

Pollution Technology Review, No. 36,
Energy Technology Review, No. 17)

PULP AND PAPER MANUFACTURE

**Energy Conservation
and Pollution Prevention**

PULP AND PAPER MANUFACTURE

**Energy Conservation
and Pollution Prevention**

Marshall Sittig

NOYES DATA CORPORATION

Park Ridge, New Jersey, U.S.A.

1977

Copyright © 1977 by Marshall Sittig

No part of this book may be reproduced in any form
without permission in writing from the Publisher.

Library of Congress Catalog Card Number: 77-89631

ISBN: 0-8155-0675-9

Printed in the United States

Published in the United States of America by
Noyes Data Corporation
Noyes Building, Park Ridge, New Jersey 07656

FOREWORD

The pulp and paper industry is especially hard hit by problems of pollution which are subject to restrictive environmental legislation. These problems include release of spent pulping and bleaching chemicals into waterways and emission of odorous sulfur gases into the air.

Efficiency in waste reduction may, in the case of the pulp and paper industry, fortuitously bring about energy-saving capabilities. It follows then, that pollution control procedures can also become an essential part of an energy conservation program. This feature of pollution control is amply demonstrated in this book which is based on government-funded studies and important U.S. patents. One should have to go no further than this compendium of condensed information to establish a sound background for action towards both combating pollution and saving energy in the pulp and paper industry.

Advanced composition and production methods developed by Noyes Data are employed to bring our new durably bound books to you in a minimum of time. Special techniques are used to close the gap between "manuscript" and "completed book." Technological progress is so rapid that time-honored, conventional typesetting, binding and shipping methods are no longer suitable. We have bypassed the delays in the conventional book publishing cycle and provide the user with an effective and convenient means of reviewing up-to-date information in depth.

The table of contents is organized in such a way as to serve as a subject index and provides easy access to the information contained in this book. The bibliography at the end of the volume lists the highly important government reports and a source of their purchase.

CONTENTS AND SUBJECT INDEX

INTRODUCTION	1
PAPER AND PAPERBOARD INDUSTRY PROCESS DESCRIPTIONS	12
Pulpwood Acquisition	18
Debarking and Chipping	19
Pulping	26
Mechanical (Groundwood)	30
Thermomechanical	34
Chemical—NSSC (Neutral Sulfite Semichemical)	36
Chemical—Kraft	41
Chemical—Soda	53
Chemical—Sulfite	53
Pulp from Wastepaper	60
Pulp Bleaching	70
Paper and/or Paperboard Production	82
Converting	92
TYPES OF FUELS USED	93
Oil	96
Gas	96
Coal	96
Bark and Hogged Fuel	97
Bark	97
Hogged Fuel	98
Black Liquor	99
ENERGY CONSUMPTION PATTERNS	100
FACTORS AFFECTING ENERGY EFFICIENCY	128
ENERGY CONSERVATION APPROACHES	134
Housekeeping Measures and Alternative Operating Procedures	143
Capital Improvements in Existing Capacity	149

New, More Energy-Efficient Capacity	164
Alternate Fuels	165
ENERGY CONSERVATION TARGETS	168
Technologically Feasible Improvements	170
Economically Feasible Improvements	172
Final Energy Conservation Target Definition	177
Sensitivity of Target to Key Variables	181
WATER REQUIREMENTS OF THE INDUSTRY	184
WATER POLLUTION PROBLEMS	189
Discussion of Levels I and II	192
Discussion of Levels III and IV	194
Discussion of Level V	195
New Source Performance Standards	196
Control Options	197
IN-HOUSE WASTEWATER CONTROL	201
Spill Containment Systems	201
In-Process Effluent Containment with Established Technology and Equipment	204
Close-up of Screen Room to Eliminate Thickener Filtrate Effluent	205
Recycle and Reuse of Digester Vent and Blow Condensates and Contaminated Evaporator Condensates	207
Cooling and Service Water Segregation and Reuse with Recooling	211
Countercurrent Bleached Pulp Washing	212
Pulp Dryer or Board Machine White Water Collection and Treatment	214
Groundwood White Water Recovery	215
Deinked and Wastepaper Pulping System White Water Reuse	215
Stock Preparation and Paper Machine Wastewater Collection and Treatment	216
Process Changes with Prospective Technology and Equipment	219
Wood Processing—Dry Barking	220
Screening Rejects Handling	221
Causticizing Dregs and Grits Rewashing	221
Oxygen Pulping and Bleaching	221
Recycle and Reprocessing of Bleach Plant Effluent	229
Multistage Bleaching and Diffusion Washing in a Single Tower	229
Gas Phase Bleaching	230
Separate Bleach Plant Effluent Treatment	230
Rapson Effluent-Free Kraft Process	230
By-Product Recovery	233
EXTERNAL WASTEWATER TREATMENT	236
Removal of Coarse Solids and Floating Objects	236
Reduction of Suspended Solids	236
Plain Sedimentation	240
Chemical Coagulation and Clarification	240
Dissolved Air Flotation	241
Reduction of BOD by Biological Methods	241
Cooling Towers	242
Activated Sludge Treatment	242

