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RISK CONTROL PRACTICE: OCCUPANCY

Wood Processing Pulp & Paper Industry Handbook

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SCOR
The Art & Science of Risk

As a founding signatory of the United Nations Environment Programme's Principles for Sustainable Insurance, and a member of industry Net-Zero Alliances, SCOR is committed to engaging with policymakers and other stakeholders to identify and implement the required measures to tackle climate change. Through the review of our underwriting and investment policies and guidelines and future targets and commitments under the Net Zero frameworks, we seek to enable and indeed accelerate society's shift to a net-zero carbon economy by 2050.

Our conviction is that we have an important role to play in insuring the transition and will actively support our clients in their own commitments to follow credible transition pathways as they transform their business model toward net zero.

Important notices and disclaimer:

This Handbook | Guidance Note has been prepared to identify and flag issues a prudent underwriter ought to consider and evaluate relating to the wood processing, pulp & paper industry risk selection, determination and calculation of loss estimates when determining whether to accept a risk and, if so, on what terms.

Although this Handbook | Guidance Note is detailed and deals with a number of perils and potential scenarios, it is not intended to be a comprehensive analysis of every peril and potential scenario an underwriter may be requested to provide cover for. Any estimation or projection of an MPL and final loss amount must be based on reliable, accurate and current values, applicable scenarios and consideration of the relevant perils.

SCOR accepts no responsibility or liability for any use of this handbook by any party to underwrite any particular risk or to determine an MPL or final loss amount – it is the responsibility of the relevant underwriter and (re)insurer to independently determine whether to accept, or not, any particular risk as well as the contract terms and price required.

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SCOPE

The purpose of this Handbook | Guidance Note is to provide comprehensive technical support to Underwriters and Risk Control Engineers.

The main processes of wood, pulp & paper and related special hazards are described.

This guide is mostly focused on fire explosion hazards and natural perils. Boiler & machinery hazards are not covered in detail in this document. Examples of losses are also given when relevant.

Standard recommendations based on recognized international standards and good practices are proposed. Moreover, very good NFPA (National Fire Protection Association) and Factory Mutual Data Sheets (FM Global Data Sheets) upon these subjects exist. As there is no need to reinvent the wheel, readers are redirected to those references when relevant.

- NFPA free viewing at http://www.nfpa.org/
- FM Global Data Sheets free viewing and download when registered at http://www.fmglobal.com/

Note that these materials are periodically revised and updated. Please monitor the above websites for updates and/or revisions.

This occupancy guide was finally discussed and reviewed by Risk Control Engineers and Claims Managers working for insurance, reinsurance and qualified consultant companies or working as freelance consultants. Many thanks to them. Their names are mentioned in this document with their permission.

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1 WOOD PROCESSING, PULP & PAPER INDUSTRY OVERVIEW

1.1 WOOD AS A MAIN RAW MATERIAL

Wood produced in man-made forests constitutes the main raw material for both the Wood Processing and Pulp & Paper Industries.

A forestry company usually manages various plots of harvestable forests (very commonly pine tree and eucalyptus). Southern softwood trees grow very fast and may be cut after only 11-20 years of growth, whilst in boreal zones, bringing trees to maturity may take as much as 100 years.

1.1.1 Sustainable Forest Management & Certified Forests

Forests used for industrial wood processing and pulp & paper industries are not usually native, they are man-made forests. A planted forest is a forest project lasting at least 20 years, and it often consists of a very sophisticated planting and harvest management for constant provisioning of raw material. Pruning, re-sprouting, evolving genetics of different varieties and distance to processing plants are the main corner stones. To maintain a minimal resilience of the labored system in the long run (resilience is defined as the ability to react to change in specificities in demand, economic & legal frameworks / vision, climate, etc.), it is very important to have sustainable forest management.

Sustainable Forest Management is based on three fundamental pillars: economic, social and environmental, as detailed below:

- **ECONOMIC:** the existence of an economic interest facilitates forest conservation. When it does not exist, interest in it is lost, the local population usually leaves the environs, the space begins to degrade and therefore ceases to produce value for both the owners and the community.
- **SOCIAL:** forestry favors the establishment of a population in the given rural area, thus enhancing the care and monitoring of these forest environments, the anchoring of cultural traditions and the creation of leisure areas.
- **ENVIRONMENTAL:** sustainable forest management allows nature itself to regenerate and conserve resources indefinitely. In turn, it helps maintain biodiversity, helps reduce greenhouse gases, intervenes in water regulation and protects the soil.

Forests that receive that type of management can be certified. Some industries and/or final customers in some markets may request the final product to be made exclusively of wood issued from certified forests. These certified forests must meet the following criteria:

- Provide us with renewable energy resources
- Be a home to numerous species of plants and animals
- Contribute to mitigating climate change
- Protect the ground (soil)
- Intervene in water regulation
- Seek harmony between the economic, environmental and social benefits of forests

See also Annex B: “Forest Stewardship Council” (FSC). *Courtesy of Michael Rüegger, Senior Underwriter and Rene Kunz, Chief Underwriting Officer – both SCOR Agriculture.*

1.1.2 Buffer Storage

Before delivery to the wood processing plant and/or pulp mill, wooden logs are usually stored in a yard located in the forest.

When logs stay too long in the yard, they become dry and can no longer be processed.

Note that cane sugar dry pulpy fibrous residue (bagasse) supplied from cane sugar mills can also be used as raw material used by the Pulp & Paper Industry. (See below).

1.2 WOOD PROCESSING

Wood-processing facilities manufacture basic construction materials including lumber, veneer, plywood, wood-based composite panels such as particleboard, fiberboard, hardboard and oriented strand board (OSB). The main processes are covered in this Handbook.

Woodworking facilities remanufacture these basic wooden products into other consumer products such as doors, windows, paneling, furniture, cabinets, and miscellaneous others including poles and railway sleepers. This occupancy is not covered in this Handbook.

1.3 PULP & PAPER INDUSTRY

The Pulp and Paper industry is comprised of companies that use wood (or more precisely the cellulose contained in the wood) as raw material.

There are two distinct phases in the conversion of raw wood and other materials into finished paper:

a) the manufacture of the various pulps,

b) the conversion of pulp to paper.

Cellulose is an organic compound with the formula $(C_6H_10O_5)n$, a polysaccharide consisting of a linear chain of several hundred to many thousands of linked D-glucose units. The cellulose content of cotton fiber is 90%, wood is 40–50%, that of bagasse is 45–55% and that of dried hemp is approximately 57%. Cellulose is also used to manufacture textiles and in biotechnological industries (e.g., bio-composite materials).

Wood pulp

Wood Chips

Bagasse

Fibers

While in theory any tree can be used for pulp-making, coniferous trees are preferred because the cellulose fibers in the pulp of these species are longer, and therefore make stronger paper. Some of the most commonly used softwood trees for paper making include spruce, pine, fir, larch and hemlock, and hardwoods such as eucalyptus, aspen and birch.

Market pulp is any variety of pulp that is produced in one location, before being dried and shipped to another location for further processing.

Dried pulp in bales.

Some plants produce only pulp and similar products. Others produce only paper from pulp. Others may carry out both phases of the processing operation.

Pulp can be used as raw material for manufacturing paper products.

In the conversion from pulp to paper, pulp is mixed with water and then fed into a paper machine, where it is formed as a paper web before the water is removed from it by pressing and drying (paper machine). Finished products include the following (but not limited to):

- Paper used in the printing industry
- Writing paper
- Kraft paper (e.g., for packaging)
- Other applications (e.g., construction)

The conversion of paper into various end products (paper working) may occur at or near the pulp mill site. Processing at the pulp mill normally ends with the winding, slitting, or coating of paper. Rolled and sheet paper or pulp is then shipped to a converting or processing plant located near the market.

Major paper products issued from paper working include newsprint, magazines, tissues, bags, cartons, food containers, wrapping paper, books, and writing paper.

Pulp can also be used to manufacture other cellulose-based hygienic products:

- Tissue paper, napkins
- Diapers, disposable menstrual pads (that include a lot of additives and other raw materials)

Note that recycled paper (up to 80%) is also used and mixed with pulp for manufacturing some of the above products. Some kraft paper / cardboard plants may only exclusively use recycled paper as raw material.

Recycled Paper

Pulp from recycled paper

Recycled paper & cardboard used to make kraft paper


PAPER WASTE
RECYCLING
Collection
Sorting
Screening
Pulping
Chemical
De-inking
Drying
Spinning vats
Rolling
Recycle
paper

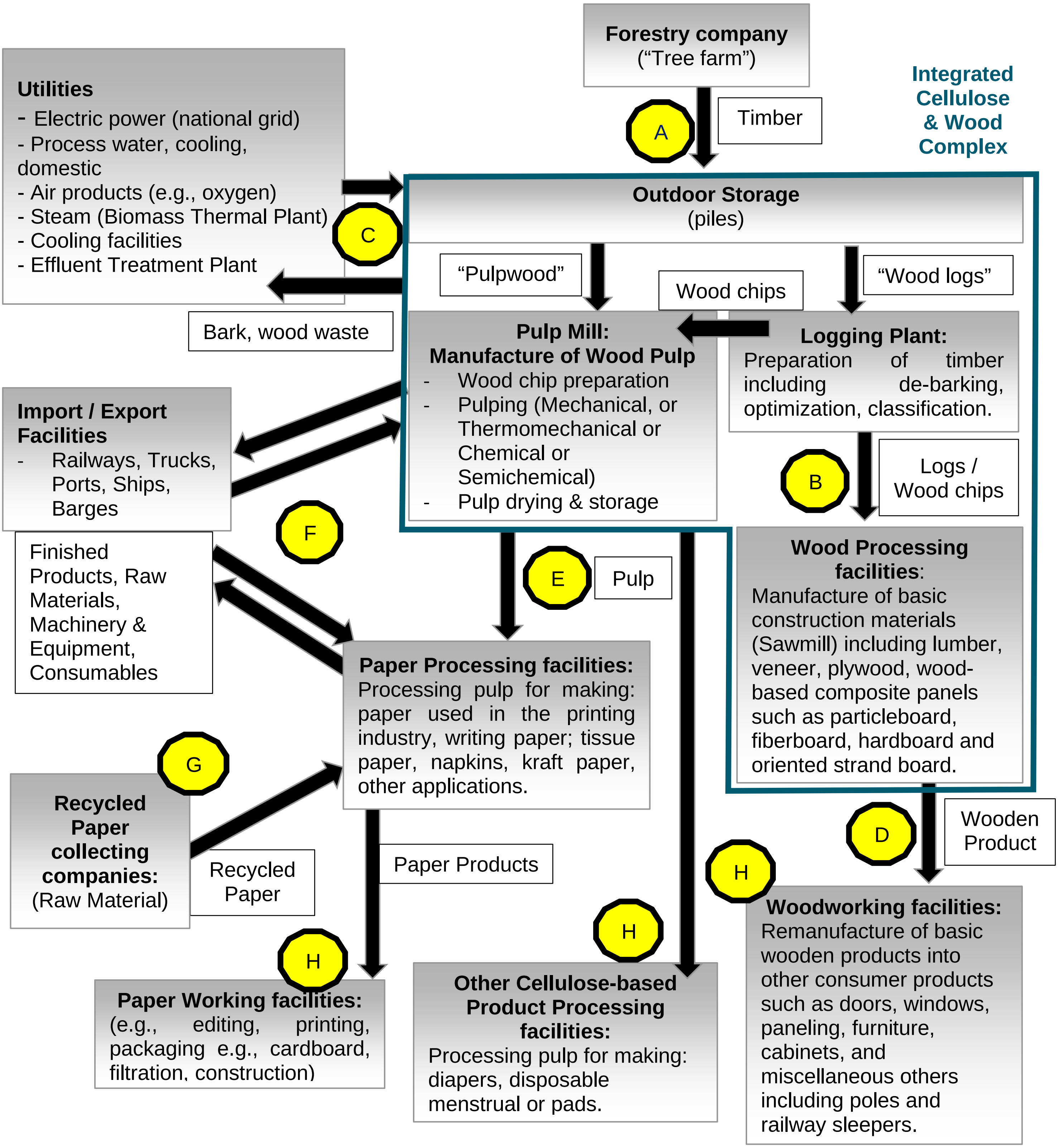
2 SUPPLY CHAIN

2.1 WORKFLOW

Legend: ➡ Interdependencies (Induced BI) and/or CBI / CTE, SI

X BI/CBI exposures (see next pages)

The process flow between the different units involved in the Wood Processing and Pulp & Paper industry can be summarized as follow:



2.2 INTERDEPENDENCIES, BI, CBI (CTE), SI

Wood Processing and Pulp & Paper industries may present a relatively high level of vertical and horizontal integration as summarized below:

- Business Arrangement:
  - A big group may include a Forestry company, Wood Processing Plants, Pulp Mills, Paper Processing and other Cellulose-based Product Processing plants divided into business units as follows:
    - Log merchandizing (logging plant)
    - Sawmill (lumber, veneer)
    - Panels (including plywood, particleboard, fiberboard (MDF), hardboard (HB) and oriented strand board (OSB).
    - Cellulose (pulp mill; different grades of pulp)
    - Paper processing (writing paper; tissue paper, napkins, kraft paper, corrugated cardboard
    - Cellulose-based product processing (e.g., hygienic products: diapers, menstrual pads)
    - Paper Working facilities (i.e., making cardboard from kraft paper)
  - Other Cellulose-based Product Processing facilities may be part of such a big group.
  - Woodworking and Paper Working facilities are usually not part of a big group. These are usually standalone operations (group customers). However, kraft paper & cardboard factories may be vertically integrated in a cardboard manufacturing facility that may belong to a big group.
  - Recycled paper companies are not usually part of a big group. These are usually standalone operations (group suppliers).
  - Such big groups may also include off-site warehouses, distribution centers and a trading network including subsidiaries worldwide in charge of merchandizing.
  - Import / Export facilities (ports, railways, trucks, ships, barges) are usually not part of a big group. These are usually standalone operations.

- Physical Arrangements:
  - Forests are preferably located near the users (see below) in order to limit transportation costs and maintain high efficiency of the supply chain.
  - All Wood Processing units and Pulp Mills may operate as a standalone unit in a given area with their own dedicated utilities and integrated logging unit.
  - Wood Processing facilities may be arranged on the same site sharing utilities and services.
  - Wood Processing facilities and Pulp Mills may be located on the same site forming a complex (see below) sharing some utilities and services such as water treatment, steam generation and a logging plant.
  - Kraft paper and cardboard manufacturing facilities may be located on the same site. This could be a standalone operation or integrated in a group using packaging (i.e., a food processing complex). Raw material could exclusively be recycled paper.

- Forestry company:
  - In charge of developing and managing forests (Tree Farm) including planting trees, maintaining and harvesting.
  - This is all about land and resource management.

- Development planning should be in line with the demand evaluated on a long-term basis – e.g., +20 years (Wood Processing, Pulp & Paper Mills).

- Integrated Cellulose & Wood Complex:
  - The outdoor storage of pulpwood and wood log is either managed by the Forestry company or by the Complex. Timber delivered to the Pulp Mill is called pulpwood while the timber delivered to the Wood Processing plant is called wood log.
  - The logging plant prepares the wood logs to be used at the Sawmill and the Panel Plants). Wood chips (by product) are sent to the Pulp Mill or Hardwood Board Plant (to be used as raw material) and bark is usually sent to the Biomass Thermal Plant (to be used as biofuel - see below) or to the Hardwood Board Plant (to be used as raw material).
  - Pulp Mills usually have their own logging plant in the form of a wood preparation area including a de-barker and chipper.

- Utilities and shared services:
  - Electric power: usually supplied from the grid to all facilities which are highly dependent on it, except for the Pulp Mill that may use electric power for black starts (or have black-start power available). Once steam is produced by the process at the Pulp Mill, Steam Turbine Generators produce electric power for the Pulp Mill process (self-sufficient) or the Integrated Cellulose & Wood Complex (if any) and the excess electric power is sold off to the grid.
  - Process water, cooling domestic water: a large amount of water is used in the process of both Wood Processing plants (drying, pressing), Pulp Mills (process and cooling) and Paper processing. These facilities are usually located near a river or on the seashore.
  - Air Products: these are dedicated for the Pulp Mill, usually third party-operated (i.e., AGA, Air Liquid) and are located on the Pulp Mill perimeter.
  - Steam: the steam produced at the Biomass Thermal Plant (using wood waste for all facilities) is sent to the Wood Processing plants (for drying and pressing). The Pulp Mill produces its own steam.
  - Cooling facilities: used in several processes and utilities and deemed as very critical for steam turbines for power generation and effluents.
  - Effluent Treatment Plants: critical for any Wood Processing, Pulp Mill and Paper processing. They should be compliant with local environmental regulations. Large-size facilities are usually owned and operated by the plant or the Complex (if any).

- Critical shortages of raw material are not usually reported for all the above facilities. There are normally several suppliers thus guaranteeing some flexibility of supply. Extra costs should be considered for transportation. The cost could be prohibitive in some cases.

- Machinery and equipment is usually manufactured in Europe, North America and Japan by specialized companies. Adequate spare parts management is therefore required.

- Import / Export facilities:
  - Most Finished Products may be exported overseas through ports which are usually operated by third parties (state-owned concessions and private operators). Goods may be stored in the yard or inside warehouses.
  - Trains between plants and harbors are usually operated by third parties also owning the rolling stock. Tracks inside plant property limits usually belong to the plant. The trains may even directly enter the warehouses (i.e., dried pulp warehouses).
  - Trucks are usually owned and operated by a third party.

As a result of the above and depending on the level of both vertical and horizontal integration of an organization involved in the Wood Processing and Pulp & Paper Industry, interdependencies and/or induced BI (sister plants belonging to the same organization) and/or Contingent Business Interruption - CBI / CTE - Contingent Time Element (independent plants) and/or Service Interruption (i.e., services and utilities) may exist.

The main potential exposures and mitigation measures are summarized below (these should be carefully investigated for Loss Estimate purposes):

A

Major loss at a Forestry Company resulting in a Timber supply disruption:

A major loss at the nearest forest (i.e., wildfire) or timber outdoor storage area (when managed by the Forestry Company) can disrupt the delivery of timber to the Wood Processing Plant(s) (via the Logging Plant - if any) and/or Pulp Mill. This would result in induced BI for the Wood Processing Plant(s) and/or Pulp Mill (in the case of interdependencies between sister plants of the same group) or contributing CBI for the Wood Processing Plant(s) and/or Pulp Mill (if the Forestry Company belongs to a different group).

Downstream operations (such as Paper Processing facilities, other Cellulose-based Product Processing facilities, Woodworking facilities) could also be impacted as they would no longer receive raw material from the Wood Processing Plant(s) (wooden products) and/or the Pulp Mill (pulp).

Mitigating measures for the Wood Processing Plant(s) (via the Logging Plant - if any) and/or the Pulp Mill would consist of:

- Maintaining a timber buffer storage and pulpwood (at the Pulp Mill level) and wood log storage (at the Wood Processing plant level) based on the maximum storage time allowed and on demand.
- Diversifying the timber supply, having settled a contract in advance with the usual Forestry Company (managing various forests) stipulating a minimum supply (from other forests if any) and/or from other forestry companies.
- This would result in an ICoW (mainly caused by transportation from remote forests) and a reduced margin. However, it would prevent any loss of reputation and of market share. Note that the required quantity may be difficult to find in a reasonable time on the market. Having settled a contract in advance with another Forestry company and securing the contract by having some quantities regularly delivered may help in reducing the delay.

Mitigating measures for Paper Processing facilities, other Cellulose-based Product Processing facilities and Woodworking facilities would consist of:

- Diversifying raw material supply (i.e., wooden products, pulp) having settled a contract in advance with other Wood Processing Plant(s) and/or Pulp Mill(s) and securing the contract by having some quantities regularly delivered.

B

Major loss at the Logging Plant (if any) resulting in a wood log supply disruption:

Any major loss at the Logging Plant can disrupt the delivery of wood logs to the Wood Processing Plant(s). This would result in an induced BI for the Wood Processing Plant(s) and the Forestry Company (in the case of interdependencies between sister plants of the same group) or contributing CBI for the Wood Processing Plant(s) and recipient CBI for the Forestry Company (belonging to a different group). Note for the Forestry Company: when logs stay too long in the yard, they become dry and can no longer be processed by Sawmills and most Panel plants. This would result in a 100% loss.

Mitigating measures for the Wood Processing Plant(s) would consist of:

- Maintaining a timber buffer storage and pulpwood (at the Pulp Mill level) and a wood log storage (at the Wood Processing plant level) based on the maximum storage time allowed and on demand.
- Diversifying the wood log supply, having settled a contract in advance with other Logging Plants and securing the contract by having some quantities regularly delivered.
- Note that diversifying customers is a good practice for reducing Interdependencies and/or CBI exposure.

Mitigating measures for the Forestry Company would consist of:

- Redirecting the timber to other Wood Processing plants (if the timber size is appropriate) may be the best solution. This may result in an ICoW due to transportation costs.
- Sending the timber to be processed as wood chip in a Pulp Mill (extra cost for transportation and subsequent loss of margin) may be another solution.

C

Major loss at the utilities resulting in a service disruption of electric power (national grid) or process water, cooling /domestic or air products (e.g., oxygen) or biomass thermal plant or effluent treatment plant:

A major loss involving the electric power supply from the national grid will result in:

- No black start (i.e., after a maintenance period) possible for the Pulp Mill (using electric power for black starts. Once steam is produced by the process at the Pulp Mill, Steam Turbine Generators produce electric power for the Pulp Mill process (self-sufficient) or for the integrated Cellulose & Wood Complex (if any) and the excess electric power is sold to the grid).
- Shutdown off all Wood Processing facilities (except when powered by Pulp Mill's Steam Turbine Generators), Paper Processing facilities, Paper Working facilities, Woodworking facilities. There is usually no alternate power source available (Diesel Engine Generators available for emergency lighting and safe shutdown of process equipment).

Mitigating measures for the above facilities in case of a loss involving the electric power supply would consist of:

- Pulp Mill: having a steam boiler dedicated to the black start without any grid support.
- Other facilities (when not powered by the Pulp Mill): having different feeders from different substations on the grid; avoiding bottlenecks (e.g., only one single critical electric room).

A major loss involving the water supply (process, cooling, domestic) will result in:

- Shutdown of the Pulp Mill, Wood Processing facilities (using water or steam produced from water, e.g., Panel plants, Sawmills), some Paper Processing facilities (re-pulping or using recycled paper) and the Thermal Power Plant (biomass boiler) producing steam for the complex (if any).

Mitigating measures for the above facilities in the case of a loss involving the water supply would consist of:

- Providing a buffer storage on site (limited duration)
- Having a second water supply whereby water could be delivered by road tankers for some Wood Processing facilities, Paper Processing facilities and Paper Working facilities depending on water consumption

A major loss involving the supply of air products will result in:

- Shutdown of the Pulp Mill. (Oxygen is usually supplied by a third-party- operated Air Separation Unit - ASU. (There is not usually any liquid process. Pulp Mill demand is normally around 75 tons per day)

Mitigating measures for the above facilities in the case of a loss involving the supply of air products would consist of:

- Having back-up tanks (e.g., 2 back-up tanks of liquid oxygen installed within the ASU perimeter representing a 4-day supply for the Pulp Mill).
- Oxygen could be delivered on trailers when needed from another ASU (e.g., (75 tons per day consumption # 3.5 trucks per day).
- The above Contingency Plans should be investigated and formalized together with Air Product suppliers.

A major loss involving the steam supply (e.g., Biomass Thermal Plant in a Complex or steam boiler for a given facility) will result in:

- Shutdown of some Wood Processing Plants, Paper Processing facilities, Paper Working facilities (i.e., cardboard plants)
- Note: the Pulp Mill produces its own steam (self-sufficient)

Mitigating measures for the above facilities in the case of a loss involving the steam supply would consist of:

- Having an agreement with the nearest facility (if any. e.g., excess of steam from a Pulp Mill)

A major loss involving the effluent treatment (e.g., fire impacting a critical electric substation, river flood) will result in:

- Shutdown of the Pulp Mill and most of the Panel Plants (Wood Processing facilities) releasing effluent with solids (note: solids are separated and used as fuel for the Biomass Thermal Plant - if any)

Mitigating measures for the above facilities in the case of a loss involving the effluent treatment would consist of:

- (If due to failure of the Effluent Treatment Plant), all effluents being directed to emergency reservoirs with as much maximum capacity as possible (usually a capacity corresponding to 24h of Complex production. After this delay, all above facilities would have to be shut down)

	• Investigating if all above facilities may release effluent to a reservoir for evaporation and sedimentation (the old-fashioned process) while the Effluent Treatment Plant is being repaired. This should be investigated with authorities.

D	**Major Loss at the Wood Processing facilities:** A major loss at the Wood Processing facilities can disrupt the delivery of wooden products to the Wood Working Plant(s). This results in induced BI for these downstream operations (in the case of interdependencies between sister plants of the same group) or contributing CBI (when belonging to a different group). Upstream operations (i.e., Logging Plant and Forestry Company that will not be able to deliver their products to their client) will also be impacted. This would result in induced BI for these upstream operations (in the case of interdependencies between sister plants of the same group) or recipient CBI (when belonging to a different group). Note for the Forestry Company: when logs stay too long in the yard, they become dry and can no longer be processed by Sawmills and most Panel plants. This would result in a 100% loss. Mitigating measures for the following operations would consist of: • For downstream operations (i.e., Woodworking Plant(s)): maintaining a wood product buffer storage and diversifying suppliers. • For upstream operations (i.e., Logging Plant): redirecting the product to other customers. This would result in extra costs and/or a reduction of margin (diversification of customers is key). • For upstream operations (i.e., Forestry Company): redirecting the timber to other Wood Processing plants (if the timber size is appropriate) may be the best solution. This may result in an ICoW due to transportation costs. Sending the timber to be processed as wood chip in a Pulp Mill (extra cost for transportation and subsequent loss of margin) may be another solution.

E	**Major loss at the Pulp Mill (Manufacture of Wood Pulp):** A major loss at the Pulp Mill can disrupt the delivery of pulp products to the Paper Processing Plant(s), other Cellulose-based Product Facilities and the Paper Working facilities. This would result in Induced BI for these downstream operations (in the case of interdependencies between sister plants of the same group) or contributing CBI (when belonging to a different group). Upstream operations (i.e., Logging Plant and Forestry Company that will not be able to deliver their products to their client) will also be impacted. This would result in induced BI for these upstream operations (in the case of interdependencies between sister plants of the same group) or recipient CBI (when belonging to a different group). Note for the Forestry Company: when logs stay too long in the yard, they become dry and can no longer be processed by Sawmills and most Panel plants. This would result in a 100% loss. Mitigating measures for the following operations would consist of: • For downstream operations (i.e., Paper Processing Plant(s), other Cellulose-based Product Facilities): maintaining a raw material (i.e., Pulp) buffer storage, and diversifying suppliers. • For downstream operations (i.e., Paper Working facilities): maintaining a raw material (i.e., Paper) buffer storage and diversifying suppliers.

	• For upstream operations (i.e., Logging Plant): redirecting the product to other customers. This would result in extra costs and/or a reduction of margin (diversification of customers is key). • For upstream operations (i.e., Forestry Company): redirecting the timber to other Wood Processing plants (if the timber size is appropriate) may be the best solution. This may result in an ICoW due to transportation costs. Sending the timber to be processed as wood chip in a Pulp mill (extra cost for transportation and subsequent loss of margin) may be another solution.

G	**Major loss at the Recycled Paper Collecting Companies:** A major loss at a Recycled Paper Collecting Company can disrupt the delivery of recycled paper to the Paper Processing Plant(s), This would result in induced BI for the Paper Processing facilities (i.e., tissue, kraft paper) and possibly to the Paper Working facility(ies) (i.e., cardboard factory) (in case of interdependencies between sister plants of the same group) or contributing CBI (when belonging to a different group, as it is usually the case). Mitigating measures for the Paper Processing facilities (i.e., tissue, craft paper) would consist of: • Maintaining buffer storage(s) of recycled paper (at a safe distance from the main facilities) • Diversifying recycled paper suppliers (with different suppliers from different regions / countries when possible) Mitigating measures for the Paper Working facility(ies) would consist of: • Maintaining a Paper Products buffer storage • Diversifying suppliers (key).

H	**Major loss at the Woodworking facilities or Paper Working facilities or other Cellulose-based Product Processing facilities:** A major loss at a Woodworking Facility or Paper Working facility can disrupt the delivery of Raw Material from the upstream operations (i.e., wood products from the Wood Processing facilities or paper products from the Paper Processing facilities). This would result in Induced BI for the upstream operations (in the case of interdependencies between sister plants of the same group) or recipient CBI (when belonging to a different group, as is usually the case). Mitigating measures for the upstream operations (i.e., Wood Processing facilities, Paper Processing facilities) would consist of: • Diversifying suppliers (key).

3 MITIGATING MEASURES – CP, BCP/M

3.1 TERMINOLOGY & DEFINITION

There is usually much confusion concerning terminology used when referring to the Contingency Plan, Business Continuity Plan or Management / Disaster Recovery Plan. Giving one standard definition would be very difficult as almost all industrial sectors have their own. The two most common definitions are given below for information:

- **Contingency Plan (CP):** The purpose of a CP is to mitigate the consequences of a potential loss in terms of Business Interruption in the case of a loss of a critical utility or piece of machinery /equipment or sub-process unit. This contingency plan should be established taking all the critical facilities into consideration, such as process machinery & equipment, electrical rooms, transformers, and lubrication oil groups. This is particularly suitable for self-sufficient sites located in remote locations.
    - All critical facilities, machinery and equipment should be identified.
        - The availability of all critical spare parts should be defined. Critical spares with a relatively long lead time should be available on site.
        - Machinery and equipment representing severe bottlenecks should be duplicated and stored or installed in separate fire areas.
        - In the case where duplication and/or separation is impossible, adequate protection should be installed.

- **Business Continuity Plan (BCP):** The BCP goes beyond the usual contingency or recovery plans. An organized BCP requires a continuous risk review, top-down or bottom-up, with the full support and commitment of top management, as resources have to be assigned, aligned or re-aligned, such as the case may be. Business Interruption could be related to an earthquake, a severe storm, a fire, power outage over a wide area or the complete inaccessibility of a facility for an extended period of time. It should be clear that the cause of the interruption is not important. What is most important is Management's ability to take control of the interruption. This is particularly suitable for sites with multiple interdependencies between sister plants and/or highly dependent on suppliers / customers.
    - Within a BCP, the above existing Contingency Plan should be extended to a scenario-based major disaster, such as the total loss of one processing unit or an event impacting several plants in a relatively wide area (e.g., earthquake, hurricane).
    - The possibility of the partial recovery of the activity, inside and outside the group, should be investigated.
    - The potential interdependencies with the sister plants, upstream and downstream, should be seriously considered.

Note:

- Business Continuity Management – BCM – is also used instead of CP and or BCP.
- Disaster Recovery Plans were originally only used for IT systems but are widely used now.

At the end of the day, the main purpose of these mitigating measures is to ensure Management's ability to take control of the interruption.

In order to prevent any confusion in this document, a BCP is used at the level of a group when one single event can impact different plants/entities (holistic view). The term CP is used at the level of a given plant/entity (site view).

3.2 RELIABILITY ISSUES

In actual fact, it is difficult, or virtually impossible, to make a CP, BCM/P foolproof or fail-safe meeting all the following criteria considering that conditions may change over time (i.e., management, organization, priorities, etc.):

- Consider all possible scenarios
- Avoid over-estimated back-up (CP) and/or resilience (BCP) capabilities
- Implement formalized documentation
- Organize regular testing
- Review, update, upgrade documents when needed
- Ensure leadership (who is responsible for what & when?)

As a result of the above, CPs, BCP/Ms are:

- Often designed as an a- posteriori disaster Supply Kit (though not everything can be done "by the book")
- Not always expecting the unexpected
- Not always ensuring companies can easily adjust to major shifts in markets or operating conditions

3.3 WHEN TO CONSIDER A CP, BCP/M

Contingency Plans, Business Continuity Management / Plans are not considered when dealing with worst-case scenarios (Maximum Possible Loss -MPL) for two main reasons:

- Philosophy: looking for the worst case including very adverse conditions (conservative approach)
- Lack of reliability (see above)

Depending on the level of confidence in the CP, BCM/P it can be considered to some extent (use risk engineering judgment) for other loss scenarios (e.g., PML, NLE).

Regarding Contingency Plans (CP) as per the definition given above (i.e., loss of a critical utility, machinery, sub-process unit), a CP can be considered for loss estimate considerations including the Worst Case (i.e., Maximum Possible Loss -MPL) when it is about duplication and to some extent about redundancy and spare capacity, as detailed below.

- Duplication: two subunits are duplicated so that in case of a loss of one unit there will not be any critical disruption in the process. This could consist of:
    - Two operating subunits (so-called hot sites in IT), such as two PLC servers or two independent substations feeding the site on a loop.
    - Two subunits, one on duty and one on standby (so-called cold sites in IT), with the standby unit taking over in case of failure of the usual unit on duty. This could take some time should a manual transfer and/or synchronization be needed (e.g., for power generating units reaching full load or national grid connections using Automatic Transfer Switches - ATS).

Note that for reliability, when possible, the duplicated units should be well separated and segregated at least from a fire and explosion standpoint, but also from a natural perils and exposure standpoint (e.g., flood). Any potential single failure point upstream or downstream from the duplicated units should be clearly identified and eliminated.

- Redundancy: the way to express the redundancy level has evolved over recent years as follows:

- Up to a recent past: N+1 meant that N units on duty were able to run normal operations and that there was one more unit available.
- Today: N-1 is used instead of N+1. This means that even with one unit out of order the operations still run normally.
- The above N+1 and N-1 (e.g., transformers) means the same: there is one more unit online available that could take over in case of failure of the unit on duty.
- Note that the main purpose of N+1 / N-1 redundancy is for maintenance: one unit can be taken offline for maintenance and replaced by the N+1 unit.
- Note that maintenance may necessitate a major overhaul or refurbishment of one unit. In some cases, this could take several months as it could include dismantling and shipping overseas (e.g., a major overhaul of Steam Turbine rotors, transformers).
- Based on the above, in the case of a loss of one operating unit while the other unit is offline for maintenance, the related process unit may have to reduce production or even shut down.
- As a result, any reliable redundancy should include N+2 /N-2 units: one standby unit allowing for maintenance and one more unit providing full backup for any one unit.
- Note that for reliability, when possible, all units should be well separated and segregated at least from a fire and explosion standpoint (e.g., transformers separated by blast walls) and from a natural perils and exposure standpoint (e.g., flood).

- Spare capacity: some units may have spare capacity (e.g., an Air Separation Plant). This spare capacity may be considered for the Loss Estimate scenarios as follows:
  - Two units with spare capacity and physically connected to each other so that one unit could partially or fully provide (depending on the spare capacity level) in reasonable time without generating a major disruption. This could be considered for the NLE and even the MPL when well documented.
  - Note that for reliability, when possible, all units should be well separated and segregated at least from a fire and explosion standpoint (e.g., a minimum separating distance between Air Separation Plants avoiding mutual exposure in case of fire / explosion) and from a natural perils and exposure standpoint (e.g., flood). Any potential single failure point upstream or downstream from the duplicated units should be clearly identified and eliminated.

4 LOSS ESTIMATE CONSIDERATIONS

4.1 SCOR LOSS ESTIMATES

In terms of loss estimates at SCOR only MPL and NLE are considered, as detailed below. There is no leeway for using any other acronym or definition (i.e., MFL, EML, PML, etc.).

4.1.1 Maximum Possible Loss (MPL)

The MPL – Maximum Possible Loss – is the estimate in monetary terms of the largest loss which can be expected as a consequence of an insured event. It corresponds to the worst-case scenario after due consideration of all possible events or combination of events, in particular:

- ***Fire:*** all fire protection systems are inoperable, manual firefighting efforts are ineffective and fire can only be stopped by an impassable obstacle or by the lack of continuity of combustible materials (See MPL Handbook for details for minimum separating distances and MPL fire wall definition).
- ***All Other Losses:*** all possible scenarios must be considered in addition to fire and explosion, in particular, natural perils (earthquakes, storms, floods), civil commotion and man-made catastrophes.

For the explosion scenario in petrochemical-related industries, the in-house Extool (former Explan) software program is used to determine the damage following a Vapor Cloud Explosion.

The MPL calculation includes PD, BI and interdependencies between sister plants, where relevant.

Neighboring exposure and CBI should be notified in the scenario, where relevant. However, they should not be considered for the MPL calculation. (See SCOR GAL; Group Accumulation Liability).

4.1.2 Normal Loss Expectancy (NLE)

NLE is the consequence of an accident which occurs when all the loss-limiting systems provided to minimize the consequences of that accident function to achieve the results intended. An assessment should be based on a single fire event unless another greater relevant exposure exists.

5 PULPWOOD AND WOOD LOGS

5.1 STORAGE & PROCESSING

Timber from the forest is called either:

- Wood Logs (or “Logs” when used in Wood Processing plants)

  or
- Pulpwood (when used for making pulp)

  or even
- “Pulpwood logs”

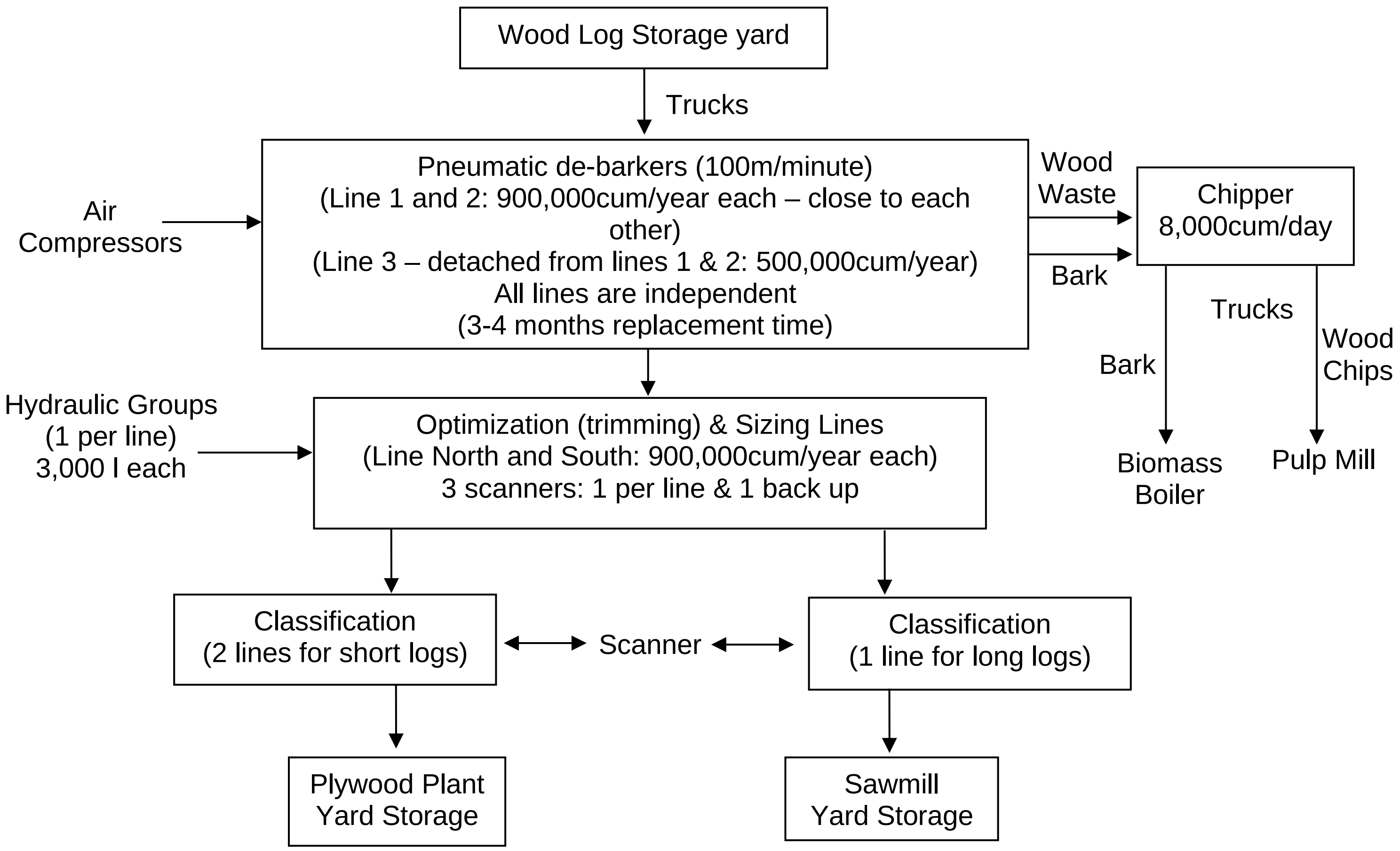
Storage occurs in two configurations:

- Stacked piles: sometimes called ‘‘tumbled’’ piles, are cone-shaped piles formed by conveying and randomly depositing logs in the center of the pile.
- Ranked piles: commonly referred to as “cold deck” piles are evenly arranged, usually by conveyors or cranes.

The storage yard is usually managed by the Integrated Cellulose & Wood Complex (if any) or the Pulp Mill or the Wood Processing facilities.

Pulpwood is usually sent to the Pulp Mill buffer storage yard to be used at the chip preparation unit (or so-called wood preparation area). (See Section 7: “Pulp Mills”).

