AIM

Materials Needs and Opportunities in the Pulp and Paper Industry

Advanced Industrial Materials
(AIM) Program

August 1995

Office of Industrial Technologies
U.S. Department of Energy

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MATERIALS NEEDS AND OPPORTUNITIES IN THE PULP AND PAPER INDUSTRY

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PREFACE

ADVANCED INDUSTRIAL MATERIALS (AIM) PROGRAM (C. A. Sorrell)

The Department of Energy's (DOE) Office of Industrial Technologies (OIT) supports research and development (R&D) in industry, the DOE national laboratories, and in universities to develop energy efficient, environmentally-acceptable industrial technologies. The Office of Industrial Technologies is working with seven energy-intensive industries to develop R&D roadmaps that will facilitate cooperative government-industry efforts to achieve energy-efficient, environmentally-acceptable, sustainable industries of the future. The forest products industry is one of the industries with which OIT is working to develop an R&D roadmap.

The Advanced Industrial Materials (AIM) Program of the Office of Industrial Technologies sponsors long-term, directed research on materials that will enable industry to develop and utilize more energy-efficient, sustainable processes and technologies. The purpose of the study described in this report was to identify the material R&D needs and opportunities for the pulp and paper mill of the future.

PULP AND PAPER MILL OF THE FUTURE (S. F. Sobczynski)

During the past 12 years, DOE has, together with industry support, 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. The paper industry has played an important role in the guidance of this R&D program.

An exciting new task is being undertaken 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 paper mill of the future.

The program will impact all National Energy Strategy (NES) goals. These include:

1. Economic Growth
   - enhance U.S. position in global markets
   - maintain U.S. competitiveness

2. Energy Security
   - encourage the use of renewable energy resources
   - promote energy self-sufficiency

3. Environmental Improvement
   - promote environmentally acceptable processes
   - maximize the utilization of resources

The program is also consistent with the mission of DOE, Energy Efficiency and Renewable Energy, and Office of Industrial Technologies (OIT). The mission of OIT is to facilitate research, development, and demonstration of energy-efficient, waste-reducing industrial technologies which are ultimately factors of successful global productivity and competitiveness.

The program plan will be responsive to industry needs. The capital intensiveness of processes will be reduced. One goal is to have the enhanced technologies be more cost effective and less capital intensive. The objective will be to improve productivity and to reduce energy consumption. The environmental impact of current and future processing methods will also be minimized. The goal is to develop improved processing methods which will reduce effluents, air emission, and/or solid waste. The program will be structured to maximize the impact by leveraging industrial and federal budgets. In general, the industry is evolutionary, not revolutionary, and has low R&D budgets which are generally ~1% of sales. DOE will leverage its funding with that from 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 technology needs that are identified should span the spectrum from fundamental, or basic research knowledge, to applied R&D activities encompassing pilot plants or commercial demonstrations. The program plan will have a time-phased approach: (1) in the near term (to year 2000), where appropriate, demonstrate particularly attractive technologies that are currently available but underutilized; (2) in the mid term (to year 2010), refine existing laboratory-scale concepts and develop these technologies with pilot-scale demonstrations; and (3) for the long term (to year 2020), develop completely improved new processes and materials and focus on areas with very substantial energy savings potential.

The major focus of the program will be on four general process areas. These include (1) chemical pulping and recovery, (2) mechanical pulping, (3) papermaking, and (4) advanced processes and systems that reduce environmental impact.

THE MISSION STATEMENT FOR THE DOE PULP AND PAPER MILL OF THE FUTURE

The mission of the DOE program is to enable the paper industry to increase production, reduce energy consumption, reduce operating costs, and meet environmental goals by 2020. The program will identify and then fund R&D to develop, improve, and demonstrate retrofit and advanced technologies and, if the demonstrated economics and market needs then warrant, to facilitate the commercial utilization of these advances in the pulp, paper, and paperboard industry in the United States. The U.S. paper industry, universities, and national laboratories who conduct paper R&D have collectively and convincingly shown that there is a significant opportunity for advances in pulp, paper, and paperboard production processes of the future that will: conserve large amounts of energy, maintain low overall costs, increase resource utilization, decrease environmental impacts of these technologies, and lower safety or health risks to the public compared to those of currently practiced technologies.

DOE's role is to stimulate and nurture the research, development, demonstration, and communication of technology advances by the pulp and paper sector and to help industry realize the full potential of these technology advances, with as little investment and cost to the Government as required to take advantage of the great promise of these new technology advances for serving the public interest in the optimization of the use of our resources.

MATERIALS NEEDS AND OPPORTUNITIES IN THE PULP AND PAPER INDUSTRY*

P. Angelini, Compiler

1. WOOD PREPARATION

An important initial step in paper manufacture is the collection and processing of large logs into a form which can be subsequently handled and made into pulp. Major steps in wood preparation include wood yard operations, debarking, and chipping. Problems in the wood yard may affect the entire pulp and papermaking process.

1.1 WOOD YARD OPERATIONS

Logs are customarily delivered to the wood yard via trucks, trains, barges, or river flotation. These usually have been de-limbed and cut to the correct size for further processing. Operations in the wood yard involve miscellaneous grapplers for holding and moving these logs. If the logs are not cut to the proper size, high-speed saws or knives are used to cut them.

Issues

Materials issues in the wood yard are generally not related to corrosion or elevated temperatures but to wear caused by erosion and abrasion. Bark contains significant quantities of soil and sand and sometimes water or saltwater, as well as contaminants such as nails, fence wire, etc. Transport chutes, belts, saws, and knives can suffer excessive wear from contamination introduced with the raw materials and also from certain types of hard wood.

Although materials used presently are almost always metallic, many ceramic materials possess the requisite strength and hardness to provide greater wear resistance. These include aluminum dioxide, zirconia-toughened alumina (ZTA), silicon nitride, silicon carbide, titanium diboride, and zirconia, along with traditional "hard metals" like cobalt-bonded tungsten carbide. Considerations for potential application are cost effectiveness (e.g., whether the reduced wear rate and lower consequent downtime for parts replacement justify the higher costs of ceramics); the ability to manufacture the requisite sizes; and durability during handling (material toughness).

1.2 DEBARKING

Debarking of the logs is required since the outer bark of trees usually does not contain fibrous materials and, consequently, is a contaminant in pulp and paper processes. Debarkers generally are open-ended cylinders through which the logs are rotated, rubbing against themselves and/or

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the wall of the cylinder. The bark removed by the rubbing action drops through slots in the cylinder wall and can be burned for energy recovery.

Issues

Abrasion by hard particulates, such as silicates retained as sand or dirt in the tree bark, causes wear of the debarking equipment.

1.3 CHIPPING

The debarked logs require further size reduction for processing. The operation for size reduction is called chipping and utilizes a large disk rotating on a horizontal axis or, alternatively, may use a drum configuration. The face of the disk, or the wall of the drum, is fitted with cutting knives that slice across the log, forming chips that pass through slots in the disk (or drum wall). The chipped wood is screened to remove large knots and oversized chips, which are separately reduced in size by mechanical means, and to remove fines, which are burned or pulped separately.

Issues

The saw blades in the slasher deck are subject to high impacts. The life of the cutting blades on the chipper is reduced if hardwoods are used. If the chipper and slasher are inoperative, chips from the storage yard are substituted. This may result in the introduction of rocks into subsequent processing steps with detrimental effects.

1.4 MATERIALS REQUIREMENTS

- Metals, ceramics, and/or surface treatments or coatings with improved abrasion and impact resistance
- Improved materials and/or surface treatments to provide greater impact-resistant edges for chipper blades, saws, knives, and slasher deck blades
- Materials and/or surface treatments for improved abrasion resistance for log transport, chutes, debarkers, and recycle paper handling

2. PULP PREPARATION

The objective of the pulping process is to separate the cellulose fibers from the other components of the wood. Both chemical and mechanical pulping processes are used. Each pulping process is designed to yield a specific set of feedstock characteristics, which are set by the product being manufactured (newsprint, tissue, pasteboard, etc.).

Grinder mechanical pulping involves grinding of wet logs against an abrasive grindstone, often at temperatures of 100° C (212° F) or slightly higher, to mechanically separate the fibers. Refiner mechanical pulping incorporates the wood chips from the chipping operation into the interface between two counter-rotating surfaces which contain a series of corrugations that mechanically degrade the chip and expose the cellulose fibers. Thermomechanical pulping (TMP) involves presteaming or a mild chemical pretreatment of the wood chips to make them soft prior to fiber separation. Although TMP requires somewhat more energy, less fiber destruction occurs and higher quality pulp results. Chemical pulping generally involves digestion of the wood chips in solutions of sodium sulfide/sodium hydroxide (the Kraft process). This may involve elevated temperatures [up to 170°C (340°F)] and pressures [up to 1 MPa (150 psi)]. After digestion, the pulp slurry is rapidly released from the pressure vessel through a vent onto a blow plate, with depressurization occurring instantaneously. Several other chemical pulping processes are used, such as the "sulfite" process, almost all of which utilize some sulfur-containing chemicals.

The materials issues depend on the type of pulping. Mechanical, or refiner pulping, causes wear from abrasion/erosion on the components, whereas chemical pulping results in exposure of containment materials to corrosive and erosive wear from the solutions/slurries.

The materials presently in common use are metals, except for the abrasive wheel in grinder mechanical pulping. Some fiber-reinforced plastics and other organic-based materials are utilized for vessel or pipe, pump, and valve linings.

2.1 MECHANICAL PULPING

In mechanical pulping, wood fibers are separated from each other by rolling, rubbing, or teasing, either against themselves or against a harder, specially designed surface. Chemical additions or the application of heat and pressure can be used to increase the quality of the pulp; however, the predominant pulping forces are mechanical. Mechanical pulping can be divided into two main areas: groundwood and disk refining.

2.1.1 Groundwood

Until recently, groundwood was the predominant means of mechanical pulping. The most common version is stone groundwood, in which pulp is formed by pressing debarked logs against a rotating grindstone, as shown in Fig. 1*(a)* [from Metals Handbook]. Water sprays are directed onto the stone, or ceramics, to prevent the fibers from burning, and the pulp is removed in the form of a slurry. Other variations include pressurized groundwood, in which pulping occurs at elevated temperature, and chemi-groundwood, in which a chemical pretreatment is used.

<u>Issues</u>

Wear resistance is the major materials concern in the groundwood process. Synthesized ceramic elements for grinding surfaces may be superior to stone grinding surfaces in some applications.

