PULP AND PAPER MANUFACTURING

INTRODUCTION

The modern pulp and paper mill is a complex, high-valued facility. To operate profitably under today's environmental constraints, a mill must efficiently integrate steam and power demands and chemical recovery systems with the pulp and paper processes. Computer control of all mill processes is the norm.

Each step in papermaking — from raw material storage, through stock preparation and papermaking, to finished roll storage — presents special loss prevention challenges. Storage areas pose severe fire loss potentials. Fires, explosions and machinery breakdowns can seriously damage critical process equipment. Pollution control equipment can also cause large losses.

Associated with these high property damage potentials are even higher business interruption potentials. In a full process Kraft mill, loss of the black liquor recovery boiler (BLRB) can result in extensive downtime. Continuous digesters and Yankee dryers can also present very large business interruption potentials.

This GAPS Guideline describes "full process" pulp and paper mills. Full process mills include pulp, paper and finishing mills, and sometimes converting mills. Figure 1 shows a simplified process flow diagram for a full process mill. Many of the processes described in this section also apply to mills that are not full process.

PROCESSES AND HAZARDS

Woodyard Operations and Storage

Pulp mills commonly maintain extensive yard inventories of logs and chips to satisfy the enormous and continuous demand of the process line and to ensure a supply despite unpredictable weather, transportation problems or seasonal harvesting. Woodyard operations can include debarking, slashing (gang sawing) and chipping. The main loss exposures are chipper disks and drives, debarkers and possibly conveyors. Equipment to move logs, such as Jack-ladders and cranes, also presents loss exposures.

Logs are usually stored in racked, corded, or tumbled piles (Figure 2), but are occasionally kept in ponds. Clean chips produced from debarked logs are stored in silos or bins. Long-term reserves are kept in large yard piles. The by-product from the debarking process, called "hog fuel," consists primarily of bark, wood chips and sawdust. Hog fuel is also stored in large piles to be used as fuel in either a hog fuel or bark boiler. Figure 3 shows the raw material handling area.

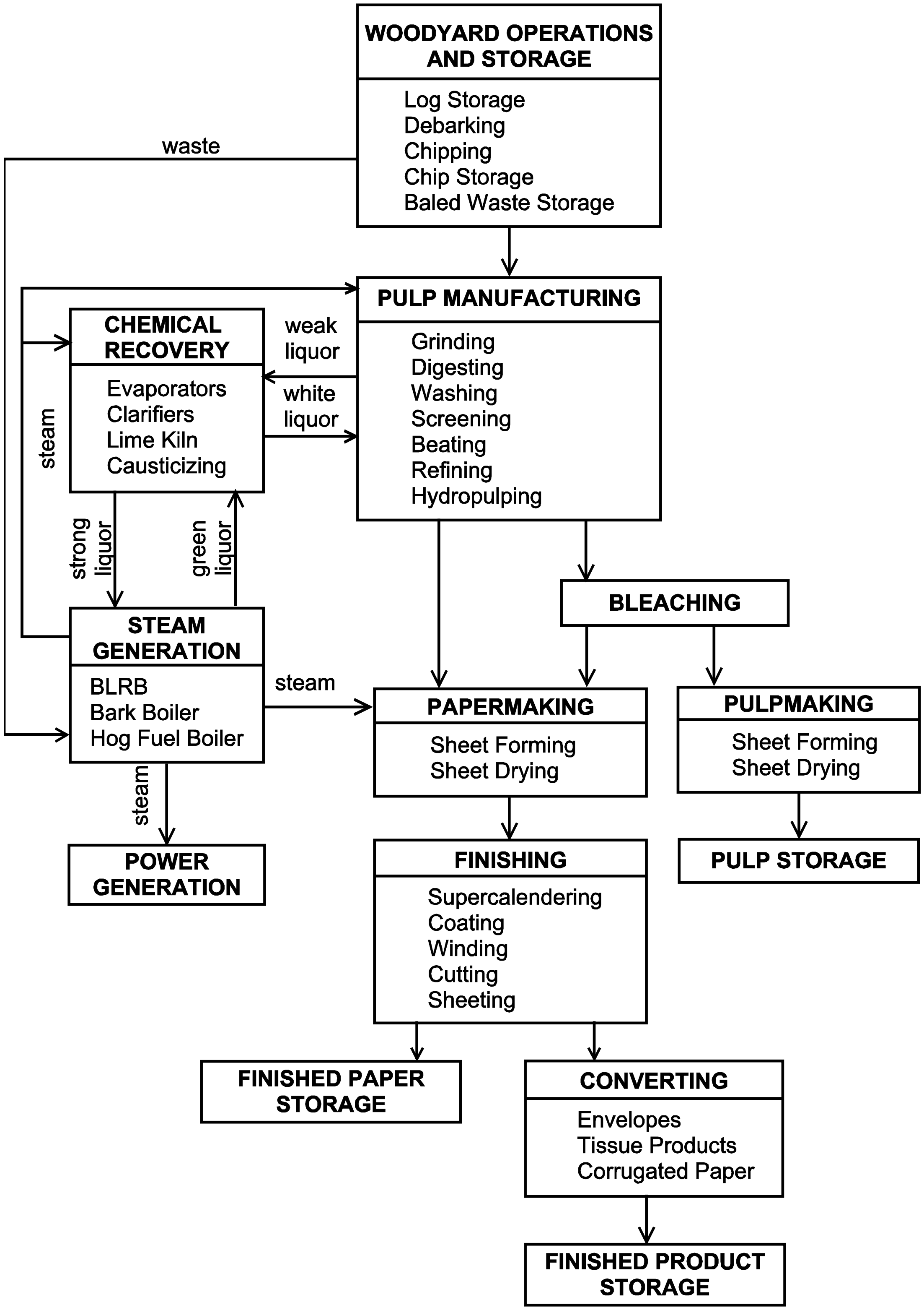

Figure 1. Simplified Process Flow Diagram For Full-Process Pulp and Paper Mill.

Figure 2. Tumbled Log Pile

Figure 3. Raw Material Handling Area Showing Log Piles, Debarker, Chipper, Chip Piles and Conveyors.

The major problem with log and chip piles is that a burrowing fire can be uncontrollable by the time it is detected. Burrowing fires are controlled by overhaul, which consists of carefully breaking down the pile, salvaging the unaffected areas, and dousing the fire. Fires in log and chip storage can develop into major conflagrations if the logs or chips are dry (Figure 4).

