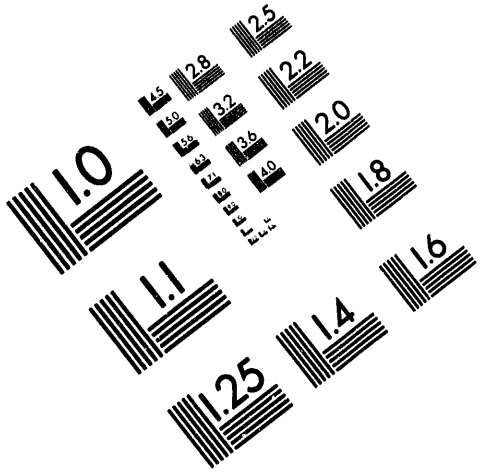

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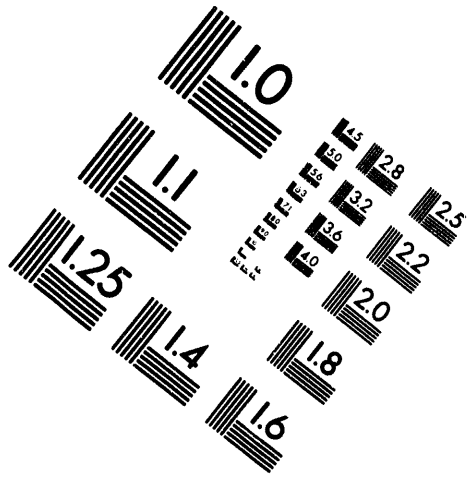

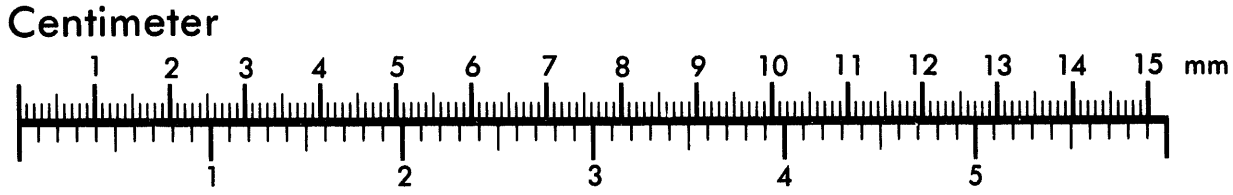

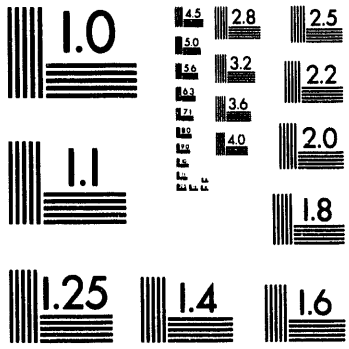

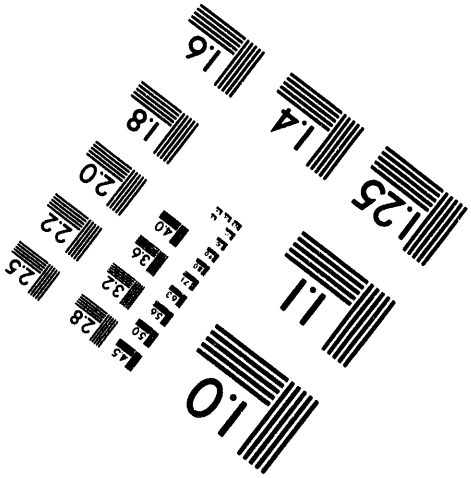

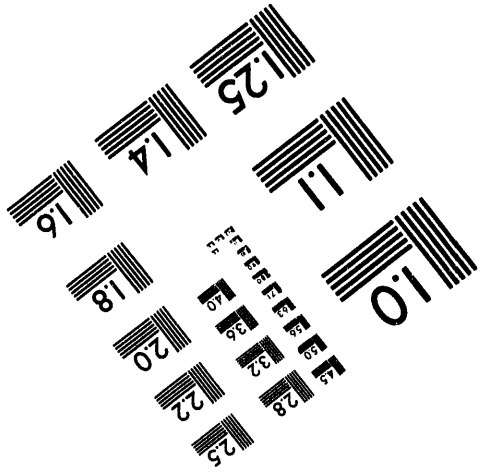

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Overview of a Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing

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SUMMARY

This report presents a synopsis of the presentations made at the two-day workshop conducted in Portland, Oregon, on August 12 and 13, 1993, for the Advanced Industrial Concepts Division (AICD) of the U.S. Department of Energy (DOE) Office of Industrial Technologies (OIT) and DOE national laboratory representatives from the pulp and paper industry. The information from the presentations is supplemented by additional statistics, as appropriate.

The workshop objectives were 1) to develop a strategy and framework for collaboration between the pulp and paper industries and DOE's national laboratories, 2) to identify major challenges to pulp and paper industry modernization, and 3) to identify research objectives for DOE national laboratories to improve materials and process technology in pulp and paper mills.

Prior to the workshop, participants had the opportunity to tour paper mills and gain familiarity with pulp and paper processing methods. During the workshop, research needs for materials and processing that were identified at earlier AICD workshops were reviewed. Major problems of the pulp and paper industry were addressed, and ways in which DOE national laboratories are interacting with other industries to foster innovation and solve problems were presented.

As a result of this and other workshops, a Pulp Paper Mill of the Future strategy is being developed to address challenges identified in these proceedings. Continued efforts are expected by AICD to match candidate materials and processes from DOE national laboratories with the technology needs of pulp and paper mills.

ACKNOWLEDGMENTS

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1.0 INTRODUCTION

The U.S. Department of Energy's (DOE's) Advanced Industrial Materials (AIM) Program requested that Pacific Northwest Laboratory (PNL) prepare and conduct a workshop to identify the most serious problems that inhibit efficient pulp and paper processing because of sub-optimal materials and equipment. The AIM Program will use the guidance provided from this workshop to develop priorities for fiscal year 1995 and beyond. This guidance is relevant for programmatic actions relating to AIM support for the Office of Industrial Technologies' (OIT's) Paper Mill of the Future.

A two-day workshop was conducted on August 12 and 13, 1993, in Portland Oregon, for the Advanced Industrial Concepts Division (AICD) of OIT and representatives from the pulp and paper industry. This workshop was the continuation of a process to assess the needs and opportunities for new and improved materials in the pulp and paper industry and to identify candidate materials and processing technology from the DOE national laboratories to meet those needs. The chronology of events to support the overall needs assessment are summarized in Table 1.1.