2.1.2 Mechanical Refining

Pulping by mechanical action in a rotating-disk attrition mill, called a refiner, as shown in Fig. 1*(b)* [from Metals Handbook], is widespread in the industry. Presteaming, with and without additional chemical treatment, may be used to enhance the fibrillization process. The refiner utilizes the action of two closely spaced disks as one rotates with respect to the other, or as they both rotate in opposite directions. Wood chips are fed into the gap between the disks at the

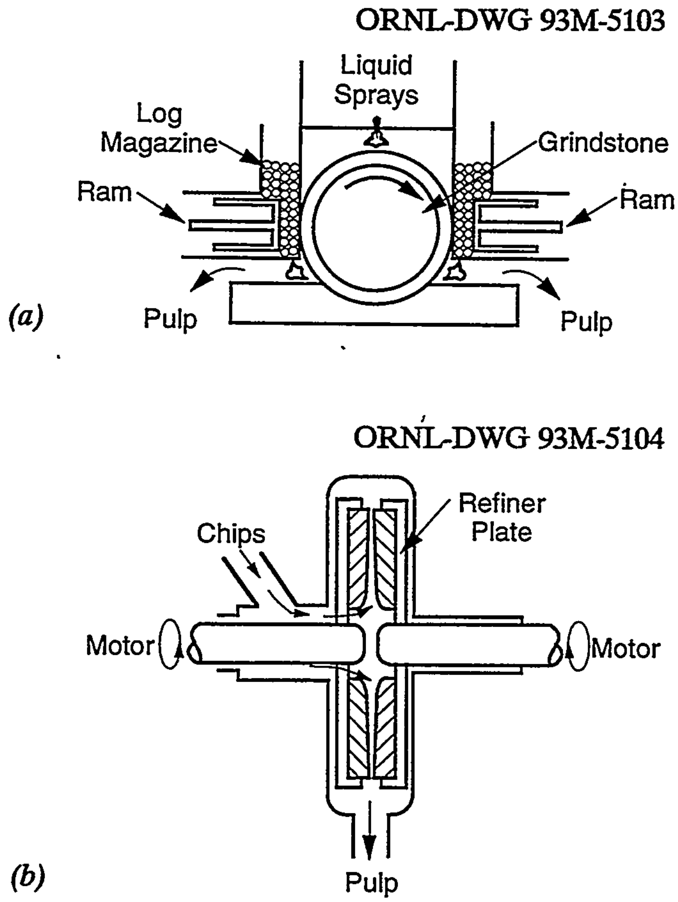

Figure 1. Schematic diagram of
(a) groundwood machine and *(b)* disk refiner
(from Metals Handbook).

rotation axis and are reduced to fibers as they move radially through the gap. The faces of the disks are covered with plates containing raised bars (3 mm x 6 mm x 25 cm), the bars being large near the entry point of the chips, and increasingly finer as the outer radius of the plate is approached. Plates spin at ~1800 rpm with an axial gap of 0.5 to 1.2 mm. Refiners are usually powered by electric motors of up to 30,000 to 40,000 hp. Water is introduced with the chips in order to prevent oxidation of the wood. Refiner plates can be either cast or wrought, but most are cast. The alloys used are generally a white cast iron or cast stainless steel.

Issues

Corrosion associated primarily with presteaming, condensates containing sulfur-bearing acids and chlorides, and wear of refiner plates affect pulp quality and process efficiency. Pounding of the bar edges results in lessening of the refining capability of the system. Pitting of the bars by cavitation erosion is a major factor affecting materials selection for disk refiners. In addition, dashing of plates which can occasionally come in contact due to inadequate clearance (with the resultant formation of grooves and serrations on the face of the plates) is a severe issue.

Improved materials or surface treatments which provide extended bar life and resist contact damage are important development needs for refiner plates.

Larger diameter, higher speed refiner operation is also a goal for current and future systems because of the energy benefits involved. Lighter weight refiner plate materials suitable for higher rotation rates would tend to decrease the stresses on the disks. At higher rotation rates, fracture toughness of the refiner disk materials is also a very significant issue. If cracks occur in the disks, they may grow rapidly resulting in catastrophic failure and significant damage to the systems. Life prediction modeling of these systems is extremely important in order to minimize risk of materials failure and downtime. At increased system throughputs and greater rotation rates, cavitation between refiner plates may also become more severe, and greater cavitation resistance may be necessary in the plate materials.

The incorporation of advanced ceramic materials may yield improved component lifetimes in mechanical or refiner pulping operations. This is especially true for the refiner plates, where there has been discussion of the use of tungsten carbide plates. Although this material is much more resistant to wear than the currently used metals, its density is so high that, at the higher speeds currently in vogue, the rotational energy involved would be excessive. Consequences of a catastrophic failure are serious at these energy levels. The use of ceramics, which are less dense than the metals currently used (especially the tungsten carbides) would provide greater wear resistance, use less energy, and have less dangerous consequences during failure. Several tough ceramics such as partially stabilized zirconias with K_{Ic} values over 25 MPa $\sqrt{m}$ (23 ksi $\sqrt{in.}$) have recently been developed and may have the required durability.

2.2 CHEMICAL PULPING

The predominant chemical pulping process used in the United States is the Kraft process. The Kraft process incorporates a system to recover the sodium hydroxide and sulfide, burn off the lignin and other organics, and at the same time provide steam and electrical power. This is done by separating out the pulp from the slurry and injecting the concentrated residual liquid (black liquor) into a recovery boiler where it is burned. Some of the sodium and sulfur follows the gas path as fume, deposits on upper heat-transfer surfaces, is separated in the electrostatic precipitator, and some is captured on the bottom of the boiler as sodium carbonate and sodium sulfide, which form as a molten stream ("smelt") at the bottom of the boiler. There are three main areas in the chemical pulping process: the digester (see Fig. 2), and the recovery boiler and the chemical recovery system (see Fig. 3) [from Metals Handbook]. Current materials of choice are carbon steel for nominal service and type 304 for cases where high-velocity streams are involved. The limits of steels to handle chlorides in alkaline sodium sulfide solutions are of concern due to the buildup in the concentration of these chemicals. Extended delignification processes involve adding more sodium sulfide and sodium hydroxide partway through the process, resulting in the possibility of increased corrosion or stress corrosion cracking.

Materials issues are mainly related to corrosion, especially in the boiler itself where elevated temperatures and highly corrosive species abound. Heat-exchanger tubes carry water into the boiler for heating, and these must not be allowed to leak or burst, as the smelt/water reaction can be explosive. It is therefore critical that tube leaks be prevented in the boiler.

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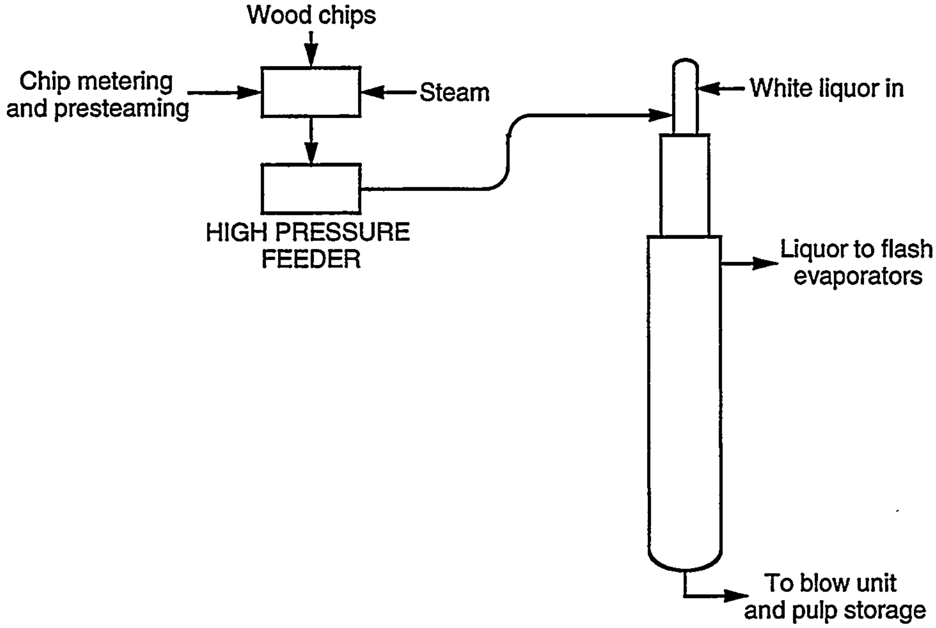

Figure 2. Schematic diagram of digester.

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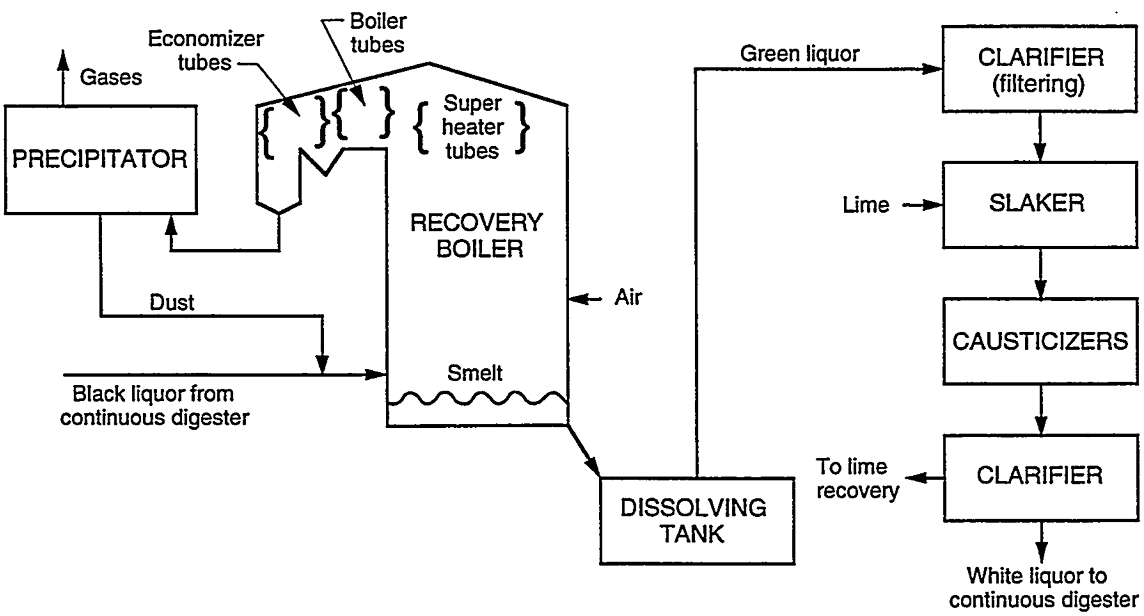

Figure 3. Schematic diagram of the recovery boiler and the chemical recovery system.

2.2.1 Digester

In the digester, an alkaline sulfide liquor dissolves (digests) the lignin from wood fibers in a batch process or a continuous process. After digestion, the treated chips pass through a washing and cooling zone. The spent pulping solution (black liquor) is extracted from the top of this zone, and the chips are extracted from the bottom of the zone through a blow valve to the blow tank. The release and impact fiberize the chips. After leaving the digester, the black liquor is concentrated to 60% solids in multiple evaporators.

Issues

Adding a second point of introduction of the delignification chemicals in the digester tank can cause significant changes to the material behavior and requirements. For example, introducing pulping chemicals in the middle of the digester tanks could lead to enhanced corrosion effects. Carbon steel would probably not be sufficient, and even type 304 stainless steel may undergo stress corrosion cracking. Corrosion/erosion of metallic components including pipes, valves, pumps, etc., by sodium hydroxide/sulfide slurries also occurs.

With an appropriate filter, it should be possible to easily, rapidly, and economically remove a significant fraction of the liquid from various process washings and from black liquor. The filters would be metal-based and are expected to be easily cleaned by vibration or back-flushing. These filters will have a very long lifetime, and the waste stream will be reduced by many orders of magnitude. Reverse osmosis membranes may also be useful as they would require less than one-half the energy required by multiple-effect evaporation.

Significant wear may occur in the blowdown vessel for the digested pulp. The target plate of the blow unit, upon which the digested pulp/slurry is directed, experiences the most significant wear problem.

2.2.2 Recovery Boiler

The boiler is used to incinerate black liquor while providing steam for cogeneration and plant processes. The main by-product of the recovery boiler is CO_2. Smelt, consisting principally of molten Na_2C0_3 and Na_2S, is formed at the bottom of the boiler. If boiler tubes leak or burst, then there is a possibility for an explosion due to the stream reaction between water and the molten smelt. In the United States, there are 1 to 2 explosions per year due to this effect. Thus, the integrity of the pressure tubes is extremely important.

Recovery boilers are expected to operate 358 d/year with about a 1-week downtime for servicing. About 50% of the mills in the United States have only one boiler. This means that if the boiler is not operating, the entire mill is shut down.

One of the developments which has occurred over the last 10 years has been the introduction of composite tubes (stainless-steel-clad carbon steel tubes developed and evaluated previously in Europe) in the boilers. Prior to that time, the material of use was carbon steel which had 2-cm studs on the outer surface to enhance the attachment and solidification of smelt onto the tube in order to provide corrosion protection. Spray metallized tubes have also shown limited success. The lifetime of the metallized layer ranges between 3 to 5 years; however, corrosion products and tube cleaning processes tend to remove the protective coating. Composite tubes have solved many of the corrosion problems except at the port openings.