Log pile storage presents different challenges than chip pile storage. Log pile fires are usually started by outside ignition sources and develop slowly. If they are attacked promptly with many hose streams, they can usually be contained within the pile until overhaul permits final extinguishment. But if the fire is well established, the intense thermal updrafts prevent effective hose penetration and make control and overhaul operations extremely difficult. This is especially true in a large, tumbled pile.

Chip pile fires may be started by outside ignition sources or by spontaneous combustion within the pile. Under normal conditions, wood chips may have up to 50% moisture content and are not easily ignited. But after a prolonged dry spell, this can change drastically. A rapidly spreading surface fire may become severe if fanned by the wind. A flying brand problem can also result. Brands are capable of starting fires over a mile away.

The probability of spontaneous combustion is influenced by the height, size, and age of the pile; moisture content of the chips; ambient temperature; and the amount of bacterial action within the pile. Also, the concentration of fines in the pile increases over time. If air circulation is hindered within a chip pile that has been undisturbed for months, the pile may spontaneously ignite. Then, if a smouldering fire is suddenly exposed to the air, the entire pile can burst into flames or even explode. For that reason, piles must be used or turned over regularly.

Some mills can use “whole tree” chips, which are transported from the point of harvest to the mill. Because “whole tree” chip piles contain bark, needles, twigs, cones, seeds and other fine materials, these piles are more apt to heat spontaneously than chip piles made from debarked logs. The same can be true of hog fuel piles.

Chip and log storage both represent high values. However, a clean chip pile probably has greater loss potential than a log pile of comparable value. This is because ash and charred ember may make unburned chips unusable. Similar contamination can be readily washed off unburned logs before the chipping process begins.

The water supply and pumping capacities required for raw material storage areas will probably represent the highest fire protection water demand for the entire facility. The demand can be up to 6000 gpm at 100 psi (22,680 L/min at 6.9 bar). This is because major log or chip pile fires are difficult to extinguish and require heavy hose stream coverage for extended time periods.

Storage and Pulping of Baled Waste

At some mills, baled waste is used as a primary or secondary source of raw materials. This can be a severe fire hazard, especially if stored outdoors. Baled waste is easily ignited by sparks, flying brands, discarded smoking materials or contact with hot surfaces.

Once ignited, the irregular exposed surfaces of baled waste promote rapid flamespread and release of burning brands. Winds or induced drafts from the fire readily disperse the brands, threatening any other yard storage and nearby buildings. Heavy smoke, flying brands, shifting winds, and radiant heat can create extremely difficult firefighting conditions. Even after fire in baled waste is initially knocked down by hose streams, the fire is difficult to extinguish and will repeatedly flare up during overhaul. For these reasons, bales should be stored in properly protected warehouses (Figure 5).

Figure 4. Log Pile Wetting

Figure 5. Baled Waste

Waste paper may be purchased or taken from either the mill's paper machine or other mill areas. The waste paper is usually converted into pulp by beating it with water in machines called hydropulpers. Hydropulpers resemble large kitchen blenders. Their motors, which can be several hundred or even thousands of horsepower in size, drive the hydropulpers through gear sets. Pulp made in the hydropulpers is processed through beaters, cleaners and refiners. The recycled pulp produced can be used alone or can be blended with virgin pulp made at the mill or with purchased pulp.

Mills that recycle printed paper, such as newspaper and magazines, must de-ink the paper. De-inking involves a specialized group of screens, cleaners, filters, presses, bleaching units and waste handling systems. Recycling usually includes provisions for removing plastic and metal bands, paper clips, staples, glue, bindings and other materials likely to be found in paper being recycled. Mills that depend on recycling must make sure equipment is kept in good operating condition and protected from foreign object damage.

Pulp Preparation

Pulp is manufactured by thermochemical or mechanical processes, or a combination of both. The chemical processes involve pressure cooking in large vessels called digesters. The mechanical processes use large stone grinders or steel plate refiners.

Most pulping processes start by conveying chips from outside piles or from chip bins to the digester. Belt conveyors may be overhead or underground and are subject to fires. Experience shows that the primary causes of such fires are:

- Frictional heat from belt slippage or jamming.
- Electrical arcing or motor fires.
- Welding and cutting sparks.
- Hot bearings.

Belts are usually made of rubber or synthetics, such as neoprene and polyvinylchloride. All are combustible and capable of high heat-release rates once ignited, including those marked "Fire Resistant" by the Bureau of Mines. The advantage of the fire resistant belts is that they are more difficult to ignite.

In air conveying, high volume compressors blow chips through overhead piping to the digester. Air leaks in these pipes can allow chips and wood dust to accumulate on roofs. If this accumulation is not removed it presents a fire exposure. If allowed to become deep enough, it presents a collapse exposure should the accumulation become water soaked.

Wood fibers are actually cellulose fibers in a lignin matrix. To make virgin pulp, the cellulose fibers are separated from the lignin. The mass of cellulose fibers, or pulp, then passes through various combinations of screens, knotters, washers, beaters, and refiners. This process mechanically alters the cellulose fibers to achieve the desired length, flexibility, surface area, and degree of fibrillation. Special additives may be introduced at this point.

Some mills sell part or all of their pulp instead of making it into paper. The pulp passes from the last refiner to a pulp dryer, which is very similar to a paper machine; the pulp then goes to a baling press. The press compresses the pulp sheets from the dryer into bundles for shipping.

When pulp is used to make paper, stock chests store the pulp at several points in the papermaking process. The chests are usually located behind the washers and refiners. If bacterial action on pulp stored in the chests is not controlled during shutdown, flammable gases such as methane can be generated.

Chemical Pulping Processes

In chemical pulping, liquor from the chemical recovery process is mixed with the wood chips in digesters and heated. Heating is usually done by steam injection. The digesters are actually large “pressure cookers” in which chips are processed to remove resins and dissolve the lignin. Off-gases from the top of a digester are primarily terpenes, which are usually burned in the lime kiln. Turpentine may be recovered from the off-gases and sold, but this is becoming less common. Another product from the digester is tall oil, which is usually burned in a hog fuel or bark boiler.

There are two types of digesters: continuous (Figure 6) and batch. Both operate at high temperature and pressure, and both contain a corrosive mixture. The major hazard involved is vessel rupture.

Digester vessel integrity depends on its thickness, materials of construction, and pressure relief capacity. Digester failure is usually due to corrosion or stress corrosion cracking and can be disastrous for the mill. This is particularly true in modern plants, where one or two large continuous digesters have replaced the many, relatively small, batch-type units used in the past.