The workshop began with presentations by Stan Sobczynski and Charles Sorrell of DOE OIT and Peter Angelini of Oak Ridge National Laboratory (ORNL) on the issue of planning for the Pulp and Paper Mill of the Future, as well as AICD objectives and previous efforts. The second presentation, given by Richard Haynes of the U.S. Forest Service, was on critical problems that are facing the Pacific Northwest (PNW) forest products industry. Next, Margaret Gorog of Weyerhaeuser discussed general industry problems in corrosion, and Bob Giese of Giese and Associates discussed general industry problems in energy use. The final presentations were made by representatives of DOE national laboratories, the Institute of Paper Science and Technology (IPST), the University of Washington, and the Technology Development Center of Finland; each organization presented a brief review of their capabilities that may be of interest to the pulp and paper industry.

As a result of the events in Table 1.1, a program is being developed for AICD at ORNL to focus on improving materials and technologies for recovery boilers. The program includes studies of degradation mechanisms, improved technologies, and materials; evaluation of alternate designs and materials for boiler components; and manufacture and testing of components. Other DOE national laboratories are also focusing efforts on understanding pulp and paper industry needs.

Table 1.1. Activities to Define Areas of Interest to DOE and Industry

Event[a]	Time	Result
Guidance and Evaluation Panel meeting for the DOE AIM	June 1992	Work with pulp and paper industry.
IPST meeting with ORNL	November 1992	Preliminary identification of needs.
IPST and industry representatives meeting at ORNL	December 1992	Additional needs identified.
Draft report prepared	December 1992	
Pulp and Paper Mill of the Future in Washington, D.C.	January 1993	Draft report distributed for comment.
Workshop in Portland, Oregon	August 1993	All DOE national laboratories attended and exchanged information with pulp and paper industry.
Workshop in Orono, Maine	September 1993	All DOE national laboratories attended and exchanged ideas with pulp and paper industry.

(a) AIM = Advanced Industrial Materials Program
IPST = Institute for Paper Science and Technology
ORNL = Oak Ridge National Laboratory.

(Source: Presentation of Peter Angelini, ORNL, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.)

Sections 2.0 and 3.0 of this report describe DOE programs within the OIT that support technology development for the pulp and paper industry. Section 4.0 describes the paper industry perspective on technology needs in the areas of energy use and corrosion prevention, and references are found in Section 5.0. Appendixes A and B contain the workshop agenda and the workshop registration list, respectively. Appendix C is a list of the capabilities of DOE national laboratories and other organizations of potential interest to the pulp and paper industry. A list of suggested readings and information is provided in Appendix D.

2.0 PULP AND PAPER MILL OF THE FUTURE

During the past 12 years, DOE and industry have provided funding for the development of technologies that could have a significant impact on the energy efficiency, productivity, and environmental compliance of paper and paperboard manufacture.[a] The paper industry has played an important role in the guidance of this DOE research and development program.

DOE supports the U.S. pulp and paper industry because it is a large energy consumer. It consumes 12% of the nation's industrial energy, or 2.55 quads, of which 57% is internally generated. In 1992, this industry consisted of approximately 600 paper and board mills and 345 pulp mills located in 42 states, employing 627,000 people. The profitability of this industry is currently threatened by price declines, high capital expenditures for environmental protection, and increasing offshore competition. Other drivers for change in the pulp and paper industry include government regulations and policies such as the Clean Air Act, as amended in 1990, and the Energy Policy Act of 1992.

A new task is being undertaken by DOE as a result of the Energy Policy Act of 1992 to develop a more comprehensive and formalized strategic plan for DOE's paper program. This new plan, entitled Pulp and Paper Mill of the Future, will address the research and development (R&D) requirements of the paper mill of the future. The program will be responsive to industry needs. One goal involves enhancing technologies to become more cost-effective and less capital-intensive. The objectives will be to improve productivity and to reduce energy consumption. The environmental impact of current and future processing methods will also be reduced. The goal is to develop improved processing methods that will reduce effluents, air emission, and/or solid waste. The program will be structured to maximize the impact by leveraging industrial and other federal programs and will seek joint ventures with sustained efforts to introduce new technologies.

Critical technologies will be evaluated that will address the near-, mid-, and long-term needs of the paper industry and those that would best benefit from federal sponsorship. The identified technology needs should span from fundamental or basic research knowledge, to applied research and

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(a) The information in this section contains a synopsis of the presentation given by Stan Sobczynski, OIT, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993. (The actual text that was presented was first provided in *Draft — Materials Needs and Opportunities in the Pulp and Paper Industry*, for the Advanced Industrial Concepts Materials Program, dated January 28, 1993.)

development activities that encompass pilot plants or commercial demonstrations. The program plan will have a time-phased approach (see Table 2.1). In the near-term (to year 2000), where appropriate, the goal will be to demonstrate particularly attractive technologies that are currently available but are not fully utilized. In the mid-term (to year 2010), the goal will be to refine existing laboratory-scale concepts and develop these technologies with pilot-scale demonstrations. For the long-term (to year 2020), the goal will be to develop completely new processes and materials and focus on areas with substantial energy savings potential.

The program will focus on four general process areas including 1) chemical pulping and recovery, 2) mechanical pulping, 3) papermaking, and 4) advanced processes and systems that reduce environmental impact. Meeting industries' needs in these areas will promote a vision of future pulp and paper mills that have reduced environmental impact and are more energy self-sufficient than current mills. This vision is summarized in Table 2.2. An example where the DOE hopes to provide assistance to the industry includes using fiber sources that are much more variable and eliminating chlorine from the bleaching process. DOE's Pulp and Paper Mill of the Future initiative seeks to ensure that this vision becomes a reality through cooperative R&D with industry.

Table 2.1. Pulp and Paper Mill of the Future: OIT Program Impacts

Near-term (by 1996)	Energy savings goal: 0.05 quad/year
	Commercially demonstrate black-liquor-pulsed combustion gasification process
	Complete pilot-scale paper impulse drying studies
	Apply particle-size distribution sensor in industry
	Use black-liquor physical property database for paper mill design and plant operations
	Demonstrate dynamic paper simulation model for thermomechanical pulping
	Commercialize improved black liquor nozzle systems for Tomlinson recovery boilers
Mid-term (to year 2010)	Energy savings goal: 0.15 quad/year
	Implement global model for conventional black-liquor recovery system
	Commercialize technology for high solids (85% firing of black-liquor)
	Commercialize technologies to improve the energy efficiency of mechanical pulping
	Initiate industrial application of biopulping (enzymatic treatment of wood chips to increase pulping rate and quality)
	Commercialize nonchlorine pulp bleaching processes (such as ozone)
	Apply impulse drying technology in industry
Long-term (to year 2020)	Energy savings goal: 0.4 quad/year
	Introduce new, sulfur-free pulping technology using anthraquinone produced from lignin
	50% market penetration for gasification technologies (black liquor, biomass, and sludge).

(Source: Presentation of Stan Sobczynski, OIT, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.)