Wood logs for the Wood Processing plants (i.e., Plywood plant including a Sawmill) are processed through the Logging plant that prepares the logs. The Process Flow Chart below is that of a typical facility on a complex. (Capacity given for example):



5.2 SPECIAL HAZARDS & RISK CONTROL

Special hazards, prevention, protection and potential mitigation measures are detailed below for each and every special hazard related to this occupancy (This follows the process flow from Raw Material to Finished Products as closely as possible). Related recommendations are also mentioned. (See. "Rec. Section 11: "Support for Loss Prevention Recommendations" for details).

5.2.1 Storage of Pulpwood and Wood Logs

- Wildland fire exposure
- Earthquake potential (seismic areas) and Tsunami (coastal areas).
- Windstorm and storm surge potential (coastal areas)
- Forestry companies store a certain amount of timber in the forest. However, when the logs stay too long in the yard, they become dry and can no longer be processed by Sawmills and most Panel plants. The same can happen during the storage of pulpwood and logs.
- Wood combustion basically occurs in two stages:
  - Destructive distillation: the heat drives off flammable gases from the wood leaving behind charcoal.
  - Burning of the airborne gases above the wood and burning of the charcoal combined with oxygen. This leaves behind a hot layer of coal. The resulting heat generates even more distillation of volatiles from the wood, which, in turn, increases temperature and combustion rates. The proper arrangement of ranked piles restricts air circulation and the surfaces are likely to burn. If a fire is not controlled in its early stage of development in a ranked pile, this will result in a very intense fire. However, it will propagate at a slower rate and radiate less heat than a fire in a similarly-sized stacked pile not properly arranged.
  - Efficient and safe firefighting measures, involving plant personnel and fire departments, is usually a key factor for mitigating the resulting loss. This is true even for fires involving large pulpwood piles, thus the absolute necessity of having well-organized and adequately-trained fire brigades using adequate firefighting equipment. Hose streams alone are not efficient for fires involving pulpwood and log piles. Monitor nozzles with a longer effective horizontal and vertical range provide great help in extinguishing a fire in a well-arranged pulpwood and log pile. These monitors should, of course, be adequately located, well maintained and used in the earliest stages of development of a fire as possible. This requires adequate supervision, alarm systems, communications, and a prompt emergency response (i.e., organization, preparedness including a firefighting plan).

<u>Prevention & Protection:</u>

- See Section 11: "Wildland Fire Exposure Mitigation".
- Buildings and structural frames should incorporate an earthquake design allowing for sustainable exposure in the area. Facilities should preferably be built outside tsunami exposed areas (i.e., distance to seashore, sufficient altitude of terrain above medium sea level).
- Buildings and structural frames should incorporate a wind design allowing for sustainable exposure in the area. Facilities should preferably be built outside storm surge exposed areas (i.e., distance to seashore, sufficient altitude of terrain above medium sea level).
- Water sprays (wetting) should be used to maintain a minimum moisture content from an operational and fire protection standpoint.
- Wood log storage (size and separation of piles) and Fire Protection (hydrants, monitor nozzles and towers) should comply with FM Global Data Sheets and NFPA standards as recommended in Section 11: "Wood Log Storage & Fire Protection".

- Dry grass and wood waste should regularly be removed. Vehicle fueling operations should be prohibited in the storage areas. Unprotected and/or combustible sheds and buildings should be moved away from this storage area.
- Adequate control of ignition sources is required, such as Hot Work Permits, a strictly enforced non-smoking policy, spark arresters on stacks of locomotives (if any), engines, and vehicles. Conveyor moving parts must be lubricated to prevent friction between belts and moving parts and there should be adequate and reliable fixed automatic fire protection systems above the conveyor (i.e., to pre-empt sparks from conveyors, sparks from passing locomotives or other vehicles or from cutting and welding operations. The latter, as well as smoking are the most common causes of fires).
- A trained fire brigade on each shift should be organized and maintained. (This could include as many as 20-30 people and an even larger group available for an emergency).
- There should be a continuous watchman service around the storage areas. Watchmen should be trained in the use of monitor nozzles and instructed to relay the alarm promptly to the emergency team as well as the fire department, regardless of the magnitude of the fire.

Courtesy of ARAUCO Chile. Raw Material Storage

5.2.2 Wood Log Processing

- Wildland fire exposure
- Buffer storage of Timber (wood logs) to be processed at the Wood Log plant
- Wood chips and bark residue may accumulate under equipment
- Wood dust hazard (fire and explosion): wood chips and sawdust constitute easily ignitable materials when they are suspended in the air in sufficient quantity
- Large wood chips and fine storage silos and/or bins
- Combustible construction material (e.g., process buildings) & combustible content

- Rubber belt conveyors
- Hydraulic oil groups: sprayed oil fires are very difficult to control. Moreover, in the case of a fire, some of the oil groups would expose equipment installed above them (e.g., wooden mezzanines, cable trays, etc.)
- Air compressors
- Electrical equipment (i.e., transformers, electric rooms, cables, and cable openings)
- LPG tanks (for vehicles, processes, domestic use)

De-barker Line

Classification line outlets for the Plywood Plant and the Sawmill

Courtesy of ARAUCO Chile. Optimization; log sizing & forming

Courtesy of ARAUCO Chile. Finished Products Yard storage

Prevention & Protection:

- See Section 11: “Wildland Fire Exposure Mitigation”.
- See Section 11: “Wood Log Storage & Fire Protection”.
- Establish adequate housekeeping routines and auditing activities.
- Dust Collectors and Collection Systems should be arranged and protected as per FM Global Data Sheets 7-73. (See also Section 11: “Dust sprinkler protection” as per NFPA). Note that some local protection may also be installed consisting of spark detectors inside ducts and water jets designed to suppress fires in the early stages of detection. Such systems are usually neither FM-approved nor UL-listed and are not a substitute for adequate and approved sprinkler protection as per FM Global Data Sheets and NFPA standards.
- Large wood chips and fine storage silos or bins should be protected according to Data Sheet 8-27: “Storage of Wood Chips”. (See Section 11: “Support for Loss Prevention Recommendations”). Automatic water spray protection (deluge) is an acceptable alternative to automatic sprinklers. This is even preferred if there is any dust explosion potential. Small bins such as truck dump bins do not need internal protection as their contents can be quickly dumped.

Courtesy of ARAUCO Chile. Chipper

- Prefer noncombustible construction avoiding wood and composite panels with combustible insulation (e.g., PUR, PIR, EPS, XPS).
- Adequate control of ignition sources is required, such as Hot Work Permits, a strictly enforced non-smoking policy, spark arresters, engines, and vehicles. Conveyor moving parts must be lubricated to prevent friction between belts and moving parts, and there should be adequate and reliable fixed automatic fire protection systems above the conveyor (i.e., to pre-empt sparks from conveyors, sparks from passing vehicles or from cutting and welding operations. The latter, as well as smoking, are the most common causes of fires). Lighting fixtures should comply with the requirements recommended in Section 11.
- Magnetic separators should be installed in the wood chip / bark belt conveyors.
- Provide grounding and bounding facilities for flammable liquid handling.
- Provide automatic sprinkler protection throughout all the general manufacturing areas and for equipment and processes, in compliance with FM Global Data Sheets 7-10: “Wood Processing and Woodwork Facilities”, for sprinkler design criteria.
- Rubber belt conveyors should be protected . (See Section 11).
- Hydraulic groups should be protected. (See Section 11).
- Air compressors should be protected. (See Section 11).

- Electrical equipment (i.e., transformers, electric rooms, cable trays and cable openings) should be protected. (See Section 11).
- All LPG bullet tanks, loading / unloading stations and vaporizers should be protected in compliance with the minimum requirements of FM Global Data Sheets 7-55: "Liquefied Petroleum Gas (LPG) Storage Tanks and Unloading Stations". (See Section 11: "Support for Loss Prevention Recommendations").

Courtesy of ARAUCO Chile. LPG Bullet Tanks

5.3 CONTINGENCY / BUSINESS CONTINUITY / RECOVERY PLAN

Warning: in order to be reliable, a Contingency / Business Continuity / Recovery Plan should be formalized. This would include formal contracts signed in advance with vendors and/or third parties. The plan should be regularly tested, reviewed and updated.

Holistic view:

- If the Pulpwood and Wood Log storage and Logging plant are part of a group with a relatively high level of vertical integration in the Wood Processing industry (i.e., a Logging plant supplying a group of Wood Processing Plants on the same complex), a Business Continuity Plan (BCP) at corporate level should be developed for the main identified risks in each and every process unit. (See Section 2.2: "Interdependencies, BI, CBI/CTE, SI").
- The impact of a loss impacting third parties (i.e., logistics, utilities) should be investigated and an adequate BCP should be established.

Site view:

- Duplication of process lines and separation is paramount. Any spare capacity per line allows for more flexibility.
- Backup for critical utilities is also important.

- There should be adequate spare parts management for process equipment with relatively long lead times.

5.4 LOSS HISTORY

- According to various studies, around 50% of major losses in Wood Processing plants are fire related.
- Wind, hail, floods and lightning account for around 20% of the losses.

Example of a minor event that could have resulted in a major loss if not controlled in its early stage of development:

Optimization, log forming, classification building: a hydraulic hose leaked causing oil vaporization and accumulation under a wooden floor located inside the process building, leading to ignition and fire following. The fire was controlled and extinguished using Portable Fire Extinguishers.

The investigation shows that the most likely cause was the mechanical deterioration of a hydraulic hose due to friction with an electric cable, damaging the insulation of the electric cable and the hydraulic hose.

Property Damage was reportedly limited. Business Interruption: 3 days, of which 1 day for the investigation, 1 day for cleaning (smoke damage) and 1 day for repair.

5.5 LOSS ESTIMATES

Maximum Possible Loss (Technical MPL):

- Major EQ in zone 3 or 4 impacting all facilities: 35% PD for zone 3, at least 50% for Zone 4, and 18 months BI. (See MPL Handbook).
- Tsunami in a coastal area. (See MPL Handbook).
- Wildfire involving flying embers starting multiple fires on a complex including a Pulp Mill and Wood Processing plant. (See MPL Handbook).
- Fire destroying one process unit (i.e., optimizing building) or even other process units depending on minimum separating distances and continuity of combustible. (See MPL Handbook). Total loss of facilities should not be excluded. This would depend on congestion, combustible loads and continuity of combustible.
- Induced BI in case of interdependencies with sister plants upstream and downstream should be considered. This could be mitigated by buffer storage (providing several extra days of production) and alternate suppliers (if any). (See Section 2: “Supply Chain”).

Normal Loss Expectancy (NLE):

- Fire would result in the same magnitude as for the MPL when neither adequate nor approved automatic fire protection is provided. Total loss of facilities should not be excluded. This would depend on congestion, combustible loads, and continuity of combustible. When adequate fixed fire protection is provided, consider the loss as equivalent to the surface of application for the content only (i.e., the building is not damaged).
- Fire involving an electric room resulting in 4 months BI.
- Fire on a major rubber belt conveyor resulting in 4 months BI.
- Induced BI in case of interdependencies with sister plants upstream and downstream should be considered. This could be mitigated by buffer storage (providing several extra days of production) and alternate suppliers (if any).

6 WOOD PROCESSING

6.1 PROCESS

The following sub-sections intend to summarize the different processes in Wood Processing.

6.1.1 Sawmill

A typical sawmill produces both green and dry dimensional lumber.

Logs are reclaimed from the yard storage by large mobile stackers, classified and loaded onto conveyor belts feeding into the de-barker. De-barkers remove bark from the logs either mechanically via rotating rings with toothed claws or hydraulically via jets of high-pressure water. Slasher saws cut the logs to the desired length. Bark is reduced in size to be burned as ‘‘fuel’’ in waste-fired boilers (so-called “bio-mass boilers”) or incinerated in burners (so-called “teepees”).

Courtesy of ARAUCO Chile. Wood Log Feeding - Upstream

De-barked logs are then processed through laser-scanning equipment determining the best position for each log for best results and a chipper-canter cuts the sides of the round timber. The remains (up to 60% of a wood log) are turned into chips.

Courtesy of ARAUCO Chile. Sawmill - Laser

After a series of subsequent cuts that are carried out automatically through a number of sawing machines, the logs are turned into lumber of various predetermined dimensions.

Sawmill Process Area (first step)

Sawmill Process Area (second step)

Courtesy of ARAUCO Chile

Lumber sorters convey lumber on chain conveyors, detect the length of each piece, and divert it into a bin or tray with other similar-sized pieces (i.e., tray sorter).

Courtesy of ARAUCO Chile

Some lumber of similar dimensions is then piled and sent to the dry kiln (up to more than 20 chambers for a Sawmill), which uses steam to increase the temperature in order to remove humidity from the lumber.

Courtesy of ARAUCO Chile. Dry Kiln

Part of the production of dried lumber undergoes a secondary transformation at the Remanufacturing plant, through planning, dovetailing or molding before the final sale. Rotating knife planers are used for final dimensioning. Sometimes high-speed belt sanders, similar to wood panel sanders, are used for final dimensioning. This is most common on boards such as pine where the knots tend to be chipped out by conventional knife planers. Planer shavings are collected for use as fuel or as a by-product material for composite panel products.

Wood Remanufacturing area

Finger Molding Radio Frequency Furnace

Courtesy of ARAUCO Chile

Water-Based Paint Line

Laminated Beams Plant

Courtesy of ARAUCO Chile

Laminated wood (“glued wood”)

Indoor storage.

Courtesy of ARAUCO Chile. Work-in-Progress Material Yard Storage (green wood)

The section containing the knots on a piece of lumber may be cut producing smaller lumber sections.

Finger joints are used to join short pieces of wood together to form units of greater length. The joint is composed of several meshing wedges or "fingers" of wood in two adjacent pieces and is held together with glue. Finger-joined lumber is used for both structural and non-structural products.

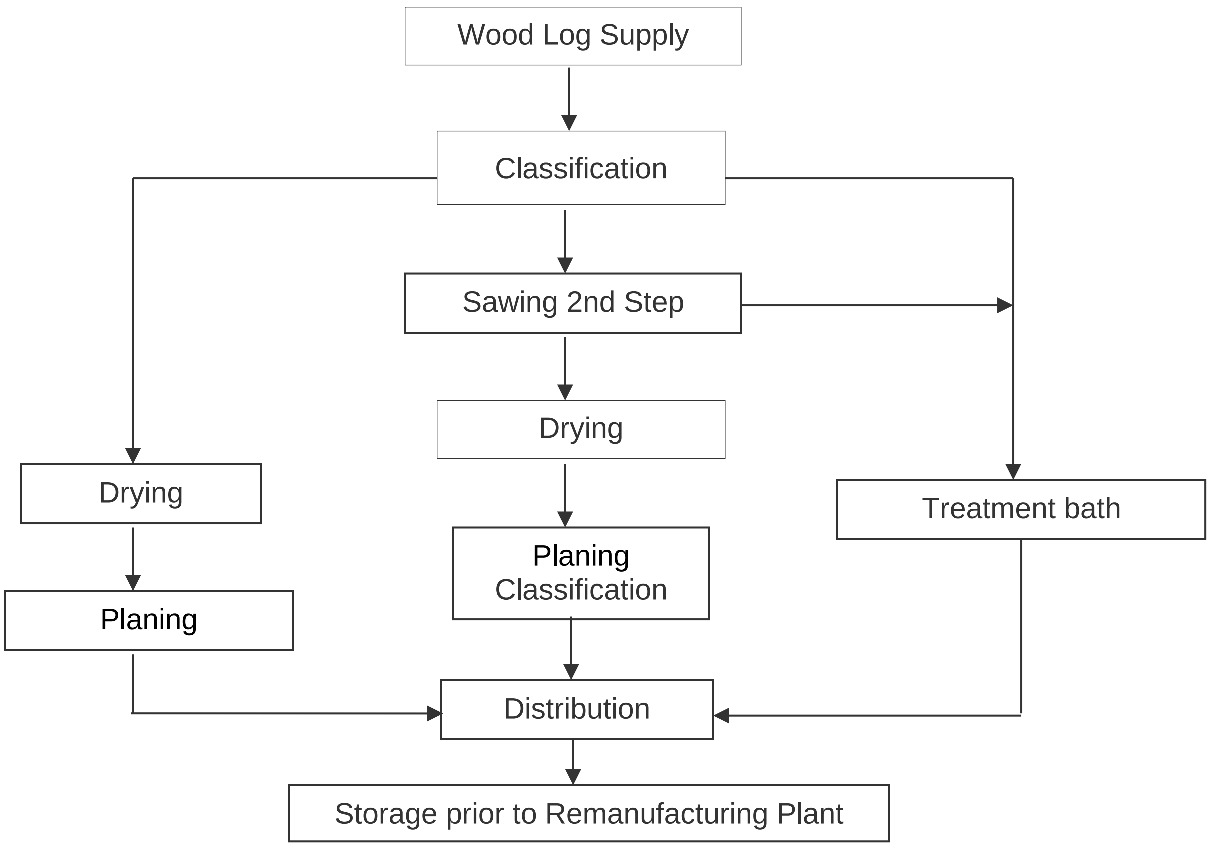
The remanufacturing can be linked with woodworking plants located on the same complex, as shown below:

Wooden floor factory

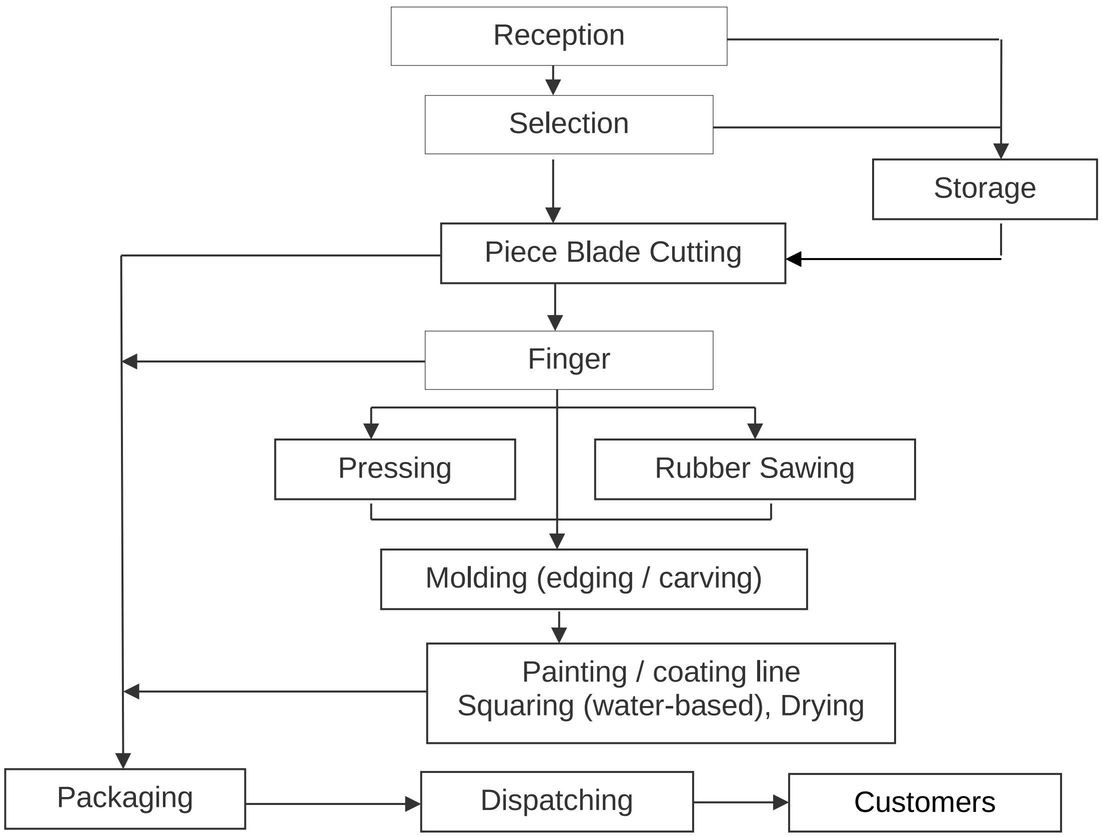
Wooden door factory

See simplified process block diagrams below.

Simplified Process Block Diagram – Sawmill:



Simplified Process Block Diagram – Wood Processing Plant:



6.1.2 Plywood (panel products)

Panel products include both plywood and composite panels made of small wood fractions held together by resin binders. The processes which manufacture these products have as many similarities as they do differences. The pressing and finishing operations are very similar for all panel products. The forming of the panels constitutes the primary differences.

Plywood panels

Logs are de-barked in equipment similar to that used in the de-barking operation of a Sawmill.

Logs are thawed (in cold climates) and/or softened (maceration) in steam or hot water vats. Once softened, the logs are conveyed to the veneer lathe to be peeled.

The peeler core remaining from each log after, all usable veneer is removed, is either chipped or processed through a Chip 'N Saw to recover lumber from the center and chips from the sides.

Freshly cut layer of plywood

Green veneer is stored awaiting drying in steam-heated veneer dryers.

Peeling Lines

Steam-heated Dryer

Courtesy of ARAUCO Chile

Dried veneer may be stored before further processing, such as patching and gluing or stitching to join smaller pieces together. The layup process prepares the veneer for pressing. Successive layers of veneer are coated with glue (typically urea formaldehyde resin for indoor applications and phenol formaldehyde resin for exterior grades) and laid on top of each other, with the veneer grain alternately placed lengthwise and crosswise to ensuring panel strength.

The glued veneer is then conveyed to the high-pressure hot press to cure the resin, forming rigid panels.

Adhesive Line

Presses

Courtesy of ARAUCO Chile

Large hydraulic press.

Pressed panels may be processed through a board cooler (hood with a high induced airflow).

Panels are trimmed to their final dimension, and if their end use so dictates, sanded to their final thickness or surface smoothness.

Polybatch Line

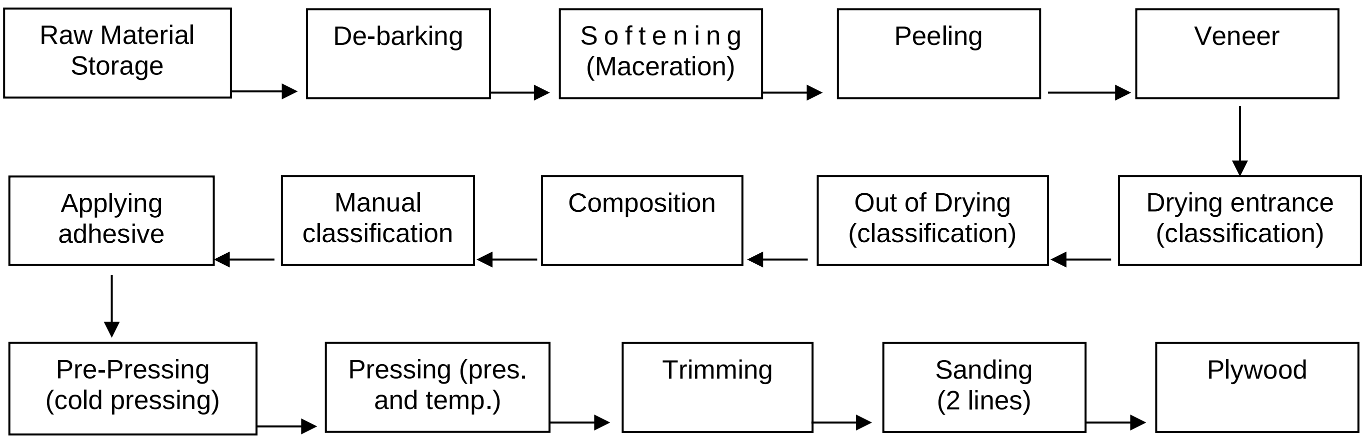
Sanding

Courtesy of ARAUCO Chile

Finished products are unitized, usually by metal banding, and stored flat, up to 6m (20ft) or higher.

Courtesy of ARAUCO Chile. Finished Products warehouse

<u>Simplified Process Block Diagram – Plywood Plant:</u>



6.1.3 Particleboard

Wood waste is the primary raw material (called "furnish"). Particleboard is formed in a dry process. The material needing to be dried is stored in large silos or open bay buildings.

Screens may also be used to remove the very fine dust for use as fuel. Special rotating ring knife flakers are used to reduce the furnish to an acceptable size. The furnish is then dried to the desired moisture content (usually less than 10% dry basis), in rotary drum dryers.

Dried material is screened to remove additional fines and conveyed to surge bins then blenders where resin (usually urea formaldehyde) and sometimes wax is also added.

The blended resin is weighed and metered into formers (usually 2 for surface material and 1 for core material) which distribute the free-falling furnish onto a moving belt. The materialis either:

- deposited on metal plates (so called "caul" plates) that carry the furnish to the hot press

  or

- pre-press rolled as it is loaded into the hot press.

6.1.4 Fiberboard

Wood waste is the primary raw material (called "furnish"). Fiberboard is formed in a wet process. The material does not need to be dried and can be stored outdoors. Preparation is similar to that of Particleboard (see above).

Screens are used to remove the very fine dust for use as fuel.

The furnish passes through a pressurized steam digester that softens it and is then reduced to fibers in rotating disk refiners (may be pressurized). Resin is added during the refining process. The fiber flows from the refiners as a wet slurry (similar to thermomechanical pulp). (See Pulp Mill Section, page 61).

The slurry is formed into a mat on a moving wire former (so-called ''Fourdrinier'). Water is removed from the formed mat by vacuum and de-watering press rolls. The dried fiberboard is trimmed to its final size.

The mat is then cut into individual panels and dried in a multi-tier dryer.

Some fiberboard products are coated.

6.1.5 Medium-Density Fiberboard (MDF)

MDF Fiberboards.

Wood waste is the primary raw material (called “furnish”). The forming process is dry. Raw material is commonly stored in large open-bay buildings.

Following foreign material separation and screening, raw material is broken down into fibers by rotating disc refiners (usually steam pressurized).

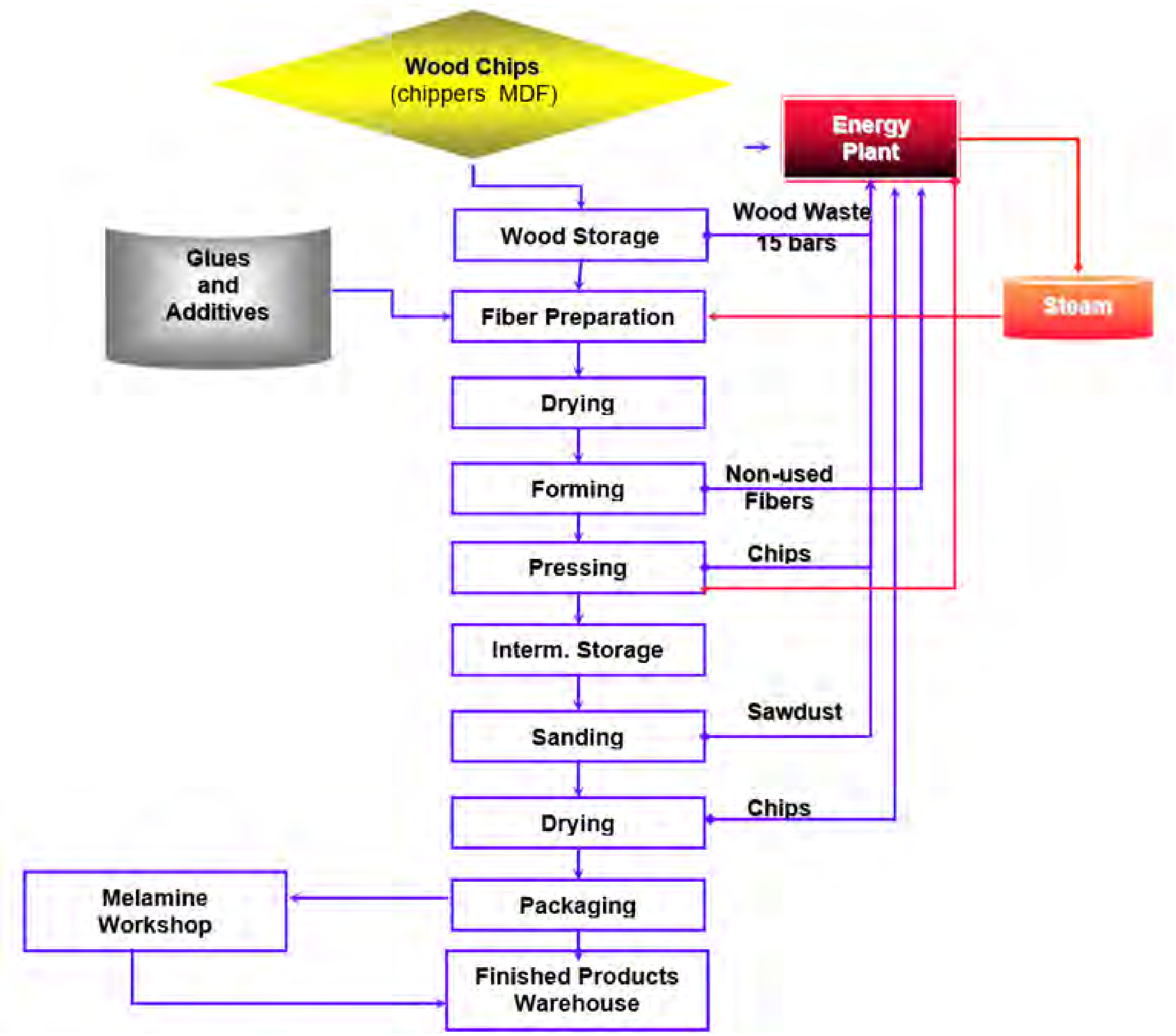
The damp fibers are dried to their final moisture content in dryers (so-called “flash dryers”) usually removing above 90% of moisture. In some processes, resin (usually urea formaldehyde) may be injected into the furnish as it enters the flash dryer (i.e., “blow line blending”).

Dried fibers are usually further screened and conveyed (e.g., pneumatic blow line) to surge bins. They then move on to blenders for resin addition (unless already injected prior to drying) and finally to weight belts (made of wire mesh with suction applied to the underside to help form the mat) before dropping into formers (“felters”). The mat is formed by at least 3 felters laying down successive layers of fiber.

After the forming line, the mat is cut into panel lengths and run through pre-press rolls before entering a hot press for final pressing and resin curing.

The finishing line operations are similar to particleboard. A hard thin layer of melamine resin may be applied on the surface of the board by a hydraulic press.

Simplified Process Block Diagram – MDF:



6.1.6 Hardboard (HB)

Wood waste is the primary raw material (called “furnish”). HB is formed in a wet process. The material does not need to be dried and can be stored outdoors.

Screens are used to remove the very fine dust for use as fuel.

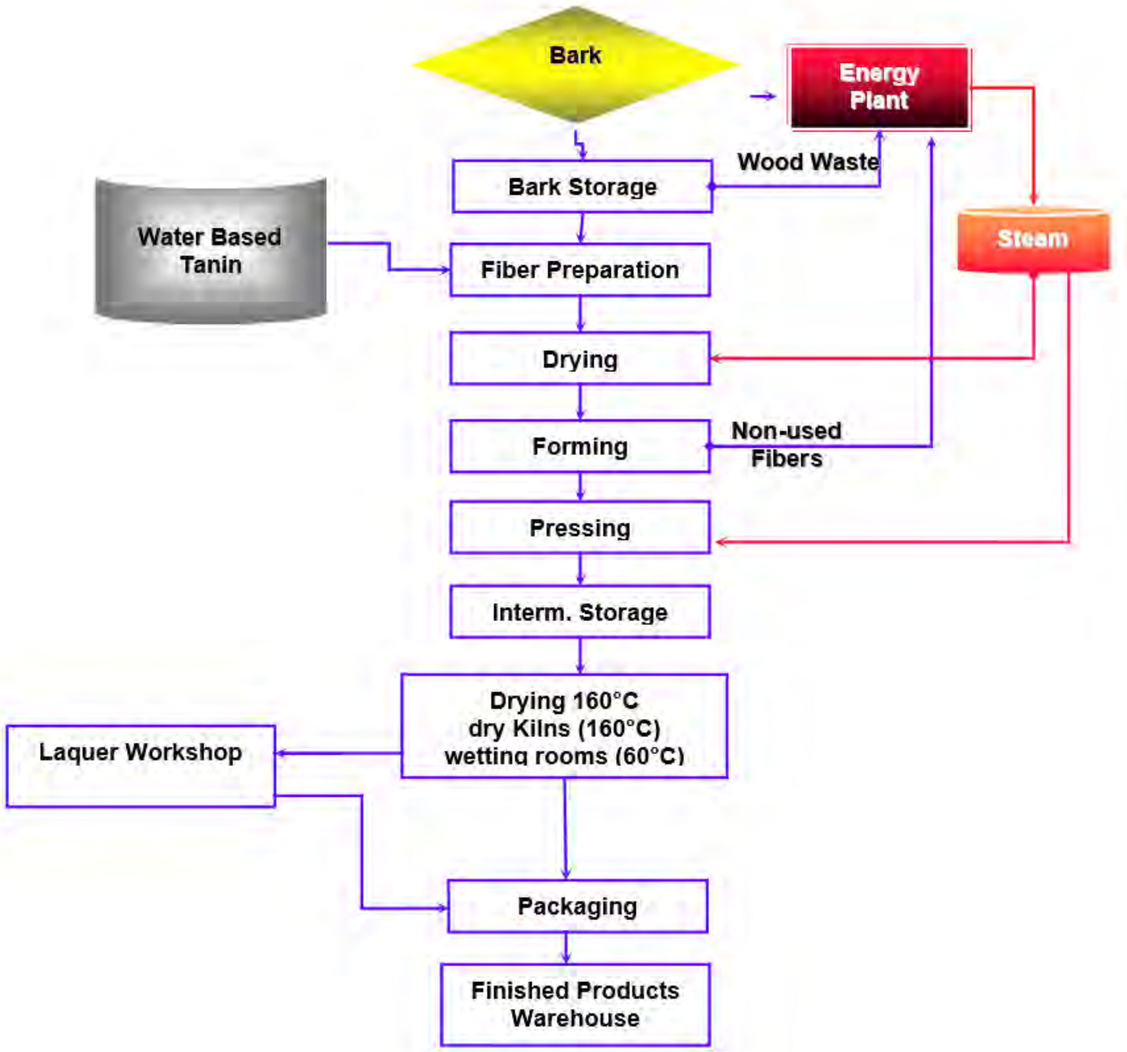
The furnish passes through a pressurized steam digester that softens it, before being reduced to fibers in rotating disk refiners (may be pressurized). Resin is added during the refining process. The fiber flows from the refiners as a wet slurry.

The slurry is formed into a mat processed through a hot press.

The finishing process for HB may include a step to temper or stabilize the moisture content in the panels, processing the panels in steam-heated batch humidifying ovens (similar to dry kilns).

The dried HB is trimmed to its final size.

Simplified Process Block Diagram – HB (numbers given for example):



6.1.7 Waferboard

Whole logs are the primary raw material. Log preparation is similar to that of plywood. Hot water soaking vats are commonly used to thaw logs and soften them before processing in special wafer chippers (so-called ‘‘waferizers’’).

The furnish is then processed through rotary dryers, formed, pressed, and finished (similar to the process for particleboard).

6.1.8 Oriented Strand Board (OSB)

OSBs.

This process is almost identical to that used for waferboard.

Powdered resins (usually phenol formaldehyde) are sometimes used instead of liquid resins.

This process usually forms and presses very large panels which are then cut into standard sheets.

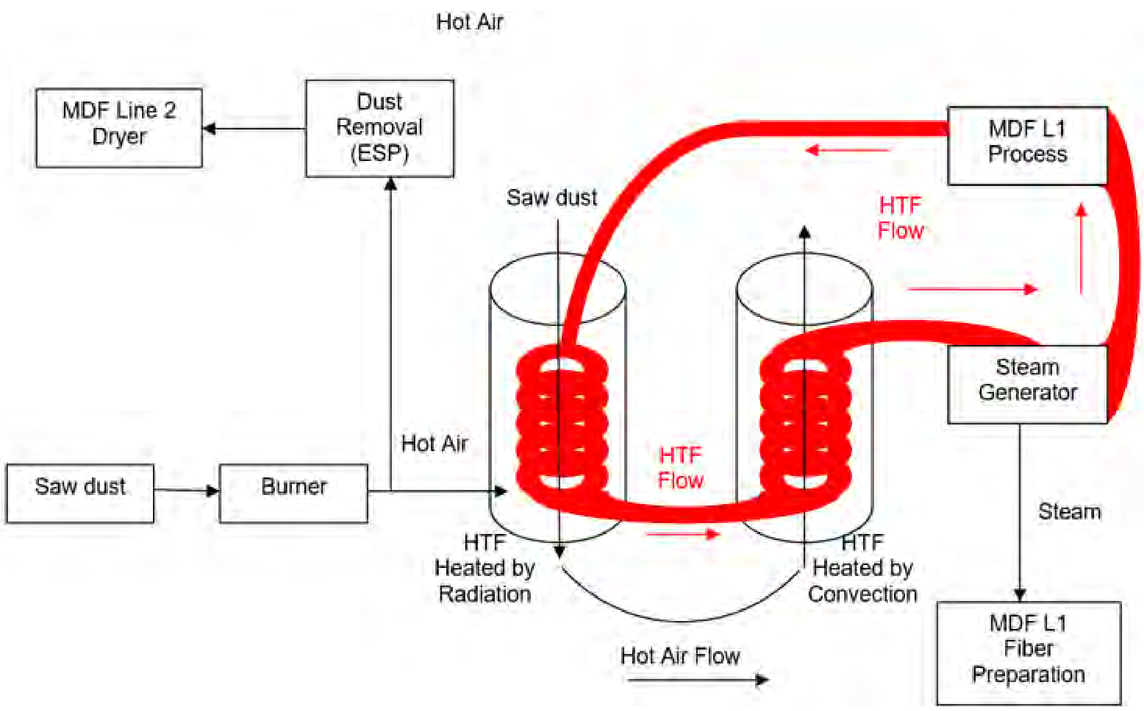
6.2 SPECIAL HAZARDS & RISK CONTROL

Special hazards, prevention, protection and potential mitigations measures are detailed below for each and every special hazard related to this occupancy (This follows the process flow from Raw Material to Finished Products as closely as possible). Related recommendations are also mentioned (See. “Rec”, Section 11; “Support for Loss Prevention Recommendations” for details).

6.2.1 Sawmills, Plywood and other Panel Plants

- Flood exposure: Wood Processing and Pulp & Paper industries are usually located near rivers due to their water consumption (for processes, cooling, domestic use, utilities and firefighting) and logistic purposes (historically used for the importing of Raw Material / exporting of Finished Products)
- Earthquake potential (seismic areas) and Tsunami (coastal areas)
- Windstorm and storm surge potential (coastal areas)
- LPG tanks (for vehicles, process, domestic use)
- Buffer storage of Timber (wood logs) to be processed
- Wood waste may accumulate under equipment
- Wood dust hazard (fire and explosion): wood chips and sawdust constitute easily ignitable materials when they are suspended in the air in sufficient quantity. Explosive dust especially for Fiberboard and MDF plants (but not limited to): wood fiber in the dry parts of the process (upstream fiber preparation area and downstream sanding area)
- Large wood chip and fine storage silos and/or bins

- Combustible construction material (e.g., process buildings) & combustible content
- Rubber belt conveyors
- Laser scanning equipment
- Treatment bath (Sawmill): usually neither fire nor explosion hazard (e.g., chloro bis triacianate methylene)
- Hydraulic oil groups: sprayed oil fires are very difficult to control. Moreover, in the case of a fire, some of the oil groups would expose equipment installed above them (e.g., wooden mezzanines, cable trays, etc.)
- Air compressors
- Electrical equipment (i.e., transformers, electric rooms, cables)
- Glues and Additives: mix of Paraffin Wax PF 230°C auto-ignition >310°C Adelite Resin (Urea-formaldehyde), and Urea. All Class 0 as per NFPA
- Paint: may be combustible or water-based. Dryer: usually hot-air blower.
- Dryers for veneer (Sawmill), fiberboard and other similar combustible material. Steam heated Kiln dryer cells (i.e.,140°C. 7)
- Rotary Dryers for composite panels using heated air (steam and hot water heated through an exchanger) or direct firing with gas oil, wood dust used as fuel, waste heat boiler, thermal oil heaters
- Flash Dryers for composite panels using heated air (steam and hot water heated through an exchanger) or direct firing with gas oil, wood dust used as fuel, waste heat boiler, thermal oil heaters
- Hot presses used to cure the resins in panel products including hydraulic groups and heating systems (i.e., flowing steam or hot oil, radio frequency energy similar to microwaves within the newest facilities).
- Machinery Breakdown potential
- Overhead cranes (lifting equipment)
- Work-in-Progress Material and Finished Products: NFPA Class II-III solids, piled up to 4-6m high.
- Thermal oil systems (e.g., MDF lines) - Thermal Oil Heating System flow diagram:



- Critical and very expensive spares are usually stored in one or more warehouses. Heavy spares and consumables are usually well separated. The inventory can represent several

Million USD (e.g., $20-40-60-80MM or more). These spares are critical to the process and can have a relatively long lead time. Some consumables used in relatively large quantities and/or having a long lead time are also deemed as critical. A major loss in such a warehouse could lead to BI for the related units due to lack of spares.