The operational characteristics of these recovery boilers are different from utility boilers. There is:

1. more material deposited on the surface of tubes, leading to reduced heat transfer (but in the lower part of the furnace, these deposits keep the tubes cool and corrosion rates low);

2. localized thinning and erosion of tubes due to the presence of particles (sulfides) in the gas streams;

3. molten salt corrosion attack of materials; and

4. lower superheat temperature [pulp and paper ~480°C (900°F); utility ~540°C (1000°F)].

Limitations are due to molten chemical attack of tubes in the superheater section of boilers. The maximum steam temperature is kept low enough to prevent corrosion in the superheater tubes due to melting of salt deposits and resultant molten salt corrosion. Salt deposits melt at temperatures between 510°C (950°F) and 565°C (1050°F).

Issues

The most challenging materials problems stemming from this process are associated with processing the spent (black) liquor. Typical problems include attack on the fireside of boiler tubes associated with molten salts, corrosion of water tubes in lower furnace sections under a frozen smelt layer, corrosion of the smelt spout, and stress-assisted corrosion on the waterside of boiler tubes. The use of uncooled ceramic spouts (given proper thermal shock, toughness, and other properties) may result in improved corrosion resistance and avoiding the risk of explosions.

Localized corrosion occurs at the air inlet ports normally located near the bottom of the boiler. Corrosion of stainless and nickel-base materials also occurs. The corrosion effects need to be determined and improvements made in materials and design.

Because it is so important that the boiler tubes not leak, a means of monitoring and measuring the thickness of tubes is required. Such a system would be extremely useful as a means to reduce accidents and resulting downtime. The current procedure is to develop a grid of points which can be checked with hand-held ultrasonic testing equipment.

Waterside corrosion fatigue cracking of materials (stress-assisted cracking) occurs in the lower part of the furnace, generally near weld attachments. Fissures grow underneath external welds from inside the tube to the outside. The mechanism responsible for this phenomenon needs to be determined and life prediction models developed. In addition, improved nondestructive evaluation methods need to be developed to detect waterside stress corrosion cracking. Current X-ray instruments cannot access needed locations without stripping off refractory.

Methods and devices for detection of external cracking of composite tubes located in the lower part of the furnace are needed. Cracks tend to grow and form through the stainless layer. The cause of the cracking needs to be determined and materials evaluated under various environmental conditions. External cracking of the composite tubes in the lower furnace due to stress corrosion cracking or thermal fatigue cracking results in significant downtime and repair costs.

Thermal fatigue cracking has also been found in composite tube butt welds in the lower furnace walls. Cracks extended approximately 0.5 mm into the carbon steel portion of the weld. Cracks were present in tubes at locations between 1 and 10 m from the bottom of the boiler.

Thermal fatigue cracking of composite tubes has also been found at the spout openings and at the liquid smelt-gas interface near the bottom of the boiler. Many tubes crack at a level between 2 to 5 cm above and below the normal location of the liquid smelt level. Since repair of the tubes is difficult and tubes would normally be replaced if cracked, one solution is to use metallized sections initially. More extensive testing of the integrity of tubes, however, is required.

Refractory coverings on the floor of the furnace are being evaluated to reduce exposures of the floor tubes. Ceramic tiles, tested in boilers, have buckled up to 50 cm above the floor level. High-alumina refractories corroded in less than 1 year.

Another option which has been available to industry for many years is chromized tubing for both the superheater section and the lower part of the boiler. A diffusion coating is used and the chrome replaces the iron in the material. There is a high percentage of chromium on the surface of the tube (30 to 50%), but the Cr concentration decreases rapidly, the depth being only ~0.2 mm. Some chromized superheater tubes have experienced severe pitting. Concerns regarding chromized tubes include loss of coating by erosion or mechanical cleaning and the inability to detect fractures or penetrations in the coating layer.

Significant materials issues also exist in recovery boiler superheater tubes. These tubes encounter the hottest environments and are often alloyed for corrosion resistance. If process conditions form molten deposits on the surfaces of tubes, attack is extremely rapid. In some cases, type 310/carbon steel composite tubes have been installed.

2.2.3 Chemical Recovery System

The smelt, consisting primarily of Na_2CO_3 and Na_2S, is dissolved in water to make "green liquor." This solution is causticized with slaked lime to convert Na_2CO_3 to NaOH, and the resultant "white liquor" is returned to the pulp digester.

<u>Issues</u>

More conventional corrosion problems are associated with the processing of the green and white liquors, including caustic corrosion and cracking, sulfur acid-induced wastage, acid-cleaning of heat-exchanger surfaces, and corrosion/erosion caused by steam impingement.

2.2.4 New Processes

Several new pulping processes are under evaluation, most of which are of the "chemical" variety. They are largely aimed at eliminating the environmental problems associated with the use of sulfur-containing chemicals. Sodium-bearing species are involved in some of these processes, as in the soda-anthraquinone process. Other processes utilize enzymatic, biological, or organic acid solvent attack on the wood structure to accomplish the pulping, and the corrosion consequences of these processes are not yet fully explored.

Black liquor gasification is a new process wherein the liquor is not burned in a recovery boiler but pyrolyzed and reacted with steam to form a fuel gas and inorganic salts. The MTCI pulse-enhanced steam reformer consists of multiple resonance tube pulse combustors with the resonance tubes immersed in a bubbling fluidized bed reactor. The heat required for gasification is provided by burning a portion of the product gas in the pulse combustor and transferring heat through the resonance tubes into the fluidized bed.

The major benefit associated with the MTCI process is that the inorganic salts are recovered in solid form (i.e., no melt is formed). The solid inorganics are dissolved to produce a sodium carbonate solution that is used to remove hydrogen sulfide from the raw product gas, thereby producing green liquor for return to the pulping process.

A wide range of biomass materials has been successfully converted in laboratory experiments. A large-scale pilot facility has been operated using rejects from a recycle mill as its feedstock. A near-commercial-scale facility for processing black liquor is under construction.

Economically useful gases may be separated from gasified black liquor. Development work is currently in progress to fabricate inorganic membranes to separate hydrogen from gasified coal at temperatures of 700°C (1300°F) to 1000°C (1830°F). Such membranes will be useful because more hydrogen is produced from the black liquor than is needed for the combustion process. The process economics could perhaps be improved by separating some of the hydrogen for sale as a separate product. There may be other valuable gases that could also be separated for sale as a marketable product.

Issues

Recycling of process streams can affect the corrosion behavior. For example, the concentrating effect of various processes leads to an increase in the thiosulfate concentration and also the concentration of chlorine in the liquids. Development of an economical process to remove chloride salts from the liquor cycle would be of great benefit.

Advanced processing methods can also lead to significant effects related to materials. Materials selection and needs must be introduced early in the process to enable the process to be successful and not result in failure or dangerous situations. Sulfur-free pulping, for example, can result in a more bleachable pulp and reduce the concentration of sulfur-bearing emission gases.

Materials issues with respect to black liquor gasification processes include sulfidation and/or alkali corrosion of metal tubes immersed within the bed, tube erosion, and refractory life.

Membranes may enable the separation of black liquor into a source of economically useful chemicals. Black liquor is such a complex mixture that, to date, no economical method has been found to achieve the separation. It should be possible to fabricate inorganic membranes with graded pore sizes that could be used to separate fractions of the black liquor containing different size chemical molecules. In addition, membranes may also be used to improve the quality and Btu content of gases produced from new black liquor gasification processes.

2.3 RECYCLED PAPER SYSTEMS

Much paper is recycled, especially newsprint, with the amount incorporated into the new paper being a function of many variables. These include the type of fibers (most may be recycled only a few times before losing significant strength and causing loss of quality of the new paper), the amount available, local regulations, etc. The operations involved are separation out of contaminants (rocks, wire, etc.) and improper paper types, de-inking, and shredding/digestion.

Recycling of post-consumer paper products constitutes an ever-increasing source of the pulp used in the U.S. papermaking industry. However, the paper generally comes from varied sources, and the identity of the inks is unknown. There are problems with deposits of the inks on equipment. Chemicals used to remove ink from fibers cause a strength degradation to occur. Material from de-inking can account for as much as one-fourth of the volume of received recycled paper.

Issues

Wear problems may be particularly severe in the handling of recycled paper products which may be contaminated by abrasive materials, metal shards, and other debris harmful to the processing equipment. De-inking involves the use of chemicals that are relatively aggressive to metallic containment systems. Materials issues in these operations are again erosion and corrosion, sometimes aggravated by unwanted biological growths brought in by recycle paper.

Other key issues include effects of incineration on materials, removal of heavy metals from solutions, and safe landfill disposal and treatment of wastes.

2.4 MATERIALS REQUIREMENTS

Mechanical Pulping

- Improved ceramics for rotating grindstones

Mechanical Refiner

- Lighter weight metals, ceramics, and composites for high-rotation-rate refiner plates
- Surface treatments (hard surface on ductile matrix) to improve wear and cavitation resistance and to increase toughness of refiner plates
- Corrosion/erosion testing of candidate refiner plates in the presence of steam and cavitation
- Improved bearing materials and failure diagnostics for disk refiners

Digester

- Digester vessel liner/weld overlay materials to combat caustic stress corrosion cracking and corrosion from caustic sulfide solutions

- Modeling of digester corrosion processes to optimize design and operating parameters
- Improved target blow plate materials to resist corrosion, cavitation, and wear by effluent from the digester

Recovery Boiler

- Sulfidation-resistant superheater and reheater tube materials and coating systems (including ceramics) to attain higher steam temperatures
- Studies of corrosion mechanisms leading to stress-assisted corrosion of water-wall tubes
- Sensors to monitor thinning and degradation of recovery boiler tubes
- Recovery boiler tube materials with improved resistance to stress-assisted waterside corrosion and fireside attack by pyrosulfates or other molten salts, molten sulfates, or pyrosulfates
- Abrasion-resistant materials for handling recycled paper
- Corrosion thermal shock and impact-resistant ceramics for uncooled water-free smelt spouts

New Processes

- Assess corrosion processes in gasifiers being developed for recovery of black liquor chemicals
- Membranes to improve the quality and Btu content of gases produced from black liquor gasification processes
- Process or materials to remove chlorides and potassium from the liquor cycle

3. BLEACHING

Pulps vary considerably in their color after pulping, depending on the wood species, method of processing, and extraneous components. For many paper types, particularly printing grades, the digested wood pulp is subjected to various oxidative (oxygen, hydrogen peroxide, or ozone) or chlorine-containing chemicals to effect an increase in the brightness or whiteness. There are basically two types of bleaching operations: those that chemically modify the chromophobic groups by oxidation or reduction but remove very little lignin or other substances from the fibers, and those that complete the delignification and remove pitch and some carbohydrate materials. The processes take place at low temperatures, inasmuch as the cellulose fibers are in waterborne suspension.

Materials issues are largely related to the corrosiveness of the chemical solutions, some of which are at $pH < 2$, others at $pH > 12$. Metals, as well as fiber-reinforced plastics, are utilized routinely.

3.1 CURRENT BLEACHING METHODS

Bleach plants have become more corrosive over the past 20 years as mills have "closed" wash water systems and reduced effluent volumes. Many mills have turned to higher alloy stainless steels, nickel-base alloys, and titanium for better corrosion resistance. Metals are chosen over nonmetals for moving equipment, such as washers. Metals are stronger, tougher, have better fatigue properties, and, if they have sufficient corrosion resistance, require virtually no maintenance. However, the more corrosion-resistant alloys are more costly, and the challenge is to choose an alloy with just enough resistance to avoid corrosion problems.

Issues

Pulp mill bleach plants have traditionally used austenitic stainless steels because of their combination of good corrosion resistance and weldability. Current materials for bleaching equipment also include titanium alloys. Some issues include evaluating the behavior of titanium alloys in alkaline environments since titanium alloys have high corrosion rates in alkaline peroxides.