Table 2.2. Industrial Vision of the Future

Characteristics	High productivity
	Energy-efficient
	Flexible, retrofitable, and modular
	Environmentally acceptable
	Low capital cost per unit production
Energy	50% implementation of combined cycle power generation by the year 2010
	Net exporters of electricity
	Fuel-oil use eliminated
	Natural gas use will increase with combined cycle implementation
Environmental	Trend toward zero discharge
	Eventually becoming "environmentally invisible"
	Elimination of chlorine for pulp bleaching
	Implementation of new, environmentally acceptable bleaching technologies
	Fiber shift from natural to recycled
	Odor-free mills
	Over 50% waste paper recovery rate by year 2020
Economics	Trend toward energy self-sufficiency in Kraft mills
	Maintained paper quality with increased recycling rate

(Source: Presentation of Stan Sobczynski, OIT, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.)

3.0 ADVANCED INDUSTRIAL CONCEPTS MATERIALS PROGRAM

The AICD is an organization within the DOE Office of Energy Efficiency and Renewable Energy (see Figure 3.1).[a] The mission of AICD is to develop and maintain a balanced program of research and development focused on high-risk, long-term, directed interdisciplinary research efforts for the industrial sector. The goal of this research is to impact the industrial sector by improving energy efficiency, enhancing fuel flexibility, and minimizing waste. AICD is responsible for identifying, supporting, and transferring the results of research and providing evidence of technical feasibility of advanced industrial concepts in the areas of combustion, heat transfer, thermodynamics, mechanics, energy conversion, bioprocessing, electrochemistry, materials processing, and chemistry.

The AIM Program supports the AICD mission, providing attention to materials engineering in the context of goals, needs, and opportunities for advanced industrial systems. The AIM initiates and conducts applied research and exploratory development in eight technical work areas encompassing the general themes of advanced materials and materials processes. The program is developing partnerships with industry to identify materials needs and opportunities, conduct cooperative research and development, and transfer technology to industry for commercialization. Specific projects currently being funded are listed in Table 3.1. The goal of the workshop was to link these and other research projects to the materials-related needs of the pulp and paper industry.

(a) The information in this section contains a synopsis of the presentations given by Charles Sorrell and Peter Angelini, OIT, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993. (The actual text that was presented was first provided in *Draft — Materials Needs and Opportunities in the Pulp and Paper Industry*, for the Advanced Industrial Concepts Materials Program, dated January 28, 1993.)

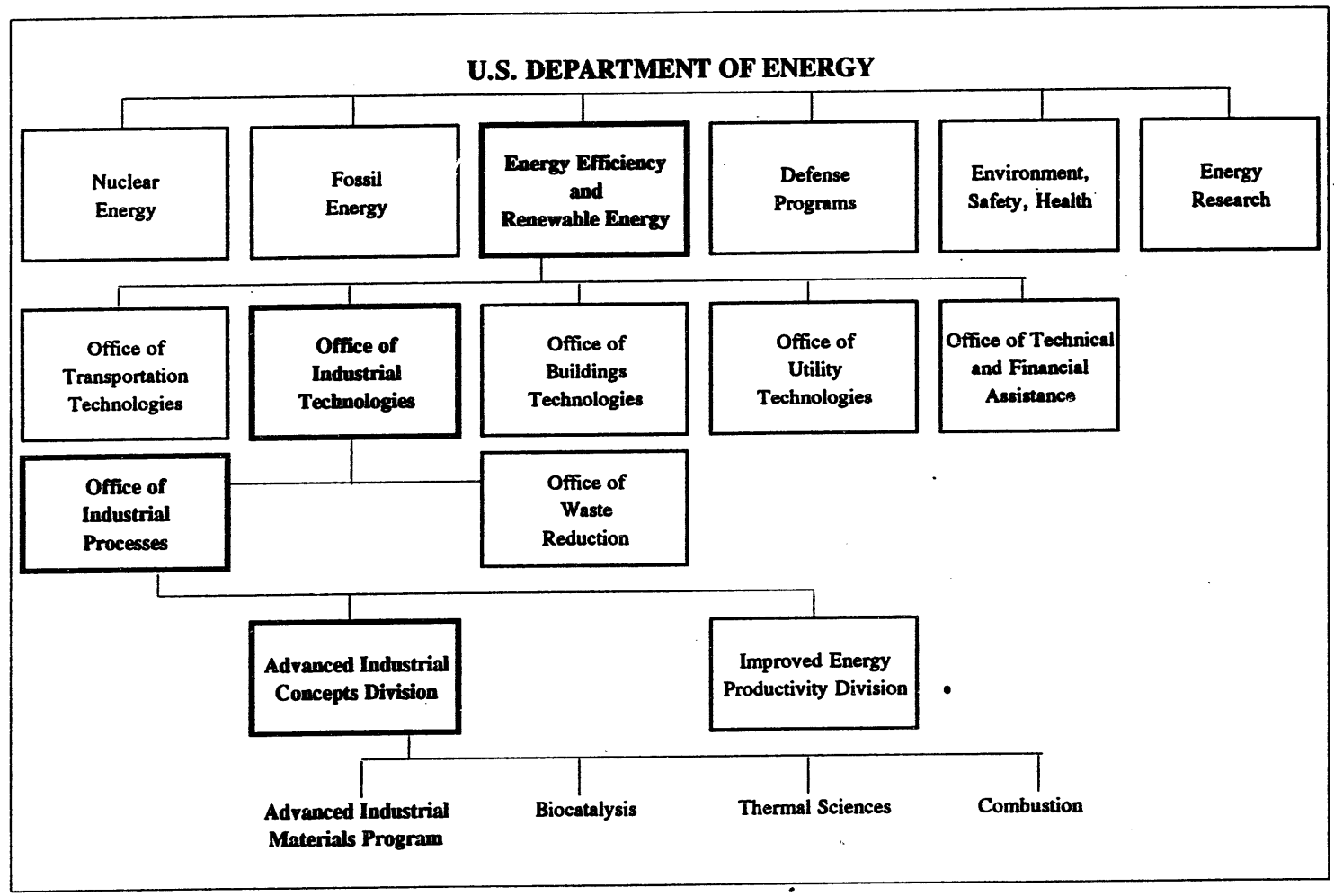

Figure 3.1. Organization of DOE

Table 3.1. Advanced Industrial Materials Program Projects[a]

Advanced ceramics and composites	In situ composites - SNLA
	Aerosphere insulation - Georgia Tech
	Silica aerogel insulation - LBL
	SiC powder synthesis - NREL
Advanced metals and composites	Intermetallic alloys and composites - ORNL, LANL
New materials and processes	Microwave processing - ORNL, LANL
	Conducting polymers - LANL
	Chemically specific thin films - SNAIL
	Magnetic field processing - INEL
	Biomimetic coatings - PNL
Polymers and biobased materials	Recycling of plastic wastes - NREL
	Biobased materials - NREL
	Magnetic field processing - LANL
	Surface modification - ORNL

(a) SNLA = Sandia National Laboratories, Albuquerque, New Mexico
LBL = Lawrence Berkeley Laboratory, Berkeley, California
NREL = National Renewable Energy Laboratory, Golden, Colorado
ORNL = Oak Ridge National Laboratory, Oak Ridge, Tennessee
LANL = Los Alamos National Laboratory, Los Alamos, New Mexico
SNLL = Sandia National Laboratories, Livermore, California
INEL = Idaho National Engineering Laboratory, Idaho Falls, Idaho
PNL = Pacific Northwest Laboratory, Richland, Washington.