Prevention & Protection:

- Flood potential should be carefully investigated. All facilities, including critical utilities such as effluent treatment plants, should preferably be located outside the flood-exposed area. Adequate physical flood protection should be provided when needed.
- See Section 11: “Wild-land Fire Exposure Mitigation”.
- Buildings and structural frames should incorporate an earthquake design allowing for sustainable exposure in the area. Facilities should preferably be built outside tsunami exposed areas (i.e., distance to seashore, sufficient altitude of terrain above medium sea level).
- Buildings and structural frames should incorporate a wind design allowing for sustainable exposure in the area. Facilities should preferably be built outside storm surge exposed areas (i.e., distance to seashore, sufficient altitude of terrain above medium sea level).
- All LPG bullet tanks, loading / unloading stations and vaporizers should be protected in compliance with minimum requirements of FM Global Data Sheets 7-55; “Liquefied Petroleum Gas (LPG) Storage Tanks and Unloading Stations”. (See Section 11: “Support for Loss Prevention Recommendations”).
- See Section 11: “Wood Log Storage & Fire Protection”.
- Establish adequate housekeeping routines and auditing activities.
- Dust Collectors and Collection Systems should be arranged and protected in compliance with FM Global Data Sheets 7-73. (See also Section 11: “Dust Sprinkler Protection” as per NFPA). Note that some local protection may be installed consisting of spark detectors inside ducts and water jets to suppress fires in the early stages of detection. Such systems are usually neither FM-approved nor UL-listed and are not a substitute for adequate and approved sprinkler protection as per FM Global Data Sheets and NFPA standards.
- Large wood chips and fine storage silos or bins should be protected according to Data Sheet 8-27 “Storage of Wood Chips”. (See Section 11: “Support for Loss Prevention Recommendations”). Automatic water spray protection (deluge) is an acceptable alternative to automatic sprinklers. This is even preferred if there is any dust explosion potential. Small bins such as truck dump bins do not need internal protection as their contents can be quickly dumped.

Courtesy of ARAUCO Chile. Saw Dust Silo and Filter

- Prefer noncombustible construction avoiding wood and composite panels with combustible insulation (e.g., PUR, PIR, EPS, XPS).
- Adequate control of ignition sources is required such as Hot Work Permits, a strictly enforced non-smoking policy, spark arresters, engines, and vehicles. Conveyor moving parts must be lubricated to prevent friction between belts and moving parts and there should be adequate and reliable fixed automatic fire protection systems above the conveyor (i.e., to pre-empt sparks from conveyors, sparks from passing vehicles or from cutting and welding operations. The latter, as well as smoking, are the most common causes of fires). Lighting fixtures should comply with the requirements recommended in Section 11.
- Magnetic separators should be installed in belt conveyors.
- Grounding and bounding facilities required for flammable liquid handling.
- Provide automatic sprinkler protection throughout all the general manufacturing areas and for equipment, processes and storage areas in compliance with FM Global Data Sheets 7-10: “Wood Processes and Woodworking Facilities”, for sprinkler design criteria. (See Section 11).

Courtesy of ARAUCO Chile. Finished Products Warehouse

- Rubber belt conveyors should be protected. (See Section 11).
- Adequate backup servers should be provided and installed in different fire areas. When installed in the same fire area, adequate and approved fixed fire protection should be provided. (See Section 11).
- Hydraulic groups should be protected. (See Section 11).
- Air compressors should be protected. (See Section 11).
- Electrical equipment (i.e., transformers, electric rooms, cable trays and cable openings) should be protected. (See Section 11).
- Prefer the use of noncombustible glues and additives.
- Prefer the use of water-based paints and hot-air or steam-heated dryers (no direct-fired heater). Finishing operations using flammable sealers, coatings, paints, etc. should be protected in accordance with the applicable parts of Data Sheets 7-9: “Dip Tanks, Flow and Roll Coaters and Oil Cookers”; 7-32: “Ignitable Liquid Operations”, and 7-27: “Spray Application of Flammable and Combustible Materials”. These operations should be cut off from other manufacturing areas, preferably in a separate building.
- Protect veneer and panels dryers with adequate and approved deluge (spray) systems as per FM Global Data Sheets 7-10:” Wood Processing and Woodworking Facilities”. (Note: a high demand for water is expected). Prefer indirect heating and noncombustible construction (e.g., heat exchangers and all rooms made of double-walled metal panels insulated with glass wool).
- Ovens or dryers used in these operations should be protected in accordance with Data Sheet 6-9: “Industrial Ovens and Dryers”.
- Direct firing for Rotary Dryers using gas or fuel oil: adequate safety combustion controls should be provided. (See Section 11).
- Direct firing for Flash Dryers using gas or fuel oil: adequate safety combustion controls should be provided. (See Section 11).

- Protect loading and unloading panel accumulators and pits with sprinkler protection including sidewall heads that can reach the center of the pit areas. The hydraulic systems should be protected. (See Section 11).
- Adequate and well maintained (and duplicated) lifting equipment (i.e., rolling cranes) should be provided inside the process hall allowing for heavy-load handling during maintenance operations. (See Section 11: " Prevention and Protection).
- Protect Work-in-Progress material and Finished Products storage in accordance with NFPA.
- Thermal oil systems should be protected. (See Section 11).
- Prevention & Protection:
- Critical spares should be clearly identified. The commodity class should be clearly established as per NFPA and the warehouse should be provided with adequate and approved automatic fire detection / protection systems. (See Section 11). Flammable and combustible liquids and spray cans should not be stored in such warehouses but rather stored in a dedicated safe area fitted with the necessary ventilation measures, leak detection & containment. Hazmat and compressed gases should be stored and protected. (See Section 11). Large drivers should be properly stored. (See Section 11).

6.2.2 Thermal Power Plant (biomass)

- Flood exposure: Wood Processing plants are usually big consumers of water for processes, domestic use, utilities, and firefighting. These plants are therefore located close to rivers.
- Wildland fire exposure due to the proximity of forests.
- Biomass fuel warehouse: a mixture of bark and wood chips is stored in a detached warehouse (e.g., 20,000cum capacity - 3 days boiler operation) linked to the Thermal Plant by a protected rubber belt conveyor network (e.g., 30% underground, 70% overhead) running from the bottom of the warehouse to the top of the Thermal Plant. Biomass is used as a main fuel for the boiler.
- Fuel oil tank: fuel oil is used for the pilot line.
- Propane bullet tank (LPG): propane is used for ignition of the pilot line.
- Sawdust silo: sawdust recovered from the plywood plant is stored in vertical silos to be used as biomass fuel.
- Rubber belt conveyors.
- Biomass steam boilers producing steam for the Thermal Power Plants and the Panel Plants (i.e., MDF, HB, Plywood, etc.): in case of a loss of the Steam Boiler(s), a total shutdown of the Thermal Power Plants (Steam Turbine Generators producing electric power) and the Panel Plants (e.g., steam-heated dryers) is expected.
- Steam Turbine Generator(s): the steam produced at the Thermal Power Plant is primarily used for the process. Excess steam is used to produce electric power to be used by the processing plant(s) and/or sold to the grid (e.g., excess of electric power sold to the grid, thus generating revenue).
- Fume treatment (e.g., Electrostatic Precipitators).
- Oil-filled transformers.
- Electric rooms, cable trays.

Prevention & Protection:

- Flood potential should be carefully investigated. All facilities including critical utilities such as effluent treatment plants should preferably be located outside the flood-exposed areas. Adequate physical flood protection should be provided when needed.
- See Section 11: "Wildland Fire Exposure Mitigation".

- Adequate separation from other facilities should be provided. As with wood waste burners, biomass thermal power plants should be located as far as practically possible from yard storage and important buildings of combustible construction. A separation of 120m (400ft) is desirable.
- Fuel oil tanks: above-ground tanks should be installed on dikes at about 50m from the Thermal Plant. In case of mutuual exposures between tanks, the fuel tanks should be protected. (See Section 11: “Ignitable Liquid Storage Tanks”.
- All LPG bullet tanks, loading / unloading stations and vaporizers should be protected as per the minimum requirements of FM Global Data Sheets 7-55: “Liquefied Petroleum Gas (LPG) Storage Tanks and Unloading Stations. (See Section 11: “Support for Loss Prevention Recommendations”).
- Sawdust silos and handling systems: Hazardous Dust Collection and Dust Handling Systems should be protected as per 7-73: “Dust Collectors and Collection Systems”, and Data Sheet 7-76: “Prevention and Mitigation of Combustible Dust Explosions and Fires”.
- Rubber belt conveyors should be protected. (See Section 11).
- Biomass steam boilers should be provided with adequate safety combustion controls (i.e., fuel lines for ignition - gas and fuel oil). (See Section 11).
- Steam Turbine Generators should be protected. (See Section 11).
- Electrostatic Precipitators: once a fire is detected, the unit should go into emergency shutdown immediately. It should be recognized that during operations the atmosphere in the precipitator is oxygen-deficient and opening doors or running system fans following a fuel trip could cause conditions to worsen (increased potential for backdraft explosion). Once the flow of air and fuel to the fire has been stopped and the electrostatic precipitator has been shut down and deenergized, the precipitator doors can be re-opened and water hoses deployed if necessary. (See NFPA850)
- Oil-filled transformers (including the Electrostatic Precipitator’s transformer) should be protected. (See Section 11).
- Electrical rooms and cable openings should be protected. (See Section 11).

6.2.3 Other Critical Utilities

The following exposures should be investigated:

- Flood exposure: Wood Processing plants are usually big consumers of water for processes, domestic use, utilities and firefighting. These plants are therefore located close to rivers.
- Wildland fire exposure due to the proximity of forests.

The following critical utilities may be included in a Wood Processing plant or may be centralized in one area inside a complex that may also include a Pulp Mill. This would give rise to the following special hazards.

- Emergency Power Supply consisting of an Uninterruptible Power System - UPS (batteries) - and Diesel Engine-Driven Generator. This could be used for an emergency shutdown (i.e., removal of Work in Progress material inside equipment, maintaining cooling and lubrication systems of process equipment and Thermal Power Plant equipment - Steam Turbine -, circulation of thermal hot oil system, hot press control, emergency lighting).
- Water used for processes, domestic, utilities (e.g., cooling, steam boilers) is usually obtained from the nearest river and/or from wells (electric-driven pumps). Water is treated according to its intended use (boiler, drinking water, process, firefighting). Water can also be stored in a retention made of earthfill material called an Embankment Dam that could also expose critical facilities. (See Handbook “Embankment Dams” for the description of the risk and related topics).
- Effluent Treatment Plants are usually installed as per local environmental regulatory requirements. Different technologies are available. Modern technology involves filters and

membranes to be replaced every year (e.g., more than USD1MM budget), handling liquids and sometimes also solids. Solids are separated from liquids either at the Plant level or at the Effluent Treatment Plant and usually sent to the Biomass Thermal Power Plant to be used as fuel. In case of failure of the Effluent Treatment Plant, all effluents are usually directed to emergency reservoir(s) with a capacity corresponding to a maximum of 24h of plant / complex production. After this delay, all plants must be shut down. These emergency reservoirs may be made of earthfill material called an Embankment Dam. (See Handbook "Embankment Dams" for special hazard descriptions of the Risk and related topics).

- Cooling Towers are usually installed at the Thermal Power Plant, Effluent Treatment Plant and may be installed at the level of the Wood Processing plant. In case of a total loss (i.e., about 4 months replacement) of the cooling towers, the following scenarios would be expected at:
  - The Thermal Power Plant: there would be a total shutdown of the Steam Turbo Generators. If there is no electric power generation on site, the complex would rely on an alternate power source (e.g., national grid) and may have to reduce production capacity depending on power available.
  - The Wood Processing Plant: cooling towers may be critical or not (i.e., the plant may use circulating water instead of a closed loop thus limiting water consumption).
  - The Effluent Treatment plant: the treated effluent could not be cooled thus rendering any release to the nearest river impossible. The Effluent Treatment Plant would have to shut down resulting in the Wood Processing plant shutting down as well.
- Electronic Data Processing: the control of process and utilities may be highly computerized. Manual control may be possible for a relatively short period of time, but the process efficiency and quality of products may be reduced. The plants may not be able to produce the full range of products.
- Heat Ventilation Air Con. (HVAC): dedicated units are usually provided for some critical substations. Main substations and electrical rooms may be over-pressurized to prevent contamination from outside (wooden fibers).

Prevention & Protection:

- Flood potential should be carefully investigated. All facilities including critical utilities such as effluent treatment plants should preferably be located outside the flood-exposed area. Adequate physical flood protection should be provided when needed.
- See Section 11: "Wild-land Fire Exposure Mitigation".
- Emergency Diesel-Engine Driven Generators (DEDG) should be tested once a week and run for 30 minutes in order to ensure reliability (for detection of electric failure and cooling issues), ensuring lubrication. UPS and DEDGs should be protected. (See Section 11: "Stationary Combustion Engine and "Battery Rooms").
- Water intake should be regularly inspected. Any kind of potential contamination should be investigated (e.g., an upstream occupancy releasing liquid or solid material). A routine should be established for removing debris (e.g., trees, rocks) after heavy rain and storms. Regular analysis of the raw water should be carried out ensuring that it can be treated according to the intended use. The electric-driven pumps for water supply should be powered from both the normal power supply and the emergency power supply. A buffer storage should be maintained on site providing several hours' production capacity (usually between 6 and 12h).
- Critical spares for Effluent Treatment Plants such as membranes and filters should be available on site. All electric rooms, transformers, cable trays, cable openings should be protected. (See Section 11).
- Embankment Dams (i.e., water, effluent, emergency basins) should preferably be located so that they do not expose any critical facilities or community areas. See Handbook "Embankment Dams" for the proper management of this special hazard.

- Critical cooling towers should be protected. (See Section 11).
- Server rooms should be arranged and protected. (See Section 11).
- Proper maintenance and inspection programs should be established for the HVAC systems.

6.2.4 Yard Storage – Warehousing

- Semi-finished goods may be stored in yard storage between buildings (e.g., Sawmill and Remanufacturing Plant) resulting in a very high combustible load and continuity of combustible.
- A so-called "seasonal" or "temporary tent" made of combustible tarpaulin or canvas on a light metal frame may be installed close to process or storage buildings.
- Packaging equipment (i.e., palletization, wrapping) may be electric-driven or provided with a hydraulic group.
- Lighting fixtures consisting of Metal Halide HID Bulbs without adequate cover may constitute a source of ignition.
- LPG, diesel-driven and electric-driven lift trucks are used to carry the semi-finished and finished products.
- Trucks and trains may enter storage areas (yard – warehousing) for loading.

Prevention & Protection:

- Sufficient spacing should be provided in between yard storage and all buildings (minimum of 40m and more depending on height of storage).
- A so-called "seasonal" or "temporary tent" made of combustible tarpaulin or canvas on a light metal frame should be replaced with sprinkler-protected permanent structures or should be located in areas not exposing process or storage buildings (at least 40m separating distance or more depending on building heights).
- Provide adequate and reliable sprinkler protection for the warehouse. (See Section 11).
- A radius of 1.5m free of combustible should be maintained around electric-driven equipment.
- Hydraulic groups should be protected. (See Section 11).
- Provide adequate lighting fixtures. (See Section 11).
- LPG lift trucks should be provided with acceptable safeguards. (See Section 11).
- Lift truck battery charging areas should be arranged. (See Section 11).
- Provide adequate ignition source control (e.g., work permits, non-smoking policy strictly enforced for all employees including lift truck, locomotive and truck drivers).

6.2.5 Import / Export Facilities

See Section 2.2: Interdependencies, BI, CBI (CTE), SI – point F. "Major Loss impacting the Import / Export facilities".

6.3 CONTINGENCY / BUSINESS CONTINUITY / RECOVERY PLAN

Warning: in order to be reliable, a Contingency / Business Continuity / Recovery Plan should be formalized. This would include formal contracts signed in advance with vendors, and/or third parties. The plan should be regularly tested, reviewed and updated.

Holistic view:

- If the Wood Processing plants are part of a group with a relatively high level of vertical integration in the Wood Processing and Pulp & Paper industry, a Business Continuity Plan (BCP) at corporate level should be developed for the main identified risks in each and every process unit.
- The impact of a loss impacting third parties (i.e., logistics, utilities) should be investigated and an adequate BCP should be established.

Site view:

- A BCP (disaster recovery plan) should be established in case of a total loss of a plant (i.e., fire, wildfire, flood).
- Water is critical for process, domestic uses and firefighting. Ensure there are multiple sources when possible, as well as backups, buffer storage on site and a Contingency Plan consisting of water delivery by truck when possible.
- Steam is critical. Full backup, including an alternate steam supply (i.e., independent back-up steam boilers) would provide adequate duplication.
- Electric power either from the grid or generated on site (i.e., Biomass Thermal Power Plant) is critical. Full backup from the grid, avoiding bottlenecks (i.e., feeders, substations) would provide adequate duplication and reliability. This should include an Automatic Transfer Switch – ATS - thus avoiding blackouts.
- A Contingency Plan should be developed in case of a loss of the cooling towers for Steam Turbine generators and effluents.
- A Contingency Plan should be developed in case of a major loss impacting the effluent treatment plant. As per local regulations, the plants may not be allowed to operate without effluent treatment. This would also include the cooling towers used to maintain the temperature of effluents at an adequate level prior to being released in the nearest river after treatment.

6.4 LOSS HISTORY

- According to various studies most major losses in Wood Processing Plants are fire- related.
- 50% of fires are caused by spontaneous ignition, mechanical friction, overheating of the kiln, or exposure.
- Electric fires account for 25% of fires, cutting, welding and smoking around 15% and arson around 10%.

Example of losses:

Sawmill: total loss due to Tsunami in coastal area.

Sawmill: total loss due to fire. Fire (smoke) was detected by the watchman during an idle period (Sunday 6pm). The alarm was relayed to the voluntary firefighters who began fighting the fire 17 minutes after their arrival on site, preventing the fire from spreading to the yard storage. The fire apparently spread in a short time over the entire sawmill destroying/damaging both the equipment and the building (consisting of a wooden roof on an LNC steel frame and wooden floors).
Most likely cause reported: planned hot work conducted (there was no hot work permit system at the time of the loss) during the idle period and ignition 1.5h after the job was terminated.

After the loss:

- A new modern sawmill was built including less combustible construction materials.
- An early air-sampling fire detection system was installed inside the sawmill and FP warehouse.
- A hot work permit system was established including the total prohibition of hot work being conducted during the idle period.

PD loss: #USD15MM which corresponds to a total loss, of which 13MM for Machinery & Equipment, 0.5MM for Buildings and 1.5MM for the spare parts warehouse, including engineering for the new sawmill. BI Loss: 12 months

Sawmill – Steam-Heated Dry Kiln (108m²): smoke was detected by Logging Plant employees (located in front of the sawmill). The Logging Plant sent 14 First Response Team Members, and then more than 90 people were on scene (50 First Response Team Members from the Sawmill, 90 from the Pulp Mill, 9 from the Plywood Plant, 9 from the Forest Entity and 8 Public Fire Fighters).
The fire was controlled and extinguished using hose reels and hydrants.
The Dry Kiln was lost, and the 2 adjacent Dry Kilns were severely damaged (made of metal and insulated with rock wool).
Most likely cause identified: introduction of wood with a lower ignition temperature than normal.
Counter measures taken after loss:

- New instructions given for inspecting the load and preventing the mix of wood types (especially those containing resin)
- Installation of new hose connections inside the plant
- Additional emergency training given

PD: USD400k. BI: none

Sawmill - Friction of rotating equipment with wooden material (#10cum) generating smoke and starting a fire which was controlled by the plant fire brigade at its early stage of development using portable fire extinguishers. No PD. No BI.

Sawmill – Roof: collapse of 1/3 of the roof due to overload of snow (no snowfall exposure reported in the area). PD: no data. BI: 1 week.

Sawmill – Reprocessing Plant: explosion of a sawdust filter in a silo outside the building. The following fire was extinguished with the manually activated home-made spray system installed in the silo. After the loss, a fire-suppression system consisting of spark detection and water jets was installed in all dust removal lines (only one system existed before the loss. No sprinkler installed). PD: no data. BI: no data.

Sawmill – Reprocessing Plant - molding plant: flood due to overflow of the rainwater-collector trench following heavy rainwater for 3 days. After the flood, regulating dams were installed on the trench and the drainage networks were upgraded.
PD: No data. BI: 1.5 days.

Plywood Plant - Entire loss due to flying embers from surrounding wildfire (600-800m distance) entering the building through doors left open. The building was made of highly combustible polyurethane sandwich panels and was provided with a partial sprinkler protection (mostly fire curtains) for both the process area and the indoor storage of Finished Products up to 6m high.

Plywood Plant – Roof: sawdust escaped onto the cyclone tower, due to leakage and sawdust accumulation on the roof of the main process building, during strong winds and heavy rain conditions. This resulted in the roof overloading and led to the collapse of 1,500m² of roof area (above the trimming equipment – no damages reported to equipment). Around 2.5 months were needed for repair. In the meantime, the plant was only producing at 70% of its maximum capacity. PD: USD3MM. BI: None reported.

Plywood Plant – Press area: hot work was conducted during the maintenance period. Sparks falling into the pit ignited the hydraulic oil. The fire was extinguished using a portable fire extinguisher. One electric driver was lost. The identified cause was insufficient protection of the space below the hot work area, despite the Hot Work permit in use at that time. PD reportedly limited. BI: none reported

Plywood Plant – Dryer: fire in one of the 23 sections due to the ignition of accumulated resin by an incandescent wood chip. The resin was entirely burnt. No damage reported. The area above the dryer was sprinkler protected. However, this is not efficient for a fire starting inside the dryer. As a result, the plant decided to install a steam injection system automatically activated by a Firefly optic detection system. This was installed in the four dryers. PD & BI: None reported

MDF Plant: fire on press.
Cause identified: N°1 air extractor fin fan misalignment and metal-on-metal friction creating sparks falling on the press, igniting accumulated wood dust. The fire was controlled by automatic sprinklers.
After-event measures taken: systematic mechanical inspection and cleaning at every shift change within this area.
PD & BI: None reported

MDF plant: thermal oil leak and fire following on the pump of the batch-type hot press (oil temperature: 260°) due to pump failure, resulting in the loss of the thermal oil pump and of the hydraulic pump, cable trays, tubing and part of the roof. After the loss, the hot oil pumps and the hydraulic pumps were installed in a sprinkler-protected (foam) cut-off room.
PD: no data. BI: 45 days

MDF plant: thermal oil boiler explosion and fire in boiler house.

- <u>Circumstances</u>: One of the operators had made a full round of the boiler house five minutes prior to the incident and did not observe anything abnormal. The instrumentation panel in the control room just before the loss did not, reportedly, indicate any abnormal condition related to the boiler. However, the boiler was overloaded due to high production demands and the oil temperature at the exit of the boiler was lower than normal at 470°F. A low temperature alarm set at 520°F was received in the Control Room. An oil analysis had been carried out by a third-party company some months before the loss. The flashpoint and the viscosity of the thermal oil were found to be low. This report recommended “venting” the thermal oil by opening manual valves on the 1-inch lines on top of the boiler just before the circulating pumps for a period of 10 to 15 minutes a day. The purpose of this action, as stated in the report, was “to eliminate the light ends” in the oil and, by so doing, increasing the flash point to a normal level. These vent lines are connected to the expansion tank. A subsequent oil analysis was made 4 months later, and a new report confirmed that “the flashpoint of the oil was back to an acceptable level, probably due to venting performed”. In the same report, this third-party company stated that “the viscosity was still too low and may lead to a reduction in the flashpoint” and went on to recommend that the oil be changed.
- <u>Cause</u>: It appears at this point that an explosion occurred in the expansion tank due to a build-up of light-end hydrocarbons in that same expansion tank. The light-end hydrocarbons may have come from the previously discussed “venting” procedure recommended by the third-party company or from the overheating of the oil in one of the tubes of the multi-tubes in the boiler. The overheating of the oil may have occurred if one of the tubes was blocked due to coking (thermal degradation where carbon deposits are formed) and a subsequent loss of oil circulation in that tube. A “low” flow condition would not have occurred because the flow of the individual tubes is not monitored. In such a scenario, a distillation column was essentially created, and light-end hydrocarbons were produced and accumulated in the expansion tank.
- The source of ignition may have been from static electricity. Another boiler was shut down at the time of loss. Normal procedure is to flow oil through the boiler to keep the tubes cool. This oil exits the boiler and flows ¾ in. into the expansion tank. The line enters the tank at the top. It is believed the oil free fell to the level of the liquid. This could create static electricity. Another possible ignition source was outside on the roof. The tank had an open

vent. If the light-end hydrocarbons accumulated to a point where the tank was constantly discharging gases in the explosive range, then an outside ignition source, such as embers, could have ignited the vapors. Plant personnel reportedly saw a flash along the roof. This may have been a flash fire burning back to the expansion tank, or it may have been the result of an explosion inside the tank.

- Loss Control: There were 72 sprinkler heads at the ceiling of the boiler house, all operational except for 2 on the northwest of the building. Ten sprinkler heads below the mezzanine area below the expansion tank operated. The sprinkler heads appear to have limited the damage to the area of the pool fire and the roof. The sprinkler prevented a loss of 80% of the value within the area. The 2000gpm @ 110psi electric was triggered by a drop in pressure. The diesel pump of the same rating is not believed to have operated, nor was it needed. The fire department arrived in about five minutes and, in conjunction with the fire brigade, fought the fire. The fire department connected their pumper to the hydrant and with their ladders tried to extinguish the flame at the roof level of the boiler house. Other hoses connected to the hydrants were used to cool all sides of the buildings and to prevent the spread of fire to the MPL plant. The roof was cut away slowly and sprayed. Flames in the roof were still observed almost two days after the fire. It is estimated that approximately 250,000 gallons of fire water was used in the firefighting efforts.
- Damage: The building wall and roof of the boiler house will have to be rebuilt as they were destroyed by fire and water damage. The structures appear to be okay except for a length of steel in one corner. Boiler insulation and metal cladding were damaged by fire. The MCC room and computer room suffered water damage. Equipment such as the steam generator and equipment below the expansion tank may have to be replaced.
- PD: about USD2MM. BI: 28 days

Wood Processing complex (Sawmills, MDF, HB): Earthquake (EQ) magnitude 8.8 Richter scale. The complex was located 70km from the epicenter. Main damages include:

- **Thermal Power Plant**: area with the highest EQ intensity. Some boiler tubes (economizer, 4 inches) were cut (up to 16cm vertical displacement of the boiler). The sawdust silo bolts were ripped from the foundations. Walls collapsed on the equipment of the main electrical room. Damage occurred to the foundations of structural members supporting the elevated conveyors, with belts mis-aligned and pulleys ejected. Piping, flanges and valves were twisted. The ESP (Electrostatic Precipitator) duct intake was disconnected. ESP oil-filled transformers leaked. The water feed pipe was displaced (20cm).
- **HB Plant**: the most damaged building (1958). Partial collapse of cement fiber roof on bar joist; replacement with metal deck roof on bar joist; collapse of some non-bearing brick walls.
- **MDF Line 1**: structural damage to roof and supporting beams in the area above the press (no roof collapse); rupture of the sprinkler piping around the press due to EQ (no bracing). Fire broke out inside the press extractor hood (manually extinguished using hose reels because of sprinkler pipe rupture); press bolt anchored, and flanges were damaged.
- **MDF Line 2**: pipe rack damages; foundations damaged; misalignment of equipment; stoppers on de-fibers damaged; Finished Product Warehouse non-bearing metal cladding walls were damaged by the internal impact with MDF boards.
- **Sawmill – Reprocessing Plant - Molding** (4 lines): slight damages to tubing, extraction ducts, lighting, filter supports, foundations of columns and insulation under roof, fire suppression system in wood dust collection system (consisting of spark detection and water jet); water supply piping damage; leakage on sprinkler systems (no bracing).

PD:

- Thermal Power Plant: USD 2MM
- Wood Board Plants: USD 8MM of which: HB:1 MDF L1: 0.132, MDF L2: 5.5 Moldings: 1

BI:

- HB: USD1MM (due to thermal plant not operating)
- MDF L1: USD7MM
- MDF L2: USD1MM
- Moldings: USD1MM
- Thermal Plant: (47 days) 2MM (also selling excess electric power to the grid – loss of revenue)

Thermal Power Plant (supplying steam to a complex housing a Sawmill and other Wood Processing Plants): rubber belt conveyor fire reportedly due to flashback from the boiler.
Following this fire, Management of the complex decided to install sprinklers on the rubber belt conveyor.
PD & BI: No data.

Thermal Power Plant: auto-ignition in sawdust stack. Fire controlled and extinguished manually using hydrants.
PD & BI: No data.

6.5 LOSS ESTIMATES

Maximum Possible Loss (Technical MPL):

- Major EQ in zone 3 or 4 impacting all facilities: 35% PD for zone 3, at least 50% for Zone 4, and 18 months BI. (See MPL Handbook).
- Tsunami in a coastal area (see MPL Handbook).
- Fire destroying one entire plant (high combustible load due to Work-in-Progress material and storage) or even other plants (i.e., storage in between) depending on the minimum separating distance and continuity of combustible (see MPL Handbook).
- Induced BI should be considered if there are interdependencies with sister plants upstream and downstream. This could be mitigated by buffer storage (providing several extra days of production) and an alternate supplier (if any). (See Section 2: "Supply Chain").

Normal Loss Expectancy (NLE):

- Fire resulting in the same magnitude as for the MPL when neither adequate nor approved automatic fire protection is provided. When adequate fixed fire protection is provided, consider the loss as equivalent to the surface of application for the content only (the building is not damaged).
- Fire involving an electric room resulting in 4 months BI.
- Fire on a major rubber belt conveyor resulting in 4 months BI.
- Fire involving a critical cooling tower resulting in 4 months BI.
- Induced BI should be considered if there are interdependencies with sister plants upstream and downstream. This could be mitigated by buffer storage (providing several extra days of production) and an alternate supplier (if any).

7 PULP MILLS

7.1 RAW MATERIAL PREPARATION & HANDLING

As explained in section 1.1: “Wood as a Main Raw Material”, cellulose consisting of a linear chain of several hundred to many thousands of linked D-glucose units is the raw material for making pulp. The main sources of cellulose used by the Pulp & Paper industry are:

- Mainly: wood (from the nearest forest - 40-50% cellulose content),
- In some areas: bagasse (cane sugar fiber residue supplied from the nearest cane sugar mills – 45-55% cellulose content).

The preparation of cellulosic material from bagasse is relatively simple, including the crushing and fiber opening steps.

The preparation of wood chips is summarized below:

- Pulpwood is supplied from the storage area (see Section 5.1.) in log form (or roundwood) as required by the mill. Roundwood is usually received with its bark on, in four- or eight-foot lengths for convenient handling, although tree-length logs may be used in some mills. Softwoods are mainly used, but improvements in technology have permitted up to 20% hardwoods in some processes. In the past, the logs were stored in the wood yard and then processed into chips only a few hours before they were needed in the digester. Modern practice consists of converting the wood into chips immediately after reception and storing the chips in piles.

Courtesy of ARAUCO Chile. Pulpwood yard storage

Courtesy of ARAUCO Chile. Preparation Area

- Chip preparation includes debarking, chipping, and piling. These operations may include several lines (i.e., debarking drums, stone traps, chippers) for better efficiency and reliability (allowing for maintenance and flexibility).


Courtesy of ARAUCO Chile. Tandem lines: Debarkers and Chippers

- Chips are frequently stored in one large pile for purposes of economy in conveying equipment and handling; however, many plants may store chips in smaller piles of different wood species for different end products (e.g., newspaper, cartons and kraft paper). Chip piles are frequently formed by pneumatic or belt conveyors. The amount of storage depends on production requirements and the available supply. (A two months' supply appears to be average).

Courtesy of ARAUCO Chile

- For removal, chips are usually pushed by bulldozers or withdrawn by screw conveyors into recovery pits usually located beneath the piles. Trucks or power scoops may also be used to move chips directly to recovery pits.

- Chips are frequently delivered to Pulp Mills in special bottom-dump cars or trucks that transport them to receiving stations consisting of one or more-track pits.
- From there they are carried by pneumatic or belt conveyors to the Pulp Mill.

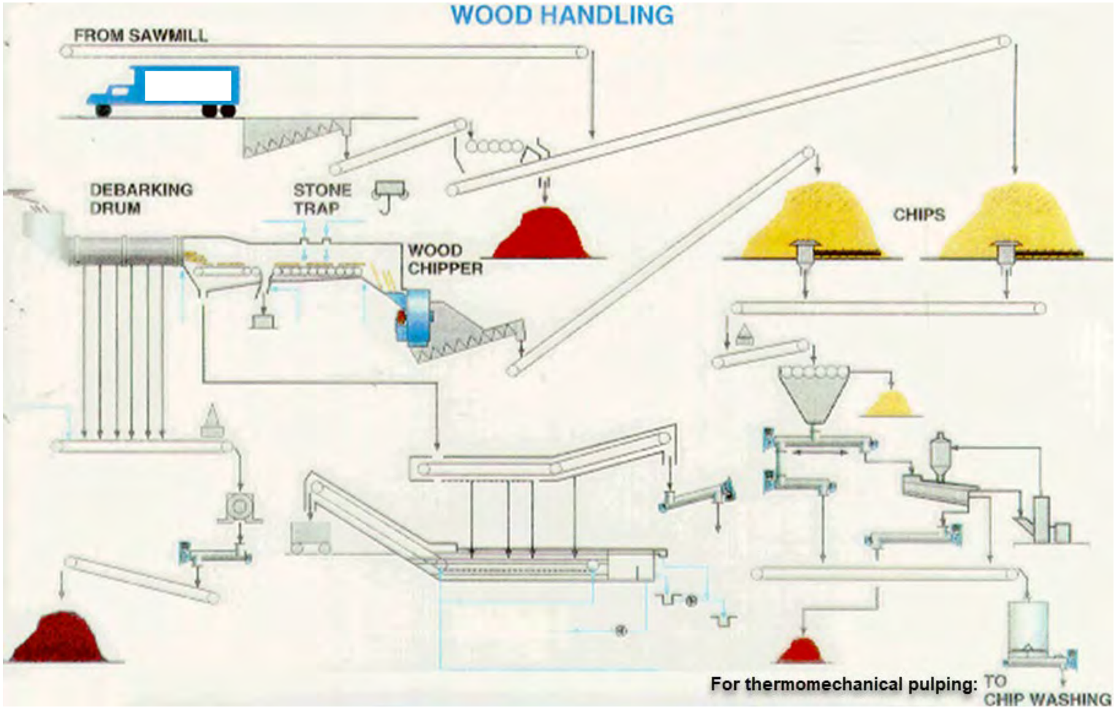
Courtesy of ARAUCO Chile
Conveyor from Chip Classification to Digesters (Spray-Protected)

The manufacture of wood / bagasse pulp is done through two main processes:

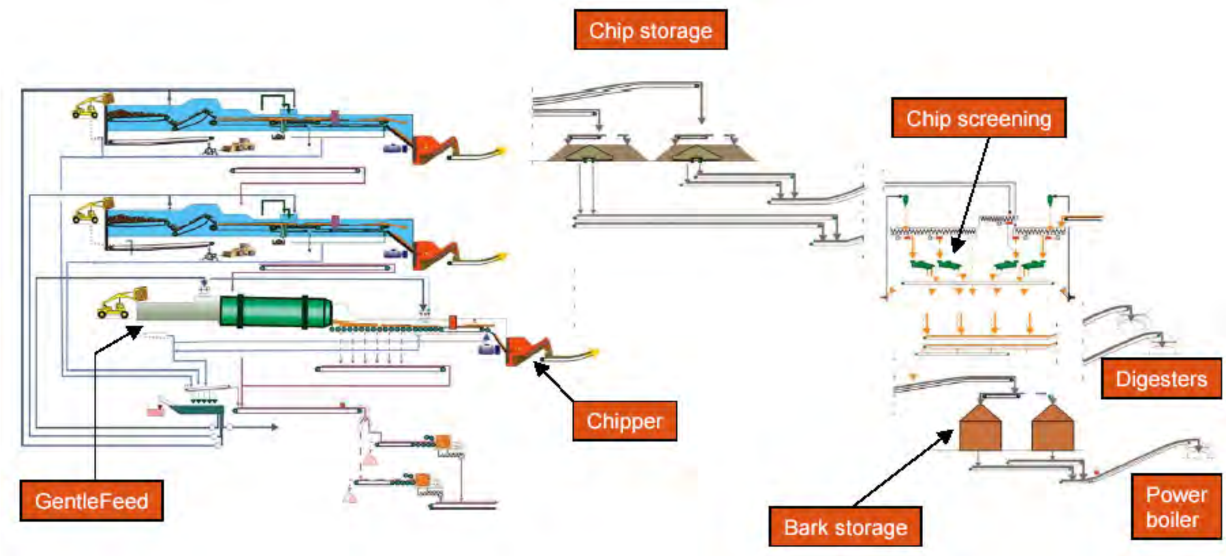
- Thermomechanical Pulping
- Chip Digestion

The preparation of the Raw Material (chips / bagasse fiber) is very similar, including some specificities of Thermomechanical Pulping and Chip Digestion processes as shown below:

Thermomechanical pulping:



Chip Digestion:



7.2 PULP MAKING

Pulping operations begin with the receipt of wood chips or other cellulosic material (i.e., bagasse) at the mill site. There are basically two ways of making pulp:

- Thermomechanical pulping
- Chemical pulping

Thermomechanical pulping is a relatively new development, but the cost and pollution potential compared to chemical treatment is reduced. It reportedly produces a better pulp than the groundwood process.

However, the pulp produced may be specific to a given paper product (e.g., newsprint) depending on the technology installed.

Details are given in the following sections.

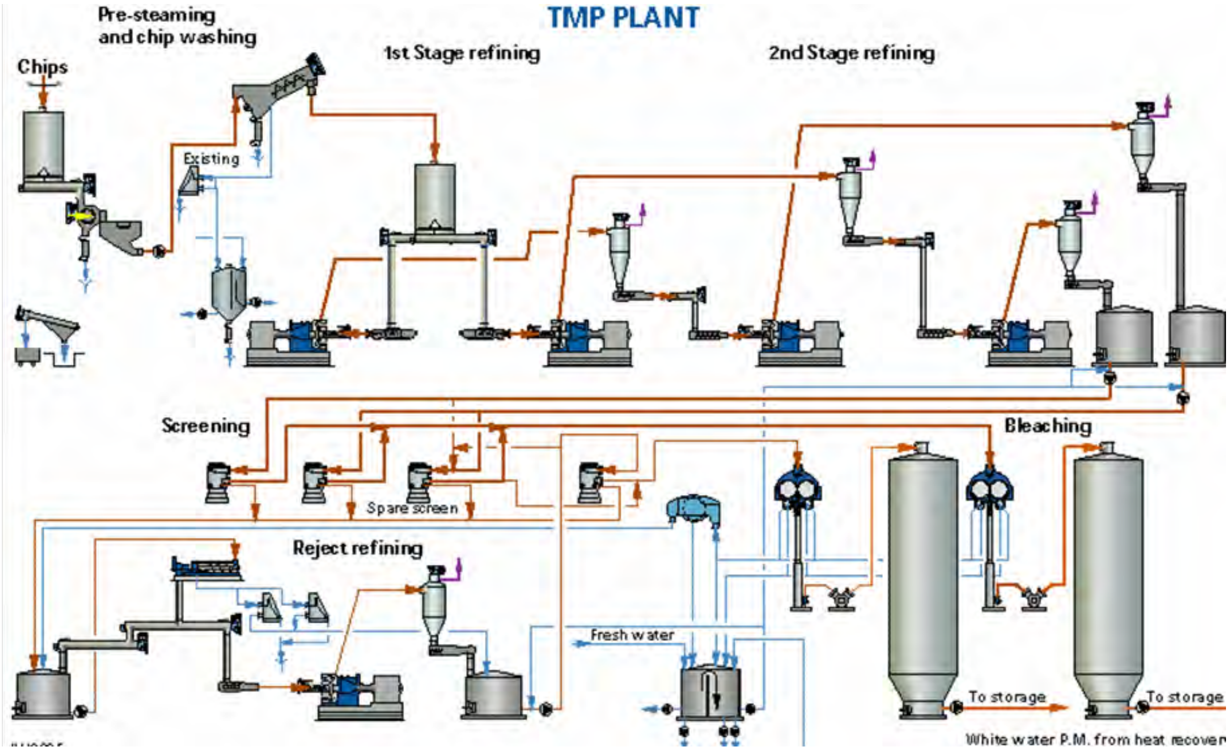
7.2.1 Raw Material In-Process Storage & Process Feeding

Wood chips or other cellulosic material (i.e., bagasse) are usually transferred by pneumatic, belt or screw conveyors from outside piles for temporary storage in silos, bins, or sheds prior to or during processing.

In modern Pulp Mills using a chemical process, wood chips / bagasse fibers are mainly transferred by elevated, inclined and covered rubber belt conveyors (e.g., 80m high, 2 belts only 1.5m apart) directly to the digesters.

7.2.2 Thermomechanical Pulping

In Thermomechanical Pulping (TMP Plants), chips are ground in a refiner, by attrition from disks, at a high temperature and pressure, in a steam atmosphere as shown below:



Thermomechanical Pulp Mill factory in Skogn, Norway

Note: the above process flow chart comes from a typical TMP plant:

- occupied for the manufacture of paper for use in the newsprint industry,
- processing pine (95%) and eucalyptus (5%) wood logs,
- via a Thermomechanical Pulping process (as shown above).

7.2.3 Chemical Pulping

Chip digestion or "cooking" is done in a digester (batch or continuous). A chip digester is a large vessel provided with raw chip feed and cooked chip discharge ports, and equipped with means for heating and maintaining its contents at a specified temperature and pressure for a required time. The recovery of the digester liquor is key for the chip digestion process allowing for its financial sustainability (recovery, reuse).

