 raw waste loads because of the relatively wide spread between the raw waste loads, i.e. mill 009's flow and BOD_5 RWL was 52.9 kl/kkg (12.7 kgal/ton) and 19.6 kg/kkg (39.2 lbs/ton) whereas mill 014's RWL was 107.6 kl/kkg (25.8 kgal/ton) and 12.0 kg/kkg (24.0 lbs/ton). Evaluation of the in plant controls used by these mills and those BATEA internal controls identified in Section VIII resulted in selection of the following RWL:

Flow:	79.0 kl/kkg (19.0 kgal/ton)
BOD_5:	16.0 kg/kkg (32.0 lbs/ton)
TSS:	45.0 kg/kkg (90.0 lbs/ton)

Since none of the mills in the GW: CMN Subcategory have biological treatment, the BOD_5 concentration used for the BOD_5 effluent limitations was based upon mill 014 in the GW: fine papers subcategory which was achieving 13 mg/l BOD_5. The TSS effluent limitation was based upon 10 mg/l as discussed previously.

Groundwood Subcategories Zinc Limitations

The zinc limitations for the groundwood subcategories are based upon the BATEA flow values and 1 mg/l zinc as in the BPCTCA limitations.

Sulfite Segment

Papergrade Sulfite Subcategory

The identified BATEA internal controls for the papergrade sulfite subcategory include vacuum drum pulp washing, full SSL recovery, and surface condensors. As shown in Table 29 in Section V, the most representative mill presently using most of the BATEA internal controls is mill 62 and the BATEA RWL was based upon the mill's RWL as shown below:

Flow: 176.8 kl/kkg (42.5 kgal/ton)
BOD5: 68.5 kg/kkg (137 lbs/ton)

The BATEA TSS RWL of 75.0 kg/kkg (150 lbs/ton) was based upon mill 66 since TSS data was unavailable for mill 62.

The effluent limitations were based upon the above flow rate and BOD5 and TSS concentrations of 20 mg/l and 10 mg/l, respectively. Mills in all of the other segments are presently achieving BOD5 levels between 10 to 17 mg/l with biological treatment systems as discussed previously. The level of 20 mg/l was selected as a conservative estimate of the capabilities of properly designed and operated biological treatment systems at sulfite mills. The level of 10 mg/l has been discussed previously.

Dissolving Sulfite Subcategory

The BATEA raw waste load for the dissolving sulfite subcategory was based upon mill 511 which had the raw waste loads below:

Flow: 268.5 kl/kkg (64.4 kgal/ton)
BOD5: 128.5 kg/kkg (257 lbs/ton)
TSS: 92.5 kg/kkg (185 lbs/ton)

Evaluation of the internal controls at the mill and the additional controls identified in Section VIII resulted in the following conservative estimates of raw waste load reductions that can be achieved by BATEA:

Flow: 18.3 kg/kkg (4.4 kgal/ton)
BOD5: 3.5 kg/kkg (7.0 lbs/ton)
TSS: 7.5 kg/kkg (15.0 lbs/ton)

Thus, the BATEA RWL used in determining the effluent limitations and in developing the costs in Section VIII were the following:

Flow: 249.6 kl/kkg (60.0 kgal/ton)
BOD5: 125 kg/kkg (250 lbs/ton)
TSS: 85.0 kg/kkg (170 lbs/ton)

The BATEA effluent limitations were based upon BOD5 and TSS levels of 20 mg/l and 10 mg/l, respectively, and the determination of these levels was discussed in the papergrade sulfite subcategory.

Deink Segment

The deink subcategory raw waste load used as the basis for BATEA effluent limitations and for developing the costs presented in Section VIII were based upon mills 205 and 216 which had flows of 78.0 kl/kkg (18.7 kgal/ton) and 79.2 kl/kkg (19.0 kgal/ton), respectively. The mill 216 flow is different than that presented in Table 47 in Section V as the actual raw waste flow is 106.3 kl/kkg (25.5 kgal/ton) but approximately 27.1 kl/kkg (6.5 kgal/ton) is reused back in the mill resulting in a final

effluent flow of 79.2 kl/kkg (19.0 kgal/ton). Evaluation of the internal controls used by mills 205 and 216 and the additional BATEA controls identified in Section VIII resulted in estimating that a flow rate of 75.1 kl/kkg (18.0 kgal/ton) was achievable by BATEA. As discussed in Section V, the deink raw waste BOD5 and TSS are related to the type of waste paper utilized, and the BATEA BOD5 and TSS raw waste loads used in the development of the costs were the same used as for BPCTCA. In this manner, maximum costs were developed for the treatment systems costed in Section VIII.

The BATEA effluent limitations were based upon a flow rate of 75.1 kl/kkg (18.0 kgal/ton) and BOD5 and TSS levels of 20 mg/l. This level of BOD5 and TSS is somewhat higher than the other subcategories, but since the purpose of the manufacturing process is to remove the impurities from the waste paper and high varying waste loads can occur, 20 mg/l was selected as a conservative estimate of the capabilities of the BATEA external controls on deink waste waters.

Non-Integrated Paper Mills Segment

N.I. Fine Papers Subcategory

The NI fine papers subcategories raw waste loads were developed by evaluation of the raw waste loads at 10 mills in relation to the extent of internal controls at each mill. Since flow is an indicator of the extent of in plant controls at NI paper mills, the mills which achieved lower flow rates than the BPCTCA average of 62.4 kl/kkg (15.0 kgal/ton) were arranged in ascending order as shown below:

Mill	Flow kl/kkg	(kgal/ton)	BOD5 kg/kkg		TSS (lbs/ton)	
284	25.8	(6.2)	7.6	(15.2)	30.4	(60.7)
261	26.3	(6.3)	8.7	(17.3)	-	(-)
279	37.5	(9.0)	-	(-)	-	(-)
255	37.9	(9.1)	-	(-)	-	(-)
272	37.9	(9.1)	10.9	(21.8)	-	(-)
276	39.2	(9.4)	19.2	(38.3)	38.5	(76.9)
257	40.0	(9.6)	9.2	(18.3)	-	(-)
266	49.2	(11.8)	12.8	(25.6)	22.9	(45.7)
250	53.8	(12.9)	-	(-)	-	(-)
402	57.5	(13.8)	7.5	(15.0)	43.6	(87.1)
Ave	40.4	(9.7)	10.8	(21.6)	33.8	(67.6)

Examination of the flow values above show two definite breaks, below 37.5 kl/kkg (9.0 kgal/ton) and above 40.0 kl/kkg (9.6 kgal/ton).

The BATEA flow was thereby based upon an average of those mills within that range, mills 279, 255, 272, 276, and 257. The average flow rate was 38.3 kl/kkg (9.2 kgal/ton) which was used

in determining the BATEA effluent limitations and in determining the costs. The BATEA BOD_5 raw waste load of 9.5 kg/kkg (19.0 lbs/ton) was based upon an average of all the mills presented above excluding mill 276 whose BOD_5 was much higher than all of the other values. Because of a lack of data, the BATEA TSS raw waste load of 30.0 kg/kkg (60.0 lbs/ton) was essentially the same as the BPCTCA TSS raw waste load. It should be noted that this estimate was used for purposes of developing costs of the BATEA external controls and does not necessarily reflect the capabilities of the BATEA internal controls.

The BATEA effluent limitations were based upon 38.3 kl/kkg (9.2 kgal/ton) and BOD_5 and TSS levels of 20 mg/l and 10 mg/l, respectively. BOD_5 levels of 10 - 17 mg/l have been shown to be achievable by mills using biological treatment systems in other subcategories. However, the effluent limitations were based upon a conservative 20 mg/l. The rationale for the TSS level of 10 mg/l has been discussed previously.

NI Tissue Papers Subcategory

The BATEA raw waste load for the NI tissue papers subcategory was developed in a similar manner as the NI fine papers subcategory raw waste load. The mills presently achieving lower flow rates than the BPCTCA average of 95.7 kl/kkg (23.0 kgal/ton) were arrayed in ascending order as shown below:

Mill	Flow kl/kkg	(kgal/ton)	BOD_5 kg/kkg		TSS (lbs/ton)	
306	43.4	(10.4)	-	(-)	-	(-)
252	48.0	(11.5)	-	(-)	-	(-)
302	50.9	(12.2)	11.8	(23.5)	-	(-)
208A	61.3	(14.7)	22.9	(45.7)*	72.5	(145)
315	66.3	(15.9)	8.7	(17.4)	-	(-)
309A	69.6	(16.7)	14.7	(29.3)*	-	(-)
326	72.6	(17.4)	-	(-)	-	(-)
259A	73.8	(17.7)	9.6	(19.2)	32.2	(64.3)
Ave	60.5	(14.5)	10.0	(20.0)	-	(-)

*Not included in average

The BATEA flow was thus an average of eight mills with better than the BPCTCA average flow rate. The BOD_5 of 10.0 kg/kkg (20.0 lbs/ton) was based upon three of the above eight mills that were achieving better than the average BPCTCA BOD_5 raw waste load were used as the basis for the BATEA BOD_5 raw waste load. The TSS raw waste load of 28.0 kg/kkg (56.0 lbs/ton) was based upon an average of mills 259A, 310, and 308 whose TSS levels demonstrated relatively high control of TSS.

The BATEA effluent limitations were based upon 50.5 kl/kkg (14.5 kgal/ton) and BOD_5 and TSS levels of 20 mg/l and 10 mg/l, respectively. The rationale for selection of the BOD_5 and TSS

levels was previously discussed for the NI fine papers subcategory.

NI Tissue Papers (fWP) Subcategory

The NI Tissue Papers (fwp) Subcategory BATEA flow was the same as that used for the NI Tissue Papers subcategory as discussed in Section IX. The BOD_5 and TSS raw waste loads used in developing the costs presented in Section VIII were based upon mills 330 and 313. The BATEA effluent limitations are the same as the NI Tissue Papers Subcategory.