From the digester, the pulp is pumped or blown to a “blow tank,” where steam is flashed off, and is then passed through a knotter, where large particles are screened out. The next step is cleansing the pulp in a series of brown stock washers (Figure 7), where weak liquor is removed or sent to the recovery system. The pulp is screened again, then sent to the bleaching process, if there is one. (See section on Bleaching.)

Figure 6. Continuous Digesters

Figure 7. Pulp Washers

Figure 8. Refiners

After bleaching, the pulp mixture is thickened in deckers and moved to beaters and refiners (Figure 8), where the pulp fiber is mechanically treated. Chemicals, such as clays, starches or pigments, are added and dispersed throughout the pulp mixture. At this point, the mixture is ready to be fed to the paper machine.

Chemical pulp preparation is a wet process from the digester to the paper machine and would not normally present serious fire protection problems. However, to reduce corrosion, a considerable amount of plastic equipment and ductwork may be involved in both the process and its pollution control equipment. Pulp preparation also presents some boiler and machinery concerns, particularly with the use of large motors.

Two major chemical pulping processes produce recoverable combustible organic constituents and chemical by-products. The Kraft recovery process uses the familiar black liquor recovery method while the acid-sulfite process involves red liquor recovery.

The Kraft process is suitable for both hard and soft woods. Black liquor recovery operations are found wherever the Kraft process is used.

The acid-sulfite process is suitable for hard woods only. The first mills using the acid sulfite process were profitable even if they did not recover the chemicals and heat content from the lignin. Nevertheless, the recovered products were usually valuable enough to justify the cost of large scale recovery operations. Today, environmental requirements have mandated installing red liquor recovery operations at all pulp mills using the acid-sulfite process.

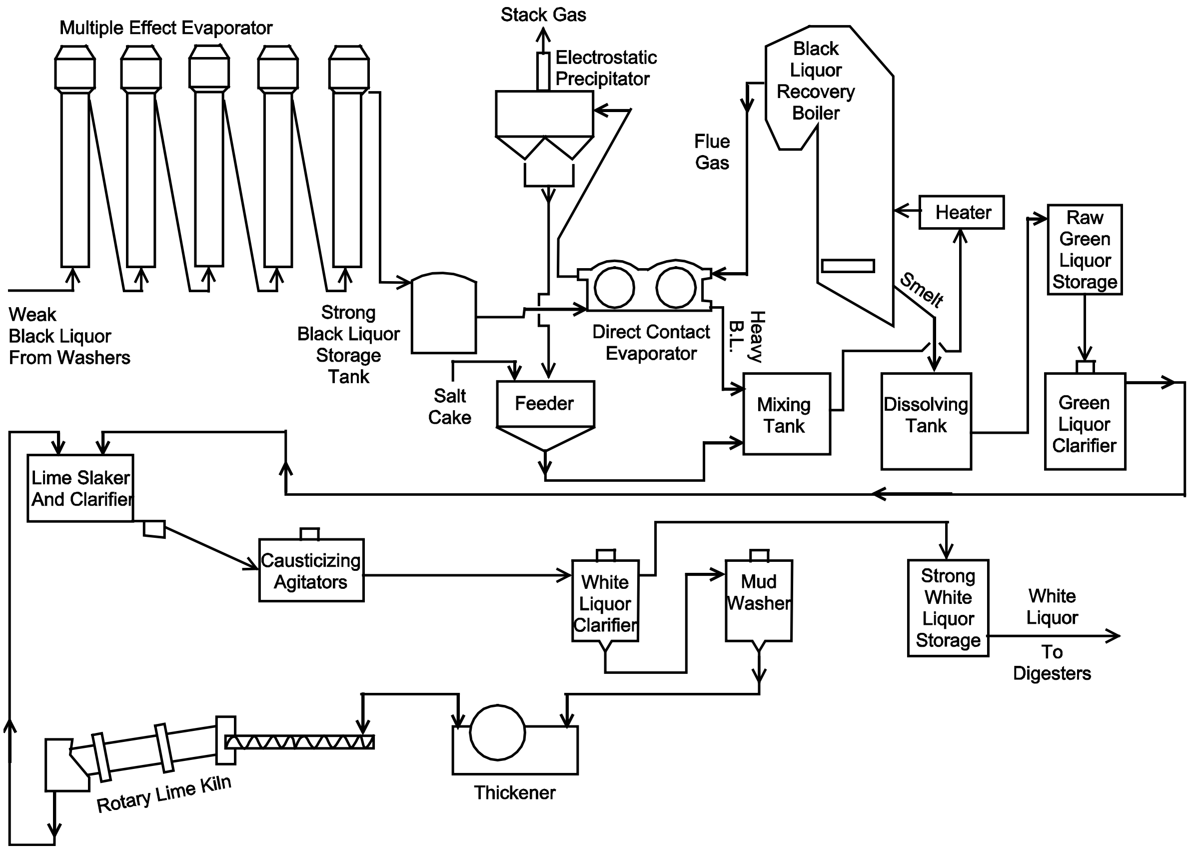

Figure 9. Kraft Recovery Process

Kraft Recovery Process

Figure 9 shows the steps involved in the Kraft black liquor recovery process. The spent cooking solution from the digesters, or “black liquor,” is recovered from the brown stock washers. The black liquor contains spent chemicals, lignins, and water from the pulp washing steps. This “weak” black liquor, with 15% dissolved solids, is concentrated in multiple-effect evaporators to “strong” black liquor, then further concentrated to “heavy” black liquor in direct-contact evaporators that use the flue gas from the black liquor recovery boiler (BLRB) to heat the evaporators. At this point the liquor is 60% – 70% solids.

Newer units that do not use direct-contact evaporators and that do use black liquor aeration are referred to as “low odor” boilers. These units rely solely on multiple-effect evaporators for concentration.

Sodium sulfate (sometimes called salt cake) is added to the concentrated liquor, and the stream is heated and pumped into the black liquor recovery boiler (Figure 10) through burner nozzles called “liquor guns.” In the boiler, the black liquor is dehydrated, and the organic portion is burned to recover the heating value. The inorganic constituents drop to the furnace floor as a molten mass (smelt) consisting of sodium carbonate and sodium sulfide. The sodium sulfide results from sulfate reduction that occurs during incineration of the organic portion of the black liquor. The primary fire hazards associated with black liquor recovery boilers are explosion from a smelt-water reaction and uncontrolled ignition of accumulated unburned fuel from auxiliary burners. The primary boiler and machinery hazard is dry firing. Loss of the BLRB shuts down the entire mill.