Concern over dioxins in effluents is mandating the switch from chlorine-type bleaching chemicals to oxygenated bleaching chemicals. Hot acid chloride solutions are difficult for certain types of steels to handle. There has been significant concern about titanium in alkaline peroxide solutions. Substitution of chlorine dioxide for chlorine does decrease effluents, but it also increases corrosion problems. New bleaching using superoxygenated compounds may shift corrosion problems to polymer materials rather than metals. There are no data on how these plastics will perform in the presence of superoxygenated compounds.

A low-pressure drop-cleanable filter can be used to easily, rapidly, and economically remove a significant fraction of the bleach from the pulp. Multiple washing cycles can be used to reduce the concentration of the bleach in the pulp to the desired level. Reverse osmosis can be used to separate concentrated chlorinated waste liquors in order to reduce corrosion problems in pulping systems. This will contribute significantly toward having an economical closed-cycle system for the pulp operation. The bleach can be concentrated, removed, purified, and returned to the bleaching cycle. The water removed from the bleach solution can be recycled for multiple washings to reduce the amount of bleach remaining in the pulp. This will contain most of the bleach in the bleach cycle and significantly reduce the potential for corrosion in other parts of the processing plant.

3.2 NEW PROCESSES

Because of the large amount of water required to be removed from the dilute bleaching slurries and the incompatibility of the chlorine-containing chemicals with other process streams at the paper plant, many alternative bleaching processes are being evaluated. The main driver of change in the bleaching operation, however, is the need for reduction of the amount of chlorinated organic compounds to minimize the consequences of disposal or release to the environment of these troublesome materials. These alternative processes may utilize oxygen, ozone, or chlorine dioxide. This change from chlorine compounds to oxygenated materials for bleaching should lessen the corrosion problems for metals. Technological questions related to joining and long-term structural integrity are also issues which need to be resolved.

Issues

The new superoxygenated bleaching processes are thought to be less corrosive; however, the corrosion characteristics of various materials are not known. The use of polymers should be explored. However, there are almost no data on these materials. Another aspect to the low use of polymer-based material relates to industrial acceptance of unfamiliar materials.

The substitution of chlorine by chlorine dioxide is another process change which can substantially affect the behavior of materials. Chlorine dioxides can lead to higher corrosion rates. Even some of the most advanced nickel-base alloys are at their limit when chlorine dioxide is present in the pulp.

The wide range of chemical conditions and the use of species which are aggressively corrosive suggests that there may be certain specific applications where ceramic materials would prove effective. These would most likely be in the form of coatings on the vessels and piping, valves, etc.

3.3 MATERIALS REQUIREMENTS

- Evaluation of currently used austenitic stainless steels and titanium alloys in peroxide and ClO_2 environments
- Identification of new alloys better able to withstand corrosion caused by oxygenated bleaching materials
- Corrosion-resistant weld filler materials and improved welding practices
- Evaluation of ceramics, ceramic coatings, and polymeric materials as replacements for metallic alloys in some applications
- Cleanable filters and membranes to separate bleach from pulp

4. PAPERMAKING

The pulp fibers in suspension are concentrated to the desired degree and fed into a box (the headbox) which contains a slit opening. The slurry is metered out of the slit (slice) onto a plastic (nylon or polyester) mesh "wire." A wet paper web is formed by drainage of the majority of the water from the slurry. The wet paper web is then transferred onto a "felt" and pressed between rolls to achieve further dewatering by mechanical pressure. The paper web is then transferred by the "felts" to the dryer section where it is dried in contact with a series of hot, steam-heated rolls. Coatings may be applied to the dry paper sheet at the dry end. The paper is cut (slit) with knife blades as required for proper sizing. A schematic diagram of the papermaking line is shown in Fig. 4.

The corrosion characteristics of this unit process can be fairly benign with the pH ranging from 4 to 10, the O_2 level as well as the dissolved salts concentration being low, and the chlorine

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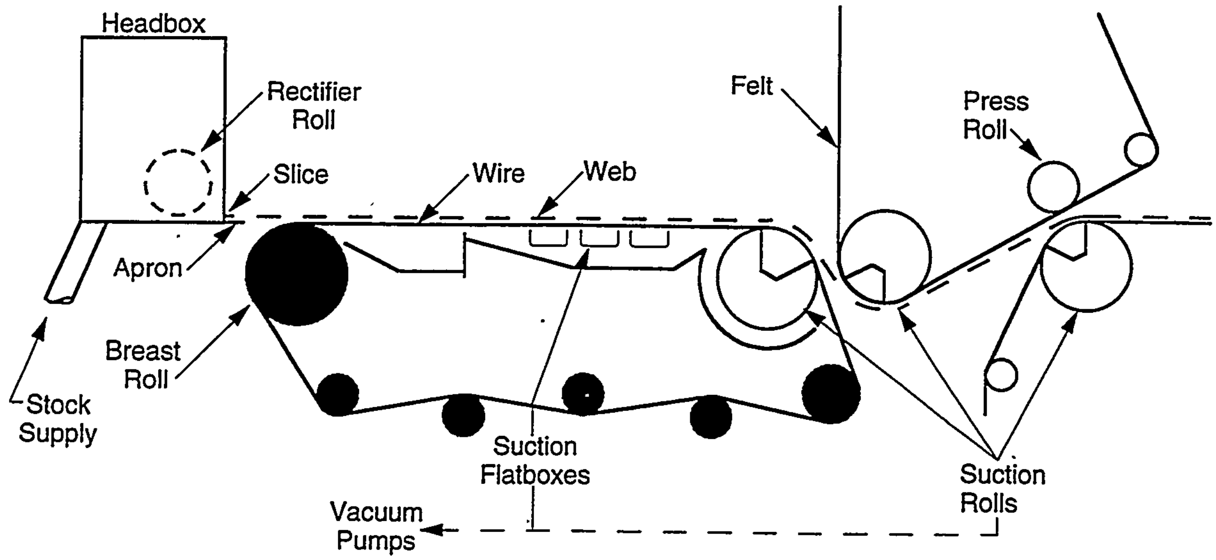

Figure 4. Schematic diagram of headbox and forming section of a paper-making machine (from Metals Handbook).

concentration in the low ppm range (typically 20 to 50 ppm for bleached pulp). Current materials used include carbon steel, stainless steel, and nickel-base alloys.

Other general issues include iron deposits which may discolor paper and microbial deposits which may affect the quality of the paper.

4.1 STOCK PIPING AND HEADBOX

Structural materials of the headbox and rolls are nearly all metallic. The slurry is often supported on an organic (plastic) webbing material or on an organic felt.

Corrosion levels are generally low. However, in closed systems, severe corrosion problems may develop due to increased thiosulfate levels, especially for carbon steel parts. Corrosion may occur on the slice lips of the headboxes. Fiber deposits found on the slice lips of the headboxes may contain a high concentration of chloride and lead to severe corrosion, which may require replacement of carbon steel parts with nickel-base alloys.

Issues

Materials issues involve corrosion and erosion/abrasion, as the solution carrying the cellulose fibers still contains several chlorine-containing compounds. These may cause pitting attack on metals, particularly where surface deposits form on such areas as the slit orifice and the rolls, and in the latter case may lead to catastrophic failure and costly subsequent paper line shutdowns for replacement. Durability of components in the headbox is an area where improvements may be made.

There are many applications where ceramic components may be introduced into this unit operation including the slit edge in the headbox, the knife edge on the coater, the slitter knives, and perhaps as rolls or roll coatings. However, the large size of rolls will present a challenge to ceramic manufacturers. Ceramic bearings for long life at high speeds in poor lubrication environments may also yield improvements. Several advanced ceramic bearing materials are now in production, all based on silicon nitride. Bearings made from these materials are finding use in extreme environments in high-speed machine tool spindles, where they allow speeds impossible with metallic bearings, because the oil lubrication is spun out of the bearing race. Papermaking machine screen baskets, which are subject to corrosion fatigue and corrosion erosion, appear to be a good application for ceramic fiber composites.

4.2 INTERMEDIATE STRUCTURES/DRYERS

Intermediate structures in the papermaking line including rolls, webs, felts, wires, etc., are designed to create undamaged paper pulp web and to remove as much water as possible before entering the dryer section.

Suction rolls draw water from the paper by vacuum. These rolls are probably one of the highest cost capital equipment items in the pulp and paper plants. Their cost is approximately $1 million each.

Paper is dried by passing it through top and bottom rolls. The rolls are heated with steam and are normally made from cast iron. Metallic and microbiological deposits are of concern from the viewpoint of paper discoloration. Opportunities exist for improved materials which are not as brittle or that are lighter than the present materials.

The critical properties which felts must possess include the ability to hold water and the ability to prevent rewetting of the paper. Currently, felts are made from needle-punched non-woven nylon with possibly some other polymeric fibrous materials. Wires are usually made from nylon. The type of weave is also important in determining the durability of the wire. A set of felts on typical papermaking machines costs approximately $30,000 each and is generally replaced once per month and drying fabrics every 6 months.

<u>Issues</u>

Increasing quality, minimizing waste, and process control lead to the need for improved materials in both the process equipment and sensing devices. A need also exists to improve and control the distribution of pulp on the wire mesh belt. In addition, microbiological deposits need to be controlled since dislodged deposits can cause damage to the paper web.

The need exists for felts and wires to be more wear resistant and be able to operate at higher temperatures. At the present time, the thickness of the outermost fiber in contact with the rolls and ceramic plates is measured as a way of determining the necessity to replace the felt.

Suction rolls are typically made from hardenable duplex stainless steels and are subject to corrosion fatigue cracking. Cracking is sometimes traceable to cosmetic weld repairs, to defects in the casting, and to drill holes. Needs exist for alloys with improved corrosion and mechanical characteristics, manufacturing improvements in the casting process, and modeling. Suction rolls are very expensive, and failures occur due to cracking and corrosion. When these rolls fail, much damage may be done to adjacent parts of the papermaking machine. When dryers fail, 3 or 4 other dryers may be damaged. New versions of suction rolls are being introduced, and innovations are concentrating on structure and new alloys.

4.3 PAPER FINISHING AND HANDLING

Coatings are applied at very high speeds to various types of paper products. For example, clay, latex, and whitening agents are applied to paper to produce printing surfaces. Typically, the speed of the paper through the machines depends on the product type being produced. For example, newsprint may be produced at a speed of 7.5 m/s (1500 ft/min) to 25 m/s (5000 ft/min). However, the speed of paper which is coated is in the range of 2000 to 3000 ft/min on the machine.

Issues

The efficiency and uniformity of applying the coating is an opportunity for improvement. The clay-bearing solution must be uniformly distributed on the take-up roll without having skipped regions. The clay solution must then be uniformly transferred and applied to the paper supported by a backing roll. The interactions of the doctor blade with the backing roll must also be considered. There is also a need to understand the fundamentals and dynamics of the process to improve efficiency.

4.4 NEW PROCESSES/GENERAL ISSUES

The impulse drying process under development at the Institute of Paper Science and Technology employs a heated roll press to activate a more efficient water removal mechanism. During the process, wet paper is brought into contact with a hot-press roll, typically heated to between 200°C (400°F) and 400°C (700°F), while pressures between 3 MPa (400 psi) and 5 MPa (700 psi) are maintained in the sheet for times between 15 to 30 ms.

Issues

Durability of ceramic coatings on steel rolls in impulse dryers is a concern. Good wear resistance is required. Current operating temperature is approximately 200°C (400°F). Higher temperatures, 260°C (500°F) to 315°C (600°F), and pressures are desirable. The survivability of the ceramic coatings needs to be tested. Ceramic coatings need to be applied to full-size rolls to evaluate the materials, coating technology requirements, and the behavior of the rolls tested in a pilot facility. Alternate ceramic materials coatings and application methods need to be evaluated.

The ceramic coated steel roller requires a lubricated hydrostatic element located inside the roll. This element must have good wear resistance at high temperatures, 260°C (500°F) to 315°C (600°F). Scaleup will result in higher loads on presses, increased demand on lubrication, and increased wear. Felt properties also influence impulse drying efficiency.

Roll pressure shoes are of various sizes. However, a typical shoe has a pressure-bearing length of approximately 50 cm. This may result in pressures in the 14 MPa (2000 psi) range on the rubber rolls and presses.