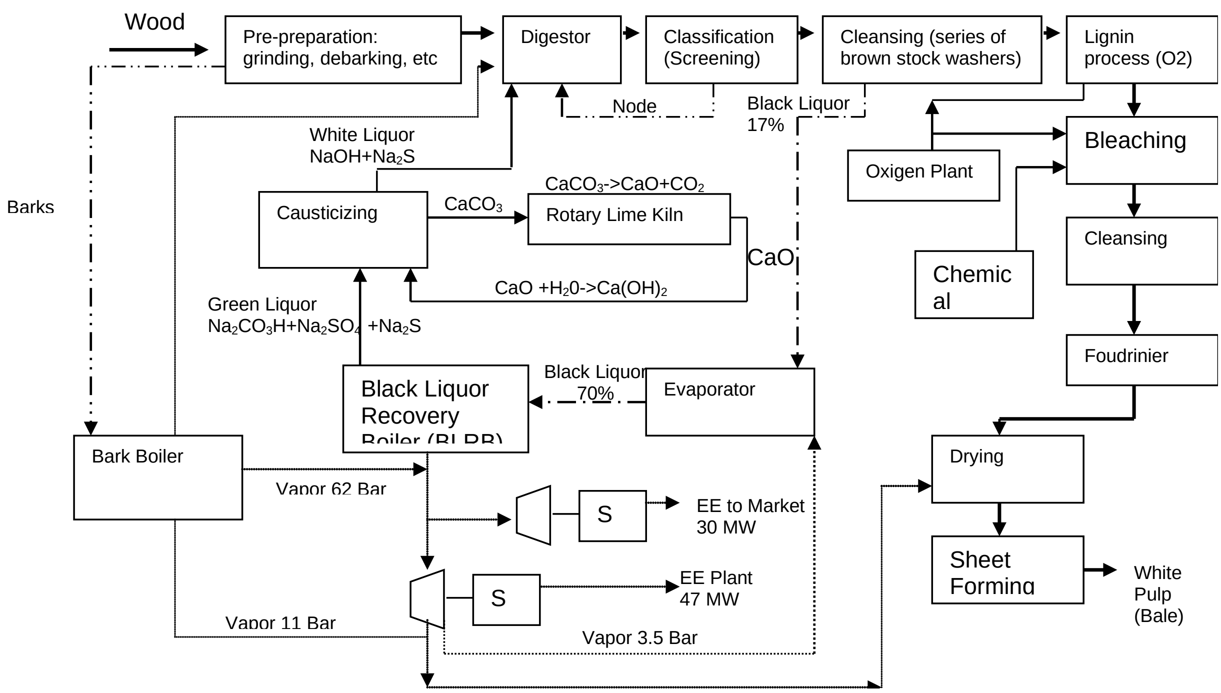
A Pulp and Paper Mill, Amelia Island, Florida

Operating temperatures, pressures, and time vary with the type of process, as summarized below:

Sulfate Process (Kraft Pulp process):

- The digester liquor is an alkaline process using a solution of sodium hydroxide and sodium sulfide, or *white liquor*, in the digesters.
- Large batch digesters (old fashioned) or continuous digesters (modern technology) are used.
- Continuous digesters may be horizontal and/or inclined, designed to move the chip charge through the digester by mechanical screws or bucket conveyors.
- Continuous digesters may be vertical allowing chip movement by gravity in downflow digesters or by a lifting mechanism in upflow digesters.
- Note: In the continuous downflow digester (most common), chips are conveyed from storage and blended when needed (hardwood and softwood chips). The chips are fed through a chip meter and are then discharged into a steaming vessel (at about 1bar (15 psi), preheating the chips and expelling air. Chips and cooking liquor are then fed into an impregnation zone at a temperature of 11°C (20°F) for approximately 20 minutes and then fed into the digester cooking zone. Cooking takes place at 170°C (340°F) for 90 to 120 minutes. Pressure is between 6.9 and 9.3bar (100 to 135psi). When the cooked chips reach the bottom zone of the digester, they are mixed with filtrate from the pulp washer for cooling and dilution purposes. Cooked chips are then cooled down at a temperature ranging from 120°-127°C (250° - 260°F) and forced by digester pressure through an adjustable orifice valve, through a blow line to a blow tank at atmospheric pressure.

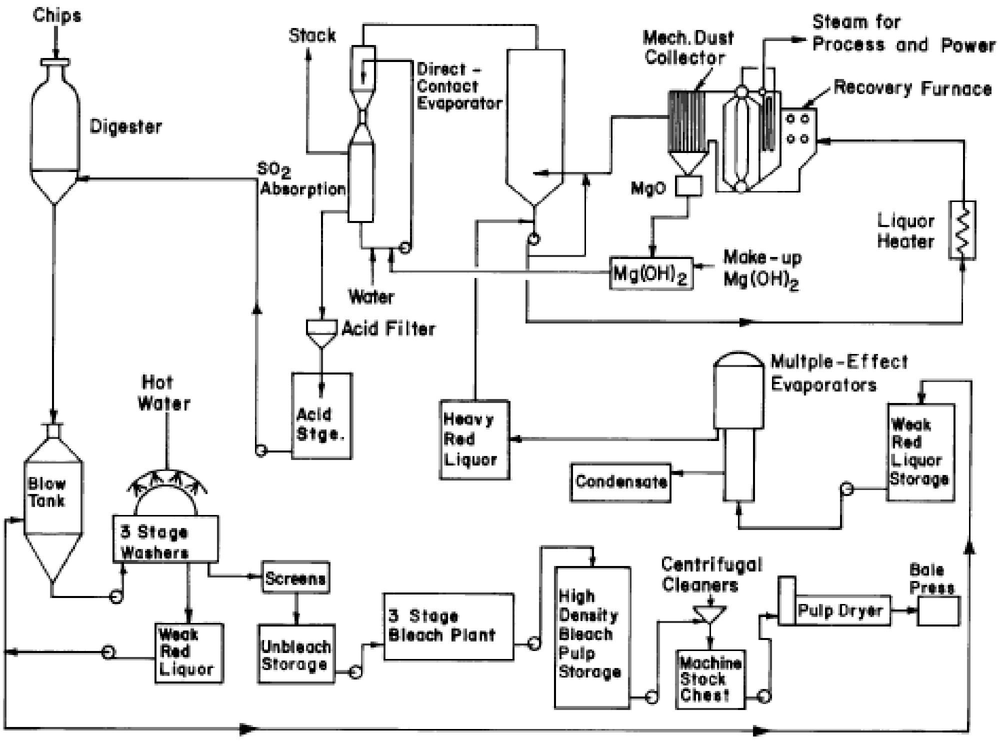
Typical Kraft Recovery Process Unit with liquor recovery and reuse.



- Recovery of the sulfate liquor (black liquor) from the digestion process involves the following steps: the black liquor is washed from the pulp with a solid content of 12 to 15% It is sent to multiple-effect evaporators and concentrated to a 45 to 50% soluble solid content first then to 62 to 65% solid content prior to being burned in a Black Liquor Recovery Boiler (BLRB) and converted to sodium carbonate and sodium sulfide, leaving the furnace as smelt. The generated steam is recovered to be used for the process and to run the Steam Turbine Generator (if any).

Acid Sulfite Process:

- This chemical process involves digesters made of cylindrical steel vessels internally lined with cement, crushed quartz, and acid-resisting brick, for corrosion resistance.
- The digester liquor is an aqueous solution containing calcium or magnesium bisulfite and an excess of sulfur dioxide. During the preparation of sulfite liquor, sulfur is burned to form sulfur dioxide, which is cooled and absorbed in a water spray tower where calcium or magnesium compounds are converted to bisulfite absorbing the excess sulfur dioxide.
- The digester is either heated with direct steam or through stainless-steel heat exchangers that circulate the cooking liquor to be heated before pumping it back to the digester (thus preventing dilution of the liquor by the steam condensate).
- “Cooking” consists of dissolving the lignin and binding components allowing the separation of cellulose fiber into pulp.
- “Cooking” conditions are adjusted in accordance with the type of wood and the composition of the cooking liquor.
- Pressure ranges from 4.8 to 15.7bar (70 to 160psi).
- Time and temperature vary from 6 to 12 hours and from 171° to 175°C (340° to 350°F).
- When “cooking” is achieved, the pulp is discharged into a blow tank and washed with fresh water.



FM Global Data Sheets 7-57: Pulp and Paper Mills Fig 2 Flowchart of magnesium sulfite acid pulping and magnesium oxide recovery.
Posted and reprinted with permission of FM Global.

- Recovery of the sulfite liquor (called weak red liquor) from the digestion process is done through evaporation resulting in heavy red liquor which is then burned in a boiler to produce magnesium oxide and sulfur dioxide. Note: there is no smelt bed for the red liquor boiler compared to the black liquor boiler. The magnesium oxide is carried through the boiler exhaust and recovered through a collection system. It is then slaked to magnesium hydroxide and mixed with regained and make-up sulfur dioxide to produce fresh bisulfite liquor. Other byproducts may include lignin, vanillin, tanning material, road binders, special cements, core binders, plastics, yeast.

Semichemical or NSSC (neutral sulfite semichemical) Pulping:

- This process uses smaller chips and more hardwoods than the chemical processes.
- This process involves both chemical digestion (stainless steel material required) and mechanical grinding to produce the pulp.
- The chips are mechanically disintegrated and converted into pulp by disk refiners. This mechanical treatment completes separation of the wood fibers into pulp.
- The cooking liquor is sodium sulfite buffered with sodium carbonate.
- Digestion takes place at 6.9-15.7bar (100 to 160psi).
- Time and temperatures range from 160° to 182°C (320° to 360°F) for 12 to 48 minutes.
- The pulp is then washed, as in the acid sulfite and sulfate processes, in order to separate it from the cooking liquor.
- The pulp then passes over screens to separate it from larger undigested particles.
- Metal is removed and knots and undigested fibers are usually returned for another pass through the digester.
- The semichemical liquor from the digestion process is recovered in Black Liquor Recovery Boilers. This process is similar to the sulfate process above.

Note:

- The alkaline sulfate (kraft process) accounts for about 70%, the acid sulfite 5%, semichemical 10%, groundwood 10%, and the remainder is miscellaneous.
- There is a wide range of chemical pulp such as Fluff Pulp (also called comminution pulp or fluffy pulp): a type of chemical pulp made from long fiber softwoods. More than 90% of the fluff pulps are fully bleached chemical softwood pulps, of which more than 90% are kraft pulps. Important parameters for fluff pulp are bulk and water absorbency (see Section 9: “Paper Working – Conversion of Tissue Paper”).

7.2.4 Bleaching

- Dyes are formed from the tannin in the wood during the digestion process.
- The purpose of bleaching is to improve pulp brightness, cleanliness and chemical purity.
- The bleaching agents oxidize and destroy the dyes. They also dissolve and remove the remaining lignin in the pulp, leaving pure cellulose fibers.
- Bleaching wood pulp is an extension of the pulping process. In the thermomechanical pulping process, bleaching is done after screening. In the chemical pulping process bleaching occurs after digestion.
- Bleaching involves multi-stage processing and reactions between chemicals and fiber components. Because each user has specific needs, a variety of bleaching processes and sequences have been developed.
- The bleaching process may represent a major production bottleneck at a papermill.

7.2.5 Pulp Drying

Most market pulp is dried to about 10% moisture, but pulp that will only travel a short distance might be dried to about 50% moisture. The higher moisture pulp is known as "wetlap."

Pulp is produced on several types of machines called pulp dryers or Fourdrinier machines: these are devices for producing paper, paperboard, and other fiberboards, consisting of a moving endless belt of wire or plastic screen that receives a mixture of pulp and water and allows excess water to drain off, forming a continuous sheet for further drying by suction, pressure, and heat. Calenders (rollers or plates) smooth the paper or board and impart gloss or another desired finish to the surface. The first machine to produce a continuous web (roll), the Fourdrinier machine, was invented in France in 1799 by Louis Robert and was subsequently improved in England, where it was patented by Henry and Sealy Fourdrinier.

Pulp drying machines are similar to paper machines and typically include the following processes: forming thick pulp web, pressing, drying.

Pulp dryers basically consist of an assembly of shells, heads, suction rolls, pressure rolls, heated press rolls, shafts, and head bolts. Dryers typically have internal balance weights, siphons (a device to remove condensate from the dryer) and may have spoiler bars (a system for improving heat transfer by inducing turbulence in the condensate).

Pulp dryers may also be summarized as follows:

- Wet end: the section that receives the mixture of pulp and water
- Drying section: the main drying body including multi-stage drying sections
- Dry end: the end side where the continuous pulp web is visible

There are basically two main types of dryers:

- Airborne Pulp dryers (sheet drying process): an airborne dryer is a large, enclosed structure. The pulp web enters the top of the enclosure and makes several horizontal passes around unheated rolls. Fans force air through blow boxes and onto the pulp web. The air removes water and carries it away from the pulp web. These dryers remove water from the pulp leaving the pulp machine, reducing the water content from 40% to 10 to 18%. Their steam consumption is high. (Note: blow boxes are air headers that direct air onto the pulp sheet. The pulp web travels between upper and lower blow boxes. The lower boxes blow air to help hold the sheet above the box).
- Flash Dryers: for Mechanical Pulp, flash drying is the main method of producing dried pulp in high-capacity plants. The pulp web for these fibers is not strong enough for a sheet-drying process. For Chemical Pulp, flash drying is typically used in integrated mills where the excess pulp is dried and sold as market pulp. In general, the investment costs for flash-drying systems are much lower than for a sheet-drying plant. The pulp suspension is first dewatered to a dryness of up to approximately 50%. The pulp is then fluffed into small pieces and dropped into the flash dryer where it is pneumatically transported by hot air while being dried. The flash dryer has up to three drying stages.

7.2.6 Pulp Rolls / Bale Making

Some pulp mills are not integrated with papermaking operations, so they produce market pulp and sell it to papermaking facilities.

Market pulp is dried, and the web is then either:

- wrapped into kraft paper and/or rolls provided with a circumference steel / plastic strap [3/9in. (9.5mm) or wider] at each end.
- cut lengthwise by slitters. A rotary cutter then cuts the sheet widthwise before stacking it into bales. Two larger sheets of pulp are folded around the stack of cut pulp sheets and secured with either wires or straps.

Courtesy of ARAUCO Chile. Dry End – Cutting & Balls Composer Area

Courtesy of ARAUCO Chile. Ball Press Area

7.2.7 Pulp Rolls / Bale Warehousing

Pulp rolls and bales are usually stored in a warehouse adjacent to the roll-making area just after the dry end.

Trains and/or trucks may enter this building for loading and transportation to the nearest paper processing / working / other cellulose-based products processing facilities and/or to the harbor for export.

7.3 SPECIAL HAZARDS & RISK CONTROL

Special hazards, prevention, protection, and potential mitigation measures are detailed below for each and every special hazard related to this occupancy. (This follows the process flow from Raw Materials to Finished Products as closely as possible). Related recommendations are also mentioned. (See. “Rec” Section 11: “Support for Loss Prevention Recommendations” for details).

7.3.1 All Facilities

- Flood exposure: Wood Processing and Pulp & Paper industries are usually located near rivers due to the water consumption (process, cooling, domestic use, utilities and firefighting) and for logistic purposes (historically used for the import of Raw Materials/ export of Finished Products).
- Wildland fire exposure due to the proximity of forest.
- Earthquake potential (seismic areas) and Tsunami (coastal areas).
- Windstorm and storm surge potential (coastal areas).
- Combustible construction material (e.g., process buildings) & combustible content.
- LPG tanks (for vehicles, process, domestic use).
- High Machinery Breakdown potential.
- Industrial (Process) Control Systems with a relatively high level of automation including centralized process control. Manual control is reportedly possible for a relatively short period, but the process efficiency and quality of products may be reduced. Moreover, the Pulp Mill may not be able to produce the full range of products.
- Critical and very expensive spares are usually stored in one or more warehouses. Heavy spares and consumables are usually well separated. The inventory can represent several Million USD (e.g., $20-40-60-80MM and more). These spares are critical to the process and can have a relatively long lead time. Some consumables used in relatively large quantities and/or having a long lead time are also deemed as critical. A major loss in such a warehouse could lead to BI for the related units due to lack of spares.

Courtesy of ARAUCO Chile. Spare Parts Warehouse

Prevention & Protection:

- Flood potential should be carefully investigated. All facilities including critical utilities such as effluent treatment plants should preferably be located outside the flood-exposed area. Adequate physical flood protection should be provided when needed.
- See Section 11: “Wildland Fire Exposure Mitigation”.
- Buildings and structural frames should incorporate an earthquake design allowing to sustain the exposure in the area. Facilities should preferably be built outside tsunami-exposed areas (i.e., distance to seashore, sufficient altitude of terrain above medium sea level).
- Buildings and structural frames should incorporate a wind design allowing to sustain the exposure in the area. Facilities should preferably be built outside storm surge exposed areas (i.e., distance to seashore, sufficient altitude of terrain above medium sea level).
- Prefer noncombustible construction avoiding wood and composite panels with combustible insulation (e.g., PUR, PIR, EPS, XPS).
- All LPG bullet tanks, loading / unloading stations and vaporizers should be protected as per the minimum requirements of FM Global Data Sheets 7-55: “Liquefied Petroleum Gas (LPG) Storage Tanks and Unloading Stations”. (See Section 11: “Support for Loss Prevention Recommendations”).
- Adequate maintenance and inspection programs should be established and strictly enforced including the use of modern Non-Destructive Technics (e.g., Thickness Gauging, Infra-Red Scanning, etc.). This should be part of the Mechanical Integrity (MI) / Electric Integrity (EI) program and Asset Management Strategy (e.g., spare parts / obsolescence management).
- An adequate Management of Change (MOC) procedure should be strictly enforced.
- An adequate online monitoring system of key parameters (e.g., vibration, temperature, pressure, etc.) should be provided and report to a constantly attended location including alarm levels, high-high alarms and trip systems.
- Industrial (Process) Control Systems should be provided with an Uninterruptible Power Supply (i.e., batteries backed up with Emergency Diesen Engine-Driven Generators) with sufficient capacity allowing for the safe shut down of key process and utility equipment. The Emergency Shutdown (mushroom button on the control panel of the control room) should be independent from the normal operating system and preferably hardwired. An adequate by-pass procedure should be established. Updated (controlled document) hard copies of Standard Operating Procedure (SOP), Emergency Operating Procedure (EOP) manuals and Piping and Instrument Diagrams (P&IDs) should be available in the control room. Adequate back-up servers should be provided and installed in different fire areas. When installed in the same fire area, adequate and approved fixed-fire protection should be provided. (See Section 11).

Courtesy of ARAUCO Chile.

- Critical spares should be clearly identified. The commodity class should be clearly established as per NFPA and the warehouse should be provided with adequate and approved automatic fire detection / protection. (See Section 11). Flammable and combustible liquids and spray cans should not be stored in such warehouses but rather stored in a dedicated safe area fitted with the necessary ventilation, leak detection & containment measures. Hazmat and compressed gases should be stored and protected. (See Section 11). Large drivers should be adequately stored. (See Section 11).

Courtesy of ARAUCO Chile - Hazmat Warehouse

7.3.2 Raw Material Preparation & Handling

- Buffer storage of Timber (wood logs)
- Wood waste may accumulate under equipment. Large quantities of combustible residue may be present around debarkers and chippers
- Large wood chip and fine storage silos and/or bins

- Rubber belt conveyors

- Hydraulic oil groups: sprayed oil fires are very difficult to control. Moreover, in the case of a fire, some of the oil groups would expose equipment installed above (e.g., wooden mezzanines, cable trays, etc.)

- Air compressors
- Electrical equipment (i.e., transformers, electric rooms, cables)

Prevention & Protection:

- See Section 11: "Wood Log Storage & Fire Protection".
- Establish adequate housekeeping routines and auditing activities.
- Large wood chip and fine storage silos or bins should be protected according to Data Sheet 8-27 "Storage of Wood Chips". (See Section 11: "Support for Loss Prevention Recommendations"). Automatic water spray protection (deluge) is an acceptable alternative to automatic sprinklers. This is even preferred if there is a dust explosion potential. Small bins (such as truck dump bins) do not need internal protection as their contents can be quickly dumped.
- Adequate control of ignition sources is required, such as Hot Work Permits, a strictly enforced non-smoking policy, spark arresters, engines, vehicles, lubrication of conveyor moving parts, preventing friction between belts and moving parts. Provide adequate and reliable fixed automatic fire protection above the conveyor. (Sparks from conveyors, sparks from passing vehicles, cutting and welding operations, and smoking are the most common causes of fires). Lighting fixtures should comply with requirement recommendations. (See Section 11).
- Magnetic separators should be installed inside belt conveyors.
- Rubber belt conveyors should be protected. (See Section 11).
- Hydraulic groups should be protected. (See Section 11).
- Air compressors should be protected. (See Section 11).
- Electrical equipment (i.e., transformers, electric rooms, cable trays and cable openings) should be protected. (See Section 11). This also includes control rooms (e.g., cables in false floors, server rooms / back rooms, battery rooms).

7.3.3 Thermomechanical Pulping

Refining & Screening

- Each electric driver of the refining and screening process step is a very expensive piece of equipment (from 1 to USD5MM) and may have a relatively long lead time.

Prevention & Protection:

- Refining / screening electric drivers should be equiped with a safety device in case of electrical failure and overheating. Moreover, in the case of an uncontrolled fire, these drivers would be unprotected. As a result, local automatic fire protection should be installed within the enclosure of the refiner's electrical drivers. This should be investigated with the manufacturer. Spare drivers should also be available

7.3.4 Chemical Pulping

Digesters

- Digester High-Pressure Vessels (over- pressurization and rupture potential): high-pressure vessels in the digestion area have the maximum energy release potential. This includes the digesters, heaters, flash tanks and blow off tanks. Digesters can operate at 170-180°C and between 1 to 15bar, with high-pressure steam used for heating. The main risk is a rupture of vessel leading to the release of a blast wave destroying equipment. (See Loss Estimates Section).
- Note: high pressure is usually defined as exceeding 1bar / 15psi
- Caustic chemical mixture is used in the digestion process (highly corrosive)

- Potential sedimentation of solid material inside tanks and piping may occur

Digester area

Courtesy of ARAUCO Chile. Digesters & Impregnators Pine Line & Eucalyptus Line

<u>Prevention & Protection</u>:

- All equipment should be made of adequate material (i.e., corrosion potential) and of an adequate thickness (pressurization).

- Adequate maintenance and inspection programs must be carried out, including (but not limited to) corrosion monitoring of piping, pressurized vessel inspection and testing (at least once every 5 years).
- Positive Metal Identification of material entering the site, prior to warehousing and installation in the field, should be systematically performed, especially for special alloys on pressurized equipment, in order to ensure that proper material is used (i.e., steel, alloys). This should be part of a Positive Metal Identification procedure that should be established and strictly enforced for all the prezzurized material made of special alloys. Some plants may rely on a certificate from the manufacturer. Materials made of wrong alloys and installed on pressurized equipment have been responsible for numerous losses within the industry, despite the certificate. The above-recommended test can be of the non-destructive type – nuclear testing – using hand-held equipment or using destructive tests on samples.
- Adequate levels of equipment redundancy should be provided. Banks of equipment (if any), working in series in this continuous process, are designed in such a way that any unit within a bank can be isolated and bypassed at any time without seriously affecting the continuous process. Adequate remotely-operated valves should be provided for the isolation of main vessels (i.e., of a fail-safe type when motorized and electrically operated). These isolation systems should be regularly tested up to the last element (i.e., the valve during the Turn Around and Inspection Period).
- All electric pumps and agitators maintaining solid material in a liquid phase (preventing sedimentation) should be powered by an Uninterruptible Power Supply in case of failure of the main supply (i.e., Diesel Engine-Driven Generators starting up on an Automatic Transfer Switch operation).
- Adequate inbuilt safety is required. This includes (but is not limited to) an adequate depressurization system (Pressure Safety Valves - PSV), safety interlocks for steam injection and Raw Material feed. Key parameters should be clearly indicated in a comprehensive way in the control room (i.e., PSVs – see note below).
- Adequate containment should be provided, consisting of adequate primary (single-walled, double-walled when needed), secondary (curb, dike retention under vessels and tanks) and tertiary retention (draining network connected to an emergency basin), in case part of the process needs to be drained off.

Notes on PSVs:

- Multiple PSVs for the same pressurized equipment inside the process area tend to chatter, losing efficiency and disturbing the proper working conditions of the valves. As a result, single valves in service are often preferred within the process area (the other PSVs are used as backup).
- PSVs welded directly onto pressurized equipment are the most reliable, ensuring a constantly operating depressurization system. However, if maintenance is needed, the process unit should be shut down and depressurized.
- Block valves should be installed between the pressurized equipment and the PSVs, in case a PSV needs to be isolated for replacement or maintenance.
- In some cases, at least two PSVs and their block valves are installed so that one valve is operating (block valve left open) and one valve is on standby (one valve left closed). In order to prevent both valves being closed (worst case), an interlock system can be used in order to ensure that one PSV is constantly operating. Without an interlock system, all block valves should be locked or sealed (car seal, plastic strip wise, etc.) in their normal operating position, and regular (weekly) inspections should be conducted in order to detect any deviations (especially after maintenance / inspection operations).
- In terms of testing, all PSVs should be regularly tested (at least once a year for every T&I, and at least every 3 years as per API) as follows: the PSV should be uninstalled from the protected pressurized equipment, the PSV should be tested on an approved calibrated test bench (i.e., pre-pop test allowing to detect any existing deviation before dismantling and conducting further investigations), dismantled and maintained, including all necessary

replacements of damaged equipment and consumables (seals, springs, etc.), before being re-tested again on the bench (pre-pop test). Rated-operating pressure and current-operating pressure should be recorded. Significant deviations should be investigated (clogging, metal premature failure, etc.). Note that in some areas, such as in some countries in Asia, only a functional test is conducted.

- New PSVs should be pre-pop tested on an approved calibrated test bench prior to being installed in the field. The plant should not rely on certificates alone. This is usually done as part of the New Equipment Commissioning Testing procedure instead.
- PSVs to be (re-)installed on process equipment should be transported and lifted in their normal operating position (vertical). Any mechanical stress (impact) should be reported, and the PSV should be checked, and pre-pop tested again prior to installation.
- PSVs should have a name plate with the registration number, rated working pressure and inspection date (to facilitate the field inspections).

Black Liquor Recovery Boiler (BLRB)

- Black liquor tanks (together with other tanks).
- In general, the operating experience for chemical recovery boilers is very similar to larger water tube boilers for all hazards except for smelt-water explosions. A BLRB can be a very big structure of 3,000 tons or more, suspended on heavy beams, and reaching up to 8-10 floors (equivalent) in height.
- Overpressure potential: In a BLRB, a tube leak can be devastating. Molten smelt has a temperature of approximately 1,000°C (1,830°F). Water from a tube leak can accumulate on the molten smelt. A disturbance or trigger, such as an ash fall from the upper furnace, initiates the smelt-water explosion. The accumulated water can be vaporized in one-tenth or two-tenths of a second. This rapid generation of steam greatly exceeds the rate at which gases can be removed from the furnace, and the pressure quickly exceeds the design pressure of the boiler enclosure. This is a physical explosion (a rapid change of state from liquid water to steam, with the accompanying change in volume. The volume change may be to the order of 1,600 times.
- Steam Explosion (rupture of water tube leading to water trapped in the smelt bed (sulfate, acid sulfide processes).
- Overheating (due to low feed water).

Pulp Batch vessel - BLRB Line

BLRB, Power Boiler and Electrostatic Precipitator Area

Courtesy of ARAUCO Chile

BLRB

- Electrostatic Precipitator explosion hazard.
- Oil-filled transformer at the top of an Electrostatic Precipitator (difficult access)

Courtesy of ARAUCO Chile. Oil-Filled Transformer above the Electrostatic Precipitator

Prevention & Protection:

- Black liquor tanks (and other tanks) should be provided with adequate containment. Fuel oil tanks should be protected. (See Section 11: “Ignitable Liquid Storage Tanks”).

Courtesy of ARAUCO Chile. Fuel Oil Tank – Black Liquor Tanks

- All equipment for the BLRB should be made of adequate material (i.e., corrosion potential) and of an adequate thickness (pressurization). (See “Digester” above for Positive Metal Indentification).
- Adequate Maintenance and Inspection programs should be established (i.e., similar to boilers, including but not limited to, thickness gauging of tubes, radiography of welds, etc.)
- There should be adequate safety combustion controls for the Methane / Bunker fuel / Diesel line (purge, flame supervision, trip system).
- An online monitoring of the Liquor Feeder concentration (Refractometer).
- Fast Emergency drainage (testing: once a month up to the final element (i.e., a remotely operated valve, with the upstream block valve closed) used during the Emergency Shutdown.
- An adequate ESD procedure should be established: tube leaks in large industrial water tube boilers are a relatively common occurrence. In a typical industrial boiler, a tube leak is generally an inconvenience requiring an unplanned shutdown of one or two days to repair the tube. But, in a black liquor recovery boiler (BLRB), a tube leak that permits water to enter the furnace results in the need to perform an emergency shutdown, attempting to prevent water from contacting the molten smelt, by draining the water from the boiler and releasing the steam energy in an expedient manner. A successful emergency shutdown may permit repairs and restarting of the BLRB in a few days. If the emergency shutdown is not successful, water mixes with the molten smelt, resulting in a smelt-water explosion. Repairing smelt-water explosion damage may take up to six months minimum or even more (i.e., 18 months).
- An adequate depressurization system should be provided (i.e., Pressure Safety valves – welded - no block valves). This must be regularly and adequately inspected and maintained. (See “Digester” above for depressurization systems including PSVs).
- Water flow and temperature sensors, as well as online monitoring and trip systems, should be provided.

- Low water alarms and trip sytems should be provided.
- Electrostatic Precipitator: once a fire is detected, the unit should go into emergency shutdown immediately. It should be recognized that during operations, the atmosphere in the precipitator is oxygen-deficient and opening doors or running system fans following a fuel trip could cause conditions to worsen (increased potential for backdraft explosion). Once the flow of air and fuel to the fire has been stopped and the electrostatic precipitator has been shut down and deenergized, the precipitator doors may be opened again and water hoses deployed, if necessary. (See NFPA850).
- Oil-filled transformers (including the Electrostatic Precipitator's transformer) should be protected. (See Section 11).
- Electrical rooms and cable openings should be protected. (See Section 11).

Note: the above recommended safety devices are considered as a minimum requirement. Please refer to FM Global Data Sheets 6-21: "Chemical Recovery Boilers" for more details and additional safeguards.

Rotary Lime Kilns

- Explosion potential due to incomplete combustion gases accumulated inside the kiln.
- Lubrication of bearings.
- Machinery breakdown (e.g., drivers, gear box pinions, ring fan rotors, ring gear segments) followed by fire and explosions, overheating and refractory collapse.

Lime Kiln Area

Rotary Kiln Area

Courtesy of ARAUCO Chile

Prevention & Protection:

- Adequate safety combustion controls should be provided.(See Section 11: "Fuel Line Safety Combustion Control").
- Centralized lubrication systems (if any) should be protected. (See Section 11).
- Electrostatic Precipitator: once a fire is detected, the unit should go into emergency shutdown immediately. It should be recognized that during operations, the atmosphere in the precipitator is oxygen-deficient and opening doors or running system fans following a fuel trip could cause conditions to worsen (increased potential for backdraft explosion). Once the flow of air and fuel to the fire has been stopped and the electrostatic precipitator has been shut down and deenergized, the precipitator doors may be opened again and water hoses deployed, if necessary. (See NFPA850).
- Oil-filled transformers (including the Electrostatic Precipitator's transformer) should be protected. (See Section 11).
- Electrical rooms and cable openings should be protected. (See Section 11).

Note: the above recommended safety devices are considered as a minimum requirement. Please refer to FM Global Data Sheets 6-17: "Rotary Kilns and Dryers" for more details and additional safeguards.

7.3.5 Bleaching

- One famous bleaching process involves the use of chlorine. This process typically involves a series of steps (i.e., kraft pulp process: chlorine treatment, extraction by sodium hydroxide, treatment with calcium/sodium hypochlorite, treatment with chlorine dioxide). An interruption of chlorine dioxide generation may severely impact paper production.
- Modern bleaching processes involve the following stages: hydrogen peroxide (P Stage) and oxygen (O Stage).
- Many hazards and exposures exist with these various processes and chemicals:
  - Chlorine Dioxide: an explosively unstable material, therefore not shipped or stored but generated at the plant and used immediately. Chlorine dioxide decomposition is an exothermic reaction: $2ClO_2 = Cl_2 + 2O_2$ (the auto-decomposition temperature reportedly varies with the concentration of chlorine dioxide from 85°C [185°F] to 135°C [275°F]). This is not a vapor-air explosion (there is no explosive range).
  - Sodium Chlorate: this is an intermediate product in the chlorine dioxide production process and may be manufactured on site. Sodium chlorate ($NaClO_3$) is a strong oxidizer. When dry or in concentrated-liquor form, this material can cause ignition and severe fires when in contact with organic materials. Normally, sodium chlorate is kept in a water solution and the hazard is reduced. Sodium chlorate becomes a concern only if spills are not promptly washed down and allowed to dry.
  - The chlorine process may also include on-site production of acid by burning hydrogen gas in the presence of chlorine gas.
  - Methanol may be used in some processes (i.e., Solvay ERCO).
  - Oxygen: oxygen gas produced on site (see Section on "Air Separation Unit in Critical Utilities") is used in the chlorine process.
  - Organic Peroxides are reactive and thermally unstable materials with an intrinsic fire hazard. Some peroxide formulations may also present an explosive decomposition or deflagration hazard. Most organic peroxides burn vigorously and once ignited, are difficult to control or extinguish.
  - Hydrogen Peroxide: an odorless, colorless, inorganic liquid, strong oxidizing agent, nonflammable, but supports combustion and can readily start fires when in contact with combustible materials such as wood, leather, cotton, and paper. It is completely miscible in water. The commonly used concentrations of 35% and 50% by weight are commercially available. The very dilute concentrations of hydrogen peroxide used in most plant processes do not present serious fire or explosion-protection problems. A continuous decomposition of hydrogen peroxide to water and oxygen gas naturally occurs under normal storage conditions (less than 1% per year at 27°C (80°F). Contamination with metals (i.e., iron, manganese, copper, chromium, nickel and zinc), alkalis, organic substances and other impurities such as certain dusts, can cause a rapid and dangerous decomposition with a drastic rise in temperature and pressure, releasing large amounts of water vapor and oxygen gas.
  - Other chemicals: represent toxic or corrosive exposures only.
- In larger bleach plants, extensive fiberglass-reinforced plastic (FRP) duct systems may exist (highly corrosive environment) in all components of the bleaching sequence.

<u>Prevention & Protection</u>:

- Provide adequate process controls and interlocks (i.e., shutdown of feed lines, diverting of air flow) in order to avoid excessive temperatures and/or chlorine dioxide concentrations, as summarized below:

- Atmospheric Reactor:
  - Low reactor air flow
  - High chlorine dioxide concentration downstream of the reactor (usually determined by analysis of liquid leaving the absorption column)
  - High reactor temperature (above 65°C [150°F]).
- Low Pressure Reactor (#0.5bar [8psi])
  - Low reactor air flow
  - High reactor pressure (caused by loss of vacuum)
  - High reactor temperature
  - High chlorine dioxide concentration downstream of the reactor
  - High gas temperature downstream of the reactor

- Provide a reliable means of isolation for feed lines, vessels and reactors (i.e., remote operated valves and accessible manual valves).
- Provide a reliable alternate power supply in case of a power failure that may disrupt air flow to the reactor.
- Provide emergency relief venting for chlorine dioxide reactors, vessels that may contain gaseous chlorine dioxide (such as dump tanks), and for atmospheric storage tanks. Overpressure relief in the event of chlorine dioxide decomposition is only practical in providing venting for decompositions involving approximately 15% chlorine dioxide concentrations in the air. Decompositions involving larger chlorine dioxide concentrations proceed too rapidly to vent. The vent size is determined by the concentration and temperature of the chlorine dioxide, and the size of the storage tank. The vent design should be based on the most severe credible temperature and concentration of the chlorine dioxide solution.
- On-site production of acid by burning hydrogen gas: the primary concern here is the safe handling of hydrogen, which is accomplished by using recognized fuel-burner-combustion safety controls.
- Automatic sprinkler protection should be provided at the ceiling of buildings of combustible construction (i.e., buildings containing significant amounts of glass fiber-reinforced plastic equipment or construction) in accordance with Data Sheet 1-57: “Plastics in Construction”.
- Provide internal and external sprinklers in ducts of high value, high importance to production or of an unusually large size, in accordance with Data Sheet 7-78: “Industrial Exhaust Systems”.
- Provide protection for methanol storage and piping, as per Data Sheet 7-32:” Ignitable Liquid Operations”, and Data Sheet 7-88: “Ignitable Liquid Storage Tanks”.
- Organic Peroxide should be stored in a detached building made of noncombustible construction material. Minimum seprating distances are related to the quantity of peroxide stored. (See FM Global Data Sheets 7-80: “Organic Peroxides and Oxidizing Materials”). Provide automatic sprinkler and manual firefighting respectively, in accordance with Table 2 and Table 3 of FM Global Data Sheets 7-80: “Organic Peroxides and Oxidizing Materials”.
- Hydrogen Peroxide: prefer stabilized commercial formulations to keep a low decomposition rate. Provide appropriate vents to relieve the oxygen pressure generated during normal decomposition. Avoid contamination with metals, alkalis, organic substances and other impurities. Provide tanks with temperature-constant on-line monitoring in order to detect early decompositions. The number of tank temperature sensors depends on the size of vessels. (See FM Global Data Sheets 7-80: “Organic Peroxides and Oxidizing Materials 7-80”).
- Provide adequate ignition source control (e.g., work permits, non smoking policy, intrinsically safe electrics).

Courtesy of ARAUCO Chile. Pulp Press Area

7.3.6 Pulp Drying

- Dryers and paper machines are expensive, complex units essential to plant production. The dryer ends of paper machines combine the fire hazards of a highly combustible product: lint deposits, oily residues, and paper scraps in the presence of such ignition sources as overheated bearings, dryer flames, mechanical sparks, friction, and electrical equipment.
- Dryer-heated rolls may be steam-heated or HTM (Heat Transfer Fluid)-heated (thermo-rolls).

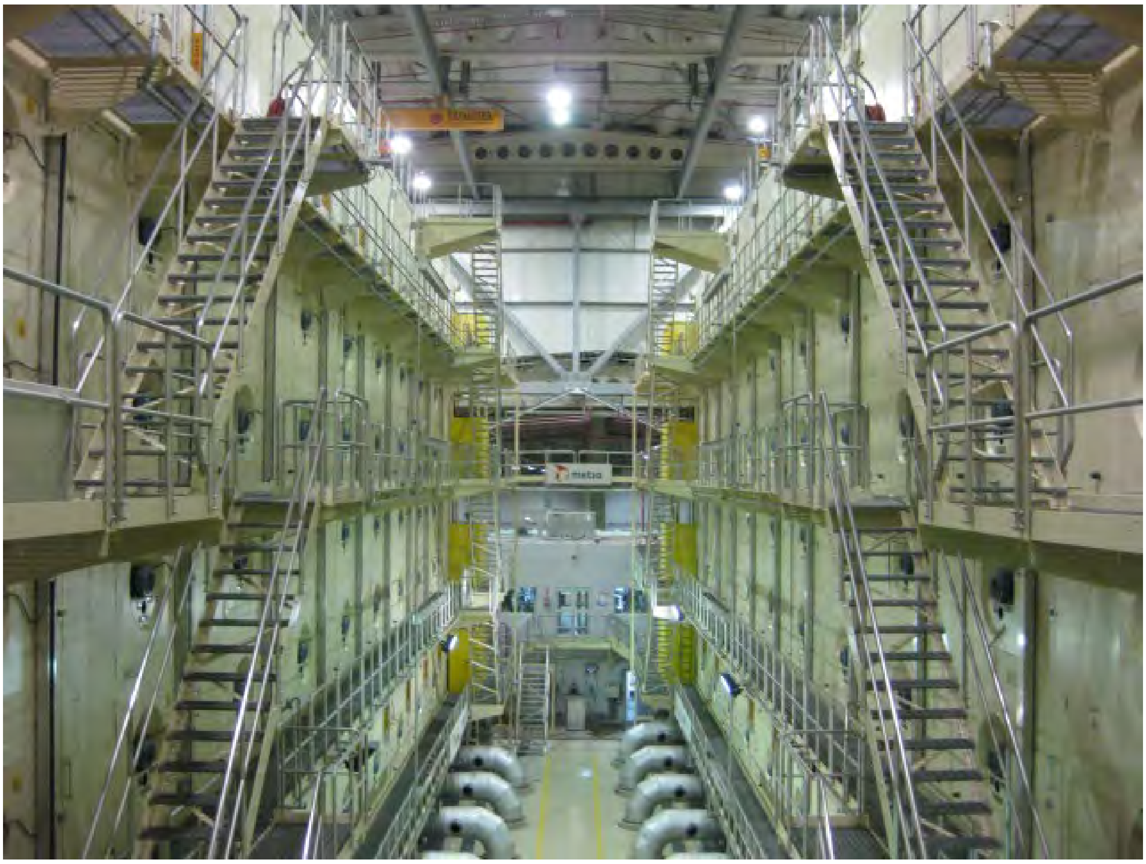
Dryer

- Gas or oil-fired heaters on the machine (if any).
- Machinery breakdown potential.
- Overhead Cranes.