Figure 10. Black Liquor Recovery Boiler (BRLB)

Figure 11. Lime Kiln

The molten smelt flows at a controlled rate to a dissolving tank where a steam shatter jet breaks up the smelt, which then dissolves in water to form “green liquor.” The green liquor is mixed with lime (calcium oxide) in the slaker and causticizer to form calcium carbonate and caustic soda. The insoluble calcium carbonate is removed from the solution in a clarifier or in filters, leaving a solution of caustic soda and sodium sulfide. This solution is the “white liquor” used in the digesters.

To reclaim the calcium carbonate removed in the clarifier, the calcium carbonate is burned to lime in a kiln. The lime kiln is a large rotary furnace (Figure 11) that operates at temperatures up to 2700°F (1481°C), and is usually fired with gas or oil. The lime is then recycled for use in the slaker and causticizer.

Some kiln installations use curtains or garlands of chains in the first zone to agitate and improve heat transfer to the lime mud, driving off the water faster and increasing kiln efficiency. These chains are usually constructed of expensive, special alloys that can withstand the temperatures they encounter. If the feed to the kiln or the rotation of the kiln is interrupted, the kiln can sag, or the chains can be damaged since they are no longer being coated with mud.

Acid-Sulfite Recovery Process

The four chemical bases used with the acid-sulfite process are calcium, ammonia, sodium and magnesium. A typical acid-sulfite process is the magnesium-bisulfite process in which sulfur is burned to sulfur dioxide, absorbed in water, and mixed with magnesium solution to form the cooking liquor, magnesium acid bisulfite. After the pulp is separated, the resulting liquid is a low-solids concentration of red liquor. This liquor is concentrated to 10% – 15% solids in a vacuum washer and further concentrated to 50% – 60% solids in multiple-effect evaporators before the liquor is fed to the recovery boiler. The feed stream is atomized at the feed nozzle, and the remaining water is vaporized by radiation from the furnace walls or from the heat of the auxiliary fuel burners. The organics are burned to produce recoverable heat, and inorganics in the form of magnesium oxide and sulfur dioxide are reclaimed from the flue gas for recycling. All but the sodium-based red liquor produce an ash which leaves the furnace with the flue gas. The ash of the sodium-based red liquor is recovered as a smelt.

The major hazard associated with the acid-sulfite process is the uncontrolled ignition of accumulated unburned fuel from the auxiliary burners. However, sodium-based red liquor presents the additional problem of smelt-water reactions, such as those that occur in the Kraft process.

Mechanical Pulping Processes

Mechanical pulping uses large, constant speed, synchronous motors. Synchronous motors are subject to total destruction if excitation is lost. The motors used in mechanical pulping can be as large as 30,000 hp (22,380 kW) in size and represent a large loss potential.

The groundwood process is the most common mechanical process. Debarked logs are fed directly into large stone grinders that mechanically separate the cellulose fiber. From the grinders, the pulp is screened, refined and thickened. The pulp may then feed either a paper machine or a pulp dryer.

Another mechanical pulping process involves the refining of chips between rotating steel plates. This process yields stronger paper than stone grinding of logs, because it causes less damage to the cellulose fibers. However, the paper from this process is still not as strong as paper made from a chemical pulping process.

A newer mechanical pulping process is thermomechanical pulping, commonly referred to as TMP. Paper made with this process rivals chemically pulped paper in strength and quality. In TMP, the wood chips are steamed and cooked under pressure before the fibers are mechanically separated (refined). This is similar to digesting except no chemicals are added to the chips. There is also a TMP process that does add chemicals, called Chemical TMP, or CTMP.

Bleaching

The natural color of pulp is brown. To produce white paper, pulp is bleached in bleaching towers (Figure 12) using oxidizing agents with varying degrees of reactivity. Bleaches contain either chlorine-based chemicals, such as chlorine dioxide and hypochlorites; or nonchlorine chemicals, such as oxygen, peroxides, and methanol. Using microorganisms to bleach paper, called biobleaching, is another bleaching method. Most mills use a chlorine dioxide bleaching system.

Chlorine dioxide is a powerful oxidizing agent. With electric spark ignition, chlorine dioxide's lower explosive limit is about 4% in air. At concentrations over 11% in air, explosions can also be initiated by:

- Temperatures over 248°F (120°C)
- Minute contamination with organic dusts
- Sunlight
- Electrostatic discharge

If the concentration of chlorine dioxide in air is over 40%, ignition from any of the above sources will cause detonation.

Figure 12. Bleaching Towers

Normally, a water solution of chlorine dioxide is not hazardous. However, the solution will gradually release chlorine dioxide gas that can collect in the vapor space. If the gas reaches critical concentrations, it can “puff,” or explode. In addition, dangerous crystals of chlorine hydrates may form at temperatures below freezing. Laboratory experiments indicate that when these crystals warm, they form a liquid with explosive vapors.

It is more efficient and economical to produce chlorine dioxide where it is used (Figure 13). Chlorine dioxide is not normally shipped long distances because of its chemical instability. There are at least a dozen processes for making chlorine dioxide at paper mills. Most use sodium chlorate, an acid, and salts as raw materials.

Some mills use a methanol bleaching system. Since methanol is a flammable liquid, these systems present the hazards associated with using flammable liquids.

Papermaking

Pulp leaves the pulp mill and passes to the paper mill, where the pulp is fed into the “wet” end of a Cylinder or Fourdrinier paper machine (Figure 14). These machines remove water from the pulp to create and dry a sheet of paper. Each type of machine has a different number of rolls and operating speeds. All rolls are exposed to typical rotating machinery losses; steam-heated rolls are also exposed to pressure vessel type failures.

The Cylinder machine is primarily used for paper with high bulk in proportion to its weight, and with most of the paper’s fibers oriented in one direction. This paper is made multiple ply to achieve the necessary strength. The outside layers are sometimes better grade, white paper, while the inside layers are unbleached, cheaper grades. To make this paper, fibers accumulate on cylinder rolls covered with wire cloth. The rolls rotate partly submerged in vats of stock suspension to produce layers of fibers. The layers are picked off the rolls by contacting felt belts, and each layer joins the preceding layers to form a multiple ply sheet. The sheet is then carried past suction boxes and through press rolls which squeeze out most of the water.