4.5 MATERIALS REQUIREMENTS

- Materials with improved abrasion resistance for doctor blades, slitters, drums, and screen baskets
- Improved lubricity between the pressure shoe and the roll
- Materials with improved corrosion fatigue resistance for headbox components
- Materials with improved wear and/or corrosion resistance for press rolls
- Surface treatments to control residual stresses and improve corrosion fatigue properties of suction rolls
- Structural analysis and design modifications to reduce cyclic loading
- Cast stainless steels with improved stress-corrosion resistance
- New ceramics or ceramic coatings with improved resistance to cleaning chemicals
- Life prediction modeling
- More ductile replacement for cast-iron dryer rolls
- Higher modulus (stiffness) material for impulse dryer rolls
- More durable felts and wires
- Improved, high-performance oils and greases for bearings

5. OTHER TECHNOLOGIES

5.1 MOTORS/GENERATORS/TURBINES

The paper and pulp industry is a significant user of power but also supplies, through cogeneration, a significant percentage (58%) of its power needs. Energy conversion efficiency is very important for the overall economics of papermaking. Utility power quality and energy conversion efficiency affect all paper and pulp unit operations from the wood yard, to papermaking, to environmental/waste minimization.

Issues

The pulp and paper industry's reliance on sensitive electronic systems for such important functions as data processing, communications, and process control has necessitated a new concern toward the quality of the electric power supply. Voltage sags are the most common power quality problem affecting facilities. Voltage sags occur during faults on the power system. Since these faults cannot be completely prevented, facilities must make sure their critical loads are not impacted by the resulting voltage. Power quality problems can produce significant cost, schedule, and performance impacts at paper and pulp facilities that require continuous power quality. The rapid response of a flywheel motor/generator system ensures no interruption of continuous manufacturing processes, electronic equipment, and computer facilities. The flywheel energy storage system has lower cost than comparable sized battery systems. Improved permanent magnets will also improve the overall round-trip efficiency of energy conversion. High-efficiency axial gap generators can improve the overall conversion efficiency of cogeneration systems. The high-efficiency axial gap motor can result in less power consumption compared to existing electric motors.

5.2 SENSORS AND CONTROLS

Currently, the need for continuous on-line process sensors is great throughout the paper industry. Almost every aspect of the pulp and papermaking process could benefit from improved, on-line sensors and control systems. Several examples are listed below.

<u>Issues</u>

Because it is so important that the boiler tubes not leak, a means of monitoring and measuring the thickness of tubes is required. Currently, this is performed off-line by ultrasound. Coating deposits of smelt material on the tubes cause variations in the signals, and the method can produce misleading data if the tubes are very thin. It is these weak areas that need to be identified. In addition, the test is performed in a statistical manner which means that not all of the tube is inspected. A robotic device is needed to monitor the entire tube. The device on the outer part of the tube would have to meet stringent requirements since the space between tubes is limited and the surface is irregular due to surface deposits. Such a system would be extremely useful as a means to reduce accidents and resulting downtime.

Motor current analysis can be used to predict bearing failure.

Although paper strength requires off-line destructive measurements, stiffness can be determined on moving webs by measuring the velocity of ultrasound. Transducers mounted in fluid-filled wheels are used to make out-of-plane (two-dimensional) ultrasound velocity measurements on paper webs moving in the nip between two such wheels. Comparisons of the arrival times of echo and transmitted pulses with and without the paper web in the nip provide a measure of the transit time and caliper. Timing requirements are very stringent (in the nanosecond range), and variations in the roundness or thickness of the fluid-filled wheels lead to noise in the signal. Currently, the signal is integrated over one or more wheel rotations to minimize these effects.

The opportunities related to the fluid-filled wheels include improving roundness, thickness uniformity and radius, wear properties, and endurance.

In-plane ultrasound velocity measurements use bimorph transducers mounted in the surface of aluminum cylinders or rolls. The needs include improving the wear behavior of the transducers and improvement in the means for electrical and signal communication with sensors located on rotating rolls. At present, communication is performed by using slip rings. Other means of signal communication, such as fiber-optic methods, may be practical.

5.3 MATERIALS REQUIREMENTS

Motors/Generators/Turbines

- Pitting-resistant materials for scrubbers
- Sulfur-resistant materials for gas turbines

Sensors/Nondestructive Evaluation

- Robotic inspection techniques to evaluate boiler tube integrity
- Motor current analyses to predict motor/generator/bearing failures
- On-line sensors to measure moisture content, thickness, stiffness, web and paper quality, and fiber properties and orientation
- Improve properties of fluid-filled rubber rolls (roundness, thickness uniformity, and wear) used in stiffness measurements
- Improve wear behavior of slip rings

6. ENVIRONMENTAL ASPECTS/WASTE HANDLING AND MINIMIZATION

Environmental and energy concerns are playing an increasing role in the design and operation of paper and pulp mills. The short-term approach has been to add scrubbers, precipitators, holding ponds, etc., to control effluents. However, the longer-term solutions will invariably lead to major modifications of current procedures or replacement technologies (e.g., the minimization or elimination of malodorous sulfur compounds and chlorine). Plant "closure" is also leading to increased concentrations of deleterious chemicals, resulting in new and unexplored corrosion concerns.

There are several stages involved in waste processing and minimization. Issues are related to toxicity, color, etc. Reduction of these parameters can occur in biotreatment stages, but little is known about the specific bioprocesses that occur. For example, it is not known if nutrients should be added or specific compounds that are toxic to the waste treatment bacteria removed, etc. This is a wide open area, but little is known and little is being done. There may also be opportunities for novel separations techniques. Plants produce solid wastes that include heavy metals. These sludges are dewatered using a screw press. Currently, the waste is landfilled or burned.

<u>Issues</u>

Biotreatment processes are anticipated new technologies to treat waste, including sludges. Key issues include: (1) development of improved biotreatment processes, including the effects of specific biological bacteria, nutrients, environment, and removal of specific and general chemicals from the waste stream; (2) development of separations technologies including chemical, biological and physical separation methods; and (3) treatment of sludges. Sludges may contain elements that were absorbed by trees during growth and impurities introduced during the pulp and papermaking process.

Materials issues in these operations are again erosion and corrosion. Corrosion appears to be a larger concern, especially as the solutions are evaporated and the corrosion-inducing ions (chlorine, etc.) become more concentrated. The ash produced from incineration may also pose wear problems.

6.1 MATERIALS REQUIREMENTS

- Membranes suitable for reverse osmosis or nanofiltration to separate volatile compounds
- Engineered porous materials for filtration of liquid waste streams
- Inorganic membranes to remove deleterious chemicals to reduce concentration and permit plant "closure"
- Improved, cavitation-resistant materials for pumps
- Materials with improved abrasion resistance in ash transport chutes and pipes

7. WEAR

From the harvesting of trees to the use of paper products in packaging and printing, wear and friction unquestionably are important issues for the pulp and paper industry. In the pulp and paper process, nearly every form of wear may be encountered: abrasive wear, erosive wear, wear by slurries, cavitation wear (in pumps), sliding wear, rolling contact wear, galling and scuffing, fretting wear, and impact wear.

Strategies for dealing with wear issues in industrial environments usually fall into the following categories:

1. accept the existing situation and plan for periodic maintenance to replace worn parts;
2. alter the process conditions to make the wear-producing environment less severe;
3. replace wear-critical portions of the machine with more durable parts, inserts, or surface treatments; and
4. replace the whole process or machine with one that does not have the same costly wear problems.

Specific Wear Problems

As noted above, there are a great number of wear problems in the pulp and paper industry. Some of these are related to corrosive environments whose influence may accelerate the wear processes involved. Shown in Table 1 are several specific process areas and components where the wear behavior of materials is important to carry out the process, and opportunities for materials improvements exist.

Table 1. Wear — needs and opportunities

Unit operation	Wear site/s	Opportunities
Wood preparation	Debarkers Chipper - cutting blades Log transport - chutes - blades Saws Knives Slasher deck - saw blades Recycle paper handling	Improved materials providing greater impact-resistant edges for chipper blades, saws, knives, and slasher deck blades Materials with improved abrasion resistance for log transport chutes, debarkers, and recycle paper handling
Pulp preparation (mechanical) (chemical)	Groundwood Refiner - disks/plates - bearings Digester blow plates Recovery - pipes - fluidized bed gasifier	Improved ceramics for rotating grindstones Improved materials for refiner plates providing extended bar life and resistance to contact damage Refiner materials suitable for higher rotation rates with lower mass and higher fracture toughness, high-speed bearings Materials providing improved corrosion/erosion resistance for digester blow plates
Bleaching	Pumps	Abrasion-resistant materials for pumping high-consistency pulp slurries

Table 1. (Continued)

Unit operation	Wear site/s	Opportunities
Papermaking	Headbox (especially outer section)	Materials with improved durability for the header box and intermediate structures
	Fabric felt (knuckle)	
	Wire belts	
	Doctor blades	Materials with improved abrasion resistance for doctor blades, slitters, drums and screen baskets
	Knifes	
	Rolls	
	Slitters	
	Drums	
	Screen baskets	
	Impulse drying - internal slider	
	Slip rings	
Other technologies		
Environmental aspects/waste handling and minimization	Pumps	Improved materials for cavitation resistance in pumps and improved abrasion resistance in ash transport chutes and pipes
	Boilers - ash transport chutes - pipes	

8. CORROSION

Corrosion is an inherent problem both in the processing of wood fiber to make pulp and in the processing of pulp to make paper and related products. Although years of corrosion studies and alloy development underpin the present papermaking processes, corrosion remains the most visible and costly materials consideration in the design and operation of these processes. It is therefore relevant to review corrosion concerns based on contacts with representatives of the industry, to prioritize these concerns in terms of energy and economic considerations, and to examine the areas of corrosion expertise within Department of Energy (DOE) facilities that have potential applicability to pulp and paper requirements. This review is intended as a first step in identifying R&D needs and opportunities that will improve the corrosion performance of materials for pulp and paper production. Shown in Table 2 are specific process areas, components, and materials opportunities where corrosion is important.

Table 2. Corrosion - needs and opportunities

Unit operation	Corrosion site/s	Opportunities
Wood preparation		
Pulp preparation (mechanical)		
	Refiner - disks/plates	Materials suitable for higher rotation rates with lower mass and increased resistance to sulfuric acid corrosion and chloride pitting in the presence of steam
(chemical)	Digester - vessel walls - pipes - pumps	Modeling of corrosion processes in digester to minimize corrosion through design considerations
		Liner materials and/or weld overlays with improved corrosion resistance to caustic corrosion and caustic stress corrosion cracking
	- Blow plate	More economical blow target plate materials which will resist corrosion/erosion by pulp-containing liquors
	- Tube and shell heat exchangers	Stainless steel heat exchanger tubes with improved resistance to caustic and chloride cracking (and acids used for cleaning)
		On-line corrosion monitoring and diagnostic techniques

Table 2. (Continued)

Unit operation	Corrosion site/s	Opportunities
Pulp preparation (continued) Chemical (continued)	Recovery boiler - water wall tubes and studs in furnace	Boiler tube materials and surface coatings with improved resistance to hydrogen sulfide and stress-assisted waterside corrosion
	Hearth zone - primary air ports - superheater tubes	Oxidation/sulfidation-resistant superheater tube materials and surface coatings suitable for service at higher steam temperatures
		Studies of external stress-assisted corrosion mechanisms of boiler tubes in the furnace hearth and floor
	- smelt spout - floor	Corrosion-resistant ceramics for uncooled water-free smelt spouts
	Recovery gasifier (new) - water wall tubes - ceramic liner	Assess corrosion processes in gasifiers being developed for recovery of black liquor chemicals
	- gas turbine	Ceramics and alloy resistant to hot surface containing gasifier gases
Bleaching	Washer - deck - drum - evaporation/ condensation sites	Determination of corrosion mechanism of titanium in alkaline peroxide solutions
		Selection of optimized alloy systems for ClO_2 bleaching environments
		Development of more corrosion-resistant weld filler materials and welding practices for aggressive bleaching environments (currently there are issues with ClO_2, and these may increase with superoxides)