Aerated Stabilization Basin	244
Rotating Biological Contactors (Biodiscs)	244
Trickling Filters	245
Fuel Clarification	246
Sedimentation	246
Filtration	246
Microstraining	246
Color Removal	246
Massive or Maximum Lime Treatment	248
Minimum Lime Treatment	248
Microlime plus Activated Carbon Treatment	250
Ultrafiltration	250
Proprietary Processes	250
Mercury Removal	252
Advanced Wastewater Treatment	254
Adsorption	254
Reverse Osmosis	255
Ion Exchange	255
Evaporation	255
Sludge Dewatering	255
Gravity Thickening	256
Vacuum Filtration	256
Centrifugation	256
Filter Pressing	256
Sludge Disposal	256
Land Disposal	258
Incineration	258
Compatibility with Municipal Systems	258
AIR POLLUTANT EMISSIONS AND THEIR CONTROL	260
Wood Waste Air Pollution Control	261
KRAFT PROCESS AIR EMISSIONS AND THEIR CONTROL	263
Digester Gases	270
Evaporation Gases	278
Noncondensable Gases	288
Condensate Treatment	303
Brown Stock Washer Gases	316
Storage Tank Vent Gases	321
Tall Oil Recovery Gases	321
Black Liquor Oxidation	324
Recovery Boiler	342
Lime Burning and Lime Dust Handling	367
Smelt Dissolving	372
Nitrogen Oxide, Hydrocarbon and Water Vapor Emissions	375
SULFITE MILL AIR EMISSIONS AND THEIR CONTROL	380
Digester Gases	382
Washer Gases	387
Evaporator Gases	387
Combustion Gases	389
Acid Preparation Gases	390
Spent Sulfite Liquor Recovery	391
Nitrogen Compounds in Ammonium Base Pulping	403

Contents and Subject Index

OTHER MILL AIR EMISSIONS AND THEIR CONTROL	406
Bleach Plant Gases.	406
Wastewater Treatment Gases.....	407
Miscellaneous Odor Problems	409
Power Boiler Flue Gases	410
LITERATURE REFERENCES	428

INTRODUCTION

The pulp and paper industry is deserving of special attention both in areas of energy and environmental concern.

As pointed out in a recent report by Arthur D. Little, Inc. (10), it is the fourth largest consumer of electricity and fuels (after chemicals, primary metals and petroleum industries in that order). Also it is the third largest consumer of fresh water (after the primary metals and chemicals industries in that order).

Table 1 shows the energy and power consumption picture and Table 2 the fresh water consumption picture.

Some additional perspective as to the relative magnitude of energy and pollution problems in the pulp and paper industry are given in Table 3 which focuses on the various major unit operations involved in paper and paperboard manufacture.

TABLE 1: LARGEST INDUSTRY CONSUMERS OF FUELS AND ELECTRIC ENERGY FOR HEAT AND POWER, 1971

Major Industry Group	Purchased Fuels and Electric Energy*
Chemicals and allied products	814.2
Primary metal industries	717.8
Petroleum and coal products	467.0
Paper and allied products	385.5
Stone, clay and glass products	382.4
Food	302.2
Transportation equipment	113.7
Machinery, excluding electrical	101.6
Textile mill products	106.6
Fabricated metal products	103.1

*billion kWh equiv

Source: Reference (10)

TABLE 2: LARGEST INDUSTRY CONSUMERS OF FRESH WATER, 1973

Major Industry Group	Annual Consumption*
Primary metal industries	4396
Chemical and allied products	2927
Paper and allied products	2295
Petroleum and coal products	639
Food and kindred products	628
Transportation equipment	220
Stone, clay and glass products	179
Textile mill products	~ 175
Machinery, excluding electrical	158
Rubber and miscellaneous plastics products	150