Table 199
NSPS
Effluent Limitations in kg/kkg(lbs/ton)

Subcategory	Maximum 30 Day Average BOD5	TSS	Maximum Day BOD5	TSS
Dissolving Kraft	5.45(10.9)	7.0 (14.0)	11.25(22.5)	15.35(30.7)
Market Kraft	1.85(3.7)	2.6 (5.2)	3.8 (7.6)	5.65(11.3)
BCT Kraft	2.85(5.7)	3.6 (7.2)	5.9 (11.8)	7.95(15.9)
Fine Kraft	1.9 (3.8)	3.05(6.1)	4.0 (8.0)	6.7 (13.4)
Papergrade Sulfite	4.1 (8.2)	3.95(7.9)	8.5 (17.0)	8.65(17.3)
Dissolving Sulfite	8.35(16.7)	8.05(16.1)	17.3 (34.6)	17.65(35.3)
GW-Chemi-Mechanical	1.25(2.5)	2.4 (4.8)	2.6 (5.2)	5.3 (10.6)
GW-Thermo-Mechanical	2.6 (5.2)	2.0 (4.0)	5.35(10.7)	4.4 (8.8)
GW-CMN Papers	1.75(3.5)	2.6 (5.2)	3.65(7.3)	5.65(11.3)
GW-Fine Papers	1.65(3.3)	2.4 (4.8)	3.45(6.9)	5.3 (10.6)
Soda	2.4 (4.8)	3.05(6.1)	5.0 (10.0)	6.7 (13.4)
Dei k	3.75(7.5)	3.6 (7.2)	7.8 (15.6)	7.95(15.9)
NI Fine Papers	1.25(2.5)	1.2 (2.4)	2.6 (5.2)	2.65(5.3)
NI Tissue Papers	2.0 (4.0)	1.85(3.7)	4.15(8.3)	4.25(8.5)
NI Tissue (FWP)	2.0 (4.0)	1.85(3.7)	4.15(8.3)	4.25(8.5)

pH for all subcategories shall not exceed 6.0 to 9.0

Subcategory	Zinc Maximum 30 Day Average kg/kkg(lbs/ton)	Maximum Day kg/kkg(lbs/ton)
GW:Chemi-mechanical	0.115 (0.23)	0.23 (0.46)
GW:Thermo-mechanical	0.095 (0.19)	0.13 (0.26)
GW:CMN Papers	0.120 (0.24)	0.24 (0.48)
GW:Fine Papers	0.115 (0.23)	0.23 (0.46)

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS (NSPS)

INTRODUCTION

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." Such commencement of construction can occur within the near future, certainly before the 1977 or 1983 compliance dates for best practicable or best achievable technologies.

The New Source Performance Standards (NSPS) are predicated on the application of the Best Available Technolgoy Economically Achievable. These standards are thus not based upon an average of the best performance within a given subcategory under study, but have been determined by identifying the best demonstrated control and treatment technology employed by the specific point source within a given subcategory. Consideration was also given to:

a. The type of process employed and process changes;
b. Operating methods;
c. The engineering aspects of the application of control technologies;
d. the cost of application in relation to effluent reduction benefits (including energy requirements);
e. The non-water quality environmental impact;
f. Use of alternative raw materials and mixes of raw materials;
g. Use of dry rather than wet processes (including substitution of recoverable solvents for water);
h. Recovery of pollutants as byproducts.

EFFLUENT REDUCTIONS ATTAINABLE THROUGH THE APPLICATION OF NEW SOURCE PERFORMANCE STANDARDS

Based upon the information available to the Agency, the point source discharge standards for each identified pollutant are shown in Table 199 and can be attained through the application of appropriate internal and external control technologies.

The average of daily values for any 30 consecutive days should not exceed the maximum 30 consecutive days average standards also shown in Table 199. The value for any one day should not exceed the daily maximum standards shown in this table. The standards shown are in kilograms of pollutant per metric ton of production (pounds of pollutant per ton of production). Effluents should always be within the pH range of 6.0 to 9.0.

Production in kkg/(tons) is defined as annual tonnage produced from pulp dryers (in the case of market pulp) and paper machines

(for paper/ board) divided by the number of production days in the 12-month period. Pulp production is to be corrected, if necessary, to the "air dry" moisture basis. No such correction is necessary for paper/board production.

Performance standards will be established for ammonia nitrogen for mills in the sulfite and dissolving sulfite subcategory using ammonia base at a later date. However, no specific standard has been developed because of the limited availability at this time of meaningful data. Indications are that discharges in the range of 1.0-3.0 kg/kkg (2.0-5.0 lb/ton) can occur. No technology for the removal of nitrogen has been applied within the pulp and paper industry, and only very limited technology has been applied in other industries. Thus, removal of ammonia nitrogen is not considered economically achievable for these subcategories at the present time. Extensive studies on effective methods for the removal of nitrogen must be undertaken in order to provide a basis for performance standards for this parameter.

Performance standards for color established for BATEA are not included for NSPS since the technology has not been demonstrated to the degree necessary in terms of engineering and performance.

IDENTIFICATION OF TECHNOLOGY FOR NEW SOURCE PERFORMANCE STANDARDS

The technology available for New Source Performance Standards consists of the Best Available Technology Economically Achievable which includes extensive application of internal control technologies and external advanced waste water treatment practices as defined in Sections VII and VIII. There is no demonstrated technology for nitrogen and color removal for application to the effluents generated by mills in the pulp and paper industry. Such technologies, therefore, are not included among those required to achieve NSPS. NSPS technology does include the utilization of mechanical clarification and chemical coagulation equipment following biological treatment and prior to discharge. The effectiveness of this external technology has been demonstrated by at least one mill included in this study. It should be pointed out that filtration of biological treatment effluents is not included as a technology for NSPS as no filtration of biological treatment effluents is presently practiced in the pulp and paper industry.

Excluding the nitrogen and color removal technologies it is expected that new source mills will be able to realize maximum efficiency in the application of Best Available Technology Economically Achievable. New source mills have an advantage over existing mills in that implementing internal control measures such as recovery, recycle, reuse, and spill control systems can be more readily incorporated at the initial engineering design stage than into existing mills.

RATIONALE FOR SELECTION OF TECHNOLOGY FOR NEW SOURCE PERFORMANCE STANDARDS

Type of Process Employed and Process Changes

No radical new in-plant processes are proposed as a means of achieving New Source Performance Standards for the subcategories studied. It will be mandatory, however, to utilize the well-known concepts associated with selective water use, cascading reuse, and water segregation practices at the engineering design stage if NSPS are to be achieved by a new production facility.

Operating Methods

Significant revisions in operating methods, both in-plant and at the waste water treatment facility, will be necessary. These improvements are not beyond the scope of well-trained personnel, and are currently being practiced in other industries. The primary areas of operational change will be in the assignment of supervisory responsibility for the performance of recycle, reuse, and spill control systems, as well as for achieving optimal performance of waste water treatment facilities.

Engineering Aspects of the Application of Control Technologies

Much of the technology to achieve these performance standards is practiced within the pulp and paper industry by outstanding mills in a given subcategory. The technology required for all best available treatment and control systems will necessitate sophisticated monitoring, sampling, and control programs, as well as properly trained personnel.

Cost of Application in Relation to Effluent Reduction Benefits (Including Energy Requirements)

The total projected costs of NSPS reflect an increase of production expenses as shown in Tables 129 through 158 of Section VIII. These increases include both internal control and external waste treatment improvements incorporated in the engineering design of the plant. They are based on 360 days of production per year.

The energy requirements associated with the application of pollution control technologies are developed in Section VIII and shown in Table 174.

Non-water Quality Environmental Impact

The technology cited will not create any significant increase in odors, or in noise levels beyond those observed in well-designed

municipal waste water treatment systems which currently are being approved by the federal government for construction in populated areas. Further, no hazardous chemicals are required as part of this technology.

Use of Alternative Raw Materials and Mixes of Raw Materials

The raw materials requirements for a given mill in each of the subcategories studied do vary, depending upon supply and demand, desired end product, and other conditions. However, alteration of raw materials as a means of reducing pollutants is not considered feasible over the long term even though such a change could possibly realize benefits of short duration in a given instance. A possible exception to this could be the development of alternatives for the use of ammonia as a base if an effective and economical method for removal of nitrogen does not become available through further study.

Use of Dry Rather Than Wet Processes (Including Substitution of Recoverable Solvents for Water)

For the subcategories studied, it was determined that technology for dry pulping or papermaking processes does not exist nor is it in a sufficiently viable experimental stage to be considered here.

Recovery of Pollutants as Byproducts

As discussed in Sections VII and VIII of this report, recovery of some potentially polluting materials as byproducts is economically feasible and is practiced to a limited extent by mills included in this study. It is anticipated that these performance standards will motivate increased research on recovering other materials for byproduct sale the recovery of which is not presently economically feasible.

RATIONALE FOR SELECTION OF NEW SOURCE PERFORMANCE STANDARDS

The NSPS are the same as the BATEA effluent limitations for most subcategories with the general exceptions that no color standards were developed, and all of the TSS limitations were increased. The technology of filtration of biological treatment effluents was excluded for NSPS and the standards were developed to reflect the TSS reduction capabilities of chemical addition in clarifloculators. The TSS NSPS were based upon a clarifloculator effluent TSS level of 20 mg/l and the raw waste load for a given subcategory. The basis for having the BOD_5 standards the same as BATEA limitations is that the BATEA limitations were based upon actual operating data from a mill or groups of mills within a given subcategory that were using pollution control technologies nearly the same or equivalent to those identified as BATEA (with the exception of filtration). BOD_5 NSPS for four subcategories

are different than the corresponding BATEA limitations and are discussed in the following sections; subcategories include: (1) bleached kraft market pulp, (2) papergrade sulfite, (3) deink, and (4) groundwood: thermo-mechanical.