Table 2. (Continued)

Unit operation	Corrosion site/s	Opportunities
Papermaking	Headbox - apron - slice lips	More cost-effective and durable alloys with pitting resistance against reactive contaminants and cleaning chemicals
	Suction press roll - shell	Surfacing treatments to ameliorate residual stresses and improve corrosion fatigue properties Development of cast stainless steels with improved stress corrosion and fatigue resistance
	Press rolls	New metals or ceramic structural or coating materials with improved resistance to stream showers and cleaning chemicals
	Screen basket	Materials with improved resistance to fatigue and wear
Other technologies	Scrubbers, precipitators, and stacks	Materials to resist chloride pitting (dew point corrosion)
Environmental aspects/waste handling and minimization	Incinerators Gas separators and absorbers	Materials resistant to heavy metals associated with effluents

9. STRUCTURAL AND OTHER ASPECTS

Structural components (chutes, rolls, vessels, and pipes) and other items such as motors, generators, turbines, and sensors are important to pulp and paper facilities since they affect all unit operations. Cogeneration of electrical power at pulp and paper mills, for example, accounts for nearly 58% of all the electricity utilized by the industry. Electric motors are used throughout plants. The power level of motors can range from less than 1 to over 30,000 hp. Advances in these areas can improve energy efficiency and reduce downtime. Structural components are also present throughout pulp and paper facilities. Issues in these areas are not directly wear or corrosion controlled. Life prediction methodology is very important to long-term operation. Activities including identifying mechanisms, determining appropriate models, developing data bases, and conducting confirmatory tests are all necessary in order to improve structural components. This review is intended as a first step in identifying research and development needs and opportunities that will improve the performance and integrity of structural and other components for pulp and paper production. Shown in Table 3 are specific process areas, components, and materials opportunities related to these areas.

Table 3. Structural and other aspects - needs and opportunities

Unit operation	Location	Opportunities
Wood preparation		
Pulp preparation (mechanical)	Refiner - disks/plates	Refiner materials suitable for higher rotation rates with lower mass and higher fracture toughness and high-speed bearings
		Life prediction modeling including stress, strain, fracture, hydrodynamic effects, and vibration analyses
	Digester	Modeling of digester to identify areas where significant corrosion could occur
(chemical)		
	Recovery boiler - composite tubes	Nondestructive evaluation technique to monitor cracks and integrity of tubes and weldments
	Recycling (new)	Membranes to improve quality and Btu content of gases from black liquor gasification processes
Bleaching	Washing	Cleanable filters and membranes to separate undesired components from bleaching effluents
	Vessels Piping Valves	Polymer-base structural materials and coatings
		Joining and long-term structural integrity of materials
		Ceramic coatings

Table 3. (Continued)

Unit operation	Location	Opportunities
Papermaking	Suction press roll	Structural analyses and design modifications to reduce cyclic loads
		Improved manufacturing processes including casting, joining, and machining
		Life prediction modeling
	Dryer rolls	More ductile replacement for cast-iron rolls
	Impulse dryer roll	Higher modulus (stiffness) to remove necessity of hydrostatic element within roll
		Improved ceramic coatings on rolls
	Paper coaters	Develop clay solutions and roll materials with improved sticking and releasing characteristics and model coating process
Other technologies	Motors	Materials resulting in more efficient motors and motor controller
	Motors/generators	Motor current analyses to predict motor/generator/bearing failures
	Pulp preparation - recovery boiler	Robotic inspection techniques to verify boiler tube integrity
		On-line sensors and control to monitor and control the web and paper
		Sensors and controls to measure web and paper properties including stiffness
		Improved materials needed which permit communication with sensors placed on rotating rolls
		Determine fiber properties including length and orientation on-line
Environmental control/waster handling and minimization	Digester	Filters and membranes to reduce waste stream and minimize evaporative processes
	Waste processing	Membrane materials for separating volatile compounds and for removing undesired constituents of liquid waste streams

10. ACKNOWLEDGMENTS

Special thanks is due to all participants in the meetings and workshops held with respect to the preparation of this report. Summaries of these meetings are listed in the Appendix.

The author also thanks P. J. Wenzel for compiling the Appendix, D. L. Balltrip for preparing the report, K. Spence for editing the report, and G. R. Carter for performing the quality assurance review.

11. APPENDIX

During the past 12 years, the U.S. Department of Energy has, together with industry support, 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. The paper industry has played an important role in the guidance of this research and development program. An exciting new task is being undertaken to develop a more comprehensive and formalized strategic plan for DOE's paper program.

Information from meetings and workshops held with representatives of the pulp and paper industry, materials and equipment manufacturers, universities and institutes, U.S. DOE, and DOE national laboratories, as well as some textbooks, was used in the development of this program and to gather information in support of this report. A listing of these meetings and workshops follow:

- Opportunities and Needs for Materials in the Pulp and Paper Industry - visit by personnel from the Institute of Paper Science and Technology, November 1992, Oak Ridge, Tennessee

- Opportunities and Needs for Materials in the Pulp and Paper Industry, December 10, 1992, Oak Ridge, Tennessee

- Bowater Pulp and Paper Plant, December 1992, Calhoun, Tennessee

- Institute of Paper Science and Technology, December 1992, Atlanta, Georgia

- Pulp and Paper Mill of the Future Workshop, February 3-5, 1993, Reston, Virginia

- Joint AFPA-BLRBAC Maintenance Seminar, April 7-8, 1993, Atlanta, Georgia

- Government/Industry Pulp and Paper Workshop, August 12-13, 1993, Portland, Oregon

- Pulp and Paper Mill of the Future - An Information Exchange, September 8-10, 1993, University of Maine, Orono

MEETING TITLE: Opportunities and Needs for Materials in the Pulp and Paper Industry
Visit by personnel of the Institute of Paper Science Technology

SPONSOR: Advanced Industrial Materials (AIM) Program

LOCATION: Oak Ridge National Laboratory, Oak Ridge, Tennessee

DATE: November 1992

The objective of this meeting was for the Institute of Paper Science Technology (IPST) personnel to identify critical materials issues related to the pulp and paper industry. The information was used to develop a preliminary needs assessment and to help define future planning meetings for the Materials Needs Assessment. Attendees included staff from ORNL, IPST, and DOE program managers.

MEETING TITLE: Opportunities and Needs for Materials in the Pulp and Paper Industry

SPONSOR: Advanced Industrial Materials (AIM) Program

LOCATION: Oak Ridge National Laboratory, Oak Ridge, Tennessee

DATE: December 1992

The goal of this meeting was to identify new applications of materials for pulp and paper processing. Information will be used to develop a program plan for the Office of Industrial Technologies, Advanced Industrial Materials (AIM) Program. An agenda and list of attendees follows.

AGENDA

"Opportunities and Needs for Materials in the Pulp and Paper Industry"

Advanced Industrial Materials (AIM) Program
Oak Ridge National Laboratory (ORNL)
Building 6008

Hosted By: Peter Angelini

Thursday, December 10, 1992

Time	Topic	Person
8:30	Welcome	Peter Angelini ORNL
8:40	Introduction and Meeting Goals	Charlie A. Sorrell DOE-AIC Materials Program
8:55	Pulp and Paper Industry Programs	Stan F. Sobczynski DOE-Pulp and Paper Program
9:40	Background on ORNL	Anthony C. Schaffhauser ORNL
10:10	Break	
10:25	Industrial Perspective	
	- Andritz Sprout Bauer	William L. Bohn
	- Bowater	John Griffey LeRoy Hershey
	- Champion International	David C. Bennett
	- Georgia-Pacific	Karl T. Morency
	- Thermo-Chem	K. Durai-Swamy William Steedman
	- Westvaco Corporation	W. B. A. "Sandy" Sharp
	- Weyerhaeuser Paper Company	Peter Gorog
	- University of Wisconsin-Platteville	Ronald A. Yeske
	- Institute of Paper Science & Tech.	Jeff Colwell Maclin Hall David Orloff
12:00	Lunch (Catered)	
1:00	Continue Industrial Perspective Session	
2:30	Discussion session on materials needs including: Corrosion/Metallic Coatings; Wear; Heat Transfer/ Insulation; Structural Materials (welding, fatigue, stress); Ceramics/Coatings; Chemical Processing; Environmental; Nondestructive Evaluation (sensing/controls); and other areas of particular interest.	All (Jack DeVan, Jim Keiser, Charles Yust, Tom Kollie, Tom Zacharia, Gus Aramayo, Chuck Brinkman, Bob Lauf, Doug Fain, Charlie Byers, Steve Hildebrand, Dan McGuire, Dan McDonald)
4:30	Adjourn	
7:30	Dinner	

AGENDA

"Opportunities and Needs for Materials in the Pulp and Paper Industry"

Advanced Industrial Materials (AIM) Program
Oak Ridge National Laboratory (ORNL)
Building 6008

Hosted By: Peter Angelini

Friday, December 11, 1992

Time	Topic	Person
8:30	Continuation of Discussion Session on Materials Needs (if not completed the previous day) followed by Discussion and Report on Selected Topics	All
10:30	Break	
10:45	Continuation of Discussions	
12:00	Lunch (Catered)	
1:00	Summary session	All
2:30	Adjourn	
2:30	Tours of Facilities available	

OPPORTUNITIES AND NEEDS FOR MATERIALS IN THE PULP AND PAPER INDUSTRY

December 10, 1992

ATTENDEES LIST

Moonis Ally, Oak Ridge National Laboratory
Peter Angelini, Oak Ridge National Laboratory
Chuck R. Brinkman, Oak Ridge National Laboratory
Charles H. Byers, Oak Ridge National Laboratory
Jefferey A. Colwell, Institute of Paper Science & Technology, Inc.
John V. Coyner, Oak Ridge National Laboratory
Janet H. Cushman, Oak Ridge National Laboratory
David Dawson, Oak Ridge National Laboratory
Jack H. DeVan, Oak Ridge National Laboratory
Doug E. Fain, K-25
Elmer Fleischman, EG&G Idaho, Inc., INEL
John E. Griffey, Bowater, Inc.
Maclin S. Hall, Institute of Paper Science & Technology, Inc.
LeRoy Hershey, Bowater, Inc.
Eugene E. Hoffman, Department of Energy/Oak Ridge
James R. Keiser, Oak Ridge National Laboratory
Robert J. Lauf, Oak Ridge National Laboratory
Dan W. McDonald, Oak Ridge National Laboratory
Karl T. Morency, Georgia-Pacific Corp.
Ronald L. Musselman, Andritz Sprout Bauer
Mitch Olszewski, Oak Ridge National Laboratory
Dave Orloff, Institute of Paper Science & Technology, Inc.
Arvid E. Pasto, Oak Ridge National Laboratory
David A. Scearce, Thermo-Chem, Inc.
Anthony S. Schaffhauser, Oak Ridge National Laboratory
W.B.A. "Sandy" Sharp, Westvaco Corp.
Philip S. Sklad, Oak Ridge National Laboratory
Stanley F. Sobczynski, Department of Energy/HQ
Charles A. Sorrell, Department of Energy/HQ
Joan K. Young, Battelle Pacific Northwest Laboratories
Charles S. Yust, Oak Ridge National Laboratory
Thomas Zacharia, Oak Ridge National Laboratory

MEETING TITLE: Bowater Pulp and Paper Plant

SPONSOR: Advanced Industrial Materials (AIM) Program

LOCATION: Calhoun, Tennessee

DATE: December 1992

The purpose of this meeting was to tour the Bowater Pulp and Paper Plant in order to gain familiarity with the papermaking process.

MEETING TITLE: Institute of Paper Science and Technology

SPONSOR: Advanced Industrial Materials (AIM) Program

LOCATION: Atlanta, Georgia

DATE: December 1992

The purpose of this meeting was to tour the Institute of Paper Science and Technology Research facilities to become familiar with capabilities.