*billions of gallons

Source: Reference (10)

TABLE 3: MAJOR UNIT OPERATIONS IN PAPER AND PAPERBOARD MANUFACTURE

	Preparation	Pulping	Heat & Chemical Recovery*	Washing & Bleaching**	Stock Preparation	Paper & Board Manufacture
	Barking Chipping	Chemical Chemi-Mech				Sheet formation, mechanical water removal, and drying
		Mechanical Deinking Nondeinking				
Energy Usage	Low	High	High	High	Moderate	High (in drying)
Pollution	Moderate	High	High	High	Low	Moderate

*for chemical and chemi-mech only

**bleaching optional

Source: Reference (10)

Table 3 shows the energy usage and pollution characteristics of each process step. Obviously, this ranking of energy usage and contribution to pollution is quantitative and varies significantly from one technique to another. Nevertheless, the table puts into proper perspective the relative importance of the operations to these two variables.

The Paper and Allied Products group of Standard Industrial Classification (SIC) 26 includes six three-digit groups with seventeen four-digit industries. Four of the six three-digit groups include primary pulp and paper manufacturing. The two remaining groups contain industries engaged in paper converting operations.

The definitions of the six groups as found in the SIC Manual, 1972 edition, are substantially as follows:

SIC 261 (with one four-digit industry): Pulp Mills — Establishments primarily engaged in manufacturing pulp from wood or from other materials such as rags, linters, waste paper, and straw. Pulp mills combined with paper mills or paperboard mills, and not separately reported, are classified with the latter in Industries 2621 and 2631 respectively.

SIC 262 (with one four-digit industry): Paper Mills, Except Building Paper Mills — Establishments primarily engaged in manufacturing paper (except building paper—Industry 2661) from wood pulp and other fibers and which may also manufacture converted paper products. Pulp mills combined with paper mills, and not separately reported, are also included in this industry; where separately reported, they are classified in Industry 2611.

SIC 263 (with one four-digit industry): Paperboard Mills — Establishments primarily engaged in manufacturing paperboard, including paperboard coated on the paperboard machine, from wood pulp and other fibers; and which may also manufacture converted paperboard products. Pulp mills combined with paperboard mills, and separately reported, are classified in Industry 2611.

SIC 264 (with eight four-digit industries): Converted Paper and Paperboard Products, Except Containers and Boxes — Establishments primarily engaged in operations required to make a finished product, generally, but not necessarily from purchased paper or paperboard.

SIC 265 (with five four-digit industries): Paperboard Containers and Boxes — Establishments primarily engaged in manufacturing folding paperboard boxes and set-up paperboard boxes from purchased paperboard; corrugated and solid fiber boxes and fiber cans, tubes, drums and similar fiber products from purchased materials; and sanitary food containers from special food board.

SIC 266 (with one four-digit industry): Building Paper and Building Board Mills — Establishments primarily engaged in manufacturing building paper and building board from wood pulp and other fibrous materials. Pulp mills combined with building paper and building board mills, and not separately reported, are included in this industry; where separately reported, they are classified in Industry 2611.

The API (American Paper Institute) classifies paper and board into six product groups, and pulp into five process categories. They are as follows (2):

Paper and Board:

- (A) Newsprint
- (B) Printing, Writing and Related Types
 - Groundwood uncoated
 - Machine and off machine coated
 - Book uncoated and chemical writing
 - Cotton fiber
 - Thin paper
 - Solid bleached Bristol
- (C) Packing and Industrial Converting
 - Unbleached kraft
 - Other packaging and industrial converting
 - Special industrial

(continued)

- (D) Tissue
 - (E) Construction Grades
 - (F) Paperboard
 - Unbleached kraft
 - Solid bleached packaging
 - Semichemical paperboard
 - Recycled
- Pulp:
- (A) Dissolving
 - Sulfite
 - Sulfate
 - (B) Sulfite
 - Softwood-Bleached
 - Hardwood-Bleached
 - Unbleached
 - (C) Sulfate and Soda
 - Softwood-Bleached
 - Hardwood-Bleached
 - Unbleached
 - (D) Semichemical
 - Bleached
 - Unbleached
 - (E) Groundwood

The character of the 14 industry subcategories adopted by EPA, and the end products manufactured are summarized below (6).