Bleached Kraft Market Pulp Subcategory

The NSPS raw waste load for the bleached kraft market pulp subcategory was based upon mill 140 which is a relatively new mill and is achieving lower raw waste loads than the BATEA average. The raw waste loads are given below:

Flow:	79.2 kl/kkg (19.0 kgal/ton)
BOD5:	27.5 kg/kkg (55.0 kgal/ton)
TSS:	65.0 kg/kkg (130.0 kgal/ton)

The TSS level of 65.0 kg/kkg (130.0 kgal/ton) was based upon the BATEA TSS raw waste load as TSS data was not available from mill 140. It should be pointed out that mill 139 which is also a relatively new mill had a flow rate of 85.1 kl/kkg (20.4 kgal/ton).

Papergrade Sulfite Subcategory

The NSPS for the papergrade sulfite subcategory were based upon mill 53 which is a relatively new mill and is presently achieving the following final effluent values:

Flow:	112.6 kl/kkg (27.0 kgal/ton)*
BOD5:	2.9 kg/kkg (5.8 lbs/ton)
TSS:	7.5 kg/kkg (15.0 lbs/ton)

*Unbleached tonnage

These values reflect an average concentration of 24 mg/l and 61 mg/l for BOD5 and TSS, respectively, for the two effluents at the mill. Addition of a chemical addition and coagulation of the biological treatment system effluent should allow the mill to achieve an average for both effluents of 20 mg/l for both BOD5 and TSS. A factor of 8% yield loss by bleaching was used to convert the data to off-the-machine production.

Deink Subcategory

As previously discussed, the deink manufacturing process can be considered as a cleaning process in removing impurities from the waste paper and as such relatively high BOD5 and TSS loadings can occur as a function of the raw materials used. Since the market for waste paper can vary and the types of waste paper available to deink mills can vary, the NSPS were increased slightly from the effluent levels normally considered achievable with the technology identified. Thus, BOD5 and TSS levels of 30 mg/l were used as the basis for NSPS for the deink subcategory.

Groundwood: Thermo-mechanical Subcategory

The groundwood: thermo-mechanical subcategory NSPS were based upon the BPCTCA raw waste load rather than the BATEA raw waste load. Thermo-mechanical pulping is relatively new in this country and thus the BPCTCA raw waste load reflects the best demonstrated technology presently used by thermo-mechanical mills.

SECTION XII

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SECTION XIII

REFERENCES

1. Casey, J. P., Pulp and Paper Chemistry and Chemical Technology, 2nd Ed., Interscience Publishers, Inc., New York (1960).

2. Pulp and Paper Manufacture, Vol. I, The Pulping of Wood, 2nd Edition, McGraw-Hill Book Co., New York (1969).

3. Rydholm, S. A., Pulping Processes, Interscience Publishers, New York (1965).

4. Scott, R. H., and Willard, H. K., "The U.S. Sulfite Industry Faces Present and Future Waste Control Needs," TAPPI, 56, 9 (1973).

5. Gehm, H. W., State-of-the-Art Review of Pulp and Paper Waste Treatment, EPA Contract No. 68-01-0012, April (1973).

6. Pulp and Paper Manufacture, Vol. II, Control, Secondary Fiber, Structural Board, Coating, 2nd Ed., McGraw-Hill Book Co., New York (1969).

7. TAPPI Standard Method T235m-60.

8. The Bleaching of Pulp, TAPPI Monograph No. 27 (1963).

9. Paper, Paperboard, Wood Pulp Capacity, 1971-1974, American Paper Institute, Oct. (1972).

10. Mechanical Pulping Manual, TAPPI Monograph No. 21 (1960).

11. Soteland, N., "Bleaching of Chemical Pulps with Oxygen and Ozone," Pulp and Paper Magazine of Canada, 75, 4 (1974).

12. Hendrickson, E. R., et al., Control of Atmospheric Emissions in the Wood Pulping Industry, DHEW, NAPCA Contract No. CPA 22-69-18, March (1970).

13. Mayer, W. C., and Donofrio, C. P., "Reductive Bleaching of Mechanical Pulp with Sodium Borohydride", Pulp and Paper Magazine of Canada, 59, 10 (1958).

14. Rapson, W. H., et al., "Carbonyl Groups in Cellulose and Color Reversion - II. Hypochlorite Bleaching and Color Removal," TAPPI, 41, 8 (1958).

15. Wayman, M., et al., "Peracetic Acid Bleaching of Groundwood from Nine Canadian Species," TAPPI, 48, 2 (1965).

16. "Northwest Paper Production Rose, Pulp Output Dropped Last Year," Paper Trade Journal, Sept. 24 (1973).

17. Walther, J. E., et al., "Recovery of Sulfite Pulping Liquor and Sulfur Dioxide Control in a Magnesia Base Recovery System," Presented AIChE meeting, Minneapolis, Minn., Aug. (1972). (In press, AIChE Symposium Series).

18. Edwardes, V. P., "Operational Survey of Collection, Evaporation and Burning of Spent Sulfite Liquor," NCASI Special Rept. (1954).

19. Peterson, R. E., and Krauth, J. A., "Progress Report -- ITT Rayonier Sodium Base Recovery System," (1968).

20. Axelson, O., "Some Views on Brown Stock Washing," International Congress on Industrial Waste Water, Stockholm (1970).

21. Chemical Recovery in the Alkaline Pulping Processes, TAPPI Monograph No. 32 (1968).

22. Harter, N., et al., "Peroxide Bleaching of Kraft Pulp," TAPPI, 43, 10 (1960).

23. Evans, J. C. W., "First Oxygen Bleaching Plant in North America in Successful Operation," Paper Trade Journal, Oct. 15 (1973).

24. "Alternate Uses and Treatments of Chlorine Dioxide Generator Effluents," TAPPI Committee Assignment Rept. No. 23 (1969).

25. Fergus, B. J., "Optimization of the CEHDP Bleach Sequence," TAPPI, 56, 1 (1973).

26. Fergus, B. J., "Bleaching Studies on the CEDED and DCEDED Sequences," TAPPI, 56, 1 (1973).

27. Deinking of Waste Paper, TAPPI Monograph No. 31 (1967).

28. Pulp and Paper Manufacture, Vol. III: Papermaking and Paperboard Making, 2nd Ed., McGraw-Hill Book Co., New York (1970).

29. "A Study of the Potential for Subcategorization within the Sulfite Pulp and Paper Industry", Technical Report No. 4, Vanderbilt University December 1974.

30. Sutermeister, E., Chemistry of Pulp and Papermaking, 3rd Ed., John Wiley and Sons, New York (1941).

31. Slatin, B., "Paper," Book of Knowledge, 1966 Ed. Grolier Inc., New York (1966).

32. Blosser, R. O., "Practice in Handling Barker Effluents in Mills in the United States", NCASI Technical Bulletin No. 194 (1966).

33. Pollutional Effects of the Pulp and Papermill Wastes in Puget Sound, FWQA, U.S. Dept. of the Interior (1967).

34. Kronis, H., and Holder, D. A., "Drum Barker Effluent," Pulp and

Paper Magazine of Canada, 69, 62 (1968).

35. Draper, R. E., and Mercier, F. S., "Hydraulic Barker Effluent Clarifier at Woods Products Division, Weyerhaeuser Co.," Proceedings 11th Pacific Northwest Industrial Waste Conf. (1962).

36. Private Communication (1970).

37. Wisconsin State Dept. of Health, Pulp and Paper Advisory Committee Rept. (1965).

38. Pulp and Paper, Mag., 1975, Combustion Engineering, Inc., pg 110.

39. L.H. Clark, Weyerhaeuser Corporation, TAPPI Environmental Conference, May 1975, (High Purity Oxygen Treatment).

40. Myburgh, C. J., "Operation of the Enstra Oxygen Bleaching Plant," TAPPI, 57, 5 (1974).

41. Canty, C., Perry, F. G., and Woodland, L. R., "Economic Impact of Pollution Abatement on the Sulfite Segment of the United States Pulp and Paper Industry," TAPPI, 56, 9 (1973).

42. Barton, C. A., et al., "A Total Systems Approach to Pollution Control at a Pulp and Paper Mill," Journal WPCF, 40,8 (1968).

43. Tyler, R. G., and Gunther, S., "Biochemical Oxygen Demands of Spent Sulfite Liquor," Sewage Works Journal, 20, 516 (1948).

44. Lawrance, W. A., "The Microbial Oxidation of Pure Carbohydrates in the Presence of Calcium Lignosulfonate," NCASI Technical Bulletin No. 80 (1954).

45. Private Communication, Nov. (1973).

46. Rexfelt, J., and Samuelson, O., "The Composition of Condensates from the Evaporation of Sulfite Spent Liquor," Swenska Papperstidnin 21, 689 (1970).

47. Clark, L. H., and DeHaas, G. G., "Volatile Acid Recovery from Vapors by Chemical Reaction," TAPPI, 52, 9 (1969).

48. Long, C. J., and DeHaas, G. G., "Conversion of Crude Acetates to Glacial Acetic Acid and Pulping Chemicals," TAPPI, 53, 6 (1970).

49. Baierl, K. W., et al., "Treatment of Sulfite Evaporator Condensates for Recovery of Volatile Components," Proceedings TAPPI Environmental Conf., 73 (1973).

50. Van Horn, W. M., "Aquatic Biology in the Pulp and Paper Industry," Part I, NCASI Technical Bulletin No. 148 (1961).

51. Van Horn, W. M., "Aquatic Biology in the Pulp and Paper Industry," Part II, NCASI Technical Bulletin No. 251 (1971).

52. Blosser, R. O., and Gellman, I.,"Characterization of Sulfite Pulping Effluents and Available Treatment Methods," TAPPI, 56, 9 (1973).

53. Harrison, M., "A Critical Review of the Literature on Slime Infestation," Part I, NCASI Technical Bulletin No. 94 (1957).