Figure 13. Bleach Processing

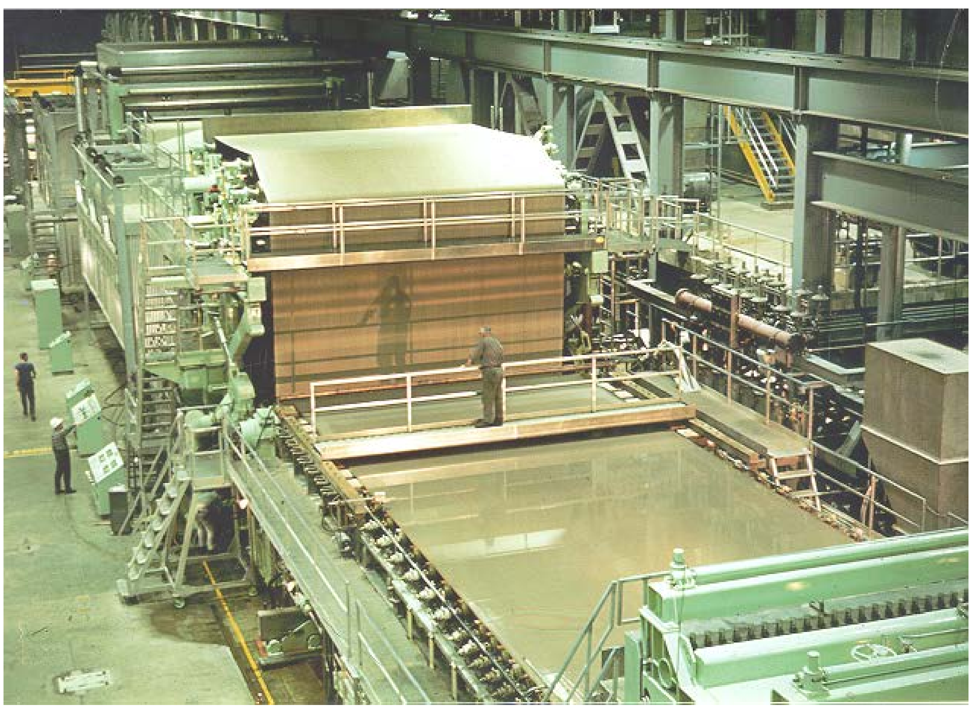

Figure 14. Fourdrinier Machine

The most common paper machine is the Fourdrinier machine. On this machine, the prepared stock is pumped from a head box at the wet end onto a finely woven endless wire or plastic mesh which travels around and between two large rolls. This horizontal wire passes over several suction boxes which drain away much of the free water, leaving the upper surface of the paper wet. The wet paper, or fiber web, is transferred to a felt, then conducted through the press rolls. After the press rolls have squeezed most of the water from the web, the web is passed over hollow, steam-heated rotating cylinders in the dryer section.

A unique exposure on a Fourdrinier machine is the “Yankee” dryer. A Yankee dryer is usually a single dryer roll machine. The roll is typically 8 ft – 19 ft (2.4 m – 5.8 m) in diameter, with face widths of 12 ft – 21 ft (3.7 m – 6.4 m). The face of the roll is highly polished. The roll differs from ordinary dryer rolls, not only in size, but also in application. A Yankee dryer has paper pressed to the roll while still in the wet state. The Yankee dryer performs three basic functions: pressing to remove free water; drying and finishing. The main difference between the typical dryer roll and the Yankee roll is that the journal and central shaft are separate from the heads of the Yankee dryer. Yankee dryers are also much more expensive, worth typically over $1 million, and can take over a year to replace.

Modern paper machines are either hooded over most of their length or totally enclosed. The hoods are called air caps. Without hoods and enclosures, which are vitally important to efficient drying, the machines would have to run at slower speeds with lower output. Some paper machines use gas flame radiant heaters under the bottom dryer rolls to speed the drying process. These heaters present a continuous ignition source.

During start-up operations or following a break in the paper on the machine, large quantities of discarded paper (broke) are likely to accumulate underneath the paper machine. Until this broke is removed, it is a direct fire threat to the machine.

Steam and Electrical Power Generation

The need to recover chemicals, dispose of combustible wastes, reduce pollution and control energy expenses has prompted paper mills to produce their own steam and electrical power. The BLRBs and bark boilers used to generate power are commonly supplemented by power boilers fired by fossil fuel. The steam produced in these boilers generates electric power from steam turbine-generators. This steam also heats digesters and paper machine dryers.

Some mills have installed gas turbine cogeneration facilities (cogens). Cogens generate both electricity and steam. Electricity is produced from a generator driven by the gas turbine. The steam is produced in a boiler, called the heat recovery steam generator (HRSG), which is heated with turbine exhaust gases. Residual heat in the exhaust gases may be recovered in the paper machine dryer hoods.

One of the most critical units in the mill’s power supply is the steam turbine-generator (Figure 15). This unit is subject to typical rotating machinery type losses.

The parts of the steam turbine most vulnerable to fire are the lubricating and governor oil systems. Oil leaking from these systems may contact extremely hot equipment surfaces. Since the inlet temperatures of steam to the turbine may be twice the autoignition temperature of the turbine oil, ignition is virtually inevitable when this happens. These fires are very difficult to extinguish and can result in large losses.

Steam turbine oil system pumps are usually driven directly by the main turbine shaft. Control valves are not permitted in these pumps’ discharge piping, so a leak in this piping cannot be isolated. As a result, oil will discharge under pressure until the turbine-generator comes to a complete stop, which could take an hour or more.

Figure 15. Steam Turbine-Generator

Finishing

The final roll from the paper machine is further processed in one or more operations known collectively as finishing. Usually, the paper goes to a rewinder where it is trimmed, cut to size, and wound tightly and evenly for shipping. Other operations may also be performed.

Supercalendering tightly squeezes and flattens the paper, making it smoother and more dense. Slippery, high-gloss paper is made by applying appropriate coatings. Other coatings provide adhesive or carbonless-copy backings.

Rolls of paper are often wrapped or banded. Paper may also be cut into sheets and stacked. Rolls and stacks of paper are then moved to a finished product warehouse until they are shipped.

Converting

Converting operations convert finished paper into finished products, such as envelopes, toilet tissue, facial tissue and corrugated paper for boxes. Converting may be done at a full process pulp and paper mill or at a separate facility. These operations may involve machines with broke pits, presses, labelers, folders, log saws, and wrappers.

Storage

Storage at full process pulp and paper mills may include dried pulp, finished paper and finished products. Dried pulp is stored in bales.

Rolled paper is usually stored on end, one roll on top of another. Paper sheets are usually stacked on pallets. The palletized sheets cannot be stored as high as the rolls, because the piles are less stable and the sheets are more subject to damage. Empty pallets are also stored in many finished product warehouses.