(Source: Presentation of Charles Sorrell, OIT, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.)

4.0 PULP AND PAPER INDUSTRY PERSPECTIVES

4.1 BACKGROUND

Almost 88% of the Pacific Northwest (PNW) region is typified by softwood Douglas fir forest reserves, and 12% of PNW timberland is hardwood, primarily the red alder species. Most of the PNW forests (approximately 80%) are on publicly owned timberlands, characterized by steeper, higher elevation terrain. The remainder of forest reserves are on extensive private plantations established in the PNW beginning in the 1940s.

Market pulp, lumber, and commercial logs are the primary products produced from PNW timber. Since the 1960s, PNW participation in log trade with Pacific Rim countries has been significant. This participation has grown throughout the last three decades, particularly with Japan and Korea. Log transactions across the ocean are particularly viable due to the low cost of ocean transport; moving a truckload of logs on the highway costs $4.50 per mile and on the ocean costs $0.09 per mile.

In 1989, intense public concern developed over exports of logs from federal forest lands and the impact of poor logging practices on spotted owl and salmon populations[a]. These trends were resulting in significant declines in PNW timber supplies (particularly of old-growth timber). In fact, the PNW was the only region in the United States where the rate of softwood removal exceeded the rate of softwood growth by as much as 20%. This has resulted in a significant percentage of forest land being removed from the timber harvest inventory.

Lack of log inventory is limiting the growth and profitability of many PNW forest product industries. For example, the PNW paper and allied products industry is subject to increased domestic pulpwood prices and reduced pulpwood availability (Flora et al. 1991).

4.2 PACIFIC NORTHWEST PULP AND PAPER INDUSTRY EMPLOYMENT

The PNW economy is highly dependent on the forest industry. The forest products industry accounts for 24% of all PNW employment in manufacturing. Approximately 20% of employment in forest products is the result of pulp and paper production, thus, pulp and paper production accounts for about 5% of all PNW employment in manufacturing. Employment for the paper and allied products industries in the PNW region totals about 71,000 people (see Table 4.1). Most of the

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(a) The Columbia River once provided passage for 16 million salmon a year; however, Pacific salmon now number less than 1.5 million. While large dams are cited as the single largest factor in salmon decline, habitat degradation due to logging exacerbated the situation.

employment relating to pulp and paper in the PNW region is concentrated in mills located in Washington, Oregon, and northern California (see Table 4.2).

Declining fiber supply is a big concern in the PNW. Softwoods are the preferred species group for the production of pulp and paper products, but these supplies are slowly declining because of removal rate that exceeds annual softwood growth. The PNW pulp and paper industry must also compete with saw board and other timber industries for softwood raw materials (see Figure 4.1). Higher costs are incurred by pulp and paper mills in the PNW for the softwood that is available because of frequent supply shortages due to the growing domestic demand and a lucrative export market for lumber.

The PNW's supply of hardwood is limited compared with other regions, and, unfortunately, the use of hardwoods is increasing throughout the pulp and paper industry. Approximately 90% of hardwood timber stock is in the eastern United States, with the remaining 10% located on the Pacific Coast (Haynes 1990). Lack of hardwood forest reserves will result in a competitive disadvantage for PNW paper mills compared with mills in the southern United States. Hardwood improves the stiffness of paperboard products and increases the quality of printing and writing papers. Hardwoods are projected to comprise 41% of total pulpwood use by the year 2040, compared with 31% in 1986.

Today and in the future, the challenge for PNW pulp and paper producers is to make optimum use of available softwood and hardwood timber stocks. One trend is that the PNW is gradually shifting toward using recycled fiber to produce more paper from available wood chips. This shift

Table 4.1. Pacific Northwest Employment in Paper and Allied Products Industry, 1991

State	Number of Employees (thousands)
Alaska	0.9
California	40.8
Idaho	2.4
Oregon	9.3
Washington	17.9
(Source: Warren 1992.)	

Table 4.2. Pulp and Paper Mills Tabulation

Location	Paper Mills	Pulp Mills[a]
Alaska		2
California	33	10
Idaho	2	1
Oregon	18	23
Washington	19	26

(a) Wood pulp mills are usually connected to paper and board mills.

(Source: Miller Freeman Publishers 1992.)

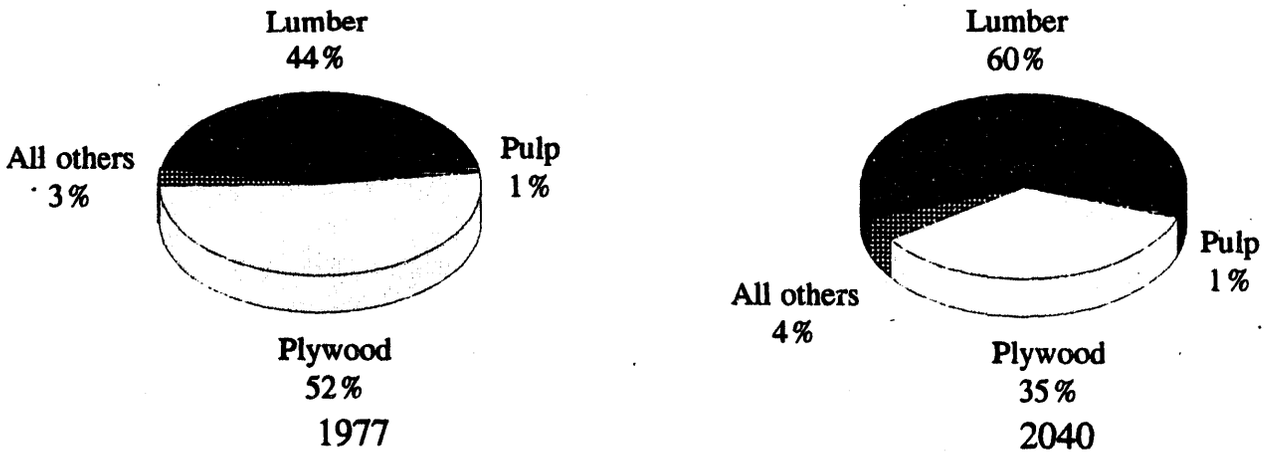

Figure 4.1. Long-Term Trends in the Demand for Softwood Products (Source: Presentation of Richard Haynes, Pacific Forest Products Laboratory, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.)

results in more extensive use of thermomechanical pulping (TMP) in the PNW than in the rest of the country. TMP also helps the PNW eliminate dioxin from industry waste streams; however, TMP favors the production of lower-quality paper stock with reduced whiteness. Cost competition for the low-quality grades is fierce, with countries such as Brazil often offering lower prices to mills. Thus, the profitability of TMP mills is difficult to maintain, so there is a significant incentive for reducing energy consumption.