MEETING TITLE: Pulp & Paper Mill of the Future Workshop

SPONSOR: U. S. Department of Energy, Office of Industrial Technologies

LOCATION: Hyatt Regency, Reston, Virginia

DATE: February 3-5, 1993

The purpose of this meeting was to gather information used to assist in the development of the Office of Industrial Technologies (OIT) Paper Mill of the Future Program Plan and acquaint attendees with the on-going program being conducted in pulp and paper R&D. This information will be used to strengthen the current Pulp and Paper R&D Program. The objectives of the workshop were to obtain meaningful input to the OIT Pulp and Paper Program Plan, to inform the paper industry of the development of this plan, to present the mission of the Office of Industrial Technologies to the paper industry, to provide the opportunity for industry, universities, and national laboratories to share technology needs and capabilities, and to provide a mechanism for a continuing dialogue with the paper industry. Attendees included personnel from the paper industry, its suppliers, universities, private R&D institutes, the DOE, and national laboratories. A draft of this report "Materials Needs and Opportunities in the Pulp and Paper Industry" was distributed for comments and review at the meeting. An agenda and list of attendees follows.

"Final Edition"
25 Jan 1993

PULP & PAPER MILL OF THE FUTURE WORKSHOP

Sponsor: U.S. Department of Energy, Office of Industrial Technologies
Location: Hyatt Regency Reston, (703)-709-1234, FAX (703)-709-2281

February 3-5, 1993

Revised Agenda

WEDNESDAY, FEBRUARY 3, 1993

10:00 am	Registration
	(Note: Lunch not provided)

The Paper Industry Vision of the Future

1:00 pm	Welcome to Participants *S. Sobczynski, U.S. Department of Energy*
1:15 pm	**The Federal Role Today in Technology Development** *A. Streb, U.S. Department of Energy*
2:00 pm	**The Paper Industry Today and Its Needs of the Future** *Speaker: Dr. D. Raymond, Weyerhaeuser Paper Company*
2:45 pm	Workshop Objectives *D. Wiley, U.S. Department of Energy*
3:00 pm	Breakout Group Assignments *S. Sobczynski, U.S. Department of Energy*
3:15 pm	Breakout Sessions -(Groups A, B, C, D): Each group will address **The Vision for the Paper Mill of the Future**
5:00 pm	FEEDBACK PRESENTATIONS
	Vision for Paper Mill of the Future (Groups A, B, C, D)
6:30 pm	*Adjourn*
7:00 pm - 8:30 pm	*Reception - hors d'oeuvre and cash bar*
	(Dinner on your own)

(Agenda, Page 2 of 3)

THURSDAY, FEBRUARY 4, 1993

7:00 am - 8:00 am	*Continental Breakfast*

Industry Drivers

8:00 am	Breakout Group Assignments *S. Sobczynski, U.S. Department of Energy*
8:15 am	Group E - Energy Supply Group F - Process Efficiency Group G - Waste Reduction
10:30 am	*Break*
10:45 am	*FEEDBACK PRESENTATIONS* Vision for Industry Drivers (Groups E, F, G)
12:00 pm	*Lunch* **Third Generation R&D** *Speaker: W. E. "Pat" Clarke, Arthur D. Little, Inc.*

Vision for Pulp and Paper Technologies

2:00 pm	Breakout Assignments *S. Sobczynski, U.S. Department of Energy*
2:15 pm	*Breakout Sessions* Group H: Pulping, TMP, CTMP Group J: Bleaching Group K: Chemical Recovery Group L: Papermaking, Other
5:30 pm	*Adjourn*
6:30 pm	*Cash Bar*
7:00 pm	*Dinner* **Competitive Factors in the International Pulp and Paper Industry** *Speaker: Dr. R. Slinn, AFPA*

(Agenda, Page 3 of 3)

FRIDAY, FEBRUARY 5, 1993

7:00 am - 8:00 am	*Continental Breakfast*
8:00 am	Announcements/Workshop Assignments
8:15 am	*FEEDBACK PRESENTATIONS*
	Vision for Pulp and Paper Technologies (Groups H, J, K, L)
10:30 am	Wrap up *S. Sobczynski, U.S. Department of Energy*
10:45 am	Closing Remarks *D. Swink, U.S. Department of Energy*
11:30 am	*Adjourn - Lunch*

OIT

OFFICE OF INDUSTRIAL TECHNOLOGIES

Productivity through Technology

PULP AND PAPER MILL OF THE FUTURE WORKSHOP

February 3-5, 1993

ATTENDEES LIST

Cyrus Aidun, Institute of Paper Science & Technology, Inc.
Robert Allen, Department of Energy/Boston
James Anderson, Herty Foundation Development
R. Anderson, Oak Ridge National Laboratory
Peter Angelini, Oak Ridge National Laboratory
Peter Ariessohn, Weyerhaeuser Paper Company
A. D. Armstrong, Georgia-Pacific Corp.
Karl Ayers, The Mead Corp.
Sujuit Banerjee, Institute of Paper Science & Technology, Inc.
Robert Bareiss, Bareiss Associates
Richard Barker, Union Camp Corp.
Joe Barsin, Goraveiken
Paul Bayer, Energetics, Inc.
Alexander Bonsu, International Paper
David Boron, Department of Energy, Office of Industrial Technologies
Joseph Bozell, National Renewable Energy Laboratory
Taz Bramlette, Sandia National Laboratories
L. Busker, Beloit Corp.
Charles Byers, Oak Ridge National Laboratory
Robert Chappell, Department of Energy/Golden
Helena Chum, National Renewable Energy Laboratory
W. E. Clarke, Arthur D. Little
John Clement, The Babcock and Wilcox Company
Jeffrey A. Colwell, Institute of Paper Science & Technology, Inc.
Charles Covino, General Magnaplate Corp.
Bruce Cranford, Department of Energy, Office of Industrial Waste Reduction
Oscar Crisalle, University of Florida
Harold Davis, Monadnock Process Engineering
Jack DeVan, Oak Ridge National Laboratory
Richard Diehl, Textron Defense Systems
Donald Dimmel, Institute of Paper Science & Technology, Inc.
Darryl Dodson-Edgars, Boise Cascade Corp.
Patricia J. Dollar, Corporation on Resource Recovery and the Environment
Elisabeth M. Drake, Massachusetts Institute of Technology
K. Durai-Swamy, MTCI/ThermoChem
Richard Ellis, Institute of Paper Science & Technology, Inc.
Jeff Empie, Institute of Paper Science and Technology, Inc.
Ronald Estridge, James River Corp.
Douglas E. Fain, Sr., Oak Ridge National Laboratory
John Fildes, BIRL/Industrial Research Laboratory
Jack Firkins, Institute of Paper Science & Technology, Inc.
Elmer Fleischman, Idaho National Engineering Laboratory
W. Frederick, Oregon State University

PULP AND PAPER MILL OF THE FUTURE WORKSHOP

February 3-5, 1993

ATTENDEES LIST
(continued)

Arthur Fricke, University of Florida
Simon Friedrich, Department of Energy, Office of Industrial Technologies
Joseph Genco, University of Maine
Gary Gettmann, Georgia-Pacific Corp.
Bob Giese, Giese and Associates
Don Gilmore, TAPPI
Peter Gorog, Weyerhaeuser Paper Company
Thomas Grace, T. M. Grace Company, Inc.
William Griffith, Oak Ridge National Laboratory
Maclin Hall, Institute of Paper Science & Technology, Inc.
Marquita Hill, University of Maine
Harold Hintz, Westvaco Corp.
Patricia Hoffman, Energetics, Inc.
Robert H. Horton, Institute of Paper Science & Technology, Inc.
Jeffrey Hsieh, Georgia Institute of Technology
Ehr Ping HuangFu, Department of Energy, Office of Industrial Technologies
Peter J. Ince, Department of Agriculture Forest Service
Robert Jacobs, ABB Combustion Engineering
Keith Johnson, Scott Paper Company
Richard Johnson, BIRL/Industrial Research Laboratory
Todd Johnson, Babcock and Wilcox
Jay Keller, Sandia National Laboratories
Michael Kelley, Advanced Refractory Technologies
Robert Kinstrey, RUST Engineering
Michael Kocurek, Herty Foundation Development
John Koning, Department of Energy Forest Products Laboratory
David Kraske
Gopal Krishnagopalan, Auburn University
Veli Lapinoja, Georgia-Pacific Corp.
Perry Lindstrom, National Critical Materials Council
Earl W. Malcolm, Institute of Paper Science & Technology, Inc.
Amal Mansour, MTCI
Momtaz Mansour, MTCI
R. C. Massey
Thomas McDonough, Institute of Paper Science & Technology, Inc.
Ronald McHugh, Department of Energy
Robert McIlroy, Babcock and Wilcox
Jim Mills, Idaho National Engineering Laboratory
Phill Mitchell, KAMYR
Algis Mockaitis, Stone Container Corp.
Richard Murphy, Oak Ridge National Laboratory
Jon Myers, P. H. Glatfelter Company

PULP AND PAPER MILL OF THE FUTURE WORKSHOP

February 3-5, 1993

ATTENDEES LIST
(continued)

James Neff, BETZ
Ogbemi Omatete, Oak Ridge National Laboratory
Gregory Ondich, Department of Energy, Environmental Protection Agency
David Orloff, Institute of Paper Science & Technology, Inc.
Ralph Overend, National Renewable Energy Laboratory
Michael Pearce, General Magnaplate
Frank H. Pichette, Scott Paper Company
John Pinkerton, NCASI
Shalendra Porwal, Battelle Pacific Northwest Laboratories
John Racine, Stone and Webster
Arthur J. Ragauskas, Institute of Paper Science & Technology, Inc.
Ram Ramarao, Empire State Paper Research Institute
G. Julian Reid, TAPPI
David Rolfe, S. D. Warren Company
Niel Rossmeissl, Department of Energy, Office of Industrial Technologies
Alan W. Rudie, Institute of Paper Science & Technology, Inc.
H. Rumph, Orion CEM, Inc.
Francis Ruppel, Oak Ridge National Laboratory
James Rushton, O'Neal Engineering, Inc.
Rolf Ryham, Ahlstrom Recovery, Inc.
Henry Said, ThermoChem, Inc.
Peter Salmon-Cox, Department of Energy, Office of Industrial Technologies
Robert Salter, Osmotek, Inc.
Dale Schaefer, Sandia National Laboratories
A. C. Schaffhauser, Oak Ridge National Laboratory
Linda Schilling, Department of Energy, Office of Industrial Technologies
Martin Schroeter, Herty Foundation Development
William Scott, Miami University
Barry Seidel, BE&K
Peter Seifert, Black Clawson Company
W.B.A. Sharp, Westvaco Corp.
Thomas Single, James River Corp.
Philip S. Sklad, Oak Ridge National Laboratory
John M. Smuk, Potlatch Corp.
Lucinda B. Sonnenberg, Institute of Paper Science & Technology, Inc.
Charles A. Sorrell, Department of Energy, Office of Industrial Technologies
Louis Sousa, Bureau of Mines
Richard Steiger, Stone and Webster Engineering Company
Frank Stodolsky, Argonne National Laboratory
David Streit, Proctor and Gamble Cellulose
Paul Stuart, BEAK Consultants, Ltd.
Samuel Suh, Champion International

PULP AND PAPER MILL OF THE FUTURE WORKSHOP

February 3-5, 1993

ATTENDEES LIST
(continued)

Raymond Taylor, Georgia-Pacific Corp.
William Thompson, Bailey Controls Company
Matthew Van Hook, AFPA
Allan Walsh, J. H. Jansen Company
Theodore Wegner, Department of Agriculture, Forest Services, Forest Products Laboratory
Henry Wells, University of Minnesota
Torsten Wesslen, Foxboro
William Wilkinson, Stone Container Corp.
James R. Whetstone, National Institute of Standards and Technology
Bernard Yaros, Scott Paper Company
Joan Young, Battelle Pacific Northwest Laboratory
Charles S. Yust, Oak Ridge National Laboratory
Erdan Yuzak, Champion International

MEETING TITLE: Joint AFPA-BLRBAC Maintenance Seminar
(American Forest Products Association and
Black Liquor Recovery Boiler Advisory Committee)

SPONSOR: Advanced Industrial Materials (AIM) Program

LOCATION: Sheraton Airport Hotel, Atlanta, Georgia

DATE: April 7-8, 1993

The topics of the seminar were inspection methods, procedures, and results. Information was presented that allowed knowledge to be gained relative to problems (corrosion, scc, etc) in black liquor recovery boilers, how the inspection programs were geared to control the problems and what non-destructive examination approaches were being used to periodically evaluate the boiler components. An agenda for this meeting follows but no attendance list was provided from the seminar.