<u>Prevention & Protection</u>:

- Dryers and pulp dryer areas should be protected. (See Section 11: "Paper Machines and Pulp Dryers").
- For HTF-heated rolls (thermo-rolls), provide a system to contain leakage from rotary joints, sight glasses, and flexible hoses for flammable oil systems, or a positive means to automatically stop oil flow upon failure of a rotary joint, flexible hose, or sight glass.
- HTM (Heat Transfer Fluid)-heated (thermo-rolls) should be protected as per FM Global Data Sheets 7-4: "Paper Machines and Pulp Dryers" (Section 2.1.4.8) and operated and maintained as per FM Global Data Sheets 7-4: (Section 2.1.6.20).
- HTM systems (Heat Transfer Fluid) should be protected. (See Section 11).
- Fuel combustion controls should be provided for any gas or oil-fired heaters on the machine. (See Section 11).
- Adequate and well maintained (and duplicated) lifting equipment (i.e., rolling cranes) should be provided within the dryer hall allowing for heavy load handling during maintenance operations. (See Section 11 for prevention and protection).

Courtesy of ARAUCO Chile. Wet Ends of Dryer line 1 & line 2



Courtesy of ARAUCO Chile. Dry Ends of Dryer line 1 & line 2

7.3.7 Turpentine Recovery

- Many pulp and paper mills using the sulfate process for cooking or digesting wood chips have turpentine recovery systems as part of their air pollution control systems.
- Turpentine is the volatile hydrocarbon portion of the oleoresinous material that is contained within and flows from coniferous trees, primarily pine trees.
- Turpentine is a hydrocarbon mixture, ignitable liquid (flashpoint of 35°C [95°F]). An equipment explosion hazard could be present. However, the primary hazard of turpentine recovery systems is the fire hazard associated with the accidental release of turpentine or other related ignitable liquids.
- Turpentine recovery systems, except for the turpentine storage tank, are frequently located in open grated multilevel buildings using gravity flow, presenting a three-dimensional spill fire hazard.
- In a typical kraft or sulfate pulp mill, the relief gases and escaped steam are passed to a condenser from the digesters. The non-condensable gases are usually passed to an incinerator, kiln or boiler where they are burned. The condensate containing approximately 1% by weight turpentine, flows to a decanter, where crude turpentine separates as an upper layer (overflow). The underflow, mainly water and approximately 1% by weight methanol and a limited amount of turpentine, is piped to a condensate storage tank (or underflow tank). From there it may be pumped to a steam stripping column or disposal area. In the stripping column, methanol is separated as a vapor and passed on to an incinerator, kiln or boiler for burning.

<u>Prevention & Protection</u>:

- Adequate process controls and interlocks (e.g., low waterflow alarm for turpentine recovery system condensers or a high temperature alarm on the condensate line to minimize the probability of introducing steam into the decanter) and means of isolation of vessels and feed lines should be provided.

- Turpentine Recovery Systems should be sprinkler protected. Requirements are available in Table 1 “Sprinkler Protection Requirements for Indoor Turpentine Recovery Systems” of FM Global Data Sheets 7-103: “Turpentine Recovery in Pulp and Paper Mills”.
- Provide adequate ignition source controls (e.g., work permits, non smoking policy, intrinsically safe electrics).

7.3.8 Pulp Rolls / Bale Making & Warehousing

- Pulp Roll / Bale making machinery is usually located either at the dry-end side of the dryer, or within the Finished Product warehouse which is usually adjacent to the dry end, and provided with a fire partition (i.e., 2-hour fire-rated wall, or less and fire doors). In such a configuration, the dryers, Roll / Bale making machinery and the warehouse are mutually exposed, resulting in a continuity of combustible for an internal fire.
- So-called “seasonal” or “temporary tents” made of combustible tarpaulin or canvas on a light metal frame may be installed close to processing or storage buildings.
- Equipment may be electrically driven and/or provided with large a hydraulic group (i.e., press, packaging equipment).
- Lighting fixtures consisting of Metal Halide HID bulbs without adequate cover may constitute a source of ignition.
- LPG, diesel-driven and electric-driven lift trucks are used to carry the semi-finished and finished products.
- Trains and trucks may enter the warehouse.

<u>Prevention & Protection</u>:

- Provide adequate and reliable sprinkler protection for both the Pulp Roll / Bale making machinery and handling areas and warehouses, including canopies, if any. (See Section 11: “Warehouses”).
- So-called “seasonal” of “temporary tents” made of combustible tarpaulin or canvas on a light metal frame should be replaced with sprinkler-protected permanent structures, or should be located in areas not exposing processing or storage buildings (at least 40m separating distance or more depending on building heights).
- A radius of 1.5m free of combustible should be maintained around electric-driven material.
- Hydraulic groups should be protected. (See Section 11).
- Provide adequate lighting fixtures. (See Section 11).
- LPG lift trucks should be provided with acceptable safeguards. (See Section 11).
- Lift truck battery charging areas should be properly arranged. (See Section 11).
- Provide adequate ignition source controls (e.g., work permits, non smoking policy strictly enforced for all employees including lift truck, locomotive and truck drivers).

Courtesy of ARAUCO Chile. Dry End – Cutting & Ball Composer Area

Courtesy of ARAUCO Chile. Finished Products Warehouse

Courtesy of ARAUCO Chile. Finished Products Warehouse

7.3.9 Critical Utilities

The following critical utilities may be included in a Pulp Mill or may be centralized in one area inside a complex that may also include wood processing plants. This would involve the following special hazards:

Electric Power:

- Electric power may be supplied from the grid, covering the full demand of the Pulp Mill or complex and/or the Pulp Mill, or the complex itself could produce electric power through Steam Turbine Generator(s) covering full demand and even producing an excess of electric power.
- Main substations include transformers, switch gear and distribution boards. Transformers may be used for importing current (especially during the black start of a pulp mill) and for exporting the excess of power produced on site (sold on to the market).
- An Emergency Power Supply may consist of an Uninterruptible Power System - UPS (batteries) and Diesel Engine-Driven Generator. This could be used for emergency shutdowns (i.e., removal of Work-in-Progress material inside the equipment, maintaining cooling and lubrication systems of process equipment and Thermal Power Plant equipment - Steam Turbines -, circulation of thermal hot oil systems, and emergency lighting).

<u>Prevention & Protection</u>:

- Multiple electric feeders on different pylons fed from different grid substations and supplying the Pulp Mill or the complex on a loop basis is the preferred arrangement. Should the Pulp Mill or complex be self-sufficient in terms of electric power, the national grid should preferably provide a 100% backup.
- Steam Turbine generators should be protected. (See Section 11).
- Transformers and electric rooms including cable trays and cable openings, should be protected. (See Section 11).

Complex– Oil-Filled Transformers

Complex– Main Substation Control Room

Courtesy of ARAUCO Chile

- Emergency Diesel Engine-Driven Generators (DEDG) should be tested once a week and run for 30 minutes in order to ensure reliability (detection of electric failures and cooling issues), ensuring lubrication. UPS and DEDGs should be protected. (See Section 11: “Stationary Combustion Engine and “Battery Rooms”).

Steam:

- Steam for the process is usually produced from a steam boiler fired with biomass (wood waste, bark) or using petroleum coke, coke, gas or fuel. A standby Steam Boiler that would only be used for black starts may also be provided. This boiler may supply steam to the process until enough steam is produced to supply the Steam Turbine Generators producing electric power for the complex. This prevents the need for importing electric power from the grid.

- A Black Liquor Recovery Boiler and its associated economizer is another source of steam. Sulfate Liquor (black liquor) or semichemical liquor from the digestion process is washed from the pulp with a solid content of 12 to 15%. It is then sent to multiple-effect evaporators and concentrated to a 45 to 50% soluble-solid content first, then to a 62 to 65% solid content prior to being burned in a Black Liquor Recovery Boiler (BLRB). The generated steam is recovered to be used in the process and to run the Steam Turbine Generator (if any).

<u>Prevention & Protection</u>:

- Refer to “Thermal Power Plants” (biomass), Section 6.2.2.
- Fuel Line Safety Combustion Controls should be provided for gas / fuel-fired boilers. (See Section 11).
- See Section 7.3.4: “Chemical Pulping – Black Liquor Recovery Boiler”.

Process Water:

- Water used for process, domestic, utilities (e.g., cooling, steam boilers) is usually received from the nearest river and/or from wells (via electric-driven pumps). The water is treated according to its intended use (boiler, drinking water, process, firefighting).
- Water can also be stored in a retention basin made of earth-filled material called an Embankment Dam that could also be exposed as a critical facility. (See Handbook “Embankment Dams” for the description of risks and related topics).

<u>Prevention & Protection</u>:

- Water intake should be regularly inspected. Any kind of potential contamination should be investigated (e.g., upstream occupancy releasing liquid or solid material). A routine should be established for removing debris (e.g., trees, rocks) after heavy rain and storms. Regular analysis of the raw water should be carried out ensuring that it can be treated according to its intended use. The electric-driven pumps of the water supply should be powered from both the normal power supply and the emergency power supply. A buffer storage should be maintained on site providing several hours production capacity (usually between 6 and 12h).
- Embankment Dams should preferably be located so that they do not expose any critical facilities or community areas. (See Handbook “Embankment Dams” for the proper management of this special hazard).

Cooling Water:

- Cooling Towers are usually installed at the Thermal Power Plant and Effluent Treatment Plant and may be installed at the level of the Pulp Mill for the Steam Turbine Generators. In the case of a total loss (i.e., about 4 months replacement) of the cooling towers at:
  - The Thermal Power Plant and the Pulp Mill: total shutdown of the Steam Turbo Generators is expected; no electric power generation on site; the complex would rely on an alternate power source (e.g., national grid) and may have to reduce production capacity depending on power available.
  - The Effluent Treatment plant: the treated effluent could not be cooled so that release to the nearest river is impossible; the Effluent Treatment Plant would have to shut down resulting in a shutdown of the Wood Processing Plant.

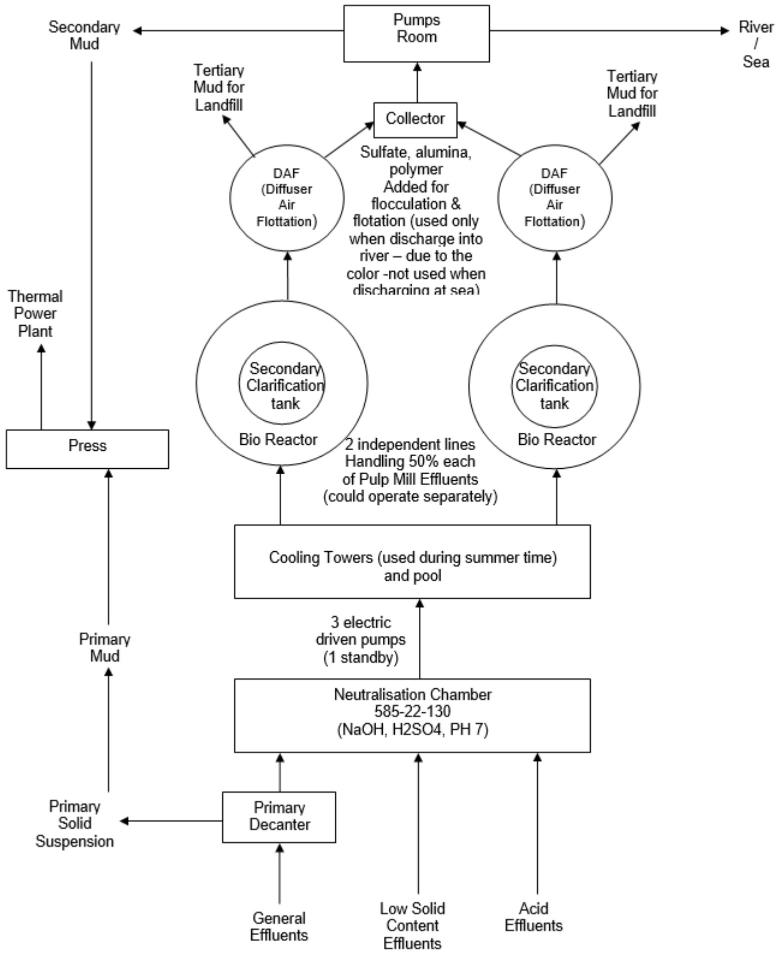
Courtesy of ARAUCO Chile. Process Cooling Tower

Prevention & Protection:

- Critical cooling towers should be protected. (See Section 11).

Effluent Treatment:

- Effluent Treatment Plants are usually installed in compliance with local environmental regulatory requirements. Different technologies are available. Modern technologies include bioreactors handling liquids and solids. Solids are separated from the liquids and usually sent to the biomass Thermal Power Plant to be used as fuel. Typical arrangements for a Pulp Mill may include:



Courtesy of ARAUCO Chile. Effluent Treatment Plant.

- In the case of a failure of the Effluent Treatment Plant, all effluents are usually directed to emergency reservoir(s) possessing a capacity corresponding to a maximum of 24h of plant / complex production. After this delay, all plants will have to be shut down. Note that these emergency basins are usually made of earth-filled material called an Embankment Dam. (See Handbook “Embankment Dams” for special hazard descriptions and related topics).

<u>Prevention & Protection</u>:

- Embankment Dams should preferably be located so that they do not expose any critical facilities or community areas. (See Handbook “Embankment Dams” for the proper management of this special hazard).
- Critical spares for Effluent Treatment Plants should be available on site.
- All electric rooms, transformers, cable trays, cable openings should be protected. (See Section 11).
- Cooling towers should be protected. (See Section 11).
- Agitators, pumps and other key equipment should be fed from an alternate power supply in case of a main power supply failure, in order to prevent sedimentation.

Air Products:

- Oxygen gas is usually supplied by a third-party operated Air Separation Unit (ASU) located near the Pulp Mill.

<u>Prevention & Protection</u>:

- The Air Separation Unit should have spare capacity and buffer storage (e.g., two back-up tanks of liquid oxygen representing 4 days’ supply for the Pulp Mill.
- Potential oxygen delivery on trailers from the nearest Air Separation Unit should be investigated (e.g., Pulp Mill demand: 75 tons per day corresponding to 3.5 trucks per day).

Compressed Air:

- Air compressors (package type) are usually provided for multiple purposes for the process and the Effluent Treatment Plant.

<u>Prevention & Protection</u>:

- Air Compressors should be protected. (See Section 11).
- In case of multiple compressors, they should be arranged in groups located in different fire areas. Back-up capacity and spare units should be provided.

Air Pollution Control:

- Modern developments in Pulp Mills include fume incinerator systems to remove harmful fumes that pollute the air and create an odor problem.
- Vapors and non-condensable gases are recovered from process tanks associated with pulp digestion and chemical treatment. These include dimethyl and hydrogen sulfides, mercaptans, alcohol, and turpentine.
- Condensable vapors may be recovered, and the non- condensable gases are incinerated, either in a separate incinerator or in a kiln or boiler.
- If the mill has an associated electrolytic chlorine plant, the hydrogen byproduct may be incinerated as a non-condensable gas to save energy.
- The hazards are a concentration of flammable gases or vapors within the explosive range, and the effect of a possible explosion on critical production equipment.
- The Electrostatic Precipitator (ESP) and its related oil-filled transformer is at the top, removing fine particles from the flowing gas using the force of an induced electrostatic charge minimally impeding the flow of gases through the unit.

Prevention & Protection:

- Prefer a dedicated fume incinerator well separated from any critical facilities.
- Fumes should not be incinerated in standard Steam Boilers, Black Liquor Recovery Boilers (BLRB) or lime kilns.
- Electrostatic Precipitator (ESP) oil-filled transformers should be protected. (See Section11).

Heat Ventilation Air Con. (HVAC):

- Dedicated units are usually provided for some critical substations. Main substations and electric rooms may be over-pressurized to prevent contamination from outside (pulp fibers).

Prevention & Protection:

- Proper maintenance and inspection programs should be established for the HVAC systems.

7.3.10 Import/Export Facilities

See Section 2.2: Interdependences, BI, CBI(CTE), SI – point F. “Major Loss impacting the Import / Export facilities”.

7.4 CONTINGENCY / BUSINESS CONTINUITY / RECOVERY PLAN

Warning: in order to be reliable, a Contingency / Business Continuity / Recovery Plan should be formalized. This would include formal contracts signed in advance with vendors and/or third parties. The plan should be regularly tested, reviewed, and updated.

Holistic view:

- If the Pulp Mill is part of a group with a relatively high level of vertical integration in the Wood Processing and Pulp & Paper industry, a Business Continuity Plan (BCP) at corporate level should be developed for the main identified risks in each and every process unit.
- The impact of a loss impacting third parties (i.e., logistics, utilities) should be investigated and an adequate BCP should be established.

Site view:

- A BCP (disaster recovery plan) in case of the total loss of a plant (i.e., fire, wildfire, flood) should be established.

- Water is critical for process, domestic uses and firefighting. Ensure there are multiple sources when possible, backup, buffer storage on site and a Contingency Plan consisting of water delivery made by trucks when possible.
- Steam is critical. Full backup, including an alternate steam supply (i.e., independent back-up steam boilers) would provide adequate duplication.
- Electrical power either from the grid or generated on site (i.e., Biomass Thermal Power Plant) is critical. Full backup from the grid avoiding any bottlenecks (i.e., feeders, substations) would provide adequate duplication and reliability. An Automatic Transfer Switch – ATS – would avoid blackouts.
- A Contingency Plan should be developed in case of a loss of the cooling towers for Steam Turbine generators and effluents.
- A Contingency Plan should be developed in case of a major loss impacting the Effluent Treatment Plant. Depending on local regulations, the plants may not be allowed to operate without effluent treatment. This would also include the cooling towers used to maintain the temperature of effluents at an adequate level prior to being released in the nearest river after treatment.

7.5 LOSS HISTORY

According to some studies of the loss history in the pulp and paper industry, the major hazard areas are:

1. Log and chip piles
2. Digesters
3. Black Liquor Recovery Boilers (BLRB)
4. Dryers and paper machines
5. Roll paper storage (warehousing)
6. Process control centers and wiring
7. Power and waste fuel boilers
8. Steam Turbine Generators
9. Material handling systems
10. Bleaching processes

The results of a study on tube leak incidents between 1970 and 2005, resulting in potential water on the bed and smelt water explosions show that:

- About 500 incidents reported 5 days BI and limited damage
- 2 explosions resulted in slight to moderate damage
- 2 explosions resulted in major damage and between 30 - 110 days BI

In fact, the higher the water volume and proximity to the bed, the more likely the explosion.

Leak location:

- 45% on wall
- 25% on generating bank
- 12% on screen
- 10% on floor
- 6% at the economizer
- 1% on the roof
- 1% other

First discovery of leak:

- 30% by instrument
- 70% by operator

Most common progression: corrosion or welding-related pinhole washes in close proximity to the tube, causing its failure and releasing water on the bed.

Example of losses:

2020 USA – Digester – rupture in the pressure vessel:

The cause of the malfunction that led to the explosion is not known.

The two paper machines were restarted a week later, using pulp produced at other pulp mills belonging to the group, and supplemented by purchases from others.

2017 USA – Digester – rupture in the pressure vessel:

An explosion involving a digester caused between USD80MM and USD120MM in damage. The mill returned to partial operations about a month after the explosion.

The most likely cause was an electrical fault in the power distribution system. The power failure forced the mill out of operation, which caused gas to build up in an on-site pulp digester. The explosion blanketed much of the adjacent neighborhood in a sticky, black debris and forced the mill out of operation for several weeks. During the cleanup, officials said they couldn't be certain what was released into the air immediately after the explosion. They said some of the debris was made of black liquor, a chemical used to break down wood fibers in the paper-making process.

2011 Latin America - Magnitude 8.8 Richter Scale Earthquake: Pulp Mill located 40km from the epicenter. Main damages included (but were not limited to):

- Line 1 (1970):
  1) Digesters: rupture of the digester piping resulting in black liquor spillage on the transformers and spillage of black liquor inside an electrical room (up to 20cm high) as well as spray on the walls. Some electric cabinets had to be replaced.
  2) Caustic unit: building displacement with high potential for collapse
- Line 2 (1990):
  1) BLRB: 6 transversal beams and 8 longitudinal beams (almost all beams at which the 3,300t BLRB is suspended) were severely damaged by the EQ shake. The BLRB body dropped down 700mm.
  2) Oxygenation columns (10% pulp, 90% water) suffered partial collapse of the skirt.

Other Issues:

- Line 1 (1970):
  - Severe damage to supporting structures (vessel anchor bolts and vessel foundations) within the pulp preparation area, and digester vessels, with a bleaching tower hat collapse.
  - Some brick walls had to be demolished
  - BLRB Line 1: the level of the BLRB dropped down by 20mm. One main supporting beam was damaged but could be repaired. Internal damaged nipples were repaired. Other supporting beams and EQ bracing were broken during the EQ shake resulting in the BLRB body hitting the surrounding frame (stairways around the BLRB and surrounding beams).
  - Feed-water piping: collapse of supports due to soil settlement.
  - Power Boiler: rupture of a steam pipe during the EQ, causing an operator to suffer 60% burns (he died a few days later). Some leaking tubes had to be repaired.

  - Power Boiler – ESP: transformers disconnected from the busbars.
  - CCR: display sets fell down, damaging control panels and toppling rack cabinets.
- Line 2 (1991):
  - Dryer – Electrical Room: a rack of 30 acid-filled UPS batteries fell down during an EQ. The plastic pieces of broken batteries released acid that reacted with both epoxy resin paint on the ground and the plastic components. This resulted in highly corrosive and toxic fumes contaminating the entire room housing several rows of cabinets. The ventilation was automatically shut down during the EQ due to a power failure preventing the extraction of fumes from the room. It took about 2 weeks to clean the entire room and equipment. This involved 50 people and 3 contractor companies.
  - CCR: display sets fell down damaging control panels and toppling rack cabinets (replaced when needed or repaired).
- Common to Lines 1 & 2:
  - Lime kiln: the central bearing support was displaced causing damages to the refractory.
  - Effluent Treatment: the pump house was flooded.
  - Finished Products Warehouse: some structural damages to the building.
  - Spare parts warehouse: all racks collapsed.

Gross Loss (MM USD): PD #120 (L1#30%, L2#70%), BI#300 12 months (L1#15%, L2#85%)

2011 Latin America - Magnitude 8.8 Richter Scale Earthquake. Pulp Mill (built 2008) located 70km from the epicenter. Main damages included (but were not limited to):

- Effluent-Bio reactor and classification tank 2 (inclined)
- Effluent pipe rack collapse
- Washing Press: leg support damaged
- Electrostatic Precipitator (ESP) oil-filled transformer collapse; fire started but was manually extinguished
- Steam Turbine Generator – TG3: labyrinth seal leak resulted in mixing of steam and lubricating oil. The Pulp Mill operated only with the TG2 turbine and electric power was purchased from the grid (PD+BI 2-months: 20MM USD as part of the EQ claim).

2007 Europe - Electric Fire in a Pulp Mill: PD: € 11MM BI: € 50MM
This integrated pulp and paper plant is one of the larger pulp and paper mills in Europe and one of three major Kraft liner mills from which this pulp & paper group derives a significant part of their brown Kraft liner paper production.

The loss involved a very intense fire in a low voltage motor control room in an "ultra large" integrated paper and pulp mill. In addition to the total destruction of the interior of the room in which the fire started, there was some collateral damage to adjacent control areas, and the end result was that a Kraft liner manufacturing machine became completely inoperable.

The repair program was very actively managed by the in-house engineering team and operated on a round-the-clock basis involving considerable logistical challenges. The repair program totaled a duration of 105 days including the equivalent of 4 days ramping up after restart. Had this work been undertaken in normal circumstances, a works' period of at least 6 months after completion of a comprehensive planning phase would have had to be expected. As the final phase of the repair program was reached, some prospects of further reducing the repair period were considered. This was to be achieved by encouraging some suppliers to undertake testing and commissioning of some aspects of their work before other aspects of their particular packages had been completed. Further manpower was inevitably required for this, and the relevant costs were approved. The end result was that the repair program was further reduced by a period of 9 days to a total period equivalent to 96 days' production cessation.

The ancillary paper machine, which is used for the manufacture of somewhat more specialized paper, was able to continue in production subject to certain changes in the virgin pulp and chemicals in the pulp mix from which paper is produced. The necessity to produce smaller quantities of pulp in turn reduced the quantity of black liquor available from the digester. This black liquor is the fuel used to run the recovery boiler which provides the greater part of the plant's steam requirement. The consequence of a reduced supply of black liquor was that the black liquor boiler had to be run using supplementary fuel in the form of biomass and some heavy fuel oil. In this way, production on the auxiliary machine was able to continue.

The initial investigations undertaken by local adjusters had resulted in the point of origin of the fire being largely determined. The source of the fire was such that there were grounds, at the time, for taking the view that the fire origins might be associated with a back-to-back capacitor, the batteries of which should have been subject to checking by the supplier, during the course of a shutdown, for capital investment to both machines.

2004 Maintenance Building Fire: a fire destroyed a maintenance building at the MeadWestvaco paper mill on a Tuesday, shutting down paper machines and forcing workers out of part of the mill. The fire was reported in a wooden building that housed maintenance offices, storage areas and an air conditioning repair shop. The building collapsed and somehow ignited a fire. The fire in turn is believed to have caused acetylene and oxygen tanks inside the building to explode. At one point, flames shot up three stories high. Smoke billowed out above the mill and into other buildings. The building that burned was attached to the old part of the mill, but the fire was contained before it could spread. The mill´s three operating paper machines, as well as a pulp dryer and finishing machines, were shut down and part of the mill evacuated. One of the machines was back up and running in the early afternoon, and the others were expected to be operating in the evening.

2003 Latin America Black Liquor Recovery Boiler (BLRB): leakage of tubes located at the bottom of the boiler (88bar pressure) resulted in the spontaneous vaporization of water under heat and pressure. The safety interlocks reacted after detecting high pressure in the combustion gas and a low water level in the reservoir. The plant was totally shut down for 10 days for investigation and repair. IR scanning inspections showed that 4 tubes (totaling 2m in length) had been damaged due to thermal stress resulting from low water flow in the tubes (low velocity, lack of cooling, vapor pockets). This could not be detected due to the lack of sensors measuring the flow and the temperature. PD: about USD7MM and BI: about 21 days.

Others:

Steam Turbine Generator: a fire damaged the STG and surrounding installations. The fire was a consequence of human error during regular maintenance. PD & BI combined: USD20MM (mainly BI).

Steam Turbine Generator: foreign particles in the steam flow resulted in the breakage of a screen steam inlet. Provisional repairs were implemented. Spares were ordered (11 months for delivery) and were installed during the next Pulp Mill maintenance period.

Steam Turbine Generator: rotor failure due to electric malfunction. PD: about USD1MM and BI: about USD18MM (12-18 months replacement. Loss of revenue: no excess power sold to the grid and power had to be purchased from the grid).

Effluent Treatment Plant: electrical room short circuit and fire. PD: about USD700,000 and BI: about 3 days.

Fire at the chip conveyor to the digester. this fire was rapidly controlled by local personnel. The conveyor was stopped for 19 hours. The plant decided to install sprinkler protection on this conveyor.

Fire on the 120m-long rubber belt conveyor running from the chip pile (40-60% humidity) to the digester (elevated up to 30m, inclined and covered with Fiber-Reinforced Plastic). The fire (in the last & highest third of the conveyor) was detected by a plant employee and was controlled and extinguished by the plant fire brigade using hydrants supplied by the fire pump in about 1h30. The entire rubber belt and about 18-20m of the steel framework were severely damaged and had to be replaced. The most likely cause was overheating of the rubber belt due to pulley displacement and misalignment. A draft standard for fire protection of rubber belt conveyors was issued after the loss. PD: 150kUSD and BI: 7 days.

7.6 LOSS ESTIMATES

Maximum Possible Loss (Technical MPL):

- Major EQ in zone 3 or 4 impacting all facilities: 35% PD for zone 3, at least 50% for Zone 4, and 18 months BI.
- Tsunami and storm surge in a coastal area. (See MPL Handbook).
- Wildfire involving flying ambers starting multiple fires on a complex including a Pulp Mill and Wood Processing Plant. (See MPL Handbook).
- High Pressure Rupture of a vessel in the Digestor area:
  - Different simulation tools – ALERT (AON), SMART BLAT (AIG), FAST (Willis), EXTOOL (Swiss-Re, SCOR) - for high pressure vessel rupture and explosion can be used to show the impact to the immediate and surrounding areas further afield.
  - Secondary fires and firefighting / debris removal may respectively represent 10% and 5% of additional Property Damages.
  - Note that high pressure is usually defined as exceeding 1bar / 15psi. Pressure vessels typically fail at a multiple of the design pressure (“MAWP”: Maximum Allowable Working Pressure). In most cases, the pressure at which the vessel will effectively burst cannot be properly predicted. Literature indicates that medium-to- low pressure vessels would fail at 2 to 4 times the MAWP (i.e., up to 10 bars used 4 times and never less than 10 bars, since a vessel operating at 1-2 bars is at least designed for a 10-bar pressure). For High-Pressure vessels, it will be more in the range of 1.5 times the MAWP.
  - The following information is usually required for a simulation:
    - Total vessel volume
    - Normal liquid and gas-free volume in the vessel (assuming normal conditions. However, a runaway reaction or overheating condition will lead to more liquid being vaporized, thus increasing the volume of gas)
    - Normal operating pressure of vessel
    - “MAWP”: Maximum Allowable Working Pressure of vessel
    - Bursting pressure of vessel (when available)
- Catastrophic event (steam explosion) at the Black Liquor Recovery Boiler (BLRB): 18 months replacement.
- Explosion of the rotary kiln at the lime plant due to an accumulation of gases resulting from incomplete combustion: at least 12-18 months BI.
- Fire destroying the dryer area and adjacent pulp roll / bale-making area and warehouse: this would depend on minimum separating distances and continuity of combustible. (See MPL Handbook). Total loss of facilities should not be excluded but would depend on congestion, combustible loads, and continuity of combustible.
- Induced BI in case of interdependencies with sister plants upstream and downstream should be considered. This could be mitigated by buffer storage (providing several extra days of production) and alternate suppliers (if any). (See Section 2: “Supply Chain”).

Normal Loss Expectancy (NLE):

- Fire would result in the same magnitude as for the MPL when neither adequate nor approved automatic fire protection is provided. Total loss of facilities should not be excluded. This would depend on congestion, combustible loads, and continuity of combustible. When adequate fixed-fire protection is provided, consider the loss as equivalent to the surface of application for the content only (i.e., the building is not damaged).

- Fire involving an electric room (e.g., cable vault) resulting in 4 months BI.
- Fire on a major rubber belt conveyor resulting in 4 months BI and even more in the case of a very long and elevated conveyor (e.g., 80m high) supplying chips to the digester.
- Explosion and fire of a critical supply transformer (e.g., used for black starts) or a big power transformer: up to 12-18 months replacement time.
- Fire on a critical cooling tower (i.e., Steam Turbine Generator, Effluent Treatment Plant) resulting in 4 months BI.
- Fire on a critical hydraulic group (i.e., wet end or dry end) resulting in at least 4 months BI.
- Major Machinery Breakdown or fire damaging the dryer. This would result in at least 8 months BI, depending on availability.
- Induced BI in case of interdependencies with sister plants upstream and downstream should be considered. This could be mitigated by buffer storage (providing several extra days of production) and alternate suppliers (if any).

8 PAPER PROCESSING

8.1 PROCESS

Paper mills can have a single paper machine or several machines processing different qualities of pulp and resulting in a variety of paper grades.

Paper processing consists of the conversion of pulp to paper including (but not limited to) the following main classes of products:

- Newsprint, Lightweight Coated, Fine Paper, and Linerboard
- Kraft paper
- Tissue paper

Paper properties and uses:

- Used in a wide variety of forms, paper and paperboard are characterized by a wide range of properties.
- In the thousands of paper varieties available, some properties differ only slightly and others grossly. The identification and expression of these differences depends on the application of standard test methods, generally specified by industry and engineering associations in the papermaking countries of the world.
- Basic properties include (but are not limited to):
  - The basis weight, substance or grammage - obviously the most fundamental property of paper and paperboard. The basis weight of paper is the weight per unit area. This can be expressed as the weight in grams per square meter (GSM or g/m^2), pounds per 1000ft^2, or weight in kgs or pounds per ream (500 sheets) of a specific size.
  - Strength and durability: resistance to rupture when subjected to various stresses is an important property in practically all grades of paper. Most papers require a certain minimum strength to withstand the treatment received by the product in use. The strength of paper is determined by the following factors in combination: (1) the strength of the individual fibers of the stock, (2) the average length of the fiber, (3) the interfiber bonding ability, which is enhanced by the beating and refining action, and (4) the structure and formation of the sheet.
  - The ability of fluids, both liquid and gaseous, to penetrate the structure of paper becomes a property that is both highly significant to the use of paper. In certain types of packaging, paper must resist grease and oil penetration.
  - Optical properties: the most important optical properties of paper are brightness, color, opacity, and gloss. The term brightness has come to mean the degree to which white or near-white paper and paperboard reflect the light of the blue end of the spectrum (i.e., their reflectance). This reflectance is measured by an instrument that illuminates paper at an average angle of incidence of 45° and a wavelength of 457μ (microns). Brightness measured in this way is found to correlate closely with subjective estimates of the relative whiteness of paper. Opacity is one of the most desired properties of printing and writing papers. Satisfactory performance of such papers requires that there be little or no "show-through" of images from one side of the sheet to the other. Satisfactory opacity in printing papers requires that white mineral pigments be incorporated with the paper stock or applied as a coating.

In the conversion from pulp to paper, pulp or recycled paper or a combination of both is mixed with water (re-pulping) and is fed to a paper machine, where it is formed as a paper web, after which the water is removed from it by pressing and drying (paper machine).

The main processes and related paper machines are detailed below.

8.1.1 Newsprint, Lightweight Coated, Fine Paper, and Linerboard

For Lightweight Coated, Fine Paper, and Linerboard, the raw material usually consists of bleached pulp issued from chemical pulping.

For newsprint, thermomechanical bleached pulp is usually preferred because of its opacity and strength properties that allow printing on both sides of the sheet and long webs of paper rather than individual sheets of paper.

These paper machines typically consist of a forming section, pressing section, and a drying section. Heat from the hood over the drying section is reclaimed through an economizer. Calenders may be located between the press and drying sections, and after the drying section.

Some machines have machine-glaze (MG) cylinders in the drying section. An MG Cylinder is a Yankee cylinder, which is used to glaze the surface of the paper. The paper sheet, in contact with the large, hot, highly polished dryer surface for a long dwell time, will start to slip and plasticize the surface fibers, improving gloss & glazed properties on one side of the paper. However, nowadays most of the glazed paper demand is being converted to Matt Finish Paper so most of the mills have changed the purpose of their installed MG cylinder and are now using it as a Post Dryer.

Note: a Yankee cylinder or Yankee machine is also a single large drying cylinder which crepes the paper (see Tissue Paper) or produces a glazed surface on one side (see above).

Modern paper machines include hydraulic equipment for press rolls and “shoe presses” (a stationary nip roll consisting of a beam-supported, hydraulically-loaded concave plate (“shoe”) enclosed by a rotating sleeve that passes over the shoe aided by lubrication). These “shoe presses” may be installed as the top or bottom roll in the nip and may be opposed by a controlled-crown roll or solid roll.

Heat Transfer Fluid (HTF)-heated calenders may be provided.

8.1.2 Kraft Paper

Kraft paper or “Kraft” is paper, or paperboard (cardboard) produced from chemical pulp produced in the kraft process.

The raw material can consist of unbleached pulp (called coffee pulp) produced at the Pulp Mill, or recycled paper, or a mix of both. Recycled paper can be manufactured relatively easily, with end products competitive in quality to those made from virgin materials. Some difficulties arise from the economics of collection and transportation of waste paper products to centers for reprocessing. Recycled paper is not usually re-bleached and, when it is, oxygen rather than chlorine is usually used. This reduces the amount of dioxin that is released into the environment as a by-product of the chlorine bleaching processes.

Paper machines are similar to those used for Newsprint, Lightweight Coated, Fine Paper, and Linerboard.

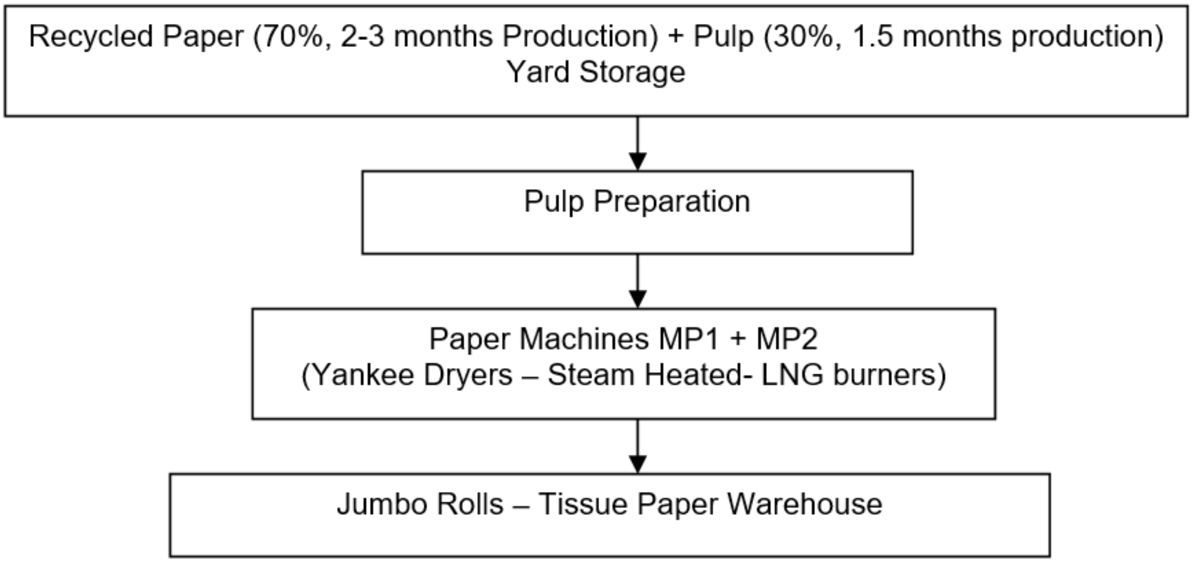
Kraft paper made from unbleached pulp and/or recycled paper can be used as primary packaging material (e.g., wrap, bags, envelopes) and as an intermediate product for cardboard manufacturing. (See “Paper Working”, page 115).

8.1.3 Tissue Paper

The raw material usually consists of (bleached) fluff pulp mixed with up to 80% recycled paper. Fluff pulp was first developed in the 1920’s for use in disposable sanitary napkins.

The most demanding application of fluff pulp is in air-laid products, used in serving utensils, various towel applications in homes, in industries, and in hospitals. Fluff pulp for air-laid products is defibrized in a hammermill. Defibration is the process of freeing the fibers from each other before entering the paper machine. Important parameters for dry defibration are shredding energy and knot content.
Fluff pulp is normally made on rolls (reels) on a drying machine (a simplified Fourdrinier machine). The objective of the drying/sheeting operation is to produce a uniform sheet (paper density, moisture, and strength) for the converting operation. The pulp may be impregnated with debonders before drying to ease defibration.

Typical process flow chart:



Tissue paper jumbo rolls are then sent to “conversion lines” (see “Paper Working”) for manufacturing so-called soft tissue products, including (but not limited to) facial tissues, toilet tissues and kitchen roll towels.

Through-Air Dried (TAD) Paper Machines: TAD was first used commercially in the 1960’s in the manufacturing of tissue and towel products. The “standard” method of making tissue and towel at the time of TAD technology development was Light Dry Creping (LDC). Dry creping of tissue had been used since the World War I era. In comparison to LDC, the TAD-produced tissues and towels have twice the bulk and absorption capacity for the same basis weight. These two factors are key to the success of TAD in making high-end retail products. Paper machines incorporating a through-air dryer do not currently present any hazard and are therefore not addressed in this handbook.

LDC or Crepe paper machines typically utilize a Yankee dryer. A tissue Yankee cylinder is a large-diameter drum which is pressurized with steam to provide a hot cylinder surface used for soft tissue products (e.g., facial tissues, toilet tissues, kitchen roll towels) by a process called Creping, which is achieved by using a creping blade to aid the release of dried tissue, preventing it from adhering to the Yankee cylinder.

Note: a Yankee cylinder or Yankee machine is also a single large drying cylinder which crepes the paper (see above) or produces a glazed surface on one side (see “Newsprint, Lightweight Coated, Fine Paper, and Linerboard”).

Some machines have an after-dryer section of can-type dryers.

Some machines have through-air dryers (TAD – see above). Other machines have fuel-fired air heating systems.

Generally, a suction press roll is provided.

A pressure roll or a shoe press may also be provided. (a stationary nip roll consisting of a beam-supported, hydraulically-loaded concave plate ("shoe") enclosed by a rotating sleeve that passes over the shoe aided by lubrication). These "shoe presses" may be installed as the top or bottom roll in the nip and may be opposed by a controlled-crown roll or solid roll.

8.2 SPECIAL HAZARDS & RISK CONTROL

Special hazards, prevention, protection and potential mitigation measures are detailed below for each and every special hazard related to this occupancy. (This follows the process flow from Raw Material to Finished Products as closely as possible). Related recommendations are also mentioned. (See. "Rec", Section 11: "Support for Loss Prevention Recommendations" for details).