Most of the growth in the domestic market is in high-quality papers, tailored to meet specified customer requirements. These drivers favor another shift in the PNW infrastructure — from large, integrated mills, to an infrastructure of "mini-mills" located near end users and utilizing local fiber sources and recycled fiber. This shift in infrastructure is occurring in the PNW as well as other regions, which results in the shutdown of aging plants and the commensurate displacement of workers.

As aging plants close, a big challenge for the PNW will be to maintain jobs. Part of this challenge includes increasing the quantity of value-added products, such as paper manufactured in the PNW. Today, the PNW pulp and paper industry exports mostly wood pulp and waste paper to the Pacific Rim countries. Exports of paper-grade pulp from the PNW have increased significantly over the past decade, as shown in Table 4.3. Exports of raw materials, such wood pulp and waste paper, result in regional revenues, but these exports also mean lost employment opportunities from the manufacture of value-added paper products. The PNW requires clean, lower cost, energy-efficient technology in papermaking to be cost-competitive in world markets.

4.3 TECHNICAL PROBLEM AREAS

Many technical and economic factors must be addressed to increase the long-term viability of the mills in the PNW region. Technical areas for further evaluation discussed at the Portland workshop included 1) the need for innovations to reduce materials-related corrosion and wear, and 2) energy-use trends driving new capital investments.

Table 4.3. Volume of Paper Grade Pulp Exports from Seattle and Columbia-Snake Customs District

Year	Volume (in thousand short tons)
1982	319
1983	438
1984	446
1985	440
1986	548
1987	554
1988	609
1989	772
1990	542
1991	599
1992	503
(Source: Warren 1992.)	

4.3.1 Corrosion[a]

Corrosion is a serious problem for the pulp and paper industry, representing 25% to 30% of all maintenance costs. Corrosion problems have been dramatically compounded in recent years because of the switch to nonchlorinated bleaching and the closing of the mill.

Corrosion control in today's mills focuses primarily upon inspection and maintenance. To prevent corrosion, mill staff will need a better understanding of the performance of materials and the factors leading to corrosion. An example of how one company, Weyerhaeuser, works to combat the deleterious effects of corrosion is summarized in Table 4.4.

Serious corrosion problems occur in digesters, recovery boilers, and paper machines. The majority of failures caused by corrosion are related to welds in process equipment. In continuous

(a) Source: Presentation of Margaret Gorog, Weyerhaeuser Paper Company, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.

Table 4.4. Corrosion-Related Activities at Weyerhaeuser Pulp and Paper Mills

Type of Activity	Cost ($1,000)	Specific Actions
Predictive	$12,300	Inspection of digesters, recovery boilers, de-aerators, pressure vessels, tanks, and piping
		Coating surveys
		Corrosion monitoring (coupons and probes)
		Corrosion scans
		Materials evaluation
		Metallographic analysis
Preventative	$15,600	Coatings under insulation
		Cleaning stainless steel deposits
		Anodic protection
		Boiler feedwater treatment
		Material selection
		Process design (cavitation)
Restorative	$42,000	Weld overlay
		Metal spray
		Clean and re-coat
		Tile repointing
		Concrete/rebar
Replacement	$42,100	Piping
		Roof systems
		Tile linings
		FRP pipe and hoods
		Recovery furnace and walls
		Precipitator rebuilds
Total spending for corrosion = $112,000 Total spending for maintenance = $381,000		

(Source: Presentation of Margaret Gorog, Weyerhaeuser, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.)

digesters, stress corrosion cracking occurs in the upper zones and the lower walls are susceptible to rapid thinning. Past experience indicates that inconel overlay and anodic protection are not always optimal corrosion control methods. Corrosion is often found in composite boiler tubes and severe pitting often occurs in the boiler scrubbing systems. There is stainless steel under-deposit corrosion in paper machines.

Relying on the metallurgical information provided by the suppliers has proven unreliable in past years. There are several new materials available, but the paper industry is reluctant to invest in new technologies or materials without adequate performance data. Samples of new materials must be obtained and tested to give users confidence that investments in these new materials are warranted.

Specific priorities identified by workshop participants in the area of corrosion are as follows:

- electronics coatings
- chloride monitoring as an adjunct to mill closure
- better understanding of digester welding, base materials and coatings, and inspection needs
- better understanding of effects of new processes on materials
- standardization of welding practices (currently, each mill performs this differently)
- open communication on recovery boiler problems
- new materials testing (i.e., duplex ss and others)
- acid cleaning inhibitors
- better coatings and paint
- predictive analysis
- development of specifications for purchasing, design, and inspections in welding and pressure vessels
- sensors to detect wear problems in mechanical refiner plate
- automated systems for process monitoring and control.

4.3.2 Energy-Related Issues[a]

Energy use estimates for a typical Kraft pulp and paper mill are summarized in Table 4.5. Note that the paper machine, pulping, and bleaching operations use the most energy. For a plant using

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(a) Source: Presentation of Robert Giese, Giese and Associates, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.

Table 4.5. Energy Flows in an Integrated Kraft Mill

Unit Operation	% of Total
Pulping	14
Washing	3
Refining	10
Bleaching	14
Paper machine	36
Evaporators	9
Lime kiln	7
Power plant	4
Space heating	3
Recovery furnace	37 (produced)
Bark	15 (produced)
(Source: Hersh 1981.)	

chemical pulping, purchased electricity is less than 7% of energy use with more than 50% as self-generated. Costs of purchased fuels and electricity represent about 9.0% of the value of the shipment.

A TMP mill uses about 40% less energy for pulping and bleaching than the Kraft process. However, TMP pulping and bleaching operations consume about five times more electrical energy than the Kraft process. This energy must be purchased because little by-product energy is available.

The PNW has been an optimum location for TMP plants in the past because of low energy costs. Hydropower has sustained the PNW electric system for more than a century, with supplements from nuclear, coal, and transmission imports. In Washington and Oregon, over 40% (or ten times the national average) of electricity is currently generated from hydroelectric power plants. In June 1993, the average price of electricity sold to industrial consumers in the United States was 5.0 cents per kilowatt-hour (kW/hr). In the PNW, the average price of electricity is as little as 2.0 cents per kW/hr (Energy Information Administration [EIA] 1993a, 1993b).

Further hydroelectric resources are likely to be developed in the PNW because of public concerns about its effect on salmon and other wildlife populations. As a result, the cost of energy for PNW

pulp and paper mills will likely increase, further affecting the profitability of paper mills in the PNW region. Cogeneration is emerging as a leading PNW energy resource, with much of it fueled by natural gas. At current natural gas prices, the average cost of this resource is about 3.3 cents per kW/hr (NewsData Corporation 1993), but natural gas prices are increasing because of rising demand. This means that in the future, the PNW may be paying prices for energy that are closer to the national average. This trend will most strongly impact the profitability of the TMP mills and could limit growth of TMP for the region.