54. Cormack, J. H., and Amberg, H. R., "The Effects of Biological Treatment of Sulfite Waste Liquor on the Growth of Sphaerotilus Natans," Proceedings Purdue Univ. Industrial Waste Conf. XIV (1959).

55. Edde, H., "A Critical Review of the Literature on Slime Infestations," Part II, NCASI Technical Bulletin No. 232 (1969).

56. Slime Growth Evaluation of Treated Pulp Mill Waste, Dept. of Microbiology, Oregon State Univ., EPA Water Pollution Control Research Series 12040DLQ (1971).

57. Aerated Lagoon Treatment of Sulfite Pulping Effluents, EPA Water Pollution Control Research Series 12040 ELW (1970).

58. Kleppe, P. J., and Rogers, C. N., Survey of Water Utilization and Waste Control Practices in the Southern Pulp and Paper Industry, Water Resources Research Institute, Univ. of North Carolina, Project No. A-036-NC (1970).

59. Timpe, W. G., et al., "Kraft Pulping Effluent Treatment and Reuse - State of the Art," Environmental Protection Technological Series, EPA-R-2-73-164 (1973).

60. Wenzl, H. F. J., Kraft Pulping - Theory and Practice, Lockwood Publishing Co., Inc., New York (1967).

61. Gehn, W. H., and Gove, G. W., "Kraft Mill Waste Treatment in the U.S. - A Status Report," NCASI Technical Bulletin No. 221 (1968).

62. Burns, O. B., and Eckenfelder, W. W., Jr., "A Statistical Study of Five Years of Operation of the West Virginia Pulp and Paper Company"s Waste Treatment Plant," Purdue Univ. Industrial Waste Conf. XVIII (1963).

63. Edde, H., "Settleable Solids Removal Practices in the Pulp and Paper Industry," NCASI Technical Bulletin No. 198 (1964).

64. Follette, R., and Gehm, H. W., "Manual of Practice for Sludge Handling in the Pulp and Paper Industry," NCASI Technical Bulletin No. 190 (1966).

65. Stovall, J. H., and Berry, D. A., "Pressing and Incineration of Kraft Mill Primary Clarifier Sludge," TAPPI 6th Water and Air Conf. (1969).

66. Wilson, D. F., et al., "Methanol, Ethanol and Acetone in Kraft Mill Streams," TAPPI, 55, 8 (1972).

67. Hrutfiord, B. F., and McCarthy, J. L., "SEKOR-I Volatile Organic Compounds in Kraft Mill Effluent Streams," TAPPI, 50, 2 (1967).

68. "Evaluation of Analytical Procedures for the Analysis of Selected Organic Compounds in Kraft Mill Effluents," NCASI Technical Bulletin No. 258 (1972).

69. Davis, C. L., Jr., "Color Removal from Kraft Pulping Effluents by Lime Addition," AIChE Chemical Engineering Symposium Series, 107, 67 (1971).

70. South, W. D., "Relating Kraft Waste Stream Properties to BOD," TAPPI, 54, 11 (1971).

71. Carpenter, W. L., "COD and BOD Relationships of Raw and Biologically Treated Kraft Mill Effluents," NCASI Technical Bulletin No. 193 (1966).

72. "Oxidation Analysis of Pulp Mill Effluents," NCASI Technical Bulletin No. 256 (1972).

73. Van Hall, C. E., and Stenger, V. A., "Use of Infrared Analyser for Total Carbon Determination," Proceedings Symposium on Water Renovation," Div. of Water and Waste Chemistry, ACS, Cincinnati (1963).

74. Hill, N. H., "Carbon Analysers for Contaminants in Water," Instrument Technology, March (1969).

75. "The Toxicity of Kraft Pulping Wastes to Typical Fish Food Organisms," NCASI Technical Bulletin No. 10 (1947).

76. Howard, T. E., and Walden, C. C., "Pollution and Toxicity Characteristics of Kraft Mill Effluents," TAPPI, 48, 3 (1965).

77. "The Effects of Sublethal Concentrations of Kraft Pulping Wastes and their Components on Fish Organs," NCASI Technical Bulletin No. 49, (1952).

78. "Laboratory and Controlled Experimental Stream Studies of Effects of Kraft Mill Effluents on Growth and Production of Fish," NCASI Technical Bulletin No. 259 (1972).

79. Private Communication, Dissolving Pulp Manufacturers (1971).

30. Private Communication (1973).

31. Jamieson, A., and Smedman, L., "Oxygen Bleaching -- A Mill Tested Approach to Pollution Abatement," TAPPI, 56, 6 (1973).

2. Nicholls, G. A., "Kraft Multistage Bleach Plant Effluents," TAPPI, 56, 3 (1973).

3. Ota, M., et al., "Low Molecular Weight Compounds in Spent Chlorination Liquors," TAPPI, 56, 6 (1973).

84. "Bleaching Effluents with Lime. I. Treatment of Caustic Extraction Stage Bleaching Effluent," NCASI Technical Bulletin No. 239 (1970).

85. Ibid, "Part II. Treatment of Chlorination Stage Bleaching Effluent," NCASI Technical Bulletin No. 242 (1970).

86. Gould, M., "Physical-Chemical Treatment of Pulp Mill Wastes, Woodland, Maine". Purdue International Waste Conference, 1972.

87. Haynes, D. C., "Water Reuse - A Survey of the Pulp and Paper Industry," TAPPI, 49, 9 (1966).

88. "Deinking Report," NCASI Technical Bulletin No. 5 (1946).

89. Hodge, W. W., and Morgan, P. F., "Characteristics and Methods of Treatment of Deinking Wastes," Sewage Works Journal, 19, 5 (1947).

90. Barton, C. A., et al., "Treatment of Sulfite Pulp and Paper Mill Waste," Journal WPCF, 45, 1 (1973).

91. Morgan, O. P., "Biological Waste Treatment Histories in the Pulp and Paper Industry," NCASI Technical Bulletin No. 220 (1968).

92. Bystedt, M. I., "What is the Future of Thermomechanical Pulp?," Pulp & Paper, Dec. (1973).

93. Rysberg, G., "Thermo-mechanical Pulp Advancing Around the World," Paper Trade Journal, Dec. 24 (1973).

94. Marton, J., and Marton, T., "Mercury in the Pulp and Paper Mill Environment -- Appraisal and Perspective," TAPPI, 55, 11, (1972).

95. Mayer, C., "Water Quality Control Program at Publishers Paper Co.," Presented at NCASI West Coast Regional meeting, Nov. (1972).

96. Hrutfiord, B. F., et al., Steam Stripping Odorous Substances from Kraft Effluent Streams, EPA-R2-73-196, Apr. (1973).

97. Matteson, M. J., et al., "SEKOR II: Steam Stripping of Volatile Organic Substances from Kraft Pulp Mill Effluent Streams," TAPPI, 50, 2 (1967).

98. Maahs, H. C., et al., "SEKOR III: Preliminary Engineering Design and Cost Estimates for Steam Stripping Kraft Pulp Mill Effluents," TAPPI, 50, 6 (1967).

99. Bengkvist, S., and Foss, E., "Treatment of Contaminated Condensates in Kraft Pulp Mills," International Congress on Industrial Waste Water, Stockholm (1970).

100. Estridge, R. B., et al., "Treatment of Selected Kraft Mill Wastes in a Cooling Tower," TAPPI 7th Water and Air Conf. (1970).

101. Timpe, W. C., and Evers, W. J., "The Hydropyrolysis Recovery Pro-

cess," TAPPI, 56, 8 (1973).

102. Fogman, C. B., "A Pollution-Controlled Polysulfide Recovery Method," Paper Trade Journal, Oct. 9 (1972).

103. Worster, H. E., and Pudek, M. F., "The Effects of Oxygen Pulping on Toxicity and Color of Effluent," 58th Annual Meeting, Technical Section, CPPA (1972).

104. Nelson, G. G., et al., "Water Reuse in Bleaching -- Panel Discussion," TAPPI, 55, 6 (1972).

105. Yankowski, A. A., "Reducing the Water Consumption in a Kraft Bleachery," TAPPI, 55, 6 (1973).

106. Rowlandson, G., "Continuous Oxygen Bleaching in Commercial Production," Paper Trade Journal, Dec. 21 (1970).

107. "Oxygen Bleaching after Seventeen Months of Operation," Paper Trade Journal, Dec. 13 (1971).

108. Land, J. G., and Campbell, R. T., "Rapid Chlorine Dioxide Bleaching of Southern Pine Kraft Pulp," Paper Trade Journal, July 30 (1973).

109. Carpenter, W. L., et al., "Effluent Characteristics from Conventional and Oxygen Bleaching," Paper Trade Journal, July 30 (1973).

110. Makkonen, H., et al., "Oxygen Bleaching as Critical Link between Chemical Fiberization and Fully Bleached Pulp," Paper Trade Journal, July 30 (1973).

111. Christensen, P. K., "Oxygen Bleaching Sulphite Pulps," Paper Trade Journal, July 30 (1973).

112. Rapson, W. H., and Reeve, D. W., "The Effluent-Free Bleached Kraft Mill," Southern Pulp and Paper Manufacturer, Nov. 10 (1972).

113. Reeve, D. W., and Rapson, W. H., "Recovery of Sodium Chloride from Bleached Kraft Pulp Mills," Pulp and Paper Magazine of Canada, 71, 13 (1970).

114. "Stream Improvement by Recovery of Bleach Plant Liquors from Kraft Pulp Mills," Pulp and Paper Magazine of Canada, June (1968).

115. Reeve, D. W., et al., "Effluent Free Bleached Pulp Mill -- Part IV Salt Recovery Process," Paper Trade Journal, July 30 (1973).

116. "Rapping with Rapson," Pulp & Paper, Oct. (1973).

117. Rapson, W. H., "Effluent Free Bleached Kraft Pulp Mill -- R-4 Process for Chlorine Dioxide Manufacture," Paper Trade Journal, July 30 (1973).