Storage in finished paper warehouses can burn intensely. The severity of fires in idle pallet storage is well known. Fires in pallets stacked with paper can also be challenging. Paper rolls can “exfoliate,” or unwind as they burn — further increasing the fire hazard. Finished products vary in degree of hazard depending on their configuration, type of coating and packaging.

LOSS PREVENTION AND CONTROL

Loss experience with pulp and paper mills has enabled Global Asset Protection Services (GAPS) to develop extensive loss prevention guidance aimed at the special requirements of this industry. This experience reveals that black liquor recovery boilers, paper machines and storage areas have the largest fire and explosion losses. Losses have also occurred in belt conveyors, continuous digesters, and electrostatic precipitators. Steam turbine-generators, lime kilns and Yankee dryers have the largest boiler and machinery loss potential. These types of losses have also occurred in chipper disks, paper machine drives and continuous digesters.

Control Rooms

Most pulp and paper mills have several computerized control rooms. Each controls a process, such as power generation, liquor recovery or papermaking, as safely and efficiently as possible. These rooms are essential to the mill, and should be arranged in accordance with GAP.17.10.1.

Safety functions implemented through programmable logic controllers (PLCs) should also be hard wired independently of the PLCs. GAP.4.0.1 has information on using programmable logic controllers with fuel fired equipment. The principles in that section apply to other types of equipment as well.

Raw Material Storage

General

- Locate raw material storage areas a minimum of 200 ft (61 m) from log and chip piles, major buildings and other important structures.
- Provide two-way hydrants with individual curb box control valves around the perimeter of storage piles, spaced 50 ft (15.3 m) from the piles and no further than 300 ft (92 m) apart. Each hydrant outlet should have a hose gate valve.
- Provide a standard hose house at each hydrant equipped with 300 ft (92 m) of 2½ in. (65 mm) woven-jacketed lined hose, three nozzles, six hose spanners and two hydrant wrenches. In lieu of standard hose houses, locate a fire truck or a protected hose reel cart to immediately convey 1500 ft (457.5 m) of 2½ in. (65 mm) woven-jacketed lined hose, six nozzles, 12 hose spanners, and four hydrant wrenches. Retain equipment, such as emergency floodlights with portable generators and three-way deluge sets, at a central location or at hose and reel houses.
- Consider providing high expansion foam generating equipment. This type foam has been proven effective in controlling fires in large storage piles.
- Loop the water supply distribution system around storage piles. The system should have adequate sectional valves and dual main feeds.
- Provide guard patrol tour stations throughout the storage areas, and locate readily accessible manual fire alarm pull stations within 300 ft (91.5 m) of any point in the storage areas.
- Provide a written, comprehensive, pre-emergency plan for the storage areas. Train and drill the plant fire brigade in storage area firefighting.
- Prohibit smoking in or near the storage areas. Also prohibit welding, cutting or other hot work in these areas.

Small Log Piles

Small log piles consist of corded or tumbled material no more than 100 ft (31 m) wide, 500 ft (153 m) long, and 25 ft (7.6 m) high. Ensure that:

- Piles are separated a minimum of 100 ft (31 m).
- The water supply can deliver at least 1000 gpm (3780 L/min) to each of four hydrants for four hours.
- Hydrants are capable of simultaneous delivery at not less than 75 psi (5.2 bar) nozzle pressure when 1⅛ in. (29 mm) nozzles and 100 ft (31 m) of hose are being used at each hydrant outlet. Two streams from each hydrant would thus be available to attack a fire, with some reserve left for

exposure protection. Waterflow from the streams totals 4000 gpm (15,120 L/min) at about 100 psi (6.9 bar) at the hydrants.

Large Log Piles

Large log piles consist of corded or tumbled logs in piles not exceeding 250 ft × 600 ft (76 m × 180 m) in area and 75 ft (23 m) high. If the piles are racked, the maximum width should be reduced to 200 ft (61 m). Ensure that:

- Piles are separated a minimum of 150 ft (45.8 m).
- Monitor nozzles are spaced on 150 ft (45.8 m) centers around the perimeter of the pile, elevated to 40 ft (12.2 m) below the crest of the pile, and at least as high as the shoulder of pile.
- Four streams, minimum, are concentrated on any one point along the crest of a pile. The volume output and the effective reach of individual streams are key factors to proper protection. Reach falls off rapidly when the nozzle is elevated more than 35° from horizontal. At a nozzle pressure of 80 psi (5.5 bar) for example, a 2 in. (50 mm) stream elevated to a 30° angle will reach 132 ft (40.1 m) at a height of 45 ft (13.7 m). If the stream is elevated 40°, it will reach 122 ft (37.2 m) at a height of 66 ft (20.1 m).

  Nozzle tips larger than 2 in. (50 mm) are not generally recommended, because they require greater pumping capacity and larger mains to supply the increased volume at adequate pressure. A 2 in. (50 mm) tip throws 1060 gpm (4007 L/min) at 80 psi (5.5 bar) nozzle pressure. A 2½ in. (65 mm) tip throws 1650 gpm (6237 L/min) at 80 psi (5.5 bar) nozzle pressure.
- The water supply meets monitor nozzle requirements and provides supplemental hose streams for low-level and exposure protection. This equals 6000 gpm (22,680 L/min) at about 100 psi (6.9 bar) at the hydrants. Laterals and risers to monitor nozzles should be sized to provide 80 psi (5.5 bar) at the nozzles. Water supply duration should be a minimum of four hours.

Because wet logs are easier to process, some mills have wet down systems for their log piles**.** These systems usually consist of open heads fed by 1½ in. (29 mm) pipe, and are controlled manually. The presence of wet down systems does not reduce the fire protection water supply requirements.

Chip Piles

Limit pre-screened, clean wood chip piles to 300 ft (92 m) wide, 500 ft (152.5 m) long, and 60 ft (18.3 m) high. Separate piles by a minimum of 50 ft (15.3 m). Limit whole tree wood chip piles to no more than 100 ft (30.5 m) wide, 400 ft (122 m) long, and 30 ft (9.2 m) high.

- Turn piles over every 15 days or, with internal temperature supervision, every 30 days.
- Provide water supplies at adequate pressure for a four-hour duration as follows:
  - Up to 10,000 cords — 1000 gpm (3780 L/min)
  - 10,000 to 25,000 cords — 1500 gpm (5670 L/min)
  - 25,000 to 40,000 cords — 2000 gpm (7560 L/min)
- Store chips on concrete or asphalt pads or on clean earth sloped away from the center and above any ground water or flood elevations. Avoid accumulations of chaff under or around the piles.