These energy and technology trends provide the PNW with significant incentive to increase energy efficiency. Several energy-efficiency measures that can help the profitability of PNW industries were identified at the workshop. These include

- high-efficiency drying
- combined cycle cogeneration systems
- recovery of low-grade waste heat
- optimization and control strategies for boilers and other equipment
- improved technology for gasification of biomass, black liquor, and process residues
- more efficient motor systems.

Much of this is available technology, but testing of test-bed prototype equipment is needed to prove the performance in the mill environment. Demonstration projects could include joint efforts between industry, DOE national laboratories, the Electric Power Research Institute, DOE's Office of Fossil Energy, and DOE's Office of Energy Efficiency. Utilities should be made aware of the energy needs of the PNW pulp and paper industry, which would allow the utilities to make funds accessible to encourage energy conservation in pulp and paper mills.

4.4 GUIDELINES FOR PARTNERSHIPS

According to workshop participants, the future looks promising for R&D partnerships between paper companies, DOE national laboratories, and vendors. The local electric and gas utilities are also potential partners because of their interest in maintaining demand for their energy resources. The Finnish Paper Research Institute expressed an interest in ideas for joint projects, but research areas of mutual interest must be better defined.

The benefits of these partnerships include the leveraging of industry and government R&D resources to improve international competitiveness of U.S. firms and accessing the capabilities of the

23,000 researchers and the $6.5 billion budget of the DOE national laboratory system. Mechanisms for partnerships with DOE national laboratories include Cooperative Research and Development Agreements (CRADAs), Memorandums of Understanding (MOU), use of DOE user facilities such as the High-Temperature Materials Laboratory at ORNL, and programmed procurements. The features of the agreements are summarized in Table 4.6.

Paper industry representatives attending the Portland workshop indicated that their mill personnel do not understand the capabilities of DOE national laboratories. Staff at DOE national laboratories must gain familiarity with normal mill operations and operational problems. Technical discussions with corporate R&D staff, mill managers and staff, and marketers of pulp and paper products will lead to a greater mutual awareness of existing problems and potential solutions. Actions are needed to enlist a wide range of DOE national laboratory and mill staff to discuss problem areas of current interest. In addition, DOE representatives must meet with executives from paper and vendor companies to get "top down" commitment for this partnership.

Table 4.6. DOE Agreement Framework

Feature	CRADA	User Facility		MOU	Programmed Procurement
		Open	Closed		
Contracting speed	3-6 months	3 months	4 months	4 months	12-20 months
IP protection	5 years	NA	17 years	Self	Government-use license
Facility access	Yes	Yes	Yes	Limited	Limited
Lab expertise	Yes	Yes	Yes	Yes	Limited
Cost share	Yes	Own	All	Own	Variable
Industrial influence on R&D agenda	Heavy	Yes	No	Limited	Yes
Degree of collaboration	Great	Medium	None	Great	Small

(Source: Presentation of Duane Deonigi, PNL, at the Government/Industry Workshop on Opportunities for New Materials and Processes in Pulp and Paper Processing, in Portland, Oregon, August 12 and 13, 1993.)

Establishing a government/industry partnership with the pulp and paper industry requires forums for first-hand exchange of knowledge about the mills and their problems on an ongoing basis. Recommended forums include the conferences and roundtables sponsored by the Technical Association of the Pulp and Paper Industry, the Paper Industry Management Association, National Association of Combustion Engineers, American Forest Products Association, Paprican, Institute of Paper Science and Technology, and the Electrochemical Society.

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APPENDIX A

WORKSHOP AGENDA

APPENDIX A

WORKSHOP AGENDA

Government/Industry Workshop on
Opportunities for New Materials and Processes
in Pulp and Paper Processing

August 12, 1993

TOURS – Non-paper industry participants -- General mill tours are intended for workshop participants who wish to be introduced to and gain familiarity with pulp and paper process methods. Northwest paper mill participants should attend in the afternoon.

Location: Portland Downtown Holiday Inn

7:00 a.m. LEAVE FROM DOWNTOWN PORTLAND HOLIDAY INN LOBBY FOR LONGVIEW, WA -- Prior reservation only, meet at Portland Downtown Holiday Inn Lobby at 7:00 a.m., or drive on your own.

Location: Longview, WA -- see map

8:30 a.m. - 11:00 p.m. TOUR OF LONGVIEW FIBRE

11:15 - 12:30 p.m. TOUR OF NORTH PACIFIC PAPER (NORPAC)

1:00 - 2:00 p.m. RETURN RIDE/BOX LUNCH

WORKSHOP SESSION BEGINS -- All

Location: 3rd Floor, 500 NE Multnomah (across from Lloyd Center and Portland Downtown Holiday Inn)

2:00 p.m. INTRODUCTIONS/AGENDA
(Joan K. Young, Pacific Northwest Laboratory)

2:15- 2:45 p.m. REVIEW OF PAPER MILL 2020 INITIATIVE
(Stan Sobczynski, U.S. Department of Energy)

2:45 - 3:00 p.m. WELCOME/Advanced Industrial Materials Program Objectives
(Charles A. Sorrell, U.S. Department of Energy)

3:00 - 3:45 p.m. REVIEW OF PREVIOUS AICD EFFORTS — Candidate Materials and Processes
(Peter Angelini, Oak Ridge National Laboratory)

3:45 - 4:15 p.m. GENERAL INDUSTRY PERSPECTIVE — General Trends in Pulp and Paper Production (Richard Haynes, U.S. Forest Service)

4:30 - TOUR OF OLD GROWTH STAND (1 hr. & 20 min. away, some van space 8:00 p.m. available with prior notice. We will stop for dinner in route.)

August 13, 1993

8:00 a.m. COFFEE/INTRODUCTIONS[a]

8:15 - 9:15 a.m. PAPER INDUSTRY/SUPPLIERS PERSPECTIVE (cont'd.) — Corrosion, Wear, and Other Problems in the Pulp and Paper Process Technology (Weyerhaeuser, Boise Cascade, James River, Simpson, Mead Corporation, others)

9:15 - 10:30 a.m. OPEN DISCUSSION — All paper mill participants have the opportunity to discuss problems and technical concerns.

10:30 - 11:45 a.m. DOE NATIONAL LABORATORY CAPABILITIES

- Battelle Pacific Northwest Laboratory, Energy and Materials Programs (Bill Samuels)
- Oak Ridge National Laboratory, Advanced Industrial Materials Program (Peter Angelini)
- Sandia National Laboratory, Programs (Bob Carling)
- Idaho National Engineering Laboratory, Programs (Bob Neilson)
- Los Alamos National Laboratory, Programs (Gerald Maestas)
- National Renewable Energy Laboratory, Programs (Helena Chum)
- Other

12:00 p.m. LUNCH PRESENTATION — CRADAs and Working with the DOE National Laboratories

1:00 - 2:30 p.m. DOE NATIONAL LABORATORY CAPABILITIES (contd.)