Integrated Pulp and Paper Mills

Unbleached Kraft: Pulp production without bleaching, by a "full cook" process, utilizing a highly alkaline cooking liquor used principally to produce linerboard used for (1) the smooth facing of corrugated boxes, (2) wrapping paper, and (3) paper for bags and shipping sacks.

Bleached Kraft: Bleached pulp production utilizing pressure, heat and a highly alkaline sodium hydroxide and sodium sulfide cooking liquor used in the manufacture of market pulp, and papers and paperboards such as tissues, foodboard, printing and writing papers.

Soda: Bleached pulp production by a "full cook" process utilizing a highly alkaline sodium hydroxide cooking liquor, used principally to manufacture a wide variety of papers such as printing and writing papers.

Sulfite: Bleached pulp production utilizing a full cook acidic cooking liquor of bisulfites of calcium, magnesium, ammonium or sodium containing an excess of free sulfur dioxide used to manufacture papers.

Dissolving Sulfite: Highly bleached and purified pulp production by a full cook process using very strong solutions of bisulfites of calcium, magnesium, ammonia, or sodium containing an excess of free sulfur dioxide, used principally for the manufacture of rayon.

Sodium Base Neutral Sulfite Semichemical (NSSC-Sodium): Pulp production by

chemical treatment of chips followed by grinding or fiberizing and cooking in a sodium base sulfite solution used in the production of corrugating medium.

Ammonia Base Neutral Sulfite Semichemical (NSSC-Ammonia): Pulp production by chemical treatment of chips followed by grinding or fiberizing and cooking in an ammonium base sulfite solution used in the production of corrugating medium.

Neutral Sulfite Semichemical with Kraft (Kraft-NSSC): Pulp production by chemical treatment of chips followed by grinding or fiberizing and cooking in a sodium base sulfite solution used in the production of corrugating medium. This process is operated in conjunction with an unbleached kraft process thereby permitting recovery of the spent NSSC liquor in the kraft chemical recovery system.

Groundwood: Pulp production utilizing a stone grinder, chemi-groundwood and chemi-mechanical groundwood used principally for the production of newsprint.

Deinking: Pulp production from recycled wastepaper utilizing an alkaline treatment to remove contaminants such as ink and coating pigments used to manufacture a variety of papers such as business, bank and printing papers, tissues and toweling, and as liner for some paperboards.

Paperboard from Wastepaper: The conversion of wastepaper to pulp by ripping, shredding and defibering for the manufacture of paperboard such as file folders, match stems, tablet backs, etc.

Nonintegrated Paper Mills

Fine Paper: The manufacture of fine paper from wood or deinked pulp prepared at another site.

Tissue Paper: The manufacture of tissue paper from wood or deinked pulp prepared at another site.

Coarse Paper: The manufacture of coarse paper from wood or deinked pulp prepared at another site.

The paper industry in the United States produces 56.9×10^6 tons of paper and fiberboard annually. It ranks as the fifth largest U.S. manufacturing industry, with annual sales of 26.5 billion dollars. The industry includes approximately 400 manufacturing plants, located predominantly in the northeast, north central, southeast, and Pacific states (1).

The U.S. paper and allied products industry is diverse and highly competitive; the largest firm controls only 9% of the market (4).

Capital expenditures by the industry rose from \$1.18 billion in the second quarter 1971 to \$2.86 billion in the third quarter of 1975. As reported by McGraw-Hill (2), the following percentages of annual expenditures have gone for replacement or modernization rather than for net additions to plant and equipment: 61% in 1971, 70% in 1972, 75% in 1973, 59% in 1974, 64% in 1975, and

59% planned in 1976. Because of rising fuel costs, it is expected that new plant and equipment will include energy saving capability as part of their design.

Approximately 55% of the total 1975 U.S. pulp and paper was produced in the South in approximately 27% of the mills. The high proportion can be explained by the many large integrated mills in the region. One reason for the concentration of integrated mills in the South is the extensive southern pine forest there. Of the other regions, the West contributed approximately 16%, the North Central States 15%, and the Northeast 14%.

Nonintegrated mills are generally smaller, though more numerous. As they rely more heavily on recycling wastepaper, they are usually located close to the more industrialized areas of the country. Of 805 installations listed in the Lockwood Directory, 475 were nonintegrated. Approximately 70% of these 475 facilities are in the Northeast and North Central Regions.