8.2.1 All Facilities

See Pulp Mill subsection 7.3.1: « All Facilities ».

8.2.2 Warehousing

- Raw Material storage consists of:
  - Rolls / bales of bleached/unbleached pulp in a high bay warehouse.
  - Yard storage of recycled paper bales (up to 80% for tissue paper and even 100% of raw material for Kraft paper used to make cardboard).
- Finished Product storage consists of:
  - Paper rolls in a high bay warehouse
  - Solid piles of paper sheets wrapped in paper.

Notes:

- Tissue Paper Jumbo rolls (2 to 4 tons each) are subject to deep-seated fire representing fire pockets lasting up to several days (e.g., 70 days reported) after a major fire. These burning embers smolder inside the rolled tissue for several days before bursting into flames, allowing the fire to spread to other rolls.
- Recycled paper located close to the plant perimeter may be subject to arson. Metal scraps can be trapped inside the recycled paper bales.
- Unbonded paper rolls (circumferences consisting of steel / plastic straps) may exfoliate rapidly in the presence of fire, providing fuel and allowing fire to spread.
- Paper rolls on pallets would prevent the rolls located outside the fire area being wetted in case of fire and sprinkler protection activation.

- So-called "seasonal" or "temporary tents" made of combustible tarpaulin or canvas on a light metal frame may be installed close to process or storage buildings.
- Ignition sources such as smokers, hot works or damaged electrical equipment are a danger.
- Lighting fixtures consisting of Metal Halide HID bulbs without adequate cover may constitute a source of ignition.
- LPG, diesel-driven and electric-driven lift trucks are used to carry the semi-finished and finished products.
- Trains and trucks may enter the warehouse.
- Considering the relatively high combustible load and the high continuity of combustible in such warehouses, safe and efficient manual firefighting would be virtually impossible in the case of a fire that cannot be controlled in its early stages of development.

Prevention & Protection:

- Buildings should be made of noncombustible construction material (avoid highly combustible insulation such as PUR, PIR, EPS).
- So-called “seasonal” or “temporary tents” made of combustible tarpaulin or canvas on a light metal frame should be replaced with sprinkler-protected permanent structures, or should be located in areas that do not expose process or storage buildings (at least 40m separating distance or more, depending on building heights).
- Provide minimum separating distances (at least 40m or more depending on building heights) between warehousing / yard storage and other critical buildings, or provide at least a 2-h fire-rated partition.
- Provide adequate ignition source controls (e.g., work permits, non smoking policy strictly enforced for all employees including lift truck, locomotive and truck drivers).
- Provide adequate lighting fixtures. (See Section 11).
- LPG lift trucks should be provided with acceptable safeguards. (See Section 11).
- Lift truck battery charging areas should be properly arranged. (See Section 11).
- Provide adequate and approved sprinkler protection inside the warehouse, in accordance with NFPA13. Storage height should also be limited to the maximum indicated in NFPA. False ceilings should be installed when needed.
- Provide adequate manual firefighting protection, including remotely operated monitors on towers for recycled paper yard storage.
- Automatic fixed-fire protection systems, fire water supply, manual firefighting equipment and Automatic Fire Alarm systems should be maintained, inspected and tested in accordance with NFPA25.
- Plant Emergency Organizations should be formalized and the First Emergency Team should be regularly trained in order to ensure a prompt response in case of fire.

8.2.3 All Paper Machines

Means of metal separation (i.e., scraps, foreign material) should be provided before sending the raw material to the paper machines.

See Pulp Mill subsection 7.3.6: “Pulp Drying”.

Paper Machine

8.2.4 Newsprint, Lightweight Coated, Fine Paper, and Linerboard

Paper machine to make coated paper

- Deposits of oily lint and paper dust are generated during the operating of the paper machine and accumulate inside dryer section hoods, exhaust ducts, and air plenums. Due to high heat and humidity, it is impossible to clean some of these enclosures without shutting down the paper machine.
- Synthetic felts, lubrication, hydraulic and HTF oil systems, and the paper web may also add fuel to a fire.

Prevention & Protection:

- Adequate and approved automatic sprinkler protection should be installed in economizers and other associated equipment, in accordance with Data Sheet 7-4: "Paper Machines and Pulp Dryers" and 7-78: "Industrial Exhaust Systems". See suggested arrangements below:

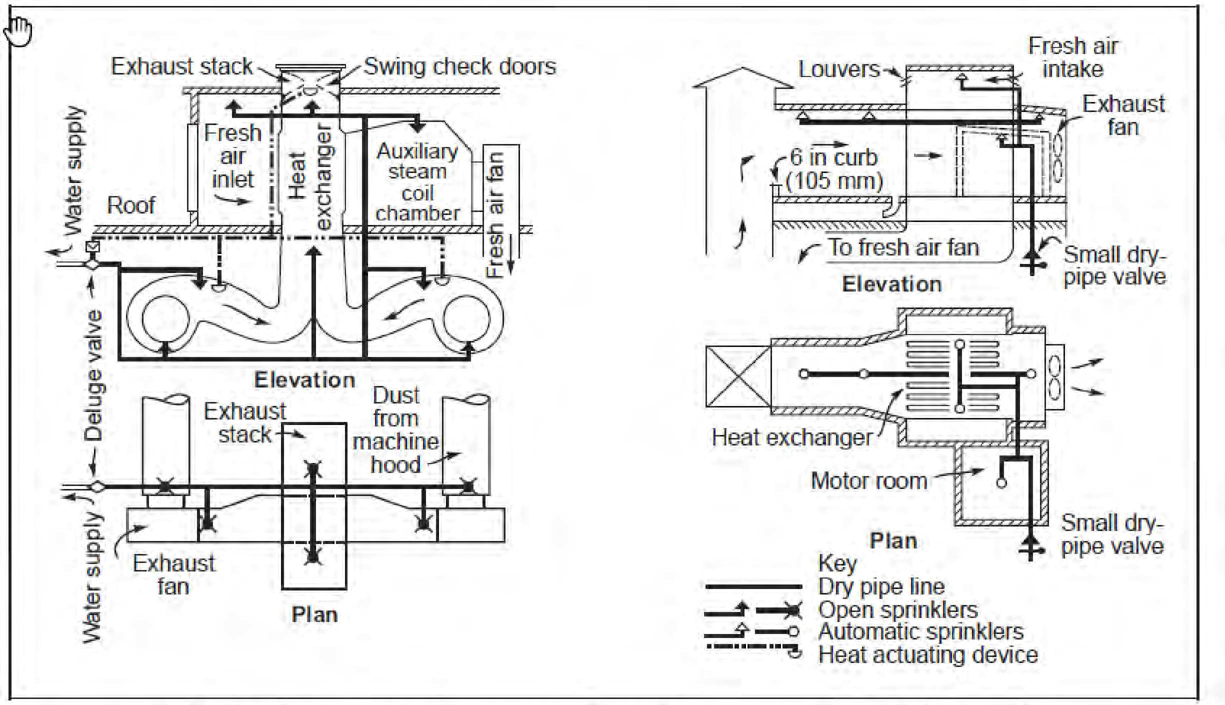


Fig. 5. Typical paper machine economizers. Suggested arragements for automatic sprinklers.

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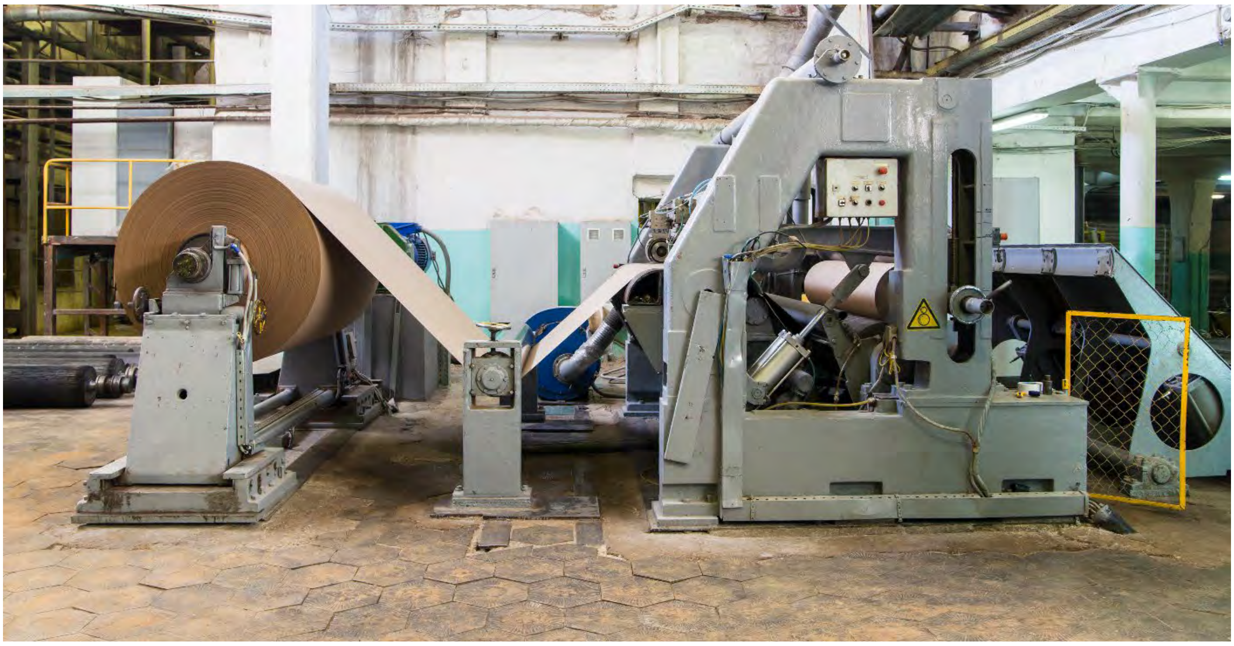
- Sprinkler piping for dryer section enclosures is independent of other sprinkler system piping, so the sprinkler systems in the other areas remain in service while fused sprinklers inside the enclosures are replaced.
- The ventilating fans should be interlocked to the fixed fire protection in order to shut down upon actuation of sprinklers inside the economizer, over the machine, or under the machine. This is to minimize the spread of fire and damage to fans.
- Drains, shields, or curbs should be provided as needed to prevent water damage in the event of sprinkler operations in the economizer.
- Air from the economizer should be returned to the paper machine room only.

8.2.5 Kraft Paper



Kraft paper

See Newsprint, Lightweight Coated, Fine Paper, and Linerboard above.

8.2.6 Tissue Paper

- Tissue dust, lint, and pieces of tissue may be ignited as follows:
  - entering either the recirculating air system or the air inlets of the Yankee dryer air caps,
  - by a burner in a direct fuel-fired hood,
  - the hot-wire grid,
  - by autoignition in the indirect fuel-fired hood,
  - accumulating on top of the air cap hood, resulting in autoignition and falling onto the web,
  - friction due to leaning blades rubbing against the Yankee.
- The center shaft of a Yankee Cylinder is a significant load-bearing element and contributes to the pressure-containing strength of the shell and heads. Corrosion may compromise the mechanical integrity.
- Machinery breakdown ensues, followed by long lead times (i.e., 12-18 months for a Yankee dryer).
- Overpressure of the pneumatics or hydraulic-loading system may damage the dryer.
- Overspeed may damage the paper machine.
- The paper machine may be directly heated by Compressed Natural Gas / Fuel-Oil / Kerosene-fired burners or indirectly heated by hot air or Heat Transfer Fluid (HTF) systems.

<u>Prevention & Protection</u>:

- Good housekeeping in and around the air cap or hood recirculation system, and frequent blowbacks are key for preventing embers from developing. Prefer vacuum cleaning of the air cap rather than blowdown to prevent suspension of a dust cloud that may contain embers.
- For Crepe paper machines:
  - with fuel-fired air heating systems: if the system has been running at temperatures below 204°C (400°F) for a prolonged period of time, before running the system at a temperature above 204° C (400°F), frequent blowbacks should be performed in order to remove dust from inside the hood or air cap (if there is a blowback duct).

- explosion vents on the air cap air recirculation systems should be provided in accordance with Data Sheet 6-9: "Industrial Ovens and Dryers".

- A spark detection system is recommended (infrared, over the web at the dry end) so that in case a spark or ember escapes from the hood, air cap, or blades, and is expelled onto the web, operators are alerted so that the roll can be segregated from other storage (in an outside area away from any combustibles) or repulped.
- For steel construction, the heads of a Yankee Cylinder must preferably be attached by welding, thus eliminating the joint corrosion hazard.
- A visual inspection routine of key equipment should be enforced. An adequate maintenance and inspection program (including Non-Destructive Technics) should be established.
- A pressure-relief device on the supply to the pneumatic or hydraulic-loading system for the suction press or pressure rolls should be provided.
- An overspeed control system, preventing a dryer from exceeding the maximum rotational speed recommended by the manufacturer, should be provided. This should include an alarm and trip system arranged so that the trip of the driver should also trip any air cap heater, and water sprays, releasing the pressure rolls and tripping steam to the Yankee.
- The fuel line for the direct heating system should be equipped with safety combustion controls. Heat Transfer Fluid (HTF) systems (if any) should be arranged and protected. (See Section 11).

8.2.7 Critical Utilities

Electric Power:

- Electric power is usually supplied from the grid (when independent from any complex).
- Main substations include transformers, switch gear and distribution boards.
- An Emergency Power Supply consists of an Uninterruptible Power System - UPS (batteries) - and a Diesel Engine-Driven Generator. This is used for emergency shutdowns (i.e., removal of Work-in-Progress material inside the equipment, maintaining lubrication systems of process equipment, circulation of thermal hot oil systems (if any), and emergency lighting).

Prevention & Protection:

- Prefer multiple electric feeders on different pylons fed from different grid substations supplying the plant (or the complex) on a loop basis.
- Protect Steam Turbine Generators (if any). (See Section 11).
- Transformers and electric rooms, including cable trays and cable openings, should be protected. (See Section 11).
- Emergency Diesel Engine-Driven Generators (DEDG) should be tested once a week and run for 30 minutes in order to ensure reliability (detection of electrical failure and cooling issues), ensuring lubrication. UPS and DEDGs should be protected. (See Section 11: "Stationary Combustion Engine and Battery Rooms").

Steam:

- Steam for the process is usually produced from Compressed Natural Gas or a fuel oil steam boiler.

Prevention & Protection:

- Fuel Line Safety Combustion Controls should be provided for the gas / fuel-fired boilers. (See Section 11).

Process Water

- Water used for process, domestic use, and utilities (e.g., cooling, steam boilers) is usually received from the nearest river and/or from wells (electric-driven pumps). Water is treated according to its intended use (boiler, drinking water, process, firefighting).
- Water can also be stored in a retention made of earth-filled material called an Embankment Dam that could also expose critical facilities. (See Handbook “Embankment Dams” for a description of the risk and related topics).

Prevention & Protection:

- The water intake should be regularly inspected. Any kind of potential contamination should be investigated (e.g., upstream occupancy releasing liquid or solid material). A routine should be established for removing debris (e.g., trees, rocks) after heavy rain and storms. Regular analysis of the raw water should be carried out ensuring that it can be treated according to its intended use. The electric-driven pumps of the water supply should be powered from both the normal power supply and the emergency power supply. A buffer storage should be maintained on site providing several hours of production capacity (usually up to 1 day).
- Embankment Dams should preferably be located so that they do not expose any critical facilities or community areas. (See Handbook “Embankment Dams” for the proper management of this special hazard).

Cooling Water:

- Cooling Towers are usually installed at the effluent treatment plant (or for Steam Turbine Generators, if any). They may be critical or not for cooling the effluent, prior to its release to the nearest river.

Prevention & Protection:

- When critical, cooling towers should be protected. (See Section 11).

Effluent Treatment:

- Effluent Treatment units are usually installed in accordance with local environmental regulatory requirements. Different technologies are available. Modern technology includes decantation and (bio) filtration prior to releasing the treated water to the nearest river.

8.2.8 Import / Export Facilities

See Section 2.2. Interdependences, BI, CBI (CTE), SI – point F: “Major Loss impacting the Import / Export facilities”.

8.3 CONTINGENCY / BUSINESS CONTINUITY / RECOVERY PLAN

Warning: in order to be reliable, a Contingency / Business Continuity / Recovery Plan should be formalized. This would include formal contracts signed in advance with vendors and/or third parties. The plan should be regularly tested, reviewed, and updated.

Holistic view:

- If the Paper Processing Plant is part of a group with a relatively high level of vertical integration in the Wood Processing and Pulp & Paper industry, a Business Continuity Plan (BCP) at corporate level should be developed for the main identified risks in each and every process unit.

- The impact of a loss impacting thirds parties (i.e., logistics, utilities) should be investigated and an adequate BCP should be established.

Site view:

- A BCP (disaster recovery plan) should be established in case of a total loss of a plant (i.e., fire, wildfire, flood).
- Water is critical for process, domestic uses and firefighting. Ensure there are multiple sources when possible, as well as backups, buffer storage on site and a Contingency Plan consisting of water delivery by truck when possible.
- Steam is critical. Full backup, including an alternate steam supply (i.e., independent back-up steam boilers) would provide adequate duplication.
- Electric power either from the grid or generated on site (i.e., complex) is critical. Full backup from the grid avoiding bottleneck (i.e., feeders, substations) would provide adequate duplication and reliability. This should include an Automatic Transfer Switch –ATS- avoiding blackouts.
- A Contingency Plan should be developed in case of a loss of critical cooling tower effluents (if any).
- A Contingency Plan should be developed in case of a major loss impacting the effluent treatment plant. As per local regulations, the plants may not be allowed to operate without effluent treatment. This would also include the cooling towers used to maintain the temperature of effluents at an adequate level prior to being released in the nearest river after treatment.

8.4 LOSS HISTORY

The loss records of Paper Processing Plants indicate that the major losses are due to fire, Machinery Breakdown (MB) or a combination of both, as summarized below:

- Fire within the warehouse involving Raw Material and/or Finished Products.
- Catastrophic failure of rolls such as the Yankee dryer, due to overpressure or overspeed, with an ensuing long lead time (12-18 months).
- Fire at the paper machine level due to:
  - Poor housekeeping and accumulations of dust and fiber, which can cause overheating and short circuits of drivers and electric equipment, or that accumulate and obstruct motor vents which can cause overheating of the motor and ignition of the paper or dust.
  - Overheated, manually-lubricated, sliding-element bearings that are not readily accessible when the machine is operating.
  - Friction of paper choking up rolls, belts, brakes, gears, and clutches.
  - Contact between tissue paper waste, dust on hot surfaces (i.e., exposed steam pipes, HTF pipe dryer hoods and ductwork, de-superheater valves, infrared radiant heaters, steam turbines (if any) operating near or above the autoignition temperature of paper dust and oil). Paper waste may accumulate for weeks on hot surfaces prior to ignition.
  - Improper maintenance and poor electrical integrity (overloading of cable trays, damaged equipment, loose connections) resulting in short circuits, arcing, static discharge.
  - Rupture of hydraulics, lubricating, or HTF pipes, or leakage at the level of a valve or flange.
  - Non-controlled hot work; cigarette butts carelessly dropped; lighting fixtures without adequate cover allowing glass fragments to fall onto Work-in-Progress material.
  - Note that damages to the paper machine are aggravated in the absence of automatic sprinklers. The experience of Factory Mutual regarding automatic sprinklers in dryer

hoods has shown that sprinkler discharge has not caused cracking, distortion, or other damage to the dryer rolls.

Examples of losses:

2008 – New Zealand Recycle Paper Slab Fire: a significant fire broke out on the recycle paper slab. Nobody was seriously hurt in this incident and the cost of the fire was approximately USD 1.2 Million. Some of the burnt paper was recovered.

The fire brigade continued to put out the remainder of the hot spots over the next two days.

High winds on the day of the fire (averaging 46.5 km/h) greatly increased the rate at which the fire spread across the recycle paper slab. It is estimated that it only took 5 to 10 minutes from the time the fire was first noticed, to when the whole slab was on fire. High winds also contributed to the number of spot fires in neighboring forest land.

The Fire Service investigation into the cause of the fire has stated that the cause cannot be confirmed, however the four potential causes that cannot be ruled out are: 1) spontaneous combustion, 2) magnification caused by contamination, 3) a chemical reaction between chlorine and very dry paper , or 4) a discarded cigarette (or other human-initiated ignition source) Their professional opinion is that a discarded cigarette is the most likely cause because: 1) the other causes need a series of very specific circumstances in order for them to have occurred, 2) the fire appears to have started very low down in the recycled bales to have caused the bales to collapse, and 3) three separate interviews by the Fire Service identified that employees were regularly entering the waste paper slab area to rest, sleep and in some cases smoke.

The inner cordon of the fire scene was managed by the firefighters, however, the outer cordon and area surrounding the fire was the responsibility of site management who were to coordinate and control. This was not well understood nor well managed, resulting in a number of bystanders congregating in potentially hazardous areas.

There were several critical failures which caused (or potentially caused) greater losses than could have been otherwise expected. For example:

- A buildup of scrub, gorse and a beautification program meant that spot fires in the area surrounding the plant quickly took hold and caused a loss of power to the water supply systems. This, in turn, caused the main power feed to the water center to trip out, leading to a temporary loss in water pressure needed to fight the fire. This could have been quickly overcome by operating electrical backup systems, if their presence had been known and they had been applied, but they were not. There are two other power feeds into the water center, but neither was explored.

- Instead, the diesel-powered pump suctioning water from a dam was initiated. This had a limited duration of about 40 minutes due to the water volume available. Unfortunately, there was also a failure in this system that led to a bypass valve being left partially open. This caused a drop in delivery pressure because water was being discharged back into the dam.

- There were also delays in responding to the fire because firefighting equipment was not readily available near the fire hydrants for site personnel to use, prior to the arrival of the firefighters at the scene.

- Another issue was the presence of unauthorized persons on site, due to the way security gates operate after a power cut or when a site-wide evacuation alarm is activated.

- Around the site there were situations where members of the public had gathered to watch the fire. A number had crossed through the forest and were at significant risk of harm due to spot fires on forestry land. Additional assistance from the Police would have been reportedly advantageous and yet they were not called to assist.

2004 UK - Fire warehouse to be demolished: More than 120 firefighters attended the fire at its greatest height. A paper warehouse hit by one of Kent's biggest ever fires was so badly damaged it would have to be demolished. The burnt-out frame of the distribution center in Northfleet was still smoldering two days after the huge fire. At the fire's culminating point, flames could be seen 20 miles away in south London. The building was storing paper products worth tens of thousands of pounds, including nappies and toilet rolls.

8.5 LOSS ESTIMATES

Maximum Possible Loss (Technical MPL):

- Major EQ in zone 3 or 4 impacting all facilities: 35% PD for zone 3, at least 50% for Zone 4 and 18 months BI.
- Tsunami / storm surge in a coastal area (see MPL Handbook).
- Wildfire impacting the facility or involving flying ambers starting multiple fires on a complex (see MPL Handbook).
- Major fire within the warehouse or the paper machine area spreading to all adjacent areas. This could lead to the total loss of the plant depending on its arrangement.
- Catastrophic event at the paper machine (e.g., Yankee Dryer Machinery Breakdown followed or not by a fire) 18 months replacement. A fire could lead to the total loss of the plant depending on its arrangement.
- Induced BI should be considered if there are any interdependencies with sister plants downstream. This could be mitigated by buffer storage (providing several extra days of production) and an alternate supplier (if any).

Normal Loss Expectancy (NLE):

- Fire resulting in the same magnitude as for MPL, when neither adequate nor approved automatic fire protection is provided. Total loss of facilities should not be excluded depending on congestion, combustible load, and continuity of combustible. When adequate fixed-fire protection is provided, consider the loss equivalent to the surface of application for the contents only (the building is not damaged).
- Major Machinery Breakdown or fire damaging the paper machine. This could result in relatively long BI (8-18 months) depending on availability.
- Fire involving an electric room (e.g., cable vault) resulting in 4 months BI.
- Explosion and fire of a critical transformer supplying the plant. Up to 18 months' replacement time.
- Fire on a critical hydraulic group resulting in at least 4 months BI.
- Fire on a critical cooling tower (i.e., effluent treatment, Steam Turbine Generator) resulting in 4 months BI, when critical.
- Induced BI should be considered if there are any interdependencies with sister plants downstream. This could be mitigated by buffer storage (providing several extra days of production) and an alternate supplier (if any).

9 PAPER WORKING

9.1 PROCESS

Paper working consists in the conversion of paper to final consumable products, including (but not limited to) the following main processes:

- Conversion of tissue paper into soft tissue products including (but not limited to) facial tissues, toilet tissues and kitchen roll towels.
- Conversion of unbleached Kraft paper into corrugated cardboard or bags
- Printing

9.1.1 Conversion of Tissue Paper

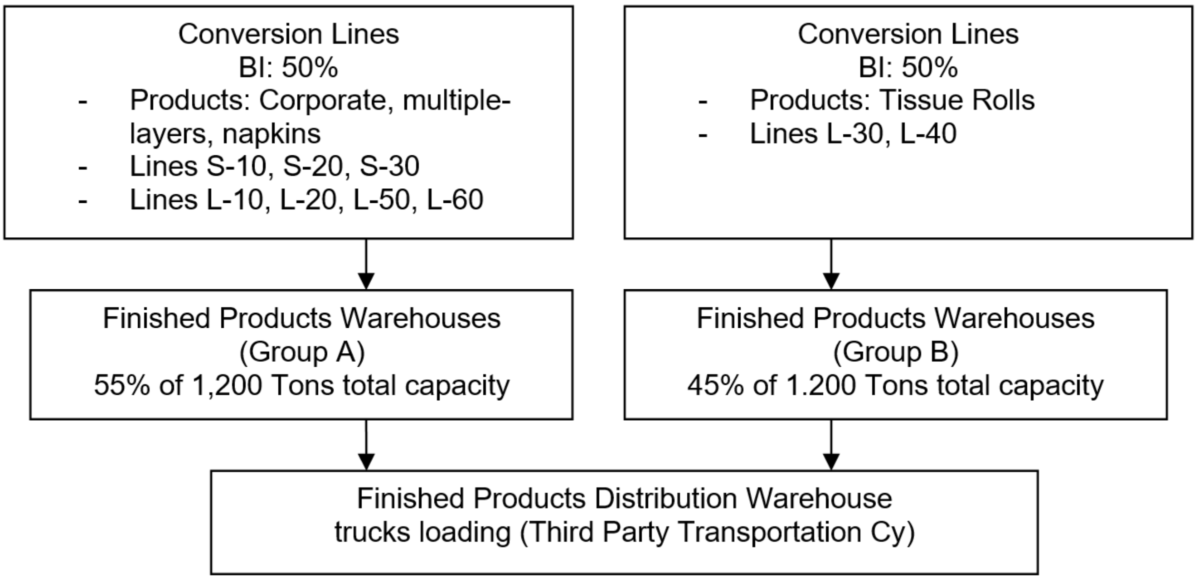
The Conversion of Tissue Paper may be included as a downstream unit in a Paper Processing Plant (converting bleached pulp / recycled paper into tissue paper. See Section 8.2.6).

Raw material consists of tissue paper rolls to be processed in conversion lines.

Conversion line process equipment usually includes numerous pieces of electric-driven equipment such as cutting blades, presses, and trimming and folding systems. There are usually several conversion lines for the same product.

Finished Products include (but are not limited to): kitchen roll towels, multiple layer products such as napkins, tissues with a logo (corporate) and tissue roll Hand Napkin Tissue Paper.

Typical process flow chart:



9.1.2 Conversion of Unbleached Kraft Paper

The Conversion of Unbleached Kraft Paper may be included as a downstream unit in a Paper Processing Plant (converting unbleached pulp / recycled paper into Unbleached Kraft Paper. See Section 8.2.5).

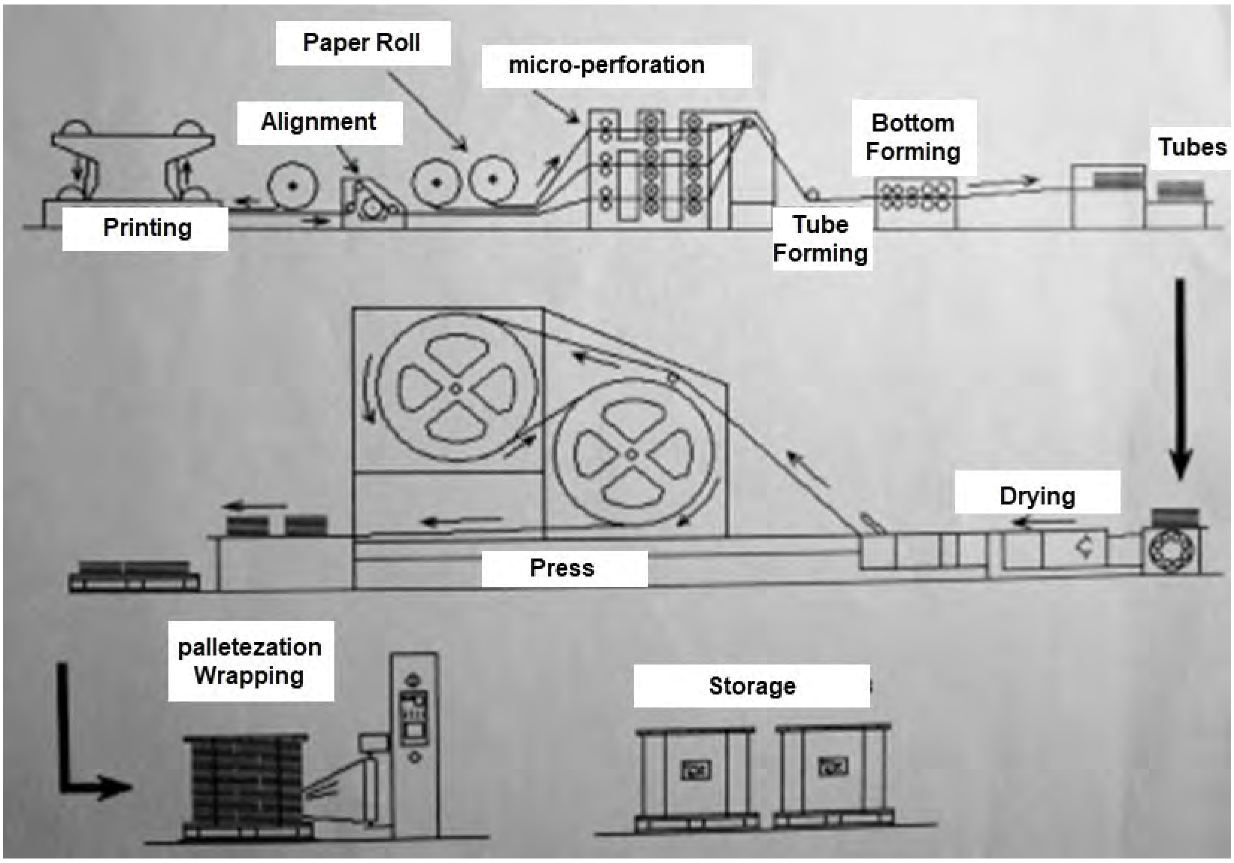
Raw material consists of unbleached Kraft paper rolls to be processed in conversion lines for the manufacture of various products for packaging:

- Paper bags (e.g., for cement products and some food products)
- Corrugated cardboard flats (e.g., cardboard boxes for fresh fruit and salmon to be exported)

The paper bags and cardboard flats may also be printed on site in accordance with customer specifications.

Paper bag manufacturing consists in the following steps within a continuous process line (see also the typical process flow chart below):

- Kraft paper printing (water-based / solvent-based),
- tube forming (starch-based glue),
- bottom forming (starch-based glue),
- drying (hot air flow / direct heating)
- palletization and wrapping.



Corrugated cardboard flats manufacturing includes the following steps within a continuous process line (numbers given by way of example):

- 1 corrugating paper machine (2.5 width, 100 tons/8 hours, steam-heated, electric-driven)
- 6 conversion lines,
- 2 gluing machines,
- 2 batch waxing lines (used for less than 10% of the products)

Corrugated cardboard is made of an inner and an outer liner of paperboard supported by the corrugated board (so called ‘flutes’) in the middle. Corrugated boards are available in a range of different strengths, which are partly determined by the type of flute, as follows:

	F Flute	a very fine flute used for corrugated carton
	E Flute	a fine flute also used for corrugated carton (less rigid than the F flute).
	B Flute	more often, mostly used, its robustness, compression strength and compactness make it a good choice.
	C Flute	larger than B and with greater compression strength, but it is more easily crushed.
	Double Wall	a combination of two flute sizes, often B & C, ideal for compression strength.
	Triple Wall	a combination of different flutes is common when creating these three-walled corrugated boxes. These are mostly used for heavy-duty product shipping.

The flutes are made in a corrugated paper-making machine called a Corrugator: a set of machines in a row, designed to adhere three (a standard board), five or seven sheets of paper that shape single, double or triple-walled corrugated boards.


Corrugator.

The corrugator is a continuous system which produces in bulk, as follows:

- First off, reels of paper are fed into the corrugator, where the paper is conditioned with heat and steam prior to being fed into the single facer.
- The single facer is a section of the corrugator which transforms the paper into a flute by creating a series of arches. These arches are created by large rotating cylinders with a corrugated profile which creates the grooves in the corrugated paper. There are different profiles for each of the flute types previously listed.
- Next, but still included as part of the previous stage, starch is applied to the tips of the flutes on one side, where an inner liner is then affixed to the fluting – this is called a single web.
- The second part of production involves a part of the machine called the Double Backer. The double backer glues the single web to the outer liner following a similar process to the step above. During the process, the product is heated to ensure that the bonds are strong, gelling the glue and removing moisture.

In addition to cardboard, so-called corrugated paper can be manufactured as follows:

- Corrugated paper consists of two types, lined and unlined.
- The lined corrugated paper is a type of tough, layered paper with a fluted layer between one or two outer paper layers.
- The fluted layer can add strength when stacked.
- The unlined one just contains the fluted layer and is elastic.
- Unlined corrugated paper is often used for protecting delicate materials when shipping, or for decoration.

9.1.3 Printing

Printing is a process for mass reproducing text and images using a master form or template.

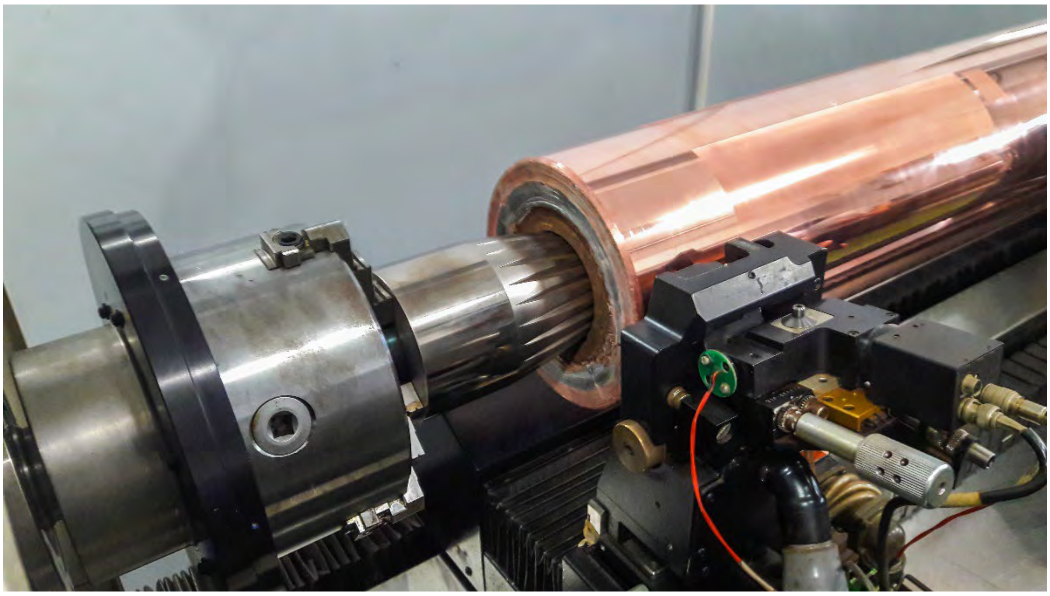
The main equipment involves a rotary printing press in which the images to be printed are curved around a cylinder. Printing can be done on various substrates, including paper, cardboard, and plastic. Substrates can be sheet-feed or unwound on a continuous roll through the press to be printed and further modified, if required (e.g., die cut, overprint varnished, embossed). Printing presses that use continuous rolls are sometimes referred to as "web presses".

There are three main types of rotary presses. Although the three types use cylinders to print, they vary in their method:

- **Offset** (including web offset): in Offset lithography, the image is chemically applied to a plate, generally through exposure of photosensitive layers on the plate material. Offset lithography works on a very simple principle - ink and water do not mix. Images (words and art) are put on plates, which are dampened first by water, then ink. The ink adheres to the image area, the water to the non-image area. Then the image is transferred to a rubber blanket, and from the rubber blanket to paper. That is why the process is called "offset". The image does not go directly to the paper from the plates, as it does in gravure printing. The quality of the final product is often due to the guidance, expertise and equipment provided by the printer.

Offset.

- **Rotogravure**: gravure is a process in which small cells or holes are etched into a copper cylinder, before being filled with ink. All the colors are etched in different angles, so that, while printing, every color is placed in its proper position to give the appropriate image.



Offset. Rotogravure.

- **Flexography**: a relief system in which a raised image is created on a typically polymer-based plate.

Flexography

Modern printing plants include Digital Printing: a method of printing from a digital-based image directly to a variety of media. It usually refers to professional printing where small-run jobs from desktop publishing and other digital sources are printed using large-format and/or high-volume laser or inkjet printers. Digital printing has a higher cost per page than more traditional offset printing methods, but this price is usually offset by avoiding the cost of all the technical steps required to make printing plates.

9.1.4 Molded Fibre Products

Typical finished products include egg cartons (500 million a year), fruit trays (500 million a year) for the food industry and also new trays for medical purposes such as “meditainers”, and kidney bowls (100MM / year). The output numbers are only given as an example for a plant with seven production lines.



Process steps include:

- Raw material storage and handling: pulp, ground wood pulp and baled waste paper. Baled waste paper is often stored in a yard (can exceed 5m in height).
- Pulping: the pulp process is purely mechanical. The paper runs via a small conveyor directly into the pulper (e.g., 3 pulpers for a plant), where the bales are mixed with water and other additives (such as aluminum sulphate, coloring, or paper glue).
- Forming and Drying: the pulp is pumped via pipes to the forming / drying machines (e.g., 7 forming / drying machines in a plant). The pulp is sucked into self-produced forms (usually using a negative pressure of -0.6 to -0.7bar). This occurs in the rotating vacuum-forming drums. The pulp-filled trays then automatically move into the conveyor-fed continuous dryers. The take-off machine is cylindrical in shape and removes the molded products from their molds before dropping them onto the conveyor.
- Finishing lines: from the dryers, molded fiber is transferred to the finishing lines (e.g., 12 finishing lines in a plant). The containers are pressed in hydraulically-operated presses (usually 1 press per line) to achieve the final shape and surface finish (in preparation for painting).
- The finished product is packaged before being transferred to the storage buildings.

9.2 SPECIAL HAZARDS & RISK CONTROL

Special hazards, prevention, protection, and potential mitigation measures are detailed below for each and every special hazard related to this occupancy. (This follows the process flow from Raw Material to Finished Products as closely as possible). Related recommendations are also mentioned. (See “Rec” Section 11: “Support for Loss Prevention Recommendations” for details).

9.2.1 All Facilities

- Flood exposure: Wood Processing and Pulp & Paper industries are usually located near rivers due to the water consumption (process, cooling, domestic use, utilities and firefighting) and for logistic purposes (historically used for the import of Raw Materials / export of Finished Products).
- Wildland fire exposure due to the proximity of forest.
- Earthquake potential (seismic areas) and Tsunami (coastal areas).
- Windstorm and storm surge potential (coastal areas).
- Combustible construction material (e.g., process, storage buildings, so-called “seasonal” or “temporary tents”) & combustible content.
- LPG tanks (for vehicles, process, domestic use).
- High Machinery Breakdown potential.

- Industrial (Process) Control Systems with a relatively high level of automation, including centralized process control. Manual control is reportedly possible for a relatively short period, but the process efficiency and quality of products may be reduced. Moreover, the plant may not be able to produce the full range of products.
- Critical and very expensive spares are usally stored in one or more warehouses. Heavy spares and consumables are usually well separated. The inventory can represent several Milion USD (e.g., $20-40-60-80MM and more). These spares are critical to the process and can have a relatively long lead time. Some consumables used in relatively large quantities and/or having a long lead time are also deemed as critical. A major loss in such a warehouse could lead to BI for the related units due to lack of spares.
- Adequate and reliable fixed-fire detection / protection sytems, manual firefighting equipment and a prompt emergency fire response are key.