Fixed chip handling facilities are more desirable than portable equipment. Mobile equipment should be electric motor driven due to a motor's high reliability. If this equipment is diesel engine-driven, the engine must be exceptionally well maintained so as not to present an ignition source in the woodyard.

Baled Waste Storage

Store baled waste in warehouses sprinklered in accordance with NFPA 13 and GAP.10.1.1. Where this is not feasible and yard storage must be used, take the following precautions:

- Limit the size of individual piles to 50 ft × 150 ft (15.3 m × 45.8 m).
- Limit the height of piles to 15 ft (4.6 m).
- Separate piles from plant buildings and other structures by a minimum of 200 ft (61 m).

- Protect all yard storage with hydrants spaced no more than 300 ft (91.5 m) apart.
- Cover long-term yard storage completely with flame-proofed tarpaulins.
- Strictly prohibit smoking and cutting or welding in or near the yard storage, and post large signs around the perimeter of the storage area.
- Reroute all overhead power lines to prevent them from passing over the storage area.
- Control public access to the area by security fencing.
- Provide adequate lighting and guard patrol tour stations throughout the storage site.

Woodyard Operations

Chip Conveyors

Because the belts are combustible, belt conveyors require some form of fire protection. Within sprinklered buildings, the building protection will usually suffice for open conveyors. But if conveyors have partial or full enclosures, or are located outside of sprinklered buildings, provide specific protection for the belts. (See GAP.9.3.1.) In addition, always use fire resistant type belts. These belts still burn, but they are harder to ignite.

Provide conveyors with vibration monitoring systems to detect excessive vibration. In the loss prevention programs, include infrared inspections to discover hot spots. (Refer to GAP.1.3.1.) Vibration monitoring and infrared inspection may detect failing bearings or other moving components before they are hot enough to ignite the belt or its contents. Also provide metal detection systems for conveyors.

Conveyor belts can have long replacement times. Minimize conveyor downtime by keeping enough spare belting on hand to repair or replace damaged portions of any of the mill’s conveyor belts.

Where chip conveyors pass through tunnels:

- Provide automatic sprinklers designed for Ordinary Hazard Group 2 throughout the tunnels, including any area under the hoppers and turntables. (See NFPA 13 and GAP.12.1.1.0.) Interlock the conveyor drive with the sprinkler system to stop the conveyor when the sprinkler system actuates. Stop the flow of chips to the conveyor system in the event of a fire.
- Equip the conveyor drive and turntable with choke stops to avoid ignition by friction.
- Ensure that all equipment in the tunnel is electrically bonded and grounded, and that all electrical equipment is approved for use in Class II, Division 1, Group G locations.
- Maintain good housekeeping throughout the tunnel areas.
- Ensure that hand hose lines and Class A fire extinguishers are immediately available for use throughout the tunnel areas.
- Arrange chip discharge hoppers for easy penetration by hose lines by providing sufficient openings or hatchways.
- Provide all mobile equipment operating in or around the chip area with suitable types of portable fire extinguishers.

Debarkers, Chippers and Grinders

Monitor debarkers, chippers and grinders for excessive vibration and conduct infrared inspections (GAP.1.3.1). Perform wear particle analysis on lubricating oil. Service gear sets as recommended by the manufacturer. Have qualified personnel conduct regular nondestructive testing of chipper disks.

Maintain drive motors and perform insulation resistance testing. Provide trips to disconnect ac power upon loss of dc excitation to synchrononous motors, such as those that drive grinders. Protect enclosures for motors 1000 hp (746 kW) or greater with double-shot carbon dioxide extinguishing systems.

Provide sprinklers over lubrication oil systems inside buildings. Design the sprinklers in accordance with NFPA 13 and GAP.12.1.1.0 for Extra Hazard, Group 1.

Pulp Preparation

Digesters

Specify a design meeting Section VIII of the ASME Boiler and Pressure Vessel Code. Establish a comprehensive metals inspection program to detect any evidence of weakness, such as cracking or thinning of the digester shell. Conduct nondestructive testing in accordance with Section V of the ASME Boiler and Pressure Vessel Code. Perform repairs in accordance with the National Board Inspection Code (NBIC).

Install appropriate pressure relief devices on digesters. Inspect, test and maintain these devices as recommended.

Provide sprinklers over the top or loading portion of batch digesters. Use Ordinary Hazard Group 2 design in accordance with NFPA 13 and GAP.12.1.1.0.

Refiners

Have qualified personnel conduct regular nondestructive testing of refiner plates, which are the key parts of the refining equipment. Provide trips to disconnect ac power upon loss of dc excitation to synchronous motors.

Hydropulpers

Monitor hydropulpers for excessive vibration and conduct infrared inspections (GAP.1.3.1). Perform wear particle analysis on lubricating oil in accordance with manufacturer’s recommendation. Service gear sets.

Maintain drive motors and perform insulation resistance testing. Protect enclosures for motors 1000 hp (746 kW) or greater with double-shot carbon dioxide extinguishing systems.

Provide sprinklers over lubrication oil systems.

Pulp Bale Presses

Establish a comprehensive metals inspection program to detect any evidence of cracking in the press base or frame. Conduct nondestructive testing in accordance with Section V of the ASME Boiler and Pressure Vessel Code. Perform wear particle analysis on hydraulic oil.

Stock Chests

Cover stock chests and vent them to a safe location. Agitate the chests continuously to prevent flammable gases generated by bacteria from building up. Before stopping agitation, add enough biocide or slimicide to the stock to retard the bacterial action in the chest.

Paper Manufacturing Areas

Paper machine hoods and enclosures are usually made of light, noncombustible materials which can be severely damaged by fire. Installing sprinklers will protect against machine-hood and gear-train fires. Originally, such protection consisted of lines of automatic sprinklers over the gear trains only, but since totally enclosed paper machines were introduced, the enclosures have been treated as rooms and full sprinkler protection is needed.

If economizers are used to recapture waste heat from machine hoods, protect the economizers with automatic sprinklers. Arrange the sprinklers to limit damage to the economizers and to the connecting ductwork from fires originating in the hooded area. Deluge sprinkler protection has proved most effective. Use a design of 0.25 gpm/ft^2 (10.2 L/min/m^2).

Verify that start-up and shutdown procedures are adequate to protect against dryer shell and head cracking, especially for Yankee dryers. Routinely examine paper machine dryer rolls internally and externally. Have qualified personnel conduct regular nondestructive testing of dryer roll shells, heads, trunnions and bolts. Conduct repairs in accordance with NBIC. If gas radiant heaters are used to supplement dryer rolls, provide adequate combustion safeguards in accordance with NFPA 85 and GAP.4.0.1.