The API reported that, in 1972, approximately 64% of pulp capacity was in the South (compared with approximately 49% of the paper and board capacity). Similarly, pulp capacity was higher than paper and board capacity in the West, (18% against 14%). In the other two Regions, Northeast and North Central, paper and board capacity was more than the pulp capacity. API figures for 1974 indicated very little change from 1972.

The primary raw material consumed by the paper industry is cellulose, chiefly in the form of wood. Cotton rag and vegetable fibers are also used for certain grades. In addition, the industry consumes quantities of clay and other inorganic fillers, starches, resins, and chemical additives which appear in the final product, as well as pulping and bleaching chemicals. Product categories include newsprint, printing and writing papers, special industrial papers, tissue papers, container and boxboard, packaging papers, and building paper and board. The annual production for each of these categories is shown in Table 4.

TABLE 4: ANNUAL U.S. PRODUCTION OF PAPER BY CATEGORY

Paper Grade	Production 10 ⁶ tons/year
Newsprint	3.435
Printing and Writing	13.497
Packaging Papers	5.033
Glassine, Greaseproof, Vegetable Parchment	0.236
Special Industrial	0.564
Tissue	3.984
Container Board	16.928
Boxboard	6.764
Building Paper and Board	6.412

Source: Reference (1)

Estimates of future production trends are given in Table 5. Table 6 shows U.S. Forest Service projections of demand for paper and board by grade through 1985.

**TABLE 5: PRODUCTION ESTIMATES BY ECONOMICS DEPARTMENT,
AMERICAN PAPER INSTITUTE**

	----- 1,000 Short Tons -----			
	Paper	Paperboard	Other Grades	Total
1970	23,220	24,940	4,297	52,457
1975	29,704	31,873	5,634	67,211
1980	36,035	38,590	6,745	81,370
1985	43,260	46,300	8,115	97,675
1990	52,700	55,700	9,850	118,250

Source: Reference (7)

**TABLE 6: U.S. FOREST SERVICE PROJECTION OF DEMAND FOR
PAPER AND BOARD**

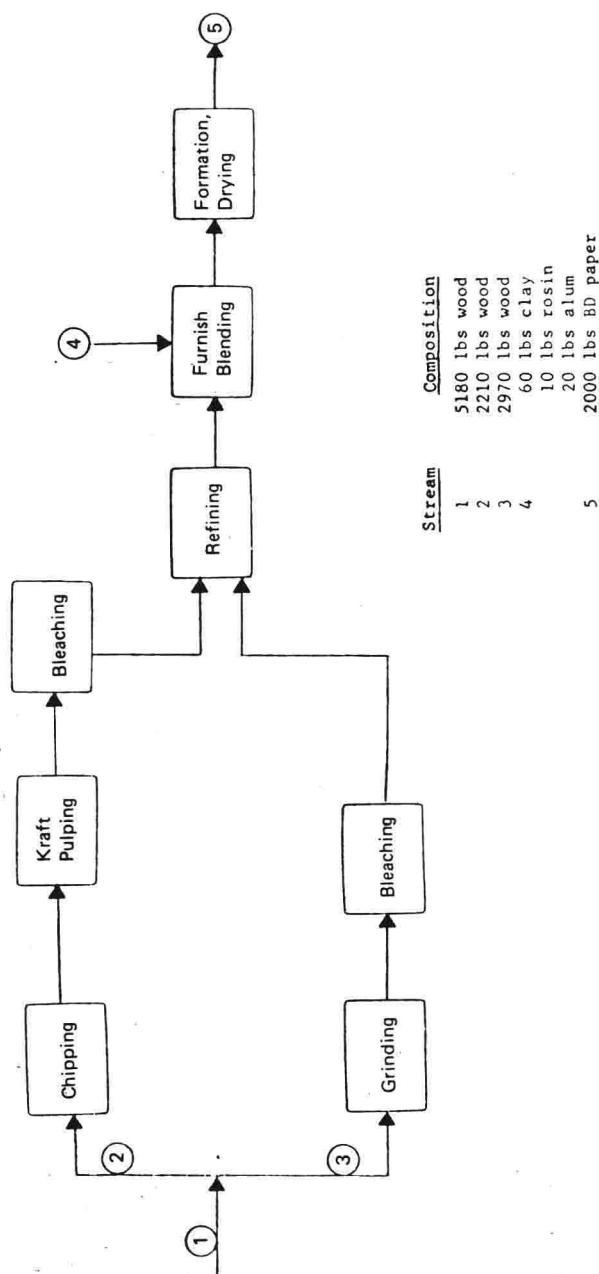
	----- Millions of Tons -----			
	1970.	1975	1980	1985
Newsprint	9.7	11.0	12.5	14.3
Groundwood paper	1.2	1.3	1.4	1.5
Book paper (total)	6.3	7.8	9.5	11.4
Coated	3.8	5.0	6.3	7.8
Uncoated	2.5	2.8	3.2	3.6
Fine Paper	3.1	3.7	4.6	5.6
Coarse and Industrial Paper	6.3	7.4	8.6	9.8
Sanitary and Tissue Paper	3.7	4.7	5.9	7.1
Construction Paper	1.7	1.8	1.9	2.0
Container Board	14.6	18.2	22.4	27.4
Bending Board (total)	7.1	8.4	9.9	11.6
Special Food Board	3.0	3.7	4.6	5.6
Folding Box Board	4.1	4.7	5.3	6.0
Building Board (total)	3.2	3.9	4.7	5.6
Insulating Board	1.4	1.6	1.8	2.0
Hardboard	1.8	2.3	2.9	3.6
Other Board	3.4	3.9	4.5	5.2