<u>Prevention & Protection</u>:

- Flood potential should be carefully investigated. All facilities including critical utilities such as effluent treatment plants should preferably be located outside the flood-exposed area. Adequate physical flood protection should be provided when needed.
- See Section 11: “Wildland Fire Exposure Mitigation”.
- Buildings and structural frames should incorporate an earthquake design allowing to sustain the exposure in the area. Facilities should preferably be built outside tsunami-exposed areas (i.e., distance to seashore, sufficient altitude of terrain above medium sea level).
- Buildings and structural frames should incorporate a wind design allowing to sustain the exposure in the area. Facilities should preferably be built outside storm surge-exposed areas (i.e., distance to seashore, sufficient altitude of terrain above medium sea level).
- Prefer noncombustuble construction material avoiding the use of highly combustible insulation (i.e., plastic-based: PUR, PIR, XPS, EPS).
- So-called “seasonal” or “temporary tents” made of combustible tarpaulin or canvas on a light metal frame should be replaced with sprinkler-protected permanent structures, or should be located in areas not exposing process or storage buildings (at least 40m separating distance or more, depending on building heights).
- All LPG bullet tanks, loading / unloading stations and vaporizers should be protected, as per minimum requirements of FM Global Data Sheets 7-55: “Liquefied Petroleum Gas (LPG) Storage Tanks and Unloading Stations”. (See Section 11: “Support for Loss Prevention Recommendations”).
- Local process control systems should either be duplicated or protected (i.e., PLCs, server rooms). (See Section 11).
- Critical spares should be clearly identified. The commodity class should be clearly established as per NFPA, and the warehouse should be provided with adequate and approved automatic fire detection / protection systems. (See Section 11). Flammable and combustible liquids and spray cans should not be stored in such warehouses but rather stored in a dedicated safe area fitted with the necessary ventilation measures, leak detection & containment. Hazmat and compressed gases should be stored and protected. (See Section 11). Large drivers should be properly stored. (See Section 11).
- Automatic fixed-fire protection systems, fire water supply, manual firefighting equipment and Automatic Fire Alarm systems should be maintained, inspected and tested, in accordance with NFPA25.
- Plant Emergency Organization Plans should be formalized and the First Emergency Team should be regularly trained in order to ensure a prompt response in case of fire.

9.2.2 Conversion of Tissue Paper

- Storage of highly combustible Raw Material (tissue paper rolls), Work-in-Progress Material and Finished Products (soft tissue products).

- LPG, diesel-driven and electric-driven lift trucks are used to carry the semi-finished and finished products.
- Dust and tissue paper waste may accumulate.
- Static discharge may initiate fire.
- Electric shocks may initiate fire.
- Lighting fixtures exposing raw material, Work-in-Progress, and finished products.
- Other ignition sources.
- Local process control systems; conversion lines are usually fully computerized and cannot be manually operated.

Prevention & Protection:

- All storage and process areas should be sprinkler-protected in accordance with international standards (i.e., NFPA13 / FM Global Data Sheets). For information as per NFPA13 Paper and Pulp Mills / Paper process plants occupancy corresponding to Ordinary Hazard Group 2 (OH2), the ceiling sprinkler design is 7mm/min/m² (0.17gpm/ft²) over 279m² (3,000ft²) (hose allowance: 250gpm # 1950LPM, duration 60-90min).
- LPG Lift trucks should be provided with acceptable safeguards. (See Section 11).
- Lift truck battery charging areas should be arranged. (See Section 11).
- Adequate dust removal systems should be provided as per FM Global Data Sheets 7-73: “Dust Collectors and Collection Systems” and adequate protection should be provided. (See Section 11: “Dust Sprinkler Protection”).
- Housekeeping is key, including routine inspections preventing the accumulation of waste material.
- All buildings and equipment should be adequately grounded.
- Proper maintenance and inspections of electrical equipment (e.g., including infra-red scanning) should be enforced in order to ensure electrical integrity.

- Lighting fixtures should be arranged. (See Section 11).
- Ignition source controsl should be established (e.g., Hot Work permits, strictly enforced non-smoking policies, friction, etc.)
- Local process control systems should either be duplicated or protected (i.e., PLCs, server rooms). (See Section 11).

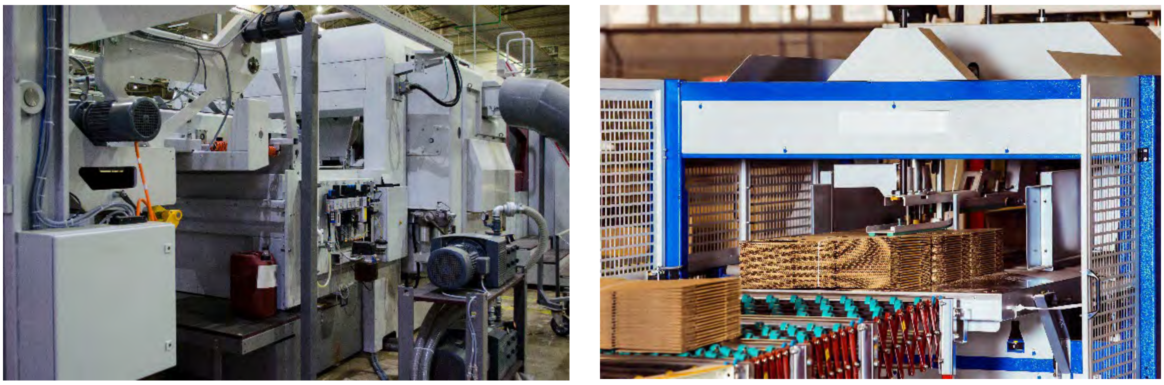
9.2.3 Conversion of Unbleached Kraft Paper

- Storage of highly combustible Raw Material (Kraft paper rolls), Work-in-Progress Material, and Finished Products (bags, cardboard flats).

Kraft paper rolls

Cardboard flats

- LPG, diesel-driven and electric-driven lift trucks are used to carry the semi-finished and finished products.
- For bag manufacturing:
  - Kraft paper printing (printing “plates” are usually made from metal, plastic, rubber, paper, and other materials. Ink may be solvent-based or water-based)
  - Tube and bottom forming
  - Drying (from 30°C hot air flow). The drying process could usually be done without the drying step but it would take 15 days
- For Cardboard manufacturing:
  - Corrugating paper machines – steam-heated, electric-driven
  - Gluing machines
  - Batch waxing lines (if any)
  - Printing (if any) - (printing “plates” are usually made from metal, plastic, rubber, paper, and other materials. Ink may be solvent-based or water-based)



Corrugated board production

- Dust and waste may accumulate
- Static discharge may initiate fire
- Electric shocks may initiate fire

- Lighting fixtures exposing Raw Material, Work-in-Progress and Finished Products
- Other ignition sources
- Local process control systems; corrugating machines and conversion lines are fully computerized and cannot be manually operated

Prevention & Protection:

- All storage and process areas should be sprinkler-protected in accordance with international standards (i.e., NFPA13 / FM Global Data Sheets). For information as per NFPA13 Paper and Pulp Mills / Paper process plants occupancy corresponding to Ordinary Hazard Group 2 (OH2), the ceiling sprinkler design is 7mm/min/m² (0.17gpm/ft²) over 279m² (3,000ft²) (hose allowance: 250gpm # 1950LPM, duration 60-90min).
- LPG Lift trucks should be provided with acceptable safeguards. (See Section 11).
- Lift truck battery charging areas should be arranged. (See Section 11).
- For bag manufacturing:
  - Prefer water-based inks or use hazmat protection. (See Section 11). Ensure printing plates are located in a sprinkler-protected area AND that printing plates can be replaced in reasonable time in case of a loss.
  - Pefer water-based glue for forming. When starch-based glue is used, proper explosion vents on silos and adequate grounding and bounding should be provided for preventing static discharge and ignition.
  - Avoid direct firing for drying. Prefer a hot-air flow produced through a heat exchanger. Hot air is usually generated in a primary loop outside the building by an LPG-fired burner and air blower.
- For cardboard manufacturing:
  - Steam boiler fuel lines should be provided with adequate safety combustion controls. (See Section 11).
  - Pefer water-based glue for forming. When starch-based glue is used, proper explosion vents on silos and adequate grounding and bounding should be provided for preventing static discharge and ignition.
  - Adequate fixed-fire protection systems should be provided for the wax machine area and supply, as per NFPA.
  - Prefer water-based inks or use hazmat protection. (See Section 11). Ensure printing plates are located in a sprinkler-protected area AND that printing plates can be replaced in reasonable time in case of a loss.
- Adequate dust removal systems should be provided (when needed) as per FM Global Data Sheets 7-73: “Dust Collectors and Collection Systems” and adequate protection should be provided. (See Section 11: “Dust Sprinkler Protection”).
- Housekeeping is key, including routine inspections to prevent the accumulation of waste material.
- All buildings and equipment should be adequately grounded.
- Proper maintenance and inspections of electrical equipment (e.g., including infra-red scanning) should be enforced in order to ensure electrical integrity.
- Lighting fixtures should be arranged. (See Section 11).
- Ignition source controls should be established (e.g., Hot Work permits, strictly enforced non-smoking policies, friction, etc.).
- Local process control systems should either be duplicated or protected (i.e., PLCs, server rooms). (See Section 11).

9.2.4 Printing

- Storage of highly combustible Raw Material (paper rolls), flammable / combustible ink, Work-in-Progress Material and Finished Products (printed paper).
- LPG, diesel-driven and electric-driven lift trucks are used to carry the semi-finished and finished products.
- Fire hazards inside a printing press are related to:
  - media being printed (paper, plastic film, printing “plates” are usually made from metal, plastic, rubber, paper, and other materials)
  - inks/solvents, (ink may be solvent-based - thus an ignitable liquid - or water-based)
  - paste inks (flowing under pressure. Flashpoints > 93°C (200°F)
  - hydraulic systems
  - heat transfer fluid (HTF) systems
  - pneumatic systems (plant air)
  - electrical wiring,
  - potential combustible deposits created by dust and ink residue
- Explosion hazards inside a printing plant are related to:
  - Ovens drying ignitable inks or solvents
  - Direct-fired ovens
  - Press operations involving or generating combustible dust (e.g., printing, cutting, slitting, folding)
  - Operations collecting combustible dust (e.g., dust collectors, cyclones)
  - Part-washing operations
  - Solvent recovery (e.g., solvent recovery stills, carbon bed absorbers, thermal oxidizers)
  - Ignitable ink-mixing operations
- Most printing equipment operates at high speed and produces high-quality printed products. The equipment is complicated and requires precise tolerances. Ceiling-level automatic sprinklers protect the building envelope against the collection of fire hazards. However, ceiling sprinklers alone will not necessarily protect the equipment from the high temperatures and non-thermal damage associated with a fire. It is therefore necessary to eliminate / minimize potential exposures to the printing equipment and provide local area protection within the equipment.
- Typical printing plants include (see design and layout below):
  - Bulk storage of ink
  - Ink mixing and pumping room
  - Ink pumping system
  - Printing presses
  - Washer Regenerative Thermal Oxidizers and solvent-recovery systems (usually needed for rotogravure and flexographic presses) presenting a fire and explosion hazard

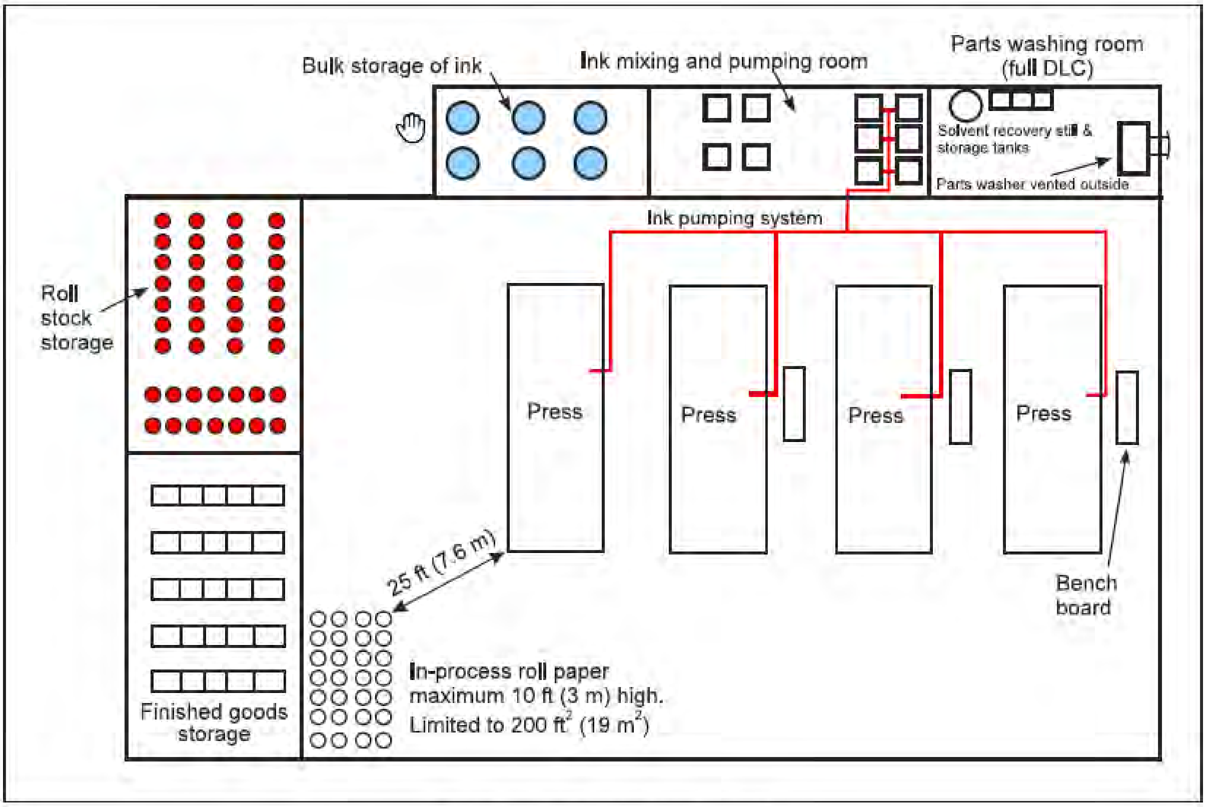


Fig. 1. Press room design and layout

Source. FM Global's Property Loss Prevention Data Sheet 7-96: Printing Plants (Interim Revisions 10/19). Posted and reprinted with permission of FM Global. ©2010-2019 Factory Mutual Insurance Company. All rights reserved.

- Heat Transfer Fluid systems may be used for paste inks
- Hydraulic systems and plant air systems may be provided on some printing presses for controlling rollers on the press. A press fire involving its hydraulic oil system will severely damage the press regardless of the system size. A press fire that is fanned by the release of compressed air will burn hotter (increased damage)
- Dust and waste may accumulate
- Static discharge may initiate fire
- Electric shocks may initiate fire
- Lighting fixtures exposing Raw Material, Work-in-Progress and Finished Products.
- Other ignition sources
- Local process control systems; printing presses are fully computerized (embedded systems) and cannot be manually operated

Prevention & Protection:

- All storage areas (Raw Material, Packaging, Finished Products) should be sprinkler - protected, as per NFPA13 or FM Global Data Sheets.
- LPG Lift trucks should be provided with acceptable safeguards. (See Section 11).
- Lift truck battery charging areas should be arranged. (See Section 11).
- Separate the bulk storage of roll stock from the pressroom and from other production areas with a one-hour fire wall.
- Prefer water-based ink. Cut off ignitable ink and paste ink operations (e.g., storage, mixing, part washers, solvent recovery,etc.) from other areas of the facility (e.g., press hall, roll paper storage, finished goods storage). Arrange and protect in accordance with Data Sheets 7-32: "Ignitable Liquid Operations"; 7-29: "Ignitable Liquid Storage in Portable Containers"; 7-2:

"Waste Solvent Recovery"; 7-88: "Ignitable Liquid Storage Tanks". (See also Section 11: "Hazmat Storage").

- Paste ink supply should be arranged as per FM Global Data Sheets 7.96. Automatic sprinkler protection will be effective on a pool fire.
- Heat Transfer Fluid (HTF) systems should be arranged and protected. (See Section 11).
- Hydraulic systems should be protected. (See Section 11). Interlock all hydraulic oil systems, (regardless of size) and plant air systems to shut down in the event of a fire. Where possible, preferably use FM-approved hydraulic fluids.
- Part washers, Regenerative Thermal Oxidizers and solvent recovery systems (e.g., exhaust systems for rotogravure presses) should be designed and arranged in accordance with Data Sheet 6-9: "Ovens and Dryers", 6-11: "Thermal and Regenerative Catalytic Oxidizers", 7-2: "Waste Solvent Recovery", and Data Sheet 7-32: "Ignitable Liquid Operations".
- Limit quantities of ignitable ink and solvent to 265L (70gal) in each fire area. Define a fire area by determining a separation distance that would prevent a spill from the largest container in one area from exposing containers in the next area. FM-approved flammable liquid cabinets can be used. Use FM-approved safety cans inside the room.
- All process areas (press rooms) and in-process storage should be sprinkler protected in accordance with FM Global Data Sheets 7-96: "Printing Plants", section 2.3.1.2 /3. For information, here are the design densities for ceiling sprinklers as per:
  - NFPA 13:
    - For Printing [using inks with flashpoints below 100°F (38°C)], occupancy corresponding to Extra Hazard Group 1 (EH1): 11mm/min/m² (0.28gpm/ft²) over 279m² (3,000ft²) (hose allowance: 500gpm # 1900LPM, duration 90-120min).
    - For Printing and Publishing / Paper process plants, occupancy corresponding to Ordinary Hazard Group 2 (OH2): 7mm/min/m² (0.17gpm/ft²) over 279m² (3,000ft²) (hose allowance: 250gpm # 1950LPM, duration 60-90min).
  - FM Global Data Sheets 7-96, section 2.3.1.2:
    - A. Design ceiling sprinkler protection for press rooms with no in-process storage to provide a 12 mm/min/m² (0.30 gpm/ft²) over 279m² (3,000ft²) using 74°C (165°F), quick-response sprinklers.
    - B. Design ceiling sprinkler protection for press rooms with limited quantities of in-process storage as described in Sections 2.1.2(B), 2.1.2(C), and 2.2.2 to provide a 12 mm/min/m² (0.30gpm/ft) over 279m² (3,000ft²) using 141°C (286°F) sprinklers.
- Adequate dust removal systems should be provided (when needed) as per FM Global Data Sheets 7-73: "Dust Collectors and Collection Systems" and adequate protection should be provided. (See Section 11: "Dust Sprinkler Protection"). Ventilation and exhaust systems are also used to control the accumulation of flammable vapors/gases or combustible dust (explosion potential) during normal operations.
- Interlock the following press systems to automatically shut down upon activation of a fire protection system:
  - Ink, solvent, thinner, and blanket wash pumping systems
  - Vacuum systems
  - Hydraulic oil systems
  - Lube oil systems
  - Pneumatic systems
- Provide local protection on the following presses as per FM Global Data Sheets 7-96. Printing Plants:
  - Lithograph – Newspaper Press: Section 2.3.2
  - Lithograph Non-Newspaper Press: Section 2.3.3
  - Rotogravure and Flexograph Press: Section 2.3.4.

- Digital Press: Section 2.3.5.
- Note that the the best way to protect a printing press is to use an automatic water spray system with heat detection located over the individual printing units. (This is an expensive approach, local protection is therefore preferred).

- Provide automatic sprinkler protection within and under sound enclosures. Provide a density of 8 mm/min/m² (0.20 gpm/ft²) over and under the area of the enclosure up to 279m² (3,000ft²).
- Ensure printing plates are located in a sprinkler-protected area AND that printing plates can be replaced in reasonable time in case of a loss.
- Housekeeping is key, including routine inspections for avoiding the accumulation of waste material and dust.
- Adequate maintenance and inspection of all individual equipment is key.
- All buildings and equipment should be adequately grounded.
- Intrinsically safe electrics should be provided in areas with flammable gases or combustible dust.
- Proper maintenance and inspections of electric equipment (e.g., including infra-red scanning) should be enforced in order to ensure electrical integrity.
- Lighting fixtures should be arranged. (See Section 11).
- Ignition source controls should be established (e.g., Hot Work permits, strictly enforced non-smoking policies, friction, etc.).
- Spare parts for local process control systems should be provided and/or protected. (See Section 11).

9.2.5 Molded Fibre Products

- Storage of highly combustible Raw Material (recycled paper bales), Work-in-Progress Material and Finished Products (Molded Fiber Products).
- LPG, diesel-driven and electric-driven lift trucks are used to carry the semi-finished and finished products.
- Pulping: bales are mixed with water and some additives (may include flammable coloring / glue or paraffin).
- Drying machines (continuous): the molded fiber drying ovens may have different zones, of which some may be directly gas-fired. The dryers are usually of the air re-circulating type. Temperatures range between 200°C and 280°C. The top section near the inlet is the hottest and the bottom section near the outlet is the coolest, with temperatures <200°C. The product may pass through twice. The combustible load inside the dryers is usually relatively limited (depending on the type of dryer) and consists mostly of the products themselves (e.g., a 2.5 m weight conveyor with one or two product layers depending on the line).
- The take-off machine is usually cylindrical in shape and removes the molded products from their molds before dropping the mold onto the conveyer. The ends of the cylinder are closed, thus forming an enclosure with the grease-lubricated mechanism inside. The take-off machine is usually powered by a gear transmission from the forming machine electric drive. The take-off cylinder is hot due to its close proximity to the dryer and conveyor chain.
- Finishing lines house hydraulically-operated presses that achieve the final shape and surface finish (preparation for painting): hydraulic fluid is usually mineral oil. The units are located in pits below the presses. The maximum capacity of each hydraulic unit can exceed 380L (100 gal).
- Cooling towers for hydraulic presses.
- Flammable paints may be used at the finishing line.
- Finished products may include hot spots.

- The finished product is packaged before being transferred to the storage buildings. The products are mostly palletized, shrink wrapped, piled and stored.
- Dust paper waste may accumulate.
- Static discharge may initiate fire.
- Electric shocks may initiate fire.
- Lighting fixtures exposing Raw Material, Work-in-Progress and Finished Products.
- Other ignition sources.

Prevention & Protection:

- Yard storage: provide a minimum separating distance (at least 40m or more depending on building heights) between warehousing / yard storage and other critical buildings, or provide at least a 2-h fire-rated partition. Baled waste should preferably be stored on blocks separated by an adequate distance.
- Provide adequate manual firefighting protection, including remotely operated monitors on towers for recycled paper yard storage.
- All storage and process areas should be sprinkler protected in accordance with international standards (i.e., NFPA13 / FM Global Data Sheets). For information as per NFPA13: “Paper and Pulp mills / Paper process plants”, occupancy corresponding to Ordinary Hazard Group 2 (OH2), the ceiling sprinkler design is 7mm/min/m² (0.17gpm/ft²) over 279m² (3,000ft²) (hose allowance: 250gpm # 1950LPM, duration 60-90min).
- Lift truck battery charging areas should be arranged. (See Section 11).
- Prefer noncombustible additives / colors / glue (i.e., water-based).
- Prefer non-direct gas-fired dryers. Adequate safety combustion controls should be provided for the gas-fired systems. (See Section 11). Dryers should be provided with a means of removing the Work-in-Progress material in case of an interruption in the continuous process so that the material is not overheated and ignited.
- Local protection consisting of automatic sprinkler systems should be installed above the area of the take-off machine where grease and combustibles can accumulate when not covered by the ceiling sprinkler sytem (i.e., shadow effect, obstruction, excess of clearance).
- All hydraulic presses and their hydraulic systems should be protected. (See Section 11).
- The inlet and outlet of the oven should be equipped with spray nozzles in the dryer outlets and exhaust ducts. Automatically-activated spray nozzles are preferred. Manual actuation only is acceptable but less reliable. In such cases, operators should be instructed and trained to shut down the oven promptly upon recognizing fire in the oven or associated equipment. They must also be trained to extinguish incipient fires with fire extinguishers and small hoses and fixed manual spray systems that are installed. Flame arrestors should be installed in the exhaust pipes leading out of the dryers.
- Finishing lines: prefer noncombustible paint (e.g., water-based).
- Cooling towers should be protected. (See Section 11).
- The finished products should be checked for hot spots (e.g., air sampling detection systems) and placed in a quarantine unit for at least two hours (e.g., fire separated by concrete walls on three sides and roof with smoke detectors and sprinklers).
- Adequate dust removal systems should be provided as per FM Global Data Sheets 7-73: “Dust Collectors and Collection Systems” and adequate protection should be provided. (See Section 11:”Dust Sprinkler Protection”).
- Housekeeping is key, including routine inspections for avoiding the accumulation of waste material.
- All buildings and equipment should be adequately grounded.

- Proper maintenance and inspections of electric equipment (e.g., including infra-red scanning) should be enforced in order to ensure electrical integrity.
- Lighting fixtures should be arranged. (See Section 11).
- Ignition source controls should be established (e.g., Hot Work permits, strictly enforced non-smoking policies, friction, etc.).

9.2.6 Critical Utilities

Biomass Boiler:

- Biomass fuel warehouse: cellulosic waste is stored in a detached warehouse linked to the boiler house plant through a protected rubber belt conveyor network (e.g., may be underground and/or overhead) running from the bottom of the warehouse to the top of the boiler house. Biomass is used as the main fuel for the boiler.
- Fuel oil tank: fuel oil is used for the pilot line.
- Propane bullet tank (LPG): propane is used for ignition of the pilot line.
- Fume treatment (e.g., Electrostatic Precipitator including transformers).
- Rubber belt conveyors.

Prevention & Protection:

- Adequate separation with other facilities should be provided. As with waste burners, biomass thermal power plants should be located as far as practically possible from yard storage and important buildings of combustible construction. A separation of 120m (400ft) is desirable.
- Fuel oil tank: above ground tanks should be installed on dikes about 50m from the Thermal Plant. In case of mutual exposures between tanks, the fuel tanks should be protected. (See Section 11: “Ignitable Liquid Storage Tanks”).
- All LPG bullet tanks, loading / unloading stations and vaporizers should be protected as per minimum requirements of FM Global Data Sheets 7-55: “Liquefied Petroleum Gas (LPG) Storage Tanks and Unloading Stations”. (Summarized in Section 11: “Support for Loss Prevention Recommendations”).
- Biomass steam boilers should be provided with adequate safety combustion controls (i.e., fuel lines for ignition, gas and fuel oil). (See Section 11).
- Electrostatic Precipitator: once a fire is detected, the unit should go into emergency shutdown immediately. It should be recognized that during operations the atmosphere in the precipitator is oxygen-deficient and opening doors or running system fans following a fuel trip could cause conditions to worsen (increased potential for backdraft explosion). Once the flow of air and fuel to the fire has been stopped and the electrostatic precipitator has been shut down and deenergized, the precipitator doors may be opened again and water hoses deployed, if necessary. (See NFPA850).
- The Electrostatic Precipitator’s transformer should be protected. (See Section 11).
- Rubber belt conveyors should be protected. (See Section 11).

Electric Power:

- Electric power is usually supplied from the grid (when independent from any complex).
- Steam Turbine generators may also be provided (see “Biomass Boiler” above for steam generation). In such cases, Biomass Boilers and Steam Turbine Generator(s) are part of a so-called Thermal Power Plant. The steam produced at the Thermal Power Plant is primarily used for the process. Excess steam is used to produce electric power to be used by the processing plant(s) and/or sold to the grid (e.g., excess electric power is sold to the grid, generating revenue).

- Main substations include oil-filled transformers, switch gear, distribution boards, and cable trays.
- An Emergency Power Supply should be provided, consisting of an Uninterruptible Power System - UPS (batteries) -and Diesel Engine-Driven Generator. This would be used for emergency shutdowns (i.e., removal of Work-in-Progress material inside equipment, maintaining lubrication systems of process equipment, circulation of thermal hot oil systems (if any), and emergency lighting).

Prevention & Protection:

- Multiple electric feeders on different pylons fed from different grid substations and supplying the plant (or the complex on a loop basis) are preferred.
- Protect Steam Turbine Generators (if any). (See Section 11).
- Transformers, electric rooms, including cable trays and cable openings, should be protected. (See Section 11).
- Emergency Diesel Engine-Driven Generators (DEDG) should be tested once a week and run for 30 minutes in order to ensure reliability (for detection of electric failure and cooling issues), ensuring lubrication. UPS and DEDGs should be protected. (See Section 11: "Stationary Combustion Engine" and "Battery Rooms").

Process Water:

- Water used for process, domestic, utilities (e.g., cooling, steam boilers) is usually obtained from the grid, nearest river and/or from wells (electric-driven pumps). Water is treated according to its intended use (boiler, drinking water, process, firefighting).

Prevention & Protection:

- Water intake (if any) should be regularly inspected. Any kind of potential contamination should be investigated (e.g., an upstream occupancy releasing liquid or solid material). A routine should be established for removing debris (e.g., trees, rocks) after heavy rain and storms. Regular analysis of the raw water should be carried out ensuring that it can be treated according to the intended use. The electric-driven pumps of the water supply should be powered from both the normal power supply and the emergency power supply. A buffer storage should be maintained on site providing several hours production capacity (usually up to 1 day).

Cooling Water:

- Cooling Towers for Steam Turbine Generators (if any).

Prevention & Protection:

- When critical, cooling towers should be protected. (See Section 11).

9.2.7 Import / Export Facilities

See Section 2.2: Interdependences, BI, CBI(CTE), SI – point F. "Major Loss impacting the Import / Export facilities".

9.3 CONTINGENCY / BUSINESS CONTINUITY / RECOVERY PLAN

Warning: in order to be reliable, a Contingency / Business Continuity / Recovery Plan should be formalized. This would include formal contracts signed in advance with vendors and/or third parties. The plan should be regularly tested, reviewed and updated.

Holistic view:

- If the Paper Working Plant is part of a group with a relatively high level of vertical integration in the Wood Processing and Pulp & Paper industry, a Business Continuity Plan (BCP) at corporate level should be developed for the main identified risks in each and every process unit.
- The impact of a loss impacting third parties (i.e., logistics, utilities) should be investigated and an adequate BCP should be established.

Site view:

- A BCP (disaster recovery plan) should be established in case of a total loss of plant (i.e., fire, wildfire, flood).
- Water is critical for tissue paper and Kraft paper working plants, domestic uses and firefighting. Ensure there are multiple sources when possible, as well as backups, buffer storage on site (usually around 6 hours) and a Contingency Plan consisting of water delivery by truck when possible.
- Steam is critical for tissue paper and Kraft paper working plants. Full backup, including an alternate steam supply (i.e., independent back-up steam boilers) would provide adequate duplication.
- Electrical power either from the grid or generated on site (i.e., complex) is critical. Full backup from the grid, avoiding bottlenecks (i.e., feeders, substations) would provide adequate duplication and reliability. This should include an Automatic Transfer Switch –ATS- thus avoiding blackouts.
- A Contingency Plan should be developed in case of a loss of the critical cooling tower for effluents (if any).

9.4 LOSS HISTORY

Loss records of Paper Working Plants indicate that the major losses are due to fire, as summarized below:

- Fire in the warehouse involving Raw Material and/or Finished Products.
- Tissue paper & Kraft paper plants:
  - Poor housekeeping and accumulations of dust and paper waste around and under equipment.
  - Contact between tissue paper waste and dust with hot surfaces.
  - Improper maintenance and poor electrical integrity (damaged equipment, loose connections) resulting in short circuits, arcing and static discharge.
  - Rupture of hydraulic, lubricating or HTF pipes, or leakage at the level of a valve or flange.
  - Non-controlled hot work; cigarette butts carelessly dropped; lighting fixtures without adequate cover allowing glass fragments to fall onto Work-in-Progress material.
  - Note that damages to the conversion equipment are aggravated in the absence of automatic sprinklers.
- Printing Plants:
  - Major fires involving flammable ink
  - Heat transfer fluid (HTF) system leakages
  - Fire and explosion leading to the total loss of facilities especially in the case of combustible construction.

Examples of losses reported:

Fire in a cardboard factory:
PD: USD30MM (about 1/3 of TSI PD)

BI: USD5MM (about 2 months at 100% and 50% for several months)

Raw Material basically consisted of recycled paper; finished products consisted of corrugated cardboard to be used for export and domestic purposes (supplying about 30% of the national cardboard demand). The plant operated 24/7. There was no fixed fire protection installed. Only an Automatic Fire Alarm (smoke detectors) and CCTV in warehouses and offices were provided.

The fire presumably started in the yard storage before spreading to the Raw Material (RM) warehouses. A total of 3 RM (i.e., Kraft paper roll) warehouses and one adjacent building housing printing lines were totally destroyed (buildings and contents). Potential damages to process equipment and utilities would have to be investigated.

The fire was controlled and extinguished by the Public Fire Department.

Fire inside rolled tissue (Raw Material) paper warehouse:
PD: USD9MM of which 5MM for building and 4MM for content

BI: None reported. Only extra costs.

Total loss of the warehouse (4,500sqm 26m high, 3,700ton of tissue paper, PE wrapped, considered as Work-in-Progress material representing 15 days of production, with up to 5 jumbo rolls stored up to 12.5m high).

The building was made of a Heavy Noncombustible construction type (5cm thick pre-stressed concrete panels, roof on pre-stressed concrete beams on concrete columns, with non-bearing concrete walls and metal cladding at 1/2 of the wall height joining the roof). The building was sprinkler protected. However, the fire protection was impaired due to leakage (internal bacteria corrosion of piping). The design of the protection was reportedly 0.75GPM @ 3,000sqm, standard sprinkler.

The fire scene was filmed on the inside by a CCTV. It was reported that about 20 seconds after ignition, the fire spread all over the storage and some 40 seconds later, the roof collapsed. The fire was detected by an automatic fire alarm (late detection reported). Some 30 Fire Brigades went on site using 10,000 LPM specifically in order to cool down the surrounding buildings located 15-20m from the warehouse on fire. The canopies (made of noncombustible material) linking this warehouse with the other buildings collapsed. There was a total loss of the warehouse (building and content). Deep burning ashes were reported up to 70 days after the loss.

The most likely cause reported by the plant for ignition was arson (an empty LPG cylinder was reportedly found). However, this was not confirmed, and is being investigated by authorities.

In order to mitigate the loss (BI), tissue paper was purchased on the market, stored in a rented remote warehouse and transported on site for conversion (extra cost).

Note concerning the sprinkler protection: considering NFPA, the existing sprinkler protection was apparently designed to protect the storage of tissue paper up to a maximum height of 7.5m. As a result, this sprinkler protection would have been overtaxed resulting in a total loss. This warehouse was therefore not adequately protected. (Large drop or ESFR protection would have been required).

Machinery Breakdown (Paper Machine for Tissue):
PD: USD500k

No BI reported

The paper machine represented 60% of tissue paper production. Cracks were noticed on the hot press roll - cause unknown. The hot press was originally manufactured in the US (no longer manufactured). Shortest delivery time was 5 months. However, 3 spares were available at the plant and the damaged hot press was rapidly replaced. In the meantime, tissue paper was purchased on the market (extra cost). This mitigated BI.

Circumstances of the loss: restart about 3 hours after the unplanned power outage. Strong vibrations were noticed, at which time the drying press was not pressed against the Yankee dryer. The paper machine was shut down and visually inspected revealing no anomaly. The paper machine was restarted and operated at low speed pressing against the Yankee. Vibration persisted. It was decided that the bearing replacement was the cause of the vibration. When dismantling the press, it was noticed that the superficial rubber of the roller had a perimeter crack and premature damage to the rubber. The press had reportedly been recently overhauled. Further investigation the day after showed cracks on the skirt of the roller which were consistent with the cracks noticed on the superficial rubber.

Machinery Breakdown (Kraft paper bag manufacturing):
Machinery Breakdown involving the tube-forming line (roll bolster failure)
PD paid by manufacturer
BI: around 15 days

Fire in the recycled paper yard storage due to friction of equipment:
Loss of 2,000 tons of Raw Material
The fire was manually extinguished
PD reportedly limited
No BI reported

Fire in the recycled paper yard storage due to hot work:
The fire was extinguished manually
PD reportedly limited
No BI reported

Fire starting outside on the canopy of the Paper Machine due to ignition of paper dust accumulated and ignited by the electric driver of an air extractor:
PD reportedly limited
No BI reported
This was reportedly a design and management issue. The canopy was removed and assignment and duty for maintenance and housekeeping were defined.

Steam flash tank rupture:
PD: USD700k
No BI reported
8-10-year-old steam flash tank rupture at lower pressure than the pressure safety valve rating. Design issue reported. The rupture point was outside the welding area. The steam system was replaced with a new system without a flash tank.

Wax tank fire resulting in full destruction of 2 cardboard waxing machines:
PD#USD1MM
No BI reported
The fire was extinguished by plant employees using Hose Reels.

Fire in a Motor Control Center (MCC) Room of the tissue paper machine:
PD: no data
BI: 5 days
Dry-type breaker failure and fire. Smoke detection was activated and the fire was manually extinguished. Three breaker cabinets were lost. (Projections could be seen on the polyurethane sandwich panel located in front). The original breaker manufacturer was not able to provide spare parts immediately. As a result, the damaged cabinets were replaced with cabinets from another supplier. At the time of the loss, CO_2 fire protection was installed in the cable vault below the cabinets. However, this system was manually activated.

Subsequent preventive action was taken: drivers were interlocked with temperature sensors in order to stop automatically. Moreover, $C0_2$ fire protection discharging inside cabinets and automatically activated with an air sampling detection system was installed. The existing CO_2 system installed inside the cable vault was subsequently arranged so that it is now automatically activated upon smoke detection.

Fire in a Motor Control Center (MCC) Room of the tissue paper machine:
PD: USD3MM
BI: 3 months for the paper machine-related unit, but mitigated (extra cost)

MCC room of tissue paper machine: failure of insulation on cable, short circuit and fire resulting in the total loss of the MCC room. IR scanning was conducted on the room prior to the loss. However, these cables were not accessible (situated below the cabinet). The BI loss was mitigated by purchasing tissue paper on the market (extra costs).

Fire in a Warehouse B2 housing Jumbo Rolls (WIP materials) and Finished Products:
PD: USD3
BI, none, Extra Expenses: USD300k
The building was typically noncombustible made of a cement fiber roof on metal trusses on concrete beams on concrete columns with metal sheet walls. The fire occurred at night time; 4 hours manual firefighting; total loss of the warehouse; no damages to adjacent and attached buildings. The most likely cause was arson.

Fire in a Finished Products Warehouse and Palletization area:
PD: USD700k
Extra Expenses: USD100k
No BI
Fire and total loss of a Finished Products Warehouse and palletization area: light noncombustible construction without insulation; housing of tissue paper rolls was in solid piles, palletized PE wrapping up to 5m high. The cause of the fire is unknown. The most likely cause was arson. At the time of the loss, there was no fire detection nor supervision of the buildings.

Fire in a Molded Fiber Product Plant:
This plant produces egg cartons, fruit trays for the food industry and trays for medical purposes.
2006: Fire in the Finished Products warehouse resulted in a total loss despite sprinkler protection. The most likely cause was reportedly a smoldering fire involving recently processed Finished Products (hot spot due to drying process in gas-fired oven). The reason why the sprinklered protection was not able to control the fire is still unknown. No design issues were reported. Faulty operations when firefighters went on site could be the cause but could NOT BE CONFIRMED. The warehouse was demolished and replaced by a tent made of combustible canvas (automatic fire alarm provided and fire partition provided with the rest of the site).
2009: fire involving the yard storage where Raw Materials – bales of recycled paper – were stored.
The fire was controlled and extinguished manually by the firefighters. 50% of the Raw Material yard storage was lost. No damages were reported to other facilities.

9.5 LOSS ESTIMATES

Maximum Possible Loss (Technical MPL):

- Major EQ in zone 3 or 4 impacting all facilities: 35% PD for zone 3, at least 50% for Zone 4, and 18 months BI.
- Tsunami, storm surge in coastal areas (see MPL Handbook).
- Wildfire impacting the facility or involving flying ambers starting multiple fires on a complex (see MPL Handbook).
- Major fire inside the warehouse or process areas spreading to all adjacent areas. This could lead to the total loss of the plant depending on its arrangement.
- Induced BI should be considered if there are any interdependencies with sister plants downstream. This could be mitigated by buffer storage (providing several extra days of production) and an alternate supplier (if any).

Normal Loss Expectancy (NLE):

- Fire resulting in the same magnitude as for MPL when neither adequate nor approved automatic fire protection is provided. Total loss of facilities should not be excluded depending on congestion, combustible load, and continuity of combustible. When adequate fixed fire protection is provided, consider the loss equivalent to the surface of application for the contents only (the building is not damaged).

- Major Machinery Breakdown or fire damaging the corrugator (cardboard flats plant). This could result in a relatively long BI (8-18 months) depending on availability.
- Fire involving an electric room (e.g., cable vault) resulting in 4 months BI.
- Explosion and fire of a critical transformer supplying the plant. Up to 18 months replacement time.
- Fire on a critical hydraulic group resulting in at least 4 months BI.
- Fire on a critical cooling tower (i.e., Steam Turbine Generator - if any) resulting in 4 months BI when critical.
- Induced BI should be considered if there are any interdependencies with sister plants downstream. This could be mitigated by buffer storage (providing several extra days of production) and an alternate supplier (if any).

10 OTHER CELLULOSE-BASED PRODUCT PROCESSING FACILITIES

10.1 PROCESS

There are many different cellulose-based products available on the consumer market. All these products are based on fluff pulp which was first developed for use in disposable sanitary napkins. First advertisements for products made with wood pulp (Cellucotton) appeared in 1921.

The intention of this section is not to address all cellulose-based products but to summarize the manufacture of two major disposable sanitary products:

- Diapers
- Menstrual pads

Disposable diaper producers were also early to convert to fluff pulp because of its low cost and high absorbency. Normal usage of fluff pulp in a diaper was about 55%. In the 1980s, the commercialization of air-laid paper began, which gave better bulk, porosity, strength, softness, and water absorption properties compared with standard tissue paper. Also in the 1980s, the use of super-absorbents in diapers began, reducing the need for fluff pulp which is now down to 15 grams or even less. The requirement of pulp in diapers has gone from being a liquid absorbent to giving the products dry and wet strength.