Provide the following protection features:

- Ensure that hoods and enclosures for paper machines are of noncombustible construction.
- Arrange electric lighting underneath paper machines and protect lighting so that light bulbs will not be shattered by falling paper or come in contact with broke accumulations. Run all wiring in conduit.
- Provide adequate overpressure protection for dryer rolls. Base the protection on maximum allowable working pressure of the lowest rated roll and on the maximum steam capacity from the extraction steam or reducing station.
- Provide automatic sprinklers in accordance with NFPA 13 and GAP.12.1.1.0 in the following areas around the paper machine:
    - General building protection. Use Ordinary Hazard Group 2 design.
    - Under dryer hoods. Use Ordinary Hazard Group 2 design.
    - Under obstructing paper machine walkways. Use Ordinary Hazard Group 2 design.
    - In broke pits and all broke areas, including areas containing broke carts. Use Ordinary Hazard Group 2 design.
    - Over lubricating and hydraulic oil tanks, pumps, and filters. (See GAP.9.2.4.)
    - Inside economizers. Use a deluge system designed for 0.25 gpm/ft^2 (10.2 L/min/m^2).
    - Inside exhaust air ducts and plenums.
    - Inside the large air supply ducts of vapor absorption systems where the ducts are combustible or where combustible deposits collect due to the content of recycled exhaust air.
- Provide interior hose connections equipped with 75 ft (25 m) of 1½ in. (40 mm) woven-jacketed lined hose at 100 ft (30.5 m) intervals on both sides.

Black Liquor Recovery Operations

Follow the Recommended Good Practices established by the Black Liquor Recovery Boiler Advisory Council (BLRBAC). Information on arranging and protecting black liquor recovery boilers in accordance with these practices is in GAP.17.5.1.

Lime Kilns

Proper startup and operating procedures are important to prevent these high valued and important furnaces from being damaged. Also provide combustion safeguards in accordance with GAP.4.0.1. Since kilns usually operate for long periods without shutdown, the combustion safeguards should be capable of being tested without shutting down the kilns.

Provide an auxiliary drive to prevent the kiln from sagging in the event the primary drive fails and rotation stops. For example, an electric motor drive should be backed up with either a diesel engine drive or a steam turbine drive if the steam supply can be maintained when the electric power fails. Also provide an emergency cooling water supply and instrumentation to sound an alarm if the slurry feed stops.

Monitor kilns for excessive vibration and conduct infrared inspections (GAP.1.3.1). Perform wear particle analysis on lubricating oil in accordance with manufacturer's recommendation. Service gear sets as recommended.

Maintain drive motors and perform insulation resistance testing. Protect enclosures for motors 1000 hp (746 kW) or greater with double-shot carbon dioxide extinguishing systems. Protect smaller motors if their failure can result in extensive damage to the kiln.

Steam Turbine-Generators

Uninterrupted electric power is essential to pulp and paper mills. The steam turbine-generator is important to mill operations, because enough power to run the mill may not always be available from the electric utility, and because the steam turbine may be needed as a steam pressure reducing station. Also, the power purchased from the utility may be more expensive than the power the mill generates.

Guidance on protecting steam turbine-generators and the associated pollution control equipment is found in GAP.6.1.1.0.2, GAP.6.1.1.0.3, GAP.6.1.1.0.5, GAP.9.3.2.1, GAP.17.12 and GAP.17.12.1. Preventive maintenance is very important for power generating equipment. GAP.1.3.1, GAP.5.4.5, and GAP.5.9.1 contain information on preventive maintenance programs relevant to power generating equipment.

Protection guidelines for combustible cables concentrated in the power house, pulp mill, paper machine building and under the process control and computer rooms is provided in GAP.17.12.1. Damage to any part of the electrical network almost invariably results in large business interruption losses. It is particularly important to isolate switchgear rooms and electrical control centers, to eliminate combustibles from such areas and to protect massed or stacked cable trays.

The boilers that supply the steam to steam turbine-generators must also be properly arranged, inspected, tested and maintained. Pertinent guidance is found in GAP.4.0.1, GAP.7.1.0.3, and GAP.7.1.0.5.

Bleaching

To ensure safe operations in chlorine dioxide manufacturing facilities, incorporate the following safeguards in the process design:

- Provide a high-temperature and, in some cases, a low-temperature interlock in the reactor vapor space to shut off the reactant flows and actuate an air or inert gas purge of the vapor space.
- Monitor and interlock the bleaching process where pressure or vacuum is critical to safe operation. Shut off reactant flows when abnormal conditions are detected.
- Filter all process feeds. Use water and raw materials that are free of any organic contamination. If there are impurities in the process, chlorine dioxide will decompose at lower concentrations and lower temperatures, and explosive decompositions can be triggered at lower initiation energies.
- Arrange all interlocks for fail-safe operation.
- Provide overpressure protection for reactors in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code. The size of the relief vents will depend upon the design pressure of the reactor and the amount of vapor space to be vented. Strippers, effluent tanks and chlorine dioxide solution storage tanks should also have relief vents.
- Provide continuous air purging for any tank into which reactor contents are dumped when repairing a reactor.

Specific processes may require additional process interlocks or design features. Submit plans for new installations to the GAP Services Plan Review Office for review and acceptance. In addition to incorporating process design features, establish maintenance procedures to ensure that organic materials do not get into the system.

Most bleaching chemicals will create or increase the fire or explosion hazard if they are allowed to contact combustible or flammable materials. For this reason, these materials should be handled according to manufacturers' recommendations. Facilities that store gaseous bleaching chemicals, such as chlorine or oxygen, should be arranged in accordance with NFPA 55.

Methanol bleaching systems require process design, process equipment, control systems and safety interlocks which are suitable for handling flammable liquids. Protection should include sprinklers or waterspray systems, mechanical ventilation, appropriate electrical equipment, explosion venting, vapor detection and equipment bonding and grounding. Consult GAPS for guidance.

Finishing and Converting

To protect finishing and converting operations, monitor and maintain the winders and calendars like any other piece of rotating equipment. Maintain and test presses, folders and all other mechanical equipment in accordance with the ASME Boiler and Pressure Vessel Code. Properly store and protect any flammable or combustible coatings, and keep in-process storage to a minimum.

Storage

Cut off warehouses from all other operations with three hour rated fire walls and self-closing fire doors. Protect the storage in these warehouses in accordance with NFPA 13, NFPA 1, and GAP.12.1.1.0, as applicable.