118. Waste Treatment Plant at ITT Rayonier, Inc. Mill Fernandina Beach,

Florida," Southern Pulp and Paper Manufacturer, July 10 (1972).

119. Kleinau, J. H., "Toward a Pollution-Free System of Secondary Fibre Usage," Pulp and Paper Magazine of Canada, March (1960).

120. Lardieri, N. J., "Recovery of Usable Solids," Pulp and Paper Magazine of Canada, March (1960).

121. Gavalin, G., "A New Concept in Papermaking -- The Lean Water System," Paper Trade Journal, March 5 (1973).

122. Nerou, J. M., and Garrigues, Y., Sapoxal Oxygen Bleaching Goes On Stream at Cellulose d' Aquitaine," TAPPI Annual Meeting, Jan. 16 (1974).

123. Gould, M., and Walzer, J., "Mill Waste Treatment by Flotation," Chem 26/Paper Processing, Nov. (1972).

124. Fuller, R. S., "Screening of Effluents," TAPPI, 56, 6 (1973).

125. Warren, C.E., Biology of Water Pollution Control, W.B. Saunders, Philadelphia (1971).

126. Carpenter, W. L., "Foaming Characteristics of Pulping Wastes During Biological Treatment", NCASI Technical Bulletin No. 195 (1966).

127. Nowacki, J., "Nutrient Salt Reduction in the Biological Purification of Kraft Mill Effluents," Fortachr Wassechen ihrev Grengzch #11, 135 (1969).

128. Nowacki, J., "Influence of Addition of Phosphorus and Nitrogen to Pulp and Paper Mill Effluents," Pregeglad Papier 25, (6), 211, Poland, June (1969).

129. Tracy, J. C., "Secondary Waste Treatment Nutrient and Aerator Studies," Southern Pulp and Paper Manufacturer, Feb. (1970).

130. Eckenfelder, W. W., Jr., Industrial Waste Water Control, McGraw-Hill Book Co., New York (1966).

131. Edde, H., "Field Research Studies of Hydraulic Mixing Patterns in Mechanically Aerated Stabilization Basins," Proceedings International Congress on Industrial Waste Waters, Stockholm (1970).

132. McKeown, J. J., and Buckley, D. B., "Mixing Characteristics of Aerated Stabilization Basins," TAPPI 8th Water and Air Conf. (1971).

133. Grader, R. J., et al., "The Activated Sludge Process Using High-Priority Oxygen for Treating Kraft Mill Wastewater," TAPPI, 56, 4 (1973).

134. Ayers, K. C., and Patton, T. H., Jr., "Biological Treatment Alter-

natives for Kraft Effluents," TAPPI 8th Water and Air Conf. (1971).

135. Bennett, D. J., et al., "Pilot Application of the Rotating Biological Surface Concept for Secondary Treatment of Insulating Board Mill Effluents," TAPPI, 56, 12 (1973).

136. Edde, H., "A Manual of Practice for Biological Waste Treatment in the Pulp and Paper Industry," NCASI Technical Bulletin No. 190 (1966).

137. "Temperature Relationships in Aerobic Treatment and Disposal of Pulp and Paper Wastes," NCASI Technical Bulletin No. 191 (1966).

138. Pelzar, M.J., Jr., Reid, R.D., "Microbiology", McGraw-Hill Book Company, 1972.

139. Benedict, A.H., and Carlson, D.A., "Temperature Acclimation in Aerobic B10-oxidation Systems," Journal Water Pollution Control Fed. 45, 10 (1973).

140. Serafin, J. F., and Axen, A., "Oxygen Bleaching at Aspa Bruk Division of Munksjo A B, Sweden," TAPPI Annual Meeting, Jan. 14-16 (1974).

141. Oledal, J., "Use of the Multi-Roll Press for Dewatering Clarifier Sludges," Paper Trade Journal, Jan. 7 (1974).

142. Carpenter, W. L., "Mechanical Pressing of Primary Dewatered Paper Mill Sludges," NCASI Technical Bulletin No. 174 (1964).

143. "Great Lakes Has Copeland System to Handle Bark Fines and Sludge," Paper Trade Journal, Oct. 2 (1972).

144. Aspitarte, T. R., et al., "Pulp and Paper Mill Sludge Utilization and Disposal," TAPPI Environmental Conf. (1973).

145. Harkin, J. M., and Crawford, D. L., "Bacterial Protein from Paper Mill Sludges," TAPPI Environmental Conf. (1973).

146. Vercher, B. D., et al., "Paper Mill Waste Water for Crop Irrigation and Its Effects on the Soil," Louisiana State Univ. Agricultural Experiment Station Bulletin No. 604 (1965).

147. Gehm, H. W., "Control of Sulfite Pulping Wastes in the United States," Pure and Applied Chemistry, 29, 281 (1972).

148. Gehm, H. W., "Factors Affecting the Appearance of Surface Waters," NCASI Technical Bulletin No. 227 (1969).

149. Palladino. A. J., "Final Report -- Aeration Development Studies," NCASI Technical Bulletin No. 12 (1959).

50. Blosser, R. O., "Oxidation Pond Studies for Treatment of Deinking

Wastes," Purdue Univ. Industrial Waste Conf. XVII (1962).

151. Laing, W. M., "New Secondary Aerated Stabilization Basin at the Morraine Division of Kimberly-Clark Corp.," Purdue Univ. Industrial Waste Conf. XXIV (1969).

152. MacAleese, J. E., "How Newton Falls Solved a Clean Water Problem," Paper Trade Journal, Nov. 14 (1966).

153. Flower, W. A., "Spray Irrigation for the Disposal of Effluent Containing Deinking Waste," TAPPI, 52, 1267 (1969).

154. "Wisconsin Tissue Effluent Plant Pioneers European Process Here," Paper Trade Journal, March 11 (1970).

155. Nadelman, A. H., "A Study of Practical Approaches to Utilization of Solids from Deinking Mills," NCASI Technical Bulletin No. 67 (1964).

156. Davis, W. S., et al., "Recycling Fine Paper Mill Effluent by Means of Pressure Filtration," TAPPI Environmental Conf. (1972).

157. Aldrich, L. C., and Janes, R. L., "White Water Reuse on Fine Paper Machines," TAPPI Environmental Conf. (1972).

158. "New Approaches to In-Plant Load Control and Monitoring," NCASI Technical Bulletin No. 248 (1971).

159. Mason, O.A., Statement by Alaska Lumber and Pulp Co., Inc., for FPA Public Meeting Concerning National Pollutant Discharge Elimination System (NPDES), Application No. 071-OYD-2-000055 and Proposed Permit.

160. "G-P's 'Pipe Organ' Aeration System," Southern Pulp and Paper Manufacturer, May 10 (1972).

161. "K-C to Spend $92 Million at Coosa Pines Mill to Boost Pulp Output and Control Pollution," Paper Trade Journal, May 20 (1974).

162. Tall Oil and Its Uses, Pulp Chemicals Assn., New York (1965).

163. Ellerbe, R. W., "Why, Where and How U.S. Mills Recover Tall Oil Soap," Paper Trade Journal, June 25 (1973).

164. "Resource Engineering Associates, "State-of-the-Art Review on Product Recovery," FWPCA Contract No. 14-12-495, Nov. (1969).

165. Stengle, W. B., "Crude Tall Oil Manufacture," Southern Pulp and Paper Manufacturer, Dec. 10 (1971).

166. Drew, J., and Pylant, G. D., Jr., "Turpentine from the Pulpwoods of the United States and Canada," TAPPI, 49, 10 (1966).

167. Dres, J.,et al., Sulfate Turpentine Recovery, Pulp Chemicals Assn., New York (1971).

168. "Tapping the Chemical Motherlode of the Southern Pines," Chem 26/ Paper Processing, 9, 11 (1973).

169. Hearon, W. H., "The Lignin Dimethyl Sulfide Process," Forest Products Journal, 7, 13 (1957).

170. Barton, J. S., "Future Technical Needs and Trends of the Paper Industry, By-Products Usages," TAPPI, 56, 6 (1973).

171. Elgee, H., "A View of the Ligno-Sulfonate Industry," AIChE Symposium Series, 133, 69 (1973).

172. Craig, D., "Justification for Pulp and Paper By-Products Development," AIChE Symposium Series, 133, 69 (1973).

173. Pearl, I. A., "Utilization of By-Products of the Pulp and Paper Industry," TAPPI, 52, 7 (1969).

174. Wiley, A. J., and Holderby, J. M., "Strong Spent Sulfite Liquors: Utilization, By-Products and Marketing," Pulp and Paper Magazine of Canada, 61, 3 (1960).

175. "Chemicals from the Other Half of the Tree," Chemical and Engineering News, 41, 6 (1963).

176. Howard, G. C., U.S. Patent No. 1,699,845 (1929).

177. Serafin, J. F., and Axen, A., "Operating Experience of the Chemetics' Oxygen Bleaching Systems," TAPPI Annual Meeting, Jan. 14-16 (1974).

178. Robeson, J. S., U.S. Patents No. 1,075,856; 1,075,857; 1,069,029; and 1,069,030 (1913).

179. Lang, C. J., and DeHaas, G. G., "Acetic Acid Recovery from Sulfite Liquor," TAPPI, 53, 6 (1970).

180. Testimony of Roland J. Stanton, Technical Director, Ketchikan Pulp Co., Ketchikan, Alaska, EPA Hearing, EPDES Permit Application No. 081-0Y2-2-000094, Aug. 16 (1973).

181. Gehm, H. W., "An Overview of Water Reuse Potential in Pulp and Paper Manufacture," Paper presented to AIChE, Washington, D.C., April 26 (1973).

82. Hendrickson, E. R., and Oglesby, H. S., "Process Design and Operation for Zero Effluent Discharge," TAPPI, 57, 4 (1974).

83. Haynes, D. C., "Water Recycling in the Pulp and Paper Industry," TAPPI, 57, 4 (1974).

84. "Cost of Achieving EPA's BPCTCA and Zero Discharge," Paper Trade Journal, April 15 (1974).