2:30 - 4:30 p.m.

- Finnish Pulp and Paper Industry (Christina Hagstrom-Nasi, TEKES)
- Pulp and Paper Research at IPST Engineering and Paper Division (David Orloff, Institute of Paper Science and Technology)

4:30 - 5:00 p.m. DISCUSSION/WRAP-UP

(a) Breaks taken as time permits.

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WORKSHOP REGISTRATION LIST

APPENDIX B

WORKSHOP REGISTRATION LIST

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APPENDIX C

CAPABILITIES OF DOE NATIONAL LABORATORIES AND OTHER ORGANIZATIONS OF POTENTIAL INTEREST TO THE PULP AND PAPER INDUSTRY

APPENDIX C

DOE NATIONAL LABORATORY AND OTHER CAPABILITIES OF POTENTIAL INTEREST TO THE PULP AND PAPER INDUSTRY

The following tables list the capabilities of DOE national laboratories and the capabilities of other organizations that may be of interest to the pulp and paper industry. This information was presented during the workshop by the individuals that are listed as the respective contacts.

Pacific Northwest Laboratory (PNL) Technologies/Capabilities
COATINGS Biomimetic • New way to control crystal growth and ceramic microstructure • Ability to combine incompatible materials • Aqueous process; no hazardous waste • Inexpensive ceramic coatings applied to complex shapes Sputter coating • Improved erosion/corrosion resistance • Little size limitation Web coating • Preparation of multi-layered materials
CORROSION Stress corrosion studies for nuclear power industry • Material microstructure and microchemistry • Degree of sensitization • Impurity segregation • Dislocation density • Material condition Environmental conditions • Oxygen content • Potential solution impurities • Temperature Sputter coating • Improved erosion/corrosion resistance • Little size limitation

Pacific Northwest Laboratory (PNL) Technologies/Capabilities (contd.)
ENVIRONMENTAL TESTING Controlled atmospheres Controlled liquids Temperatures to 1700°C Tensile testing 4-point bend testing Fracture toughness testing
WASTE TREATMENTS Thermochemical environmental energy system Waste acid detoxification and reclamation process
BARRIER MATERIALS Controlled-release delivery systems • Long-term controlled exposures • Single- or multi-agent controlled exposure • Zero-order or constant-level release • Good dose control • Decreased sample handling/less exposure hazard • Lower administration costs
ELECTRO-OPTICS AND SENSORS Optical and acoustic holography FTIR spectroscopy X-ray fluorescence spectroscopy Ultrasonics Optical fibers Photovoltaic devices
PROCESS OPTIMIZATION Nondestructive testing • Testing programs designed to establish preventative maintenance in nuclear power industry Sensor development and control • Concept generation • Breading boarding/feasibility demonstration • Fieldable prototype (with service support) • Transfer to manufacturing company

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Idaho National Engineering Laboratory (INEL) Relevant Areas of Expertise

ENVIRONMENTAL BIOTECHNOLOGY

Subsurface microbiology
- Deep terrestrial drilling, sampling, and tracer technologies
- Characterization of microorganisms from deep subsurfaces

Microbial phosphate solubilization
- Microbiology of phosphate solubilization
- Development of bioreactors for microbial phosphate solubilization

Molecular genetics and biochemistry
- Molecular mechanisms of bioadhesion
- Genetic engineering of biomining bacteria
- Isolation/genetic characterization of coal desulfurizing bacteria
- Biosensors
- Molecular characterization of coal desulfurizing bacteria
- Biocatalysis by design

Biotechnology for conversion of renewable feedstocks to chemicals

Biodegradation and bioconversion of toxic organics
- Contaminated soils and groundwater
- Industrial effluents

MATERIALS CHEMISTRY

Phosphazene polymer membranes and structures
Electrochemical processing of materials and wastes
Chemical sensors for environmental applications
Catalysis development and applications
Chemical waste treatment and minimization

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Los Alamos National Laboratory (LANL) Technology Capabilities
ENVIRONMENTAL AND WASTE MANAGEMENT Zero air emissions systems design and control engineering LIDAR air emissions monitoring systems Totally closed and recycled radioactive waste systems design and engineering Organic and acidic waste supercritical oxidation processing Plasma processing of exhaust streams New catalysts for NO_X and SO_X reduction in exhaust streams Environmental fate modeling and analysis of discharged chemicals
COMBUSTION TECHNOLOGIES Combustion cycle modeling and advanced combustor design Combustion process control Fluidized bed combustion modeling Burner and combustion chamber high-temperature materials Combustion on line diagnostics and controls Modeling of particulate trapping and flue gas scrubbing Ceramic heat pipe recuperators
SENSOR TECHNOLOGIES LIDAR monitoring of air above plants Smart Skin sensor technology Fiber optic chemical concentration sensors Neural Net/Fuzzy Logic data monitoring and analysis Resonant ultrasound for defect detection and structural change analysis
MATERIALS TECHNOLOGIES Corrosion resistant high temperature metal and metal alloy development Nickel and titanium alloy corrosion technology Hard, wear-resistant alloy development Corrosion modeling and microanalysis Low-cost, high-temperature, high-strength ceramic oxides and silicides Plasma-ion conformal coatings for surface hardening and coating
BIO-TECHNOLOGIES Bio-system take-up of heavy metals Bio-catalysis of toxic organics Genome mapping Genetic engineering of cotton fibers and cotton plant components

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Sandia National Laboratory (SNL) Technologies/Capabilities

MATERIALS AND PROCESS

Corrosion research and mitigation technologies
Aging/degradation of materials
Performance of materials in extreme environments
Packaging of electronics for extreme environments
Advanced ceramics for corrosive environments
Functional coatings technologies
Welding/joining of materials
- materials selection/materials effects/weld critical materials

Process simulation/characterization/design/optimization/control
Sensors and microsensors
Optoelectronic systems
Process waste reduction R&D
Materials analysis and characterization
- applications/advanced methods

COMBUSTION SCIENCE AND TECHNOLOGY

Combustion Research Facility (a DOE-user facility)
Burner Engineering and Research Lab (a DOE/GRI user facility)
- utility burner design and optimization
- burner characterization
- real time sensors/diagnostics/control

Biomass combustion R&D
Mechanisms of deposit formation in boilers/mitigation technologies
Fouling/ ashing research and mitigation
Combustion systems control and optimization
- for maximum energy efficiency
- for minimum emissions

Coal combustion
Advanced sensors and diagnostics for combustion
Pulsed combustion research/development/application