Source: Reference (7)

To deal adequately with the overall industry without generating an excessive number of subcategories, and for consistency with previous work, four subcategories of the paper industry were selected by Battelle (1). They are newsprint, writing paper, folding boxboard, and corrugated boxboard. In total, these 4 subcategories represent 71.4% of the industry production, and are typical of differences in processing and raw materials encountered in the paper industry. To further delineate the industry, the papermaking process was considered to begin with the first step of wood reduction (chipping or grinding) and to end as a finished product leaving the forming machine. Wood harvesting operations and paper finishing and converting operations were not included in the Battelle study.

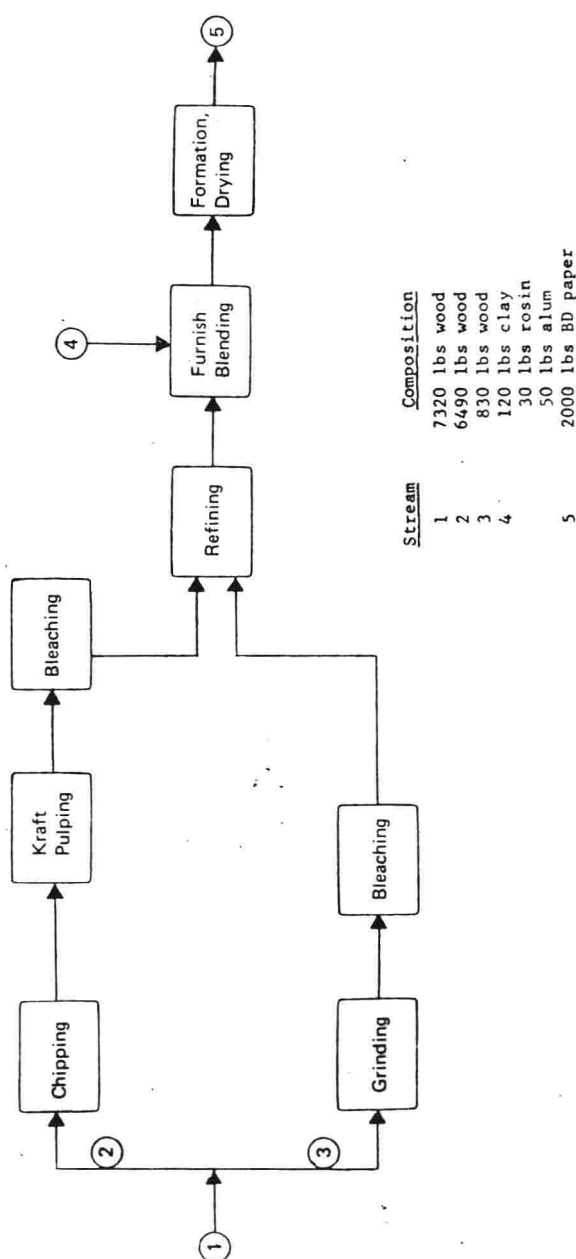
The papermaking process may consist of as many as 11 different processes, depending upon the final product. Flowsheets for 4 major paper industry subcategories are shown in Figures 1 through 4. These flowsheets show typical practice and are not intended to represent conditions existing at every plant.

FIGURE 1: NEWSPRINT



Source: Reference (1)

FIGURE 2: WRITING PAPER



Source: Reference (1)