185. Gullichsen, J., "Status of Kamyr Displacement Bleaching Project," Paper Trade Journal, July 30 (1973).

186. "New Pulp Bleaching System to be Part of Eastex Mill Expansion," Paper Trade Journal, Apr. 29 (1974).

187. Serafin, J. F., and Andrews, D. H., "Oxygen Bleaching Development from Laboratory Scale Experiments to Full Scale Commercial Installation and Operation," TAPPI Annual Meeting, Jan. 14-16 (1974).

188. Lowe, K. E., "Chesapeake Launches Oxygen Bleaching," Pulp and Paper, Oct. (1973).

189. Private Communication (1974).

190. Fary, D. A., and Schmitt, "Oxygen Bleaching at Chesapeake Corporation," TAPPI Environmental Conf., Apr. 17-19 (1974).

191. Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, and WPCF, American Public Health Assn., Inc., New York (1971).

192. "An Investigation of Improved Procedures for Measurement of Mill Effluent and Receiving Water Color," NCASI Technical Bulletin No. 253 (1971).

193. Kreissl, J. F., "Granular Media Filtration of Wastewater: An Assessment," EPA, National Environmental Research Center, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio, Jan. (1973).

194. Cruver, J. E., "Reverse Osmosis for Water Reuse," Gulf Environmental System Co., Paper presented at the National Conf. on Complete Water Reuse, Washington, D.C., Apr. (1973).

195. Schwonke, P. A., and Davis, W. S., "Enzyme Enhanced Turbidity Removal through Primary Treatment," TAPPI, 56, 1 (1973).

196. Baumann, E. R.,"Design of Filters for Advanced Wastewater Treatment," Iowa State University, Department of Civil Engineering, Paper presented at EPA Technology Transfer Design Seminar, Ames, Iowa, June (1973).

197. Weber, Walter J., Jr., Physico-chemical Processes for Water Quality Control, Wiley-Interscience, New York 1972.

198. Pilot Plant Studies of Turbidity and Residual Cell Material Removal from Mill Effluent by Granular Media Filtration. NCASI Tech. Bull. No. 266, May 1973.

199. Tchobanoglous, G., "Filtration Techniques in Tertiary Treatment, Journal Water Pollution Control Federation, 42, April 1970.

200. Tchobanoglous, G., and Eliassen, R., "Filtration of Treated Sewage Effluent," Journal of the Sanitary Engineering Division, ASCE, April 1970.

201. Culp, G.L., and Hansen, S.P., "Extended Aeration Polishing by Mixed Media Filtration", Water and Sewage Works, February 1967.

202. Culp, R. L., and Culp, C.L., Advanced Wastewater Treatment, Van Nostrand Reinhold, New York, 1971.

203. Vecchiolo, Jr., et. al., "Wastewater Reclamation and Recharge, Bay Park, New York, Journal Sanitary Engineering Division ASCE, April 1975.

204. Middlebrooks, E.J., et. al., "Evaluation of Techniques for Algae Removal from Wastewater Stabilization Ponds," Utah Water Research Laboratory, Utah State University, Logan, Utah, January 1974.

205. Baumann, E.R., "Design of Filters for Advanced Waste Water Treatment," Project 1002-S, Engineering Research Institute, Iowa State University, Ames, Iowa, June 1973.

206. Leitner, G. F., "Reverse Osmosis For Waste Water Treatment - What? When?," TAPPI 8th Water & Air Conf. (1971).

207. Morris, D. C., Nelson, W. R., and Walraven, G. O., Recycle of Paper Mill Wastewaters and Application of Reverse Osmosis, Green Bay Packaging, Inc., EPA 12040 FUB, Jan. (1972).

208. Wiley, A. J., Dubey, G. A., and Bansal, J. K., Reverse Osmosis Concentration of Dilute Pulp and Paper Effluents, The Pulp Manufacturers Research League and The Institute of Paper Chemistry, EPA 12040 EEL, Feb. (1972).

209. Johnson, J. S., Jr., Minturn, R. E., and Moore, G. E., Hyperfiltration (Reverse Osmosis) of Kraft Pulp Mill and Bleach Wastes, Chemistry Division, Oak Ridge National Laboratory (unpublished) (1973).

210. Beder, H., and Gillespie, W. J., "The Removal of Solutes from Pulp Mill Effluents by Reverse Osmosis," TAPPI, 53, 5 (1970).

211. Smith,R., and McMichael, W. F., Cost and Performance Estimates for Tertiary Wastewater Treatment Processes, FWPCA, U.S. Dept. of the Interior, June (1969).

212. Direct Filtration of Secondary Effluents, EPA Technology Transfer Program, Engineering Research Institute; Iowa State University, Ames, Iowa; Newark, N.J., Mar. 13-15 (1974).

213. Ultra High Rate Filtration of Activated Sludge Plant Effluent, EPA Office of Research and Monitoring, Washington, D.C., Apr. (1973).

214. Nelson, W. R., Walraven, G. O., and Morris, D. C., "Process Water Reuse and Upset Control Modification at an Integrated NSSC Mill," TAPPI, 56, 7 (1973).

215. McCuaig, W. B., Atkins, P. F., Jr., and Lueck, B. L., Physical-Chemical Treatment of Combined Municipal Pulp and Paper Wastes, TAPPI Environmental Conf. (1974).

216. Bishop, H. K., Use of Improved Membranes in Tertiary Treatment by Reverse Osmosis, McDonnell Douglas Astronautics Company, EPA 17020 DHR, Dec. (1970).

217. Kreusch, E., and Schmidt, K., Wastewater Demineralization by Ion Exchange, Culligan International Co., EPA 17040 EEE, Dec. (1971).

218. Herbert, A. J., "A Process for Removal of Color from Bleached Kraft Effluents through Modification of the Chemical Recovery System," NCASI Technical Bulletin No. 157 (1962), U.S. Patent # 3,120,464.

219. Berger, H. F., and Thibodeaux, L. J., "Laboratory and Pilot Studies on Water Reclamation," NCASI Technical Bulletin No. 203 (1967).

220. Linstedt, K. D., Houck, C. P., and O'Connor, J. T., "Trace Element Removals in Advanced Wastewater Treatment Processes," Journal WPCF, 43, 7 (1971).

221. Gregory, J., and Dhond, R. V., "Wastewater Treatment by Ion Exchange," Water Research (Great Britain), Pergamon Press (1973).

222. Culp, R. L., and Culp, G. L., Advanced Waste Treatment, Van Nostrand Reinhold, New York (1971).

223. Optimization of Ammonia Removal by Ion Exchange Using Clinoptilolite, University of California, EPA 17080 DAP, Sept. (1971).

224. Wastewater Ammonia Removal by Ion Exchange, Battelle-Borthwest, EPA 17010 EEZ, Feb. (1971).

225. Johnson, W. K., and Vania, G. B., Nitrification and Denitrification of Waste Water, University of Minnesota, EPA Research Grant Number WP 01028, Jan. (1971).

226. Nitrogen Removal From Wastewaters, EPA Federal Water Quality Research Laboratory, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio, Oct. (1970).

227. Shindala, A., "Nitrogen and Phosphorus Removal From Wastewaters - Part I," Water and Sewage Works, June (1971).

228. Shindala, A., "Nitrogen and Phosphorus Removal From Wastewaters - Part II," Water and Sewage Works, July (1971).

229. Process Design Manual for Carbon Adsorption, EPA Technology Transfer, Oct. (1973).

230. Hansen, S. P., and Burgess, F. J., "Carbon Treatment of Kraft Condensate Wastes," TAPPI, 51, 6 (1968).

231. Rimer, A. E., et al., "Activated Carbon System for Treatment of Combined Municipal and Paper Mill Waste Waters in Fitchburg, Mass.," TAPPI, 54, 9 (1971).

232. Smith, D. R., and Berger, H. F., "Waste Water Renovation," TAPPI, 51, 10 (1968).

233. Timpe, W. G., et al., The Use of Activated Carbon for Water Renovation in Kraft Pulp and Paper Mills. 7th TAPPI Air and Water Conf., (1970).

234. Timpe, W. G., and Lang, E. W., "Activated Carbon Treatment of Unbleached Kraft Effluent for Reuse - Pilot Plant Results," TAPPI Environmental Conf. (1973).

235. Coates, J. and McGlasson, W. G., "Treatment of Pulp Mill Effluents With Activated Carbon," NCASI Technical Bulletin No. 199 (1967).

236. Davies, D. S. and Kaplan, R. A., "Activated Carbon Eliminates Organics," Chemical Engineering Progress, 60, 12 (1964).

237. Bishop, D. F., et al.,"Studies on Activated Carbon Treatment," Journal WPCF, 39, 2 (1967).

238. Vanier, C., et al., Carbon Column Operation in Waste Water Treatment, Syracuse University, Syracuse, New York, Nov. (1970).

239. Weber, W. J., Jr., and Morris, J. C., "Kinetics of Adsorption in Columns of Fluidized Media," Journal WPCF, 37, 4, (1965).

240. Beebe, R. L., and Stevens, J. I., "Activated Carbon System for Wastewater Renovation," Water and Wastes Engineering, Jan. (1967).

241. Holm, J. D., "A Study of Treated Wastewater Chlorination," Water and Sewage Works, Apr. (1973).

242. Meiners, A. F., Light-Catalyzed Chlorine Oxidation for Treatment of Wastewater, EPA, Water Quality Office, Midwest Research Institute, Kansas City, Missouri, Sept. (1970).

243. Huibers, T. A., et al., Ozone Treatment of Secondary Effluents from Wastewater Treatment Plants, EPA, Robert A. Taft Water Research Center, Report No. TWRC-4, Apr. (1969).

244. Chen, J. W., and Smith, G. V., Feasibility Studies of Applications of Catalytic Oxidation in Wastewater, EPA, Southern Illinois University, Carbondale, Illinois, Nov. (1971).