JOINT AFPA - BLRBAC MAINTENANCE SEMINAR

APRIL 7, 1993, 10 AM - 5 PM
APRIL 8, 1993, 8 AM - NOON

SHERATON ATLANTA AIRPORT HOTEL
1325 VIRGINIA AVENUE, ATLANTA, GEORGIA

SESSION I Fundamentals of a Planned Inspection Program

- Key elements and the application of an organized planning process to optimize a maintenance inspection
  - Elements of a Successful Inspection Program
    - Jim Jordan, ABB C-E
  - Possible Discussion (No paper)
    - To be announced
  - Preparation for Repair – A Contractor's Perspective
    - Ron Blodgett, ABB C-E
  - The Inspection and the National Board Inspection Code (NBIC)
    - Barry Bobo, Hartford Steam Boiler Inspection and Insurance Company
  - Panel Discussion

SESSION II Visual Inspection Techniques

- Modern Visual Inspection Techniques to Assure Reliability and Detect Problems on a Timely Basis
  - Application of Inspection Knowledge, Equipment and Techniques
    - Carl Lohstroh, Weyerhaeuser
  - Modern Visual Inspection Techniques Recovery Boilers
    - Gunnar Thorslund, Tampella
  - Panel Discussion

SESSION III NDT/DT Inspection Techniques

- Managing a NDT/DT Program to Assure Where to Inspect, How to Assure the Quality of Inspection Training and Certification
  - (Tentative) Training and Certification to Accepted Standards
    - Jacques Brignac, ABB C-E
  - Non-Destructive Examination (NDE)
    - Ralph Murphy, Babcock & Wilcox
  - The Use of Non-Destructive Testing in a Recovery Boiler
    - Jim Treat, Longview ~~Fibre~~ Inspection
  - Corrosion Inspection of Recovery Boilers
    - W. B. A. Sandy Sharp, Westvaco Corp
  - Panel Discussions

JOINT AFPA - BLRBAC MAINTENANCE SEMINAR
APRIL 7, 1993 10:00 AM - 5:00 PM
APRIL 8, 1993 8:00 AM - 12:00 NOON

SESSION IV SPECIAL INSPECTION TECHNIQUES

- Understanding the Special Mechanisms of near Drum Corrosion and Stress Assisted Cracking/Corrosion and the Techniques for Inspection
  - Near Drum Corrosion, the Problem
    - Doug Singbill, PAPPRICAN
  - How to Inspect for "NDC"
    - Charles Guzi, Lamda Technology USA
  - Stress Assisted Corrosion, the Problem
    - Joan Barna, Babcock & Wilcox
  - X-Ray Inspection Techniques for Stress Assisted Corrosion
    - Lloyd Sutton, INDT
  - Panel Discussion

SESSION V Evaluation of Inspection Data and Long Term Planning

- How can the Inspection Results be Evaluated to Develop Proactive Maintenance Program
  - Computer Analysis and Trending
    - Tom Ridgeway, TCRI
  - Mill Perspective on Inspection Evaluation and Maintenance Planning
    - Jim West, Weyerhaeuser
  - Inspection Data Managed for Enhanced Predictive Maintenance
    - Tom Enright, ABB C-E
  - Panel Discussion

MEETING TITLE: Government/Industry Pulp and Paper Workshop

SPONSOR: Office of Industrial Technologies and Advanced Industrial Materials (AIM) Program

LOCATION: Portland, Oregon

DATE: August 12-13, 1993

The purpose of this effort was to identify further needs and opportunities for improved materials and process equipment of the pulp and paper industry. This information will be used by the Office of Industrial Technology and the Advanced Industrial Concept Division of DOE to plan new initiatives to support Paper Mill 2020. This workshop is being held to identify the most serious problems that occur during pulp and paper processing resulting from the use of suboptimal materials and process equipment. The goal of the workshop was to obtain an in-depth identification of needs and specific recommendations for joint laboratory/industry research projects. Attendees included representatives from large integrated northwest pulp and paper mills, paper industry machinery manufacturers, regional academic institutions and technical associations for the pulp and paper industry. Laboratory staff knowledgeable of both materials issues and pulp and paper technology were invited. An agenda and list of attendees follows.

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 - 8:00 p.m. TOUR OF OLD GROWTH STAND (1 hr. & 20 min. away, some van space 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 (contd.) — 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.

GOVERNMENT/INDUSTRY PULP AND PAPER WORKSHOP

August 12-13, 1993

ATTENDEES LIST

Charles A. Allen, Idaho National Engineering Laboratory
Peter Angelini, Oak Ridge National Laboratory
Helena Chum, National Renewable Energy Laboratory
Darryl Dodson-Edgars, Boise Cascade Corporation
Dennis Forbes, James River Corporation
Bob Giese, Giese & Associates
Y. P. Fang, Simpson
Jack Goldfrank, Mead Corporation
Margaret Gorog, Weyerhaeuser Company
Peter Gorog, Weyerhaeuser Company
Rick Gustafson, University of Washington
Christine Hatstrom-Nasi, TEKES Technology Development Center
Richard Haynes, PFSL
Arlon Hunt, Lawrence Berkeley Laboratory
Densmore Hunter, Weyerhaeuser Company
James R. Keiser, Oak Ridge National Laboratory
Duane Lindner, Sandia National Laboratory
Gerry Maestas, Los Alamos National Laboratory
Robert J. McTee, Weyerhaeuser Company
Robert M. Neilson, Jr., EG&G Idaho, Inc.
David Orloff, Institute of Paper Science & Technology
Wayne Robbins, Institute of Paper Science & Technology
Thomas P. Roberts, Mead Central Research Laboratories
W. D. Samuels, Battelle Pacific Northwest Laboratory
Stanley F. Sobczynski, U.S. Department of Energy
Charles Sorrell, U.S. Department of Energy
W. W. Vantzelfden, James River Corporation
Carol Wiseman, Boise Cascade Corporation
Ainslie T. Young, Los Alamos National Laboratory
Ray Witter, James River Corporation

MEETING TITLE: Pulp and Paper Mill of the Future - An Information-Exchange

SPONSOR: Office of Industrial Technologies and Advanced Industrial Materials (AIM) Program

LOCATION: University of Maine, Orono

DATE: September 8-10, 1993

The DOE has historically sponsored research in the pulp and paper industry under the program direction of Stan Sobczynski. DOE recognizes the need to work more closely with U.S. industry in other program areas, including, for example, materials research, recycling, and waste minimization. The National Laboratories are a resource for collaborative research with industry, and there is an increased realization of the need for the Laboratories to perform research that supports U.S. industry. For effective cooperative efforts among interested parties, each needs to understand the needs, interests, and capabilities of the others. At this meeting, industry personnel summarized the research needs of the pulp and paper industry, and colleges and others with pulp and paper technology programs made use of a poster session to present their capabilities to address these needs. The DOE National Laboratories discussed their capabilities and how they might be useful to the pulp and paper industry. An agenda and list of attendees follows.

Pulp and Paper Mill of the Future -- an information-exchange

September 8 - 10, 1993

University of Maine, Orono, Department of Chemical Engineering

Sponsored by the
U.S. Department of Energy *Office of Industrial Technologies and the U.S. DOE Laboratories*

Wednesday September 8

8 am - 5 pm — **Introduction to Pulp and Paper Making** for newcomers to the industry with *Dr. Joseph Genco, Univ. of Maine*, followed by afternoon paper mill visit.

Wednesday Evening -- plenary session begins

6-7:30 pm — Reception (*cash bar*) Jenness Hall lobby includes tour of *P&P Pilot Plant.*

Dinner on your own.

Thursday September 9

8:30 - 9 am	**Welcome,** *Judy Bailey, Vice President, Research and Public Service*, Univ of Maine **Purpose of meeting,** *Stanley Sobczynski, U.S. DOE* **U.S. DOE's Advanced Industrial Concepts Division** -- what they do and what they need to know about P&P needs
9- noon	**Pulp and Paper Mill of the Future -- Vision Statement** **P&P industry representative presentations** -- research needs in raw materials, the environment, pulping and bleaching, paper-making, surface and structural materials, sensors and process control, chemical recovery, recycling, materials & maintenance.
12 - 1	***Lunch***
1-5 pm	**Finish P&P industry presentations on research needs** **R&D capabilities of colleges and others** working to meet industry needs -- an overview presentation followed by a poster session served up with refreshments.
6 pm	**Dinner** at Black Bear Inn **Research funded by DOE's P&P Processes program,** ***S.Sobczynski, DOE*** **Major presentation being arranged** ***Entertainment***

Friday September 10

8:30 am - noon	**Capabilities and interests of the U.S. DOE National Labs** -- presentations **Discussion and closing**
noon	**Lunch**

For more information, call Marquita Hill, Tel: 207/ 581-2301 or Betty Ingraham, Tel: 207/581-2281 (FAX 207/ 581-2323).

Pulp & Paper Mill of the Future--An Information Exchange
List of Speakers as of July 30, 1993

Pulp and Paper Industry

	Phone	Fax
Vision statement		
Delmar Raymond, Weyerhaeuser	206/ 924-6850	924-6540
Raw materials		
William Foster	517/ 631-0908	631-1755
Environmental Concerns		
Ron Estridge, James River	804/ 649-4209	343-8592
Pulping/bleaching		
Harry Hintz, Westvaco	212/ 318-5412	
Paper making processes		
Dan W. Manson, Manson and Associates	404/ 237-3939	261-6920
Surface & structural materials		
Anthony Lyons, Repap Technologies	215/ 630-9630	630-0966
Sensors/process control		
Gary Baum, James River	414/ 729-8161	729-8161
Recycling		
Tom Friburg, Weyerhaeuser	206/ 924-6204	
Chemical Recovery		
Tom Grace, T.M. Grace Co.	414/ 734-4434	734-4505
Materials/maintenance		
Sandy Sharp, West Vaco	301/ 497-1330	497-1309

National Lab speakers

	Phone	Fax
Oak Ridge		
Peter Angelini, lead talk on Sep 10	615/ 574-4565	574-6098
Los Alamos		
Gerald Maestas	505/ 667-3973	667-8873
Sandia		
Dale Schaefer	505/ 844-7937	844-4947
NREL		
Estabon Chornet	303/ 231-1384	
(*Robert Evans, contact person*)		
Battelle, Pacific Northwest Lab		
Douglas Eliott	509/ 375-2248	375-2059

DOE

	Phone	Fax
Pulp and Paper Processes		
Stanley Sobczynski	202/ 586-1878	586-8134
Advanced Industrial Concepts Div.		
Charles Sorrell	202/ 586-1514	586-7114

PULP AND PAPER MILL OF THE FUTURE - AN INFORMATION EXCHANGE

September 8-10, 1993

ATTENDEES LIST

Said M. Abubakr, Forest Products Laboratory
Peter Angelini, Oak Ridge National Laboratory
Raja G. Aravamuthan, Western Michigan University
James E. Battles, Argonne National Laboratory
Gary A. Baum, James River Corporation
Roger C. Bavoux, U.S. Department of Energy-Boston
Douglas Bousfield, University of Maine
Mike Boyle, University of Maine
Charles H. Byers, Oak Ridge National Laboratory
Med Byrd, North Carolina State University
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Jack Chinn, Madison Paper Industries
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