SYSTEM ENGINEERING

System design/modeling/demonstration
- Manufacturing systems and subsystems
- Electric power systems

Pressure vessel engineering
- design/simulation/manufacturing processes/qualification

Nondestructive evaluation
- applications/advanced methods development

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University of Washington Pulp and Paper Research Activities
Surface and colloid science of papermaking Improved de-inking in recycling operations Stability of flexographic inks in water
Process simulation and control Process models of the pulp mill to study improvements in quality and efficiency
Effluent-free pulping and bleaching Investigating methods of produce more uniform pulp Various projects underway to investigate the consequences of large-scale recycling in the pulp mill include the effect of build up of various metals on the pulping and bleaching performance and the development of cheaper and more environmentally sound chelating agent to remove these metals
Use of diverse fiber sources for the production of pulp and paper Study of the pulping characteristics of wheat straw and the possibility of using recycled, old, corrugated containers for the production of bleached paper

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Institute of Paper Science and Technology - Overview

CHEMICAL AND BIOLOGICAL SCIENCES DIVISION

Areas of technical expertise

- Forest biology
- Wood chemistry
- Pulping processes
- Bleaching processes
- Kraft chemical recovery
- Corrosion

Highlights of recent research accomplishments

- Forest biology
  - Growth of hardwood seedlings from leaf cultures
  - Growth of softwood seedlings from single cells
- Wood chemistry
  - New pulping catalyst using wood as a raw material
  - Understanding of how cellulose structure inhibits degradation during pulping and bleaching
- Pulping and bleaching
  - Effect of bleaching variables on dioxin formation
  - Use of pretreatment to improve oxygen bleaching
- Kraft chemical recovery
  - Droplet formation with black liquor injections
  - Complete furnace model development
- Corrosion
  - Measurement of fireside corrosion in recovery boilers

Institute of Paper Science and Technology - Overview (contd.)

ENGINEERING AND PAPER MATERIALS DIVISION

Areas of technical expertise

- Papermaking
  - Fluid dynamics
  - Pressing and drying
  - Coating processes
  - Recycle utilization
- Paper physics
  - Strength of composite structures
  - Sensors
- Converting
  - Performance packaging
  - Converting processes
  - Printing of corrugated containers
- Process simulation and control
  - Mill closure

Highlights of recent research accomplishments

- Papermaking
  - Use of ceramics in impulse drying
  - Alternative fibers with impulse drying
  - Numerical explanation for the behavior of short-dwell coaters
- Paper physics
  - On-machine sensor for Z-direction measurement of strength
  - Measurement of paper strength using ultrasonic technology
  - Measurement and explanation of in-plane mechanical anisotropy
- Converting
  - Role of liner and medium properties in the double-backer operation
  - Role of fiber orientation in twist warp
  - Identification of liner and medium machines with "fiber orientation problems"
  - Matching the surface characteristics of linerboard and printing ink
- Process simulation and control
  - Model that predicts the physical and optical properties of paper

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Technology Development Centre (TEKES) of Finland - Overview
MAIN FUNCTIONS Preparation in framing Finland national technology policy Financing of applied technical research and risk-intensive industrial R&D projects Coordination and financing of international technological cooperation Consulting services and information (especially for small- and medium-sized companies)
TECHNOLOGY PROGRAMS Applied technical research projects Technology-based national programs Programs in individual sectors of industry Corporate groupings programs and technology implementation programs Industrial R&D project
NEW GENERATION PAPER TECHNOLOGY PROGRAM Raw materials • Recycled fiber • Surface chemistry • Fine chemicals Wet-end • Chemistry • Measurements • Retention Coating and surface treatment • Reology • Microstructure Homogeneity of properties • Structure • Wet pressing • Reology • Measurements

Technology Development Centre (TEKES) of Finland - Overview (contd.)
COMPLETED TECHNOLOGY-BASED NATIONAL PROGRAMS Semiconductor technology Information technology, FINPRIT Wood as raw material for the process industry Gene technology Sensor technology Manufacturing automation Continuous casting of steel Metal working and forming technology Engineering ceramics Arctic offshore technology Powder metallurgy Microelectronics Mechatronics Software technology, FINSOFT Polymer matrix composites Functional paper technology Industrial chemical technology Biotechnology Industrial building technology
TECHNOLOGY-BASED NATIONAL PROGRAMS IN 1993 Biodegradable polymers Pharmaceutical technology Synthesis technology Process technology New generation paper technology Mechanical wood processing Wood-based panels Quality in construction industries Building renovation Rock engineering and construction 2000 Machine vision Industrial applications of engineering materials

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APPENDIX D

SUGGESTED READING AND INFORMATION

APPENDIX D

SUGGESTED READING AND INFORMATION

If you would like to read more about materials issues or general trends, the following list will provide you with additional sources of information.

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General Statistics

American Paper Institute. 1992. *1992 Statistics of Paper, Paperboard, & Wood Pulp*. 260 Madison Ave., New York, NY 10016.

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Smook, G. A. 1992. *Handbook for Pulp & Paper Technologists*. Angus Wilde Publications, #203 - 628 West 13th Ave., Vancouver, British Columbia V5Z 1N9

Key Periodicals

Paper . Benn Publications, Ltd., Sovereign Way, Tonbridge, Kent TN9 1RW, England.

Paper Age. Business Press, Inc., Norwood, NJ 07648.

Pulp and Paper. Miller Freeman Publications, Inc. Send subscription correspondence to: Circulation Dept., PULP & PAPER, 600 Harrison St., San Francisco, CA 94107; or call subscription office at 415-905-2350.

Paper Technology. PITA Office, Pira House, Randalls Road, Leatherhead, Surrey KT22 7RU.

Pulp and Paper Canada. Southam Business Communications, Inc., 1450 Don Mills Road., Don Mills, Ontario M3B 2X7

Pulp and Paper International. Miller-Freeman Publications. 600 Harrison Street, San Francisco, CA 94105.

Pulp & Paper Project Report. Miller-Freeman Publications, Inc., 500 Howard Street, San Francisco, CA.

Pulp and Paper Week. Miller-Freeman Publications Inc. 500 Howard Street, San Francisco, CA. 94105. Calling Subscription Office at 415-397-1881.

PIMA Magazine. Paper Industry Management Association. Arlington Heights, Illinois 60005-4898.

TAPPI Journal. Technology Park, Atlanta, P.O. Box 105113, Atlanta, GA 30348.

Conferences

International Symposiums on Corrosion in the Pulp & Paper Industry. Sponsored by the Swedish Corrosion Institute, the Swedish Association of Pulp and Paper Engineers, and the Swedish Forest Products Research Laboratory. These are held every three years.

National Association of Corrosion Engineers Conference. This symposium is held every year. It seeks to transfer knowledge between industries to solve corrosion problems.

TAPPI Engineering Conference. Committee Meetings. The conference is held every year. The corrosion tract has several subcommittees to solve particular corrosion problems.

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