245. Eckenfelder, W. W., Jr., Krenkel, P. A., and Adams, C. A., Ad-

vanced Waste Water Treatment, American Institute of Chemical Engineers, New York (1972).

246. Moggio, W. A., "Experimental Chemical Treatments for Kraft Mill Wastes," NCASI Technical Bulletin No. 50 (1952).

247. Oswalt, J. L., and Lund, J. G., Jr., Color Removal from Kraft Pulp Mill Effluents by Massive Lime Treatment, EPA 12040 DYD (1973).

248. Swanson, J. W., et al., Kraft Effluent Color Characterization Before and After Stoichiometric Lime Treatment, EPA 12040 DKD (1973).

249. Lowe, K. E., "Is Pulping Technology on Verge of Revolution," Pulp & Paper, July (1974).

250. Private Communication, Interstate Paper Corporation (1973).

251. Rapson, W. H., and Reeve, D. W., "Bleached Kraft Pulp Mills Can be Made Free of Liquid Effluents," Paper Trade Journal, Oct. 16 (1972).

252. Ranhagen, G., "The Entirely Closed Mill - A Utopia or a Realistic Approach," Paper Trade Journal, Jan. 22 (1973).

253. Chang, H., Reeves, R. H., McKean, W. T., and Gratel, J. S., "Seminar on Soda-Oxygen Pulping Held by North Carolina State University," Paper Trade Journal, Sept. 10 (1973).

254. Gilmont, P. L., "Water Requirements of Pulp Bleaching - Survey of Mill Practice in the United States," TAPPI, 50, 10 (1967).

255. Histed, J. A., and Nicolle, F. M. A., "Water Reuse and Recycle in Kraft Bleacheries," Pulp and Paper Magazine of Canada, 74, 12 (1973).

256. Histed, J. A., and Nicolle, F. M. A., "Water Reuse and Recycle in the DcEDED Bleach Sequence," CPPA-TAPPI Conf., Vancouver, B.C. Se (1973).

257. Gall, R. J., and Thompson, F. H., "The Anti-Pollution Sequence - A New Route to Reduce Pollutants in Bleach Effluent," TAPPI, 56, 11 (1973).

258. Improved Machinery, Inc., Impco Papribleach Pulp Bleaching Proces (Trade Pamphlet), Nashua, N.H. (1972).

259. Jamieson, A., Noreus, S., and Pettersson, B., "Advances in Oxyge Bleaching III, Oxygen Bleaching Pilot Plant Operation," TAPPI, 5. 11 (1971).

260. Lescot, J. C., "Oxygen Bleaching - A Flexible Process for Pollution Abatement," CPPA-TAPPI Conf., Vancouver, B.C., Sept. (1973)

261. Lowe, K. E., "Bleaching at Crossroads," Pulp & Paper, Aug. (1973).

262. Carpenter, W. L., McKean, W. T., Berger, H. F., and Gellman, I., "A Comparison of Effluent Characteristics from Conventional and Oxygen Bleaching Sequences - Results of a Laboratory Study," CPPA-TAPPI Conf., Vancouver, B.C., Sept. (1973).

263. Berger, H. F., "Development of an Effective Technology for Pulp and Bleaching Effluent Color Reduction," NCASI Technical Bulletin No. 228, (1969).

264. Spruill, E. L., Draft of Final Report, Color Removal and Sludge Disposal Process for Kraft Mill Effluents, EPA 12040 DRY (1973).

265. "Treatment of Calcium-Organic Sludges Obtained From Lime Treatment of Kraft Pulp Mill Effluents -- Part I," NCASI Technical Bulletin No. 62 (1955).

266. "Treatment of Calcium-Organic Sludges Obtained From Lime Treatment of Kraft Pulp Mill Effluents -- Part II," NCASI Technical Bulletin No. 75 (1955).

267. "Development Studies on the Removal of Color from Caustic Extract Bleaching Effluent by the Surface Reaction Process -- Part II," NCASI Technical Bulletin No. 107 (1958).

268. Berger, H. F., and Brown, R. I., "The Surface Reaction Method for Color Removal from Kraft Bleachery Effluents," NCASI Technical Bulletin No. 119. (1959).

269. "Development Studies on the Removal of Color from Caustic Extract Bleaching Effluent by the Surface Reaction Process -- Part II," NCASI Technical Bulletin No. 122 (1959).

270. Davis, C. I., Color Removal from Kraft Pulping Effluent by Lime Addition, Interstate Paper Corporation, EPA 12040 ENC (1971).

271. Spruill, E.L., Color Removal and Sludge Recovery from Total Mill Effluent, TAPPI Environmental Conf. (1972).

272. Gould, M., Color Removal from Waste Effluents, U.S. Patent 3,531,370 (1970).

273. Spruill, E. L., "Color Removal from Paper Mill Waste," Proceedings Purdue Univ. Industrial Waste Conf. XXV (1970).

274. Private Communication, Continental Can Company, Inc. (1973).

275. Gould, M., "Color Removal from Kraft Mill Effluent by an Improved Lime Process," TAPPI, 56, 3 (1973).

276. Gould, M., "Physical - Chemical Treatment of Pulp Mill Wastes, Woodland, Me.," Proceedings Purdue Univ. Industrial Waste Conf. XXV (1970).

277. Private Communication, Georgia Pacific Corporation (1974).

278. Private Communication, International Paper Company (1974).

279. Berov, M. B., et al., "pH and the Effectiveness of Effluent Treatment," Bum. Prom. (USSR), No. 2, 6 (1973); Abs. Bull. Inst. Paper Chem., 44, 1561 (1973).

280. Willard, H. K., "Coagulation of Pulp and Paper Aerated Lagoon Effluents for Color and Solids Removal," AIChE Symposium Series, 69 (1973).

281. Smith, S. E., and Christman, R. F., "Coagulation of Pulping Wastes for the Removal of Color," Journal WPCF, 41, 2., Part I, (1969).

282. Middlebrooks, E. J., et al., "Chemical Coagulation of Kraft Mill Wastewater," Water and Sewage Works, 116, 3, (1967).

283. Scott, R. H., "Sophisticated Treatment at Baikal Pulp Mill in U.S.S.R.," Pulp and Paper, Apr. (1974).

284. Private Communication, Gulf States Paper, Tuscaloosa, Alabama (1974)

285. Fremont, H. A., Tate, D. C., and Goldsmith, R. L., "Color Removal from Kraft Mill Effluents by Ultrafiltration," Environmental Protection Technology Series, EPA-660/2-73-019, Office of Research and Development, EPA, Dec. (1973).

286. Private Communication, Union Carbide Corp., S. Charleston, W. Va. (1974).

287. Rock, S. L., Kennedy, D. C., and Brunner, A., "Decoloration of Kraft Mill Effluents with Polymeric Adsorbents," TAPPI Environmental Conf., Apr. 17-19 (1974).

288. Anderson, L. G., Groddevall, B., Lindberg, S., and Phillips, Jr., "A New Color Removal Process: A Field Report," TAPPI, 57, 4 (197

289. Sanks, R. L., "Ion Exchange Color and Mineral Removal from Kraft Bleach Wastes," Environmental Protection Technology Series, EPA-R2-73-255, Office of Research and Monitoring, EPA May (1973).

290. McGlasson, W. G., et al., "Treatment of Pulp Mill Effluents with Activated Carbon," NCASI Bulletin No. 199 (1967).

291. Whittemore, R. C., "An Evaluation of the Adsorptive Properties of Fly Ash and Bark-Derived Activated Char," NCASI Technical Bulletin No. 267 (1973).

292. Hanzawa, M., et al., "Clarification of NSSC Waste Liquor by Active Carbon, etc.," Res. Bull. Coll. Expt. Forests Hokkaido Univ. (Jaup. 29, 361 (1972); Abs. Bull Inst. Paper Chem., 43, 11803 (1973).

293. MacDonald, D. G., and Nguyen, T., "Activated Carbon from Bark for Effluent Treatment," Pulp & Paper, 75, 5 (1974).

294. Bauman, H. D., and Lutz, L. R., "Ozonation of a Kraft Mill Effluent," TAPPI Environmental Conf., Apr. 17-19 (1974).

295. Rapson, B., Sullivan, D. P., and Brothers, J. A., "NSRF Seawater-Lime Clarification Process for Kraft Effluents," Paper Trade Journal, Feb. 25 (1974).

296. "Color Removal Process," Pulp and Paper International, May (1973).

297. Twitchell, J. P., and Edwards, L. L., "Kraft Mill Material Balance Calculations for Brown Stock Washing, Screening and Oxygen Bleaching," TAPPI Environmental Conf. (1974).

298. Narrstrom, H., "The Environmental Care Project of the Swedish Pulp and Paper Industry," TAPPI Cnvironmental Conf. (1974).

299. Nichols, G. A., "Kraft Multistage Bleach Plant Effluents," TAPPI, 56, 3 (1973).

300. Chen, H. T., et al., "Evaluation of Four Biological Systems on Integrated Paper Mill Effluent," TAPPI Enviornmental Conf. (1974).

301. Gillespie, W. J., et al., "A Pilot Scale Evaluation of the Efficacy of Rotating Biological Surface Treatment of Pulp and Paper Mill Wastes," TAPPI Environmental Conf. (1974).

302. MaAliley, J. E., "A Pilot Plant Study of a Rotating Biological Surface for Secondary Treatment of Unbleached Kraft Mill Wastes," TAPPI Environmental Conf. (1974).

303. Gorham International Inc., Study of Solid Waste Management Practices in the Pulp and Paper Industry, EPA, Office of Solid Waste Management Program, Feb. (1974).

304. Tyler, M. A., and Fitzgerald, A. D., "A Review of Colour Reduction Technology in Pulp and Paper Mill Effluents," Presented at the 58th Annual Meeting Technical Section, CPPA, Montreal, Jan. 24-28 (1972).

SECTION XIV

GLOSSARY

Active alkali

A measure of the strength of alkaline pulping liquor indicating the sum of caustic soda and sodium sulfide expressed as Na20.

Air Dry (AD) Ton

Measurement of production including a moisture content of 10 percent by weight.

Bark

The protective covering of a tree.

Barking

Removal of bark from logs in a wet or dry process.

Black Liquor

Spent liquor recovered from a kraft digester up to the point of its introduction into the recovery plant.

Bleaching

The brightening and delignification of pulp by addition of chemicals such as chlorine.

Blow

Fjection of the chips from a digester.

Boil-Out

A procedure, usually utilizing heat and chemicals, to clean equipment such as evaporators, heat-exchangers, and pipelines.

Breaker Stack

Two rolls, one above the other, placed in the dryer section of a paper machine to compact the sheet and smooth out its surface defects.

Broke

Partly or completely manufactured paper that does not leave the machine room as salable paper or board; also paper damaged in finishing operations such as rewinding rolls, cutting, and trimming.

Calender Stack

Two or more adjacent and revolving rolls which provide even caliper control of the sheet and the final finishing of its surface.

Cellulose

The fibrous constituent of trees which is the principal raw materials of paper and paperboard.

Chest (or Stock Chest)

Tank used for storage of wet fiber or furnish.

Chips

Small pieces of wood used to make pulp.

Color Unit

A measure of color concentration in water using NCASI methods.

Consistency

A weight percent of solids in a solids-water mixture used in the manufacture of pulp or paper.

Cooking

Heating of wood, water, and chemicals in a closed vessel under pressure to a temperature sufficient to separate fibrous portion of wood by dissolving lignin and other nonfibrous constituents.

Cooking Liquor

The mixture of chemicals and water used to dissolve lignin in wood chips.

Countercurrent Washing

Pulp washing in which fresh water is added only at the last stage and the effluent from this stage is then used as wash water for the previous stages.

Decker

A mechanical device used to remove water or spent cooking liquor from pulp, and to thicken pulp consistency.

Digester

A pressure vessel used to cook wood chips in the presence of cooking liquor and heat.

Digestion

Cooking of chips in the above manner.

Dregs

The inert rejects from the green liquor clarifier of a pulp mill.

Extraction Water

Water removed during a pulp manufacturing process.

Felt

The endless belt of wood or plastic used to convey and dewater the sheet during the papermaking process.

Fiber

The cellulosic portion of the tree used to make pulp, paper, and paperboard.

Fines

Fiber fragments produced by fiber cutting in beaters.

Furnish

The mixture of fibers and chemicals used to manufacture paper.

Gland

A device utilizing a soft wear-resistant material used to minimize leakage between a rotating shaft and the stationary portion of a vessel such as a pump.

Gland Water

Water used to lubricate a gland. Sometimes called "packing water."

Grade

The type of pulp or paper product manufactured.

Green Liquor

Liquor made by dissolving chemicals recovered from the kraft process water and weak liquor preparatory to causticizing.

Grits

Unreactive materials mechanically removed from the causticizing of kraft and soda green liquor and disposed of as solid waste.

Headbox

The area of the paper machine from which the stock flows through a sluice onto the wire.

Lignin

A non-degradable organic compound of wood.

Newsprint

Paper made largely from groundwood pulp, with a small percentage of chemical pulp added for strength, used chiefly in the printing of newspapers.

Packing Water

See Gland Water.

Prehydrolysis

Pre-steaming of chips in the digester prior to cooking; usually associated with improved bleaching of kraft pulp.

Pulp

Cellulosic fibers after conversion from wood chips.

Pulper

A mechanical device resembling a large-scale kitchen blender used to separate fiber bundles in the presence of water prior to papermaking.

Ray Cells

Cells which carry stored food (protein, starch, and fats) from the bark to the wood of a tree and appear as impurities in the pulping process, especially unbleached operations.

Rejects

Material unsuitable for pulp or papermaking which has been separated in the manufacturing process.

Save-all

A mechanical device used to recover papermaking fibers and other suspended solids from a waste water or process stream.

Screenings

Rejects separated from useable pulp by a device such as a screen.

Side-Hill Screens

Steeply sloped, 60-mesh screens.

Spent Cooking Liquor

Cooking liquor after digestion containing lignaceous as well as chemical materials.

Stock

Wet pulp with or without chemical additions.

Suction Box

A rectangular box with holes or slots on its top surface, used to suck water out of a felt or paper sheet by the application of vacuum.

Suction Couch Roll

A rotating roll containing holes through which water is sucked out of a paper sheet on a fourdrinier machine, by the application of vacuum.

Sulfidity

Sulfidity is a measure of the amount of sulfur in kraft cooking liquor. It is the percentage ratio of NaS, expressed as NaO, to active alkali.

1__ Steel

1 Stainless Steel is steel with the following composition:

Carbon	0.08 percent maximum
Manganese	2.00 percent maximum
Silicon	1.00 percent maximum
Chromium	18.00-20.00 percent
Nickel	11.00-10.00 percent
Molybdenum	3.00- 4.00 percent
Remainder Iron	

Virgin Wood Pulp (or fiber)

Pulp made from wood, as contrasted to waste paper sources of fiber.

Wet Laps

Rolls or sheets of pulp of 30-45 percent consistency prepared in a process similar to papermaking; facilitates transportation of market pulp.

Wet Strength Additives

Chemicals such as urea and melanine formaldehydes used in papermaking to impart strength to papers used in wet applications.

White Liquor

Liquors made by causticizing green liquors; cooking liquor.

White Water

Water which drains through the wire of a paper machine which contains fiber, filler, and chemicals.

Wire

An endless moving belt made of metal or plastic, resembling a window screen, upon which a sheet of paper is formed on a fourdrinier machine.

SECTION XV

TERMINOLOGY INDEX

A.	Activated Sludge
A.	When associated with a mill code, refers to new data
AD Pulp	Air Dried Pulp
APHA	American Public Health Association
API	American Paper Institute
APS	anti-pollution sequence
ASB	Aerated Stabilization Basin
atm	atmospheres
AWT	Advanced Waste Treatment
B.	Board or Paperboard
BATEA	Best Available Technology Economically Achievable
BCT	Paperboard, Coarse, Tissue
BK	Bleached Kraft
BOD or BOD_5	Biochemical Oxygen Demand (five-day)
BPCTCA	Best Practicable Control Tehcnology Currently Available
BTU	British Thermal Units
C	Clarifier
C	Coarse
^oC	degrees Centigrade
C+F	Clays and Fillers
CMN	Coarse, Molded, Newsprint
CMP	Chemi-mechanical Pulp
COD	Chemical Oxygen Demand
cu m/min	Cubic meters per minute
cu. m./kkg	Cubic meters per 1000 kilograms

D	Deink
DAF	Dissolved Air Flotation
Diss.	Dissolving
DO	Dissolved Oyxgen
E. Coli.	Escherichia Coliform
ENR	Engineering News Record
F	Fine
FACET	Fine Activated Carbon Effluent Treatment
°F	degrees Fahrenheit
Fwp	from waste paper
"G"	Gravity
gal	gallons
gpd/sq. ft.	gallons per day per square foot
gpm	gallons per minute
GW	Groundwood
ha	hectare, 10,000 meter squared
hp	horsepower
IDOD	Immediate Dissolved Oxygen Demand
IJC	International Joint Commission
in. Hg	inches of Mercury
JTU	Jackson Turbitity Units
kg	kilogram, 1000 grams
kg BOD/kg MLVSS/day	kilogram of BOD per kilograms of MLVSS per day
kg/ha surface area/day	kilograms per hectare of surface area per day
kg/kkg	kilograms per 1000 kilograms
kg/sq cm	kilograms per square centimeter

kgal	1000 gallons
kgal/ton	1000 gallons per ton
kkg	1000 kilograms, metric ton
kw	kilowatt
L	liter
Lpd/sq. m.	liters per day per square meter
L/kkg	liters per 1000 kilograms
L/min.	liters per minute
Liquor Recovery	C - Collected B - By-products I - Incinerated
lb	pound
lb/ac/day	pound per acre per day
mgd	million gallons per day
mg/l	milligrams per liter
MKT	market
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
MM	Maximum Month
mu	millimicrons
N	News
N(NSM)	non-standard methods when associated with data
N.A.	Not Available
NCASI	National Council for Air and Stream Improvement
NI	Non-Integrated
nm	nano meters, 10 - 9 meters
NOV	Number of Values Reported

NPDES	National Pollutant Discharge Elimination System
NSPS	New Source Performance Standards
NSSC	Neutral Sulfite Semi-chemical
P	Pulp
PCB	Polychlorinated biphenyl
PCU	Platinum Color Units
PP	Purchased Pulp
ppm	parts per million
PS	Post Storage
psig	pounds per square inch gage
RBS	Rotating Biological Surface
rpm	revolutions per minute
RWL	Raw Waste Load
S	Sulfite
SB	Settling Basin
Set Slds	Settleable Solids
SO	Soda
SSL	Spent Sulfite Liquor
Std. Meth.	Standard Methods
T	Tissue
TAPPI	Technical Association of the Pulp and Paper Industry
TC	Total Carbon
TDS	Total Dissolved Solids
Temp	Temperature
TMP	Thermo-mechanical Pulp
TOC	Total Organic Carbon
TOD	Total Oxygen Demand

TOM	Total Organic Matter
ton	1000 pounds (short ton)
tpd	tons per day
TS	Total Solids
TSS	Total Suspended Solids
turbid	Turbitity
TVS	Total Volatile Solids
Type Condenser	V - Vapor Recompression S - Surface Condenser B - Barometric Condenser
UK	Unbleached Kraft

Table 200

Conversion Table

MULTIPLY (ENGLISH UNITS) English Unit	Abbreviation	by Conversion	TO OBTAIN (METRIC UNITS) Abbreviation	Metric Unit
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	.0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig+1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

* Actual conversion, not a multiplier