Raw Material for diapers consists of a total of 17 “ingredients” of which:

- Cellulose FLUFF rolls
- Adhesives
- Elastic straps
- Labels
- Super-absorbent polymers

Diaper process steps:

- FLUFF fiber opening
- pouring
- sticking
- folding
- packaging (PET film)

The process for manufacturing menstrual pads is a little simpler than for diapers and the amount of Raw Materials is more limited.

Menstrual pad process steps:

- FLUFF fiber opening,
- fiber deposition on bottom layer
- top layer deposition
- sticking
- packaging (PET film)


Both process lines involve electric-driven machines (capacity given by way of example):

- diaper process line: average of 435 units per minute; maximum capacity of 12.5MM units per month
- menstrual pad line: average of 600 units per minute; maximum capacity of 21MM units per month

A plant processing such products may also include a printing line for the packaging.

10.2 SPECIAL HAZARDS & RISK CONTROL

Special hazards, prevention, protection, and potential mitigation measures are detailed below for each and every special hazard related to this occupancy (This follows the process flow from Raw Material to Finished Products as much as possible). Related recommendations are also mentioned. (See “Rec” Section 11: “Support for Loss Prevention Recommendations” for details).

10.2.1 All Facilities

See Paper Working, Subsection 9.2.1 « All Facilities ».

10.2.2 Diaper and Menstrual Pad Process Lines

- Storage of Raw Material including fluff pulp bales / rolls, plastic-based adhesives, straps, absorbent polymer gel in cubic meter bags.
- Storage of Packaging Material: PET (polyethylene) film rolls, plasticized paper labels.
- Storage of Finished Products: group A plastic, exposed and stable as per NFPA (disposable diaper with plastic, non-woven fabric, uncartoned, plastic-wrapped, and paper products, tissue, uncartoned, plastic-wrapped).
- LPG, diesel-driven and electric-driven lift trucks are used to carry the semi-finished and finished products.
- Electric-driven process equipment.
- Dust and tissue paper waste may accumulate.
- Static discharge may initiate fire.

- Electric shocks may initiate fire.
- Lighting fixtures exposing raw material, Work-in-Progress and finished products.
- Other ignition sources.
- Local process control systems; process lines are usually fully computerized (embedded systems) and cannot be manually operated.

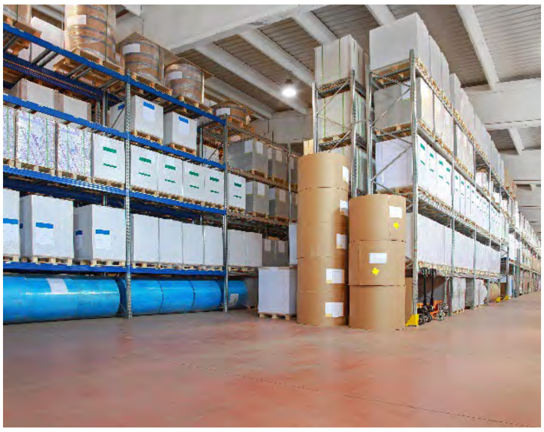
Prevention & Protection:

- Prefer noncombustuble construction material avoiding the use of higly combustible insulation (i.e., plastic-based: PUR, PIR, XPS, EPS).
- All storage and process areas should be sprinkler protected in accordance with international standards (i.e., NFPA13 / FM Global Data Sheets). For information as per NFPA13:
  - Paper and Pulp mills / Paper process plants occupancy corresponding to Ordinary Hazard Group 2 (OH2), the ceiling sprinkler design is 7mm/min/m² (0.17gpm/ft²) over 279m² (3,000ft²) (hose allowance: 250gpm # 1950LPM, duration 60-90min).
  - However, considering the relatively high combustible load (plastic-based Work in Progress material) and continuity of combustible, we recommend considering at least Extra Hazard Group 1 (EH1) for the design of ceiling sprinklers (similar to Printing [using inks having flash points below 100°F (38°C)] occupancy): 11mm/min/m² (0.28gpm/ft²) over 279m² (3,000ft²) (hose allowance: 500gpm # 1900LPM, duration 90-120min).
- LPG Lift trucks should be provided with acceptable safeguards. (See Section 11).
- Lift truck battery charging areas should be arranged. (See Section 11).
- Adequate dust removal systems should be provided as per FM Global Data Sheets 7-73: “Dust Collectors and Collection Systems” and adequate protection should be provided. (See Section 11: “Dust Sprinkler Protection”).
- Housekeeping is key, including routine inspections preventing the accumulation of waste material.
- All buildings and equipment should be adequately grounded.
- Proper maintenance and inspections of electric equipment (e.g.,, including infra-red scanning) should be enforced in order to ensure electrical integrity.
- Lighting fixtures should be arranged. (See Section 11).
- Ignition source controls should be established (e.g., Hot Work permits, strictly enforced non-smoking policies, friction, etc.).
- Local process control systems should either be duplicated or protected (i.e.,, PLCs, server rooms (if any, when not embedded). (See Section 11).

10.2.3 Printing Line

A description of one printing line is given by way of example:

- Storage of Raw Material consisting of solvent-based ink, plasticized paper labels
- Process unit includes one electric-driven Rotary Web Press type, printing PET labels
- Drying using Heat Transfer Fluid (HTF -180°C) at the level of the press.
- Diesel-fired heater for the HTF
- Circulation of hot oil (HTF) and flammable inks within the process area
- See also Section 9.2.4:” Printing for Related Hazards”



Prevention & Protection:

- See Section 9.2.4:" Printing".

10.2.4 Critical Utilities

Electric Power

- Electric power is usually supplied from the grid (when independent from any complex).
- Main substations include transformers, switch gear and distribution boards.
- An Emergency Power Supply should be provided, consisting of an Uninterruptible Power System - UPS (batteries) - and Diesel Engine-Driven Generator. This would be used for emergency shutdowns (i.e., removal of Work in Progress material inside equipment, maintaining lubrication systems of process equipment, circulation of thermal hot oil systems (if any), and emergency lighting).

Prevention & Protection:

- Multiple electric feeders on different pylons fed from different grid substations and supplying the plant (or the complex on a loop basis) are preferred.
- Protect Steam Turbine Generators (if any). (See Section 11).
- Transformers, electric rooms, including cable trays and cable openings, should be protected. (See Section 11).
- Emergency Diesel Engine-Driven Generators (DEDG) should be tested once a week and run for 30 minutes in order to ensure reliability (for detection of electric failure and cooling issues, ensuring lubrication). UPS and DEDGs should be protected. (See Section 11: "Stationary Combustion Engine and "Battery Rooms").

10.2.5 Import / Export Facilities

See Section 2.2: Interdependences, BI, CBI(CTE), SI – point F: "Major Loss impacting the Import / Export facilities".

10.3 CONTINGENCY / BUSINESS CONTINUITY / RECOVERY PLAN

Warning: in order to be reliable, a Contingency / Business Continuity / Recovery Plan should be formalized. This would include formal contracts signed in advance with vendors and/or third parties. The plan should be regularly tested, reviewed, and updated.

Holistic view:

- If the Other Cellulose-Based Product Processing Facility is part of a group with a relatively high level of vertical integration in the Wood Processing and Pulp & Paper industry, a Business Continuity Plan (BCP) at corporate level should be developed for the main identified risks in each and every process unit.
- The impact of a loss impacting third parties (i.e., logistics, utilities) should be investigated and an adequate BCP should be established.

Site view:

- A BCP (disaster recovery plan) should be established in case of a total loss of plant (i.e., fire, wildfire, flood).
- Electrical power either from the grid or generated on site (i.e., complex) is critical. Full backup from the grid avoiding bottlenecks (i.e., feeders, substations) would provide adequate duplication and reliability. This should include an Automatic Transfer Switch –ATS- thus avoiding black outs.

10.4 LOSS HISTORY

Major fire in diaper & sanitary napkins manufacturing unit:

The fire was caused by the haphazard stacking of cardboard boxes to a height of about 15-20 feet over which hanging electrical lights were installed and when the boxes touched the lights, heat, smoke and flames were generated, due to the combustible nature of cardboard boxes and the flammable nature of their contents. This, in turn, generated excessive heat radiation thereby initiating fire in the cardboard boxes which was confined for quite some time before smoke was noticed.

Neither the fire alarms, smoke alarms nor fire beam detectors purported to have been installed could alert the staff in a timely manner. The fire extinguishers and fire hydrant systems also did not operate at a critical juncture.

The fire thus initiated subsequently spread to the entire combustible and flammable stocks of finished goods kept in the Product warehouse area and also propagated to the stocks kept in other areas, eventually engulfing the entire premises.

Extent of loss:

- The entire building / shed including roofing used for storage of raw materials, production hall and finished goods, were extensively gutted/ burnt / collapsed.
- Some portions of the building, including the compressor house and reception area etc. were also damaged in varying degrees due to fire/ heat / smoke etc.
- The flooring of the affected shed was also damaged / cracked in varying degrees.
- The various pieces of plant & machinery provided inside the building/sheds involved, (mainly 8 machines / manufacturing lines for making diapers and 2 machines / lines for making feminine sanitary napkins, electrical cables / fittings, plastic crates, forklifts etc.) were extensively burnt / gutted / buried under the debris of the collapsed shed etc.

- The Air Handling Unit, ventilation ducts, pneumatic pipe lines, power supply cables of different types and sizes, laid in overhead cable trays running along the side walls/over the various machines, light fittings, control / distribution panels, were also extensively damaged/ burnt.
- The office furniture, wall-mounted fans, Almirah light fittings, computers & UPS etc. installed in the production section were also extensively damaged/ burnt.
- The entire stock and stocks in process (i.e., raw materials such as wood pulp, non-woven fabric, tissue paper etc.) stored in the rear portion of the building, as well as the finished goods, (i.e., various types / sizes of baby diapers, sanitary napkins, baby wipes etc.) stored in the front section of the building, as well as various packing materials, chemicals / lubricants, stores and spares etc., stored in the building / shed involved, were extensively burnt / gutted during the incident.

See Section 9.4: “Tissue Paper and Printing”.

10.5 LOSS ESTIMATES

Maximum Possible Loss (Technical MPL):

- Major EQ in zone 3 or 4 impacting all facilities: 35% PD for zone 3, at least 50% for Zone 4, and 18 months BI.
- Tsunami, storm surge in coastal areas (see MPL Handbook).
- Wildfire impacting the facility or involving flying ambers starting multiple fires on a complex (see MPL Handbook).
- Major fire inside the warehouse or process areas spreading to all adjacent areas. This could lead to the total loss of the plant depending on its arrangement.
- Induced BI should be considered if there are any interdependencies with sister plants downstream. This could be mitigated by buffer storage (providing several extra days of production) and an alternate supplier (if any).

Normal Loss Expectancy (NLE):

- Fire resulting in the same magnitude as for MPL when neither adequate nor approved automatic fire protection is provided. Total loss of facilities should not be excluded depending on congestion, combustible load, and continuity of combustible. When adequate fixed fire protection is provided, consider the loss equivalent to the surface of application for the content only (the building is not damaged).
- Fire involving an electric room (e.g., cable vaults) resulting in 4 months BI.
- Explosion and fire of a critical transformer supplying the plant: up to 18 months replacement time.
- Fire on a critical cooling tower (i.e., Steam Turbine Generator - if any) resulting in 4 months BI when critical.
- Induced BI should be considered if there are any interdependencies with sister plants downstream. This could be mitigated by buffer storage (providing several extra days of production) and an alternate supplier (if any).

11 SUPPORT FOR LOSS PREVENTION RECOMMENDATIONS

The following recommendations apply for the special hazards mentioned in the previous sections:

11.1 WILDLAND FIRE EXPOSURE MITIGATION

By adopting the following recommendations, a wildland fire exposure can be mitigated by creating a defensible space around the site, and developing a building envelope that provides a total spark, flame, and heat barrier:

1) Clearance zone: create a clearance zone around the buildings, outdoor structures, and yard storage by removing all vegetation (grass and trees). The clearance zone must be a minimum of 100m.

2) Complex Emergency Organization: develop a written emergency plan at the level of the complex with all the plants of the complex and the public fire service, to deal with a wildland fire/bushfire emergency or any other emergency affecting more than one plant at the same time. The plan must include access and egress paths, phone numbers for prior warning, communication channels during the emergency, and the requirements of the fire services when they are able to respond to the alarm calls. The access and egress paths must include alternatives because of the possibility of losing certain paths that might be blocked by the fire. Communication channels with the fire service must be by cellular phone or mobile radio as phone cables may be lost in a fire. Ensure that the preparedness plan for fire control gives a detailed list of firefighting resources, including personnel, apparatus, and equipment. Relocate trucks and any other valuable stock or supplies as far from the site as is practical, in anticipation of an impending wildland fire. Fully train and equip the Emergency Response Team (ERT). Additional firefighting team members are needed, compared to a ‘‘normal’’ ERT, as the public fire service may not be able to assist due to the large number of properties that may be exposed by the fire. Obtain training on how to respond to a wildland fire / bushfire emergency from the local fire authority.

3) Water Supplies: provide an adequate and reliable water supply to meet the automatic sprinkler, hose stream and hydrant demands for a fire affecting several plants of the complex at the same time. Prefer a dedicated Fire Water Supply for each plant rather than a Fire Water Supply common to all plants of the complex. When a Fire Water Supply common to all plants of the complex is installed, a secondary Fire Water Supply feeding the same Fire Water Network is recommended.

4) Protection of Openings: install shutters on all openings. If gutters are present, ensure they have leaf guards and the fascia is made of metal. Tightly seal any gaps leading into the building with sand cement mortar or fire-resistant mastic. Fit wire mesh over the tops of the gutters to prevent leaves falling in. Construct down pipes that can be closed off so that gutters flood with water in a bushfire emergency. Keep gutters free of debris. Fit air-intake openings on air conditioning systems with automatic fire doors or dampers actuated by smoke detectors.

5) Outside Sprinkler Protection: for existing facilities, combustible walls can be protected with outside sprinkler protection as an alternative to replacing the combustibles, or cover them with noncombustible sheeting. Outside sprinklers are not an alternative to fitting shutters to windows.

6) Building Design: for new facilities, design the physical shape of the building to reduce the number of re-entrant corners and changes in the roof profile where burning debris can accumulate. Avoid, where practical, changes in roof elevation, overhanging eaves, parapets, inset windows and doors, and roof valleys. Eliminate, in the detailed design, all gaps, louvers, and vents, through which sparks can enter the building.

7) Construction Material: for new facilities and other important structures, give preference to noncombustible construction materials.

Comment:

The existing standards (FM Global Data Sheets 9-19: “Wildland Fire / Bushfire Exposure”) consider that if there are no local maps, the following distances should be used as a guide for judging whether there is exposure or not: within 800m of any forest and within 30m of grasslands).

There are three ways a wildland fire can attack a building:

1. Flying embers blown by the wind can land on and ignite combustible external elements of the building construction. This is the most common ignition source.
2. Fire can spread right up to the walls of the building so there is direct flame impingement.
3. The heat radiated from the height of the flames can raise the temperature of the exposed building components, causing them to reach their autoignition point.

Further to wildland fires in LATAM, we submitted the following recommendation for all insured sites based on a conservative review of the current standard as far as clearance zones are concerned. Some insureds decided to apply the following measures to all sites:

1. Create a clearance zone around the perimeter of a plant / complex of a minimum of 100m from shrub, woodland, or forest exposure.
2. Extend this clearance zone to 200m on the south side of the perimeter of a plant / complex (taking into consideration prevailing moderate to strong winds).

We consider these measures as adequate and more conservative than our own recommendation (which is even more conservative than the current standard).

However, it should be noted that, in the case of strong wind conditions, the above-recommended and applied mitigation measures in terms of clearance (Point 1) cannot be considered as fully reliable. Forest fire history shows that fires are able to spread across 5km-large lakes (i.e., Torres del Paine, Chili 2012) and 1500m-large and 180m-deep canyons (i.e., 1988 Lewis Canyon, California, USA) due to flying embers. In such cases, an adequate emergency organization at the level of the complex (Point 2), an adequate and reliable Fire Water Supply (Point 3), and the protection of openings (Point 4) will constitute some of the key factors for successful mitigation of wildland fire exposure.

11.2 WOOD LOG STORAGE & FIRE PROTECTION

1) Storage Arrangement:

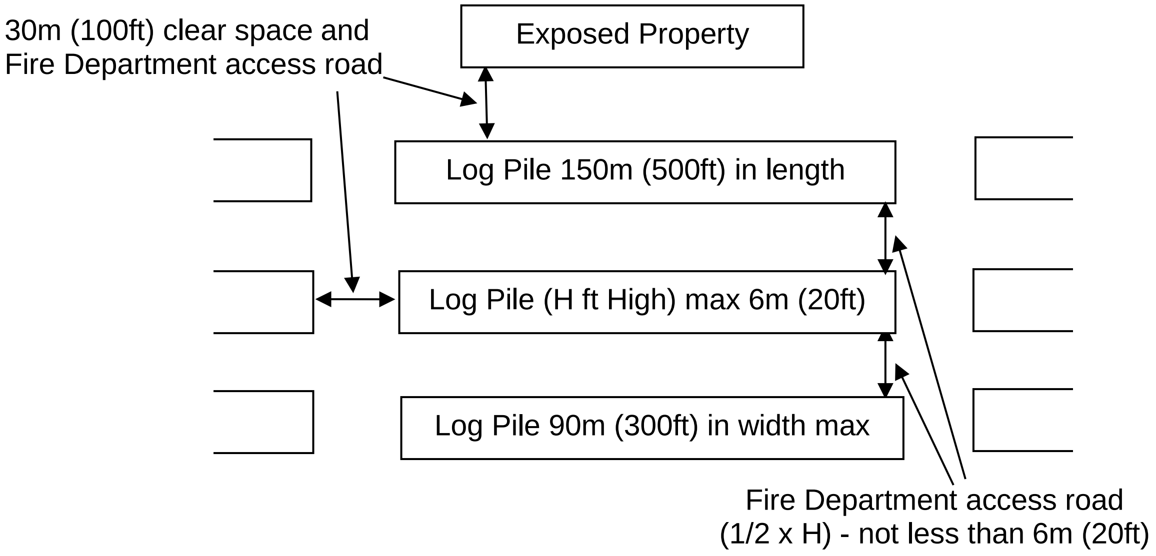
It is recommended that log storage be kept under the minimum requirements of NFPA 1 Fire Code Chapter 31: “Forest Products and Biomass Feedstock”, and FM Global Data Sheets 8-28: “Pulpwood and Outdoor Log Storage”. Some of the following minimum requirements outlined in this Standard are:

Stacked Piles: The storage site should be reasonably level, on solid ground, and on a surface paved with materials such as cinders, fine gravel, or stone.

Preferably, pile sizes should be limited to 109,000m^3 (30,000 cords).
The minimum separation between stacked pulpwood piles, regardless of capacity, should be 30m (100ft) to permit firefighters to operate effectively.
At all storage sites, a clear space of at least 30m (100ft) should be maintained between the base of piles and main buildings. Clear separation of 91m (300ft m) or more may be advisable where piles are high and have large side surfaces parallel to vulnerable important buildings.

It is necessary to limit pile widths and heights so that peaks fall within the range of monitor nozzles located along the sides of the piles. Stacked piles should not usually be over 61m (200ft) wide, but if monitor nozzles can be positioned so that they reach every part of the surface of the piles, the maximum width may be 76m (250ft). Twelve meters (40ft) is the maximum practical height for monitor nozzle towers. Pile height should be limited to 95ft (29 m) maximum to ensure that the peak is within the range of monitor nozzle streams and to limit the size of the pile.

Ranked Piles: The storage site should be reasonably level, on solid ground, and on a surface paved with materials such as cinders, fine gravel, or stone.
Individual piles should be kept as small as practicable, preferably less than 30,000 cords (109,000m³). Each pile should not exceed 150m (500ft) in length, 90m (300ft) in width, and 6m (20ft) in height.
Pile areas should be such that no point is further than 50ft (15m) from a fire lane to allow the effective application of hose streams.
Piles totaling 30,000 cords (109,000m³) should be separated from other piles by a clear space of at least 100ft (30m).
All sides of each pile should be accessible by means of fire lanes. A fire lane width of 1½ times the pile height but not less than 6m (20ft) should be provided, with fire lanes between alternate rows of two pile groups providing a clear space of at least 30m (100ft).



Fire lanes for access across each end, providing a clear space of at least 30m (100ft) to adjacent pile rows or other exposed property, should be provided. Where practical, greater widths are desirable to minimize the effects of radiated heat, particularly in high piled yards.
Separation from main buildings should be at least 30m (100ft).
See diagram below:

2) Fire Water Supply:

Stacked piles: Provide water supplies at 100 – 110psi (7 - 8bar) residual pressure at wood yard hydrants and monitors. Please use Figure 3 showing the water supply needed for stacked pulpwood piles.

Ranked piles: For ranked piles, provide water supplies at wood yard hydrants and monitors as follows:

a) *Basic Fire Protection*:

- For basic fire protection, the hydrant system should be capable of supplying not less than four 65mm (2½in.) hose streams simultaneously [not less than 3800L/min (1000gpm)] while maintaining a positive residual pressure in the fire protection hydrant system of not less than 1.38bar (20psi). Water supply should have a duration of at least 2 hours.

b) *Large-scale Firefighting operations*:

Where large-scale firefighting operations can be expected, larger water supplies with adequate mains are needed as follows (see FM Global Data Sheets 8-28 “Pulpwood and Outdoor Log Storage”):

For ranked piles, provide water supplies at wood yard hydrants and monitors as shown below:

Cubic Meters in One Yard	Water Supply, gal/min (cum/h)	Water Supply Duration
Under 36,300	1,500 (340 m3/h)	3 hours
36,300	2,000 (454 m3/h)	4 hours
73,000	2,500 (568 m3/h)	
109,000	3,000 (681 m3/h)	
145,000	4,000 (908 m3/h)	

Provide water supplies at 100 to 110psi (7 to 8bar) residual pressure at wood yard hydrants and monitors.

3) Fire Water Network:

Stacked piles of 20,000 cords (73,000m3) or less generally need 12 and 14-inch (305 and 356mm) main feeders and 8 and 10-inch (203 and 254mm) laterals. Sixteen-inch (406mm) feeders are usually needed at stacked piles.

Stacked piles of 73,000m3 or less generally need 12 and 14-inch (305 and 356mm) main feeders and 8 and 10-inch (203 and 254mm) laterals.

Sixteen-inch (406mm) feeders are usually needed at stacked piles of 109,000m3 and 20- inch (508mm) feeders at stacked piles of 163,000m3 with 10 and 12-inch (254 and 305mm) laterals.

Ranked piles need 8, 10 and 12-inch (203, 254, and 305mm) mains. Ranked pile storage greater than 30,000 cords (109,000m3) generally needs 12 and 14-inch (305 and 356 mm) main feeders and 8 and 10-inch (203 and 254mm) laterals. Ranked pile storage greater 109,000m3 generally needs 12 and 14-inch (305 and 356mm) main feeders and 8 and 10- inch (203 and 254mm) laterals.

4) Hydrants & Hose Equipment:

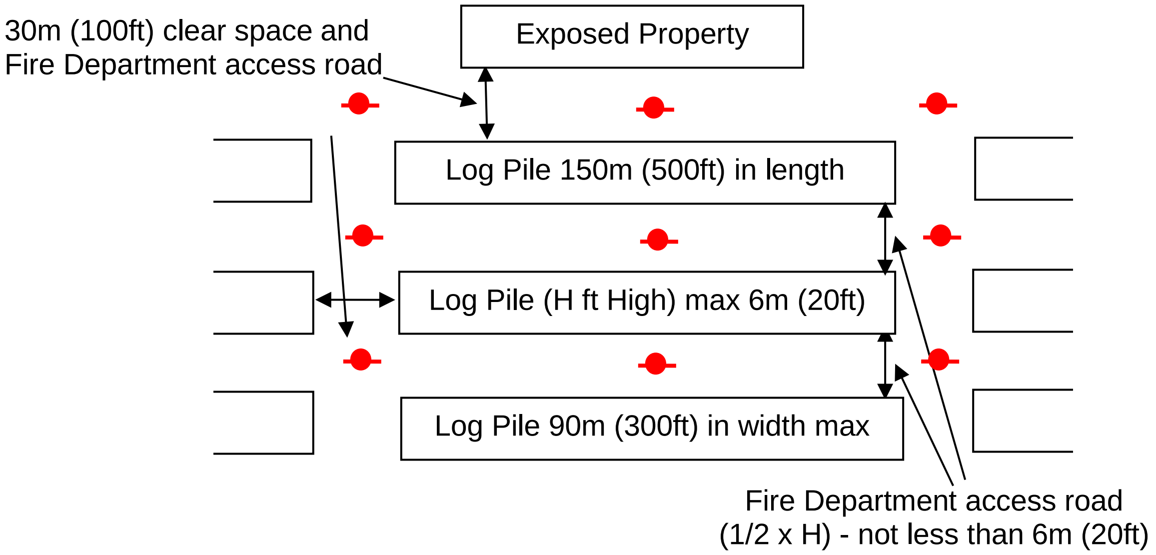
For Basic Fire Protection:

Hydrants and monitors should be installed as per NFPA 230 in order to protect the storage and surrounding facilities as follows:

Install three-way hydrants with independent gates and space them about 76m (250ft) apart. Two-way hydrants spaced about 61m (200ft) apart in each direction may be used at ranked piles.

Hydrants should be located so that any part of the yard can be reached with 61m (200ft) of sufficient 2½-inch (65mm) hose attached to allow rapid hose laying to all parts of the piling areas. (See NFPA24: “Standard for the Installation of Private Fire Service Mains and Their Appurtenances”).

For this reason, hydrants should be located at driveway intersections as shown below:



Provide completely equipped hose houses and a reserve supply of hose on reels.

Also provide two or three portable deluge nozzles at yards with 73,000m^3 (20,000 cords) piles, whether stacked or ranked, and at least one nozzle at yards with smaller individual piles. At 109,000 to 163,000m^3 (30,000 to 45,000 cords) piles, provide four to six portable deluge nozzles.

5) Monitor Nozzles:

For Large Scale Firefighting

Install monitor nozzles around piles so that every part of the pile surface is within range of at least one ‘‘good’’ 51mm (2in.) stream. (See FM Global Data Sheets 8-28 Fig. 4). Maximum spacing should be 46m (150ft) along the side of the pile and 67mm (220ft) across the pile. If the width of piles ranges from 67 to 76m (220 to 250ft) and ranking is low, locate monitor nozzles inside the pile limits and provide protection against falling logs. (2.4.3.1 See FM Global Data Sheets 8-28: “Pulpwood and Outdoor Log Storage”).

Monitor-nozzle towers are advised at piles over 18m (60ft) high and at lower piles if ranked edges prevent the stream from reaching over the peak. Monitor towers are usually steel structures with a platform and ladder. (See Fig. 5 FM Global Data Sheets 8-28:” Pulpwood and Outdoor Log Storage”). Single pipes serving as both tower and waterway are also used. Towers as high as 12m (40ft) may be constructed of a concrete-filled pipe and a second pipe to supply the nozzle. Monitor towers should be constructed and designed to withstand the impact of falling logs.

Comment:

The most common causes of fires are sparks from conveyors, sparks from passing locomotives or other vehicles, cutting and welding operations, and smoking.

Storage requirements and the economics of wood handling have led to very large piles of pulpwood. Where land is scarce, the wood is stored with limited separations between piles. All the pulpwood within one storage yard could possibly be subjected to a single catastrophe.

Fire loss experience in external log storage indicates that large undivided piles, congested storage conditions, delayed fire detection, inadequate fire protection, and ineffective firefighting tactics are the principal factors that allow log pile fires to reach serious proportions. A safe minimum distance from potential surrounding forest should also be considered.

There is no practical way to determine the space separation that would positively stop spread of fire from one pile to another. Width of the burning surface and height of the pile rather than volume of the pile, are the essential elements in radiant heat transfer. In addition to the configuration of radiating and receiving surfaces, wind direction, and promptness and effectiveness of manual firefighting are other important variables.

Recommended separations, especially those specified as minimal, will aid in fire control in three important ways: 1) by providing access areas for manual firefighting with fixed monitor nozzles, portable deluge nozzles, and hose streams; 2) by reducing the amount of heat radiated to adjacent piles; and 3) in combination with wetting of pile surfaces, by reducing the probability of igniting adjacent piles by flying sparks.

Heights in excess of 6.1m (20ft) seriously restrict effective extinguishing operations, since successful extinguishment of log pile fires requires penetration of the pile from the side by hose streams.

Each individual property has its own special conditions for yard use, stock-handling methods, and topography. For this reason, basic fire protection principles and large-scale firefighting operations are discussed herein and are intended to be applied with due consideration of all local factors involved.

The requirements for the installation of the pipe network, hydrant spacing and other features should be in accordance with NFPA Standards, particularly NFPA 24: "Standard for the Installation of Private Fire Service Mains and Their Appurtenances".

11.3 STORAGE OF WOOD CHIPS

The wood chip storage area should be protected as follows, in accordance with FM Global Data Sheets 8-27: "Storage of Wood Chips", as summarized below:

A) Wood Chip Storage Pile Arrangement:

Outdoor storage of wood chips piles dedicated to the process should be limited to 15m (50ft) in height, 91m (300ft) in width and 244m (800ft) in length, with no pile exceeding 50,000 units (285,000m^3) capacity.

Long narrow piles are known to facilitate manual firefighting.

Outdoor storage piles of sawdust and other wood waste should be limited to 7.5m (25ft) in height.

B) Minimum Separating Distances:

Between outdoor wood chip storage piles and any important plant buildings: at least 15m (50ft) separation.

Between outdoor wood chip storage piles of 15,000 units or larger: at least 15m (50ft) separation for firefighting access and mutual exposure control.

C) Manual Firefighting:

Yard mains and hydrants should be provided 75m apart. They should be capable of delivering the recommended water flow at a pressure adequate for the longest hose lines expected to be used.

Sufficient 63mm and 38mm (2½ and 1½in.) fire hose should be provided as well as large and small spray-solid stream nozzles in order to allow firefighting in any part of the chip yard.

D) Fire Water Supplies:

For single or multiple piles up to 15,000 units (85,500m^3) each: minimum of 273m^3/h (1000gpm) at 5.5bar (80psi) residual.
For single or multiple piles up to 50,000 units (285,000m^3) each: minimum of 546m^3/h (2000gpm) at 5.5 bar (80 psi) residual.

Water supply duration: minimum of six hours.

E) Automatic Sprinkler Protection

For single or multiple piles up to 15,000 units (85,500m³) each: minimum of 273m³/h (1000gpm) at 5.5bar (80psi) residual.
For single or multiple piles up to 50,000 units (285,000m³) each: minimum of 546m³/h (2000gpm) at 5.5 bar (80 psi) residual.

Water supply duration: minimum of six hours.

All tunnels or other constructions beneath wood chip storage piles (and any belt conveyor systems within the overall plant facility) should be sprinkler protected as outlined in FM Global Data Sheet 7-11: "Belt Conveyors".

Automatic sprinkler protection for wood chip storage silos, bins and sheds or other enclosures with capacities of 250 units or more should be provided, in accordance with Table 1 below:

Table 1. Sprinkler Protection Requirements for Wood Chip Silos, Bins, and Sheds or Other Enclosures

Type of Sprinkler System	*Sprinkler Temperature Rating °F (°C)*	*Density gpm/ft² (mm/min)*	*Area of Demand, ft² (m²)*
Wet	212-286 (100-141)	0.20 (8)	3000 (278.7)
Wet	160 (71)	0.20 (8)	4000 (371.6)
Dry	212-286 (100-141)	0.20 (8)	4000 (371.6)
Dry	160 (71)	0.20 (8)	5000 (464.7)

Source: FM Global's Property Loss Prevention Data Sheet 8-27: "Storage of Wood Chips" (rev. 05/00).
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Do not attempt to extinguish wood chip fires inside silos or other enclosures by smothering (i.e., excluding air), as combustible gases may accumulate and possibly create an explosion hazard.

F) Explosion Prevention & Mitigation:

Storage silos, bins, sheds or other enclosures where dried wood chips are handled or where dry wood dust can accumulate should be designed in accordance with FM Global Data Sheet 7-76: "Prevention and Mitigation of Combustible Dust Explosions and Fires".

Horizontal structural members on interior surfaces should be covered, thus minimizing the accumulation of wood dust.

G) All fire alarms, troubles and supervisory signals should be relayed to a constantly attended location.

H) All material and equipment should be approved and/or UL-listed.

I) The above water-based fire protection should be fed from an adequate and reliable Fire Water Supply, as recommended.

J) A project plan review of the fire protection systems should be conducted by qualified, recognized fire protection engineers familiar with NFPA / FM standards prior to installation, and a visit on site should be conducted during and after installation for acceptance.

Comments:

Chips are measured in "units," one unit being equal to 5.7m³ (200ft³) of compacted chips and roughly equivalent to one cord of ranked pulpwood.

Two types of incidents occur in outdoor wood chip storage piles: surface fires and internal heating, which may result in subsequent fires. The latter is far more prevalent.

In-Process and Indoor Storage spontaneous heating can also occur in contained or confined wood chip storage. Moreover, contained or confined wood chip storage may present a dust explosion hazard if dried wood chips are stored or if dry wood dust can accumulate on horizontal structural members within silos, bins, sheds or other enclosures. For stored moist or green wood chips, the dust explosion hazard is significantly reduced.

Note that:

- Close-range use of spray nozzles can help to extinguish surface fires.
- Solid streams can be used to:
  - disperse water over the surface at a relatively long distance. This would depend on nozzle size and pressure.
  - wet down exposed structures and buildings.
- Combined spray nozzles and 38mm (1½in.) hoses are known to be efficient for small burning areas.
- In case of hot spots or areas detected inside outdoor wood chip storage piles, water spray or fog coverage (while uncovering the pile) should be considered. Alternatively, the affected area may be flooded with water (i.e., using perforated piping prior to digging out the pile).
- Mobile equipment (i.e., front loaders) may be used to dig out and isolate heated areas inside wood chip storage piles.

11.4 WOOD PROCESSING AND WOODWORKING FACILITIES

Source: FM Global Data Sheets 7-10: “Wood Processing and Woodworking Facilities” (please refer to these FM Global Data Sheets for more details).

A) Construction and Location

Noncombustible construction is recommended.

Draft curtains defining the sprinkler operating area should be provided for process areas susceptible to dust / resin accumulation on roof framing members (e.g., wood waste fuel houses, particleboard raw material, screening / storage buildings, ceiling areas above hot presses, plywood veneer dryers).
Draft curtain design: at least 1.2m (4ft) deep and a flush fit with the underside of the roof. Note: no additional draft curtains are needed for laminated wood beam roof framing, including decking that is flush with the top of the structural members.

B) Fire Protection for Manufacturing Areas

Automatic sprinkler protection, in accordance with Table 1, should be provided in all process areas:

Table 1. Sprinkler Demand for General Manufacturing Areas

Density[1,2] gpm/sq ft(mm/min)	*Type System*	*Head Temp[3] °F (°C)*	*Area[2] sq ft (sq m)*
.20 (8)	Wet	286 & 212 (141 & 100)	3000 (280)
		165 (71)	4000 (370)
	Dry	286 & 212 (141 & 100)	4000 (370)
		165 (71)	5000 (460)

NOTES:
[1] Sprinkler spacing should not exceed 100 sq ft (9.3 sq m). Calculations should include 500 gpm (1900 l/min) for hose streams. Duration is two hours.
[2] This table anticipates the presence of scattered, small hydraulic units (100 gal [378 cu dm/min] or less), localized dust accumulations, etc. which can result in sprinkler demands larger than those for low-piled product storage areas. Refer to Data Sheet 7-98, *Hydraulic Fluids*, if large hydraulic systems are present.
When draft curtains are needed (e.g., particleboard raw material screening and storage buildings, wood waste fuel houses, and ceiling areas above hot presses or plywood veneer dryers), the area to be calculated should be the curtained area if larger than the area in this table. When laminated wood beam roof framing is used in lieu of draft curtains, use the area defined by the major laminated beams (2 ft [0.6 m] or more in depth) as the curtained area.

Source: FM Global's Property Loss Prevention Data Sheet 7-10: “Wood Processing and Wood Working Facilities” (rev. 05/10).

Note: special sprinkler protection may be required for special hazards, including, but not limited to, lumber dry kilns, sorters, hardboard humidifying / tempering ovens, areas containing significant quantities of flammable / combustible liquids (i.e., press pits, thermal oil process heating systems, and coating / spraying finishing operations). Please refer to the Equipment and Process Section of FM Global's Property Loss Prevention Data Sheet 7-10: "Wood Processing and Wood Working Facilities" for details.

C) Fire Protection for indoor wood product storage areas

Automatic sprinkler protection should be provided for indoor wood product storage areas, according to Data Sheet 8-9: "Storage of Class 1, 2, 3, 4 and Plastic Commodities", using the commodity classifications listed in Table 2 below:

Table 2. Commodity Classification of Wood Products

Class I	All GREEN wood products (moisture content = 20 percent or more)[1]
Class II	All DRY wood products (moisture content less than 20 percent)[1]
Class III	All FLAMMABLE-COATED wood products (regardless of moisture content)[2]

[1] The storage configuration (e.g., stuck lumber vs. solid-piled) has little effect on the degree of hazard. The moisture content is the primary factor. If green wood products might be stored for extended periods allowing them to dry (one to three months, depending on climate), design protection for dry wood products (Class II).

[2] Typical products in this category are timbers treated with creosote or oil-based preservatives, asphalt saturated fiberboard (insulation board), etc.

Source: FM Global's Property Loss Prevention Data Sheet 7-10: "Wood Processing and Wood Working Facilities" (rev. 05/10).

D) Fire Protection for outdoor storage of wood products

Outdoor storage of wood products (e.g., lumber, veneer, etc.) should be arranged and protected as follows:

a) The water supply from all sources combined, including fire department pumpers, should be able to provide the following demand flows at a residual pressure of 5.5bar (80psi).

Total yard storage (bd. ft×1000)	*Waterflow*		*Duration (hrs)*
	(gpm)	*(cu dm/min)*	
up to 1000	1000	3800	2
1000 to 2000	1500	5700	3
over 2000	2000	7600	4

FM Global's Property Loss Prevention Data Sheet 7-10: "Wood Processing and Wood Working Facilities" (rev. 05/10).

b) Yard storage should not be located under important structures at less than 6m (20ft) away horizontally (e.g., conveyors). If yard storage is located under important structures at less than 6m (20ft) away horizontally, automatic sprinklers should be installed beneath the structure, with the following design: ordinary hazard pipe schedule using 74°C [165°F] heads located 3.7m [12ft] on centers. Do not locate yard storage under power lines.

c) Protection of buildings or other important structures from yard storage exposures should be done by applying Data Sheet 1-20. Note that a minimum separation of 2m (5ft) between large blocks of storage and important buildings should be maintained at all times for firefighting access (regardless of Data Sheet 1-20 requirements).

Comment:

Regarding point B) "Fire Protection for Manufacturing Areas", Automatic Sprinkler (AS) Protection, in accordance with NFPA 13, should be designed for Extra Hazard occupancies Group 1 (EH1), including occupancies with uses and conditions similar to Plywood and Particleboard manufacturing, and sawmills.

- Density / Area AS demand for EH1: 0.28GPM @ 3000ft² / (11.4LPM @ 280m²)
- Hose requirement: EH: 500GPM/1900LPM-90min

11.5 PAPER MACHINES AND PULP DRYERS

The paper machine / pulp dryer should be protected as follows:

Protection All Machines:

A) See Table 1 from FM Global Data Sheets 7-4: “Paper Machines and Pulp Dryers” below for listing of recommended sprinkler demands related to the following points.

Table 1. Sprinkler Demands for Paper Machine Occupancies[1]

Occupancy	*Temp.°F (°C)*	*Type ofSystem*	*Density, gpm/ ft^2 (mm/min)*	*Area of Demand, ft^2 (m^2)*	*Hose Stream Demand (l/min)*
Paper machine area	Any	Wet	0.15 (6)	2500 (232.2)	250 (950)
		Dry	0.15 (6)	3500 (325.2)	
Inside dryer hoods and economizers	50°F (28°C) above operating temp.	Wet	0.20 (8)	3000 (278.7)	250 (950)
		Dry	0.20 (8)	4000 (371.6)	
Broke collection areas[2] and other areas below the paper machine	286 (141)	Wet	0.20 (8)	3000 (278.7)	500 (1900)
	165 (74)	Wet	0.20 (8)	4000 (371.6)	
	286 (141)	Dry	0.20 (8)	4000 (371.6)	
	165 (74)	Dry	0.20 (8)	5000 (464.5)	
Flammable liquid systems - thermal oil systems, lube oil systems	See Data Sheet 7-32, *Flammable Liquid Operations*				
Hydraulic systems	See Data Sheet 7-98, *Hydraulic Fluids*				

[1] See *Water Demand Modifications to Densities and Areas*, in Data Sheet 3-26 for further guidance where significant positive or negative considerations exist.

[2] For broke collection areas wider than 20 ft (6 m), provide an automatically actuated water spray system.

Source: FM Global’s Property Loss Prevention Data Sheet 7-4: “Paper Machines and Pulp Dryers” (Interim Revision 10/19).

Automatic sprinkler protection should be provided on the ceiling above and 6m (20ft) beyond the pulp dryer areas of combustible construction or combustible content. This includes the area above the dry end (i.e., the area from the press section through to the winders), such as above the dryer enclosure and the in-process storage of rolled paper. For information (as per NFPA13: “Paper and Pulp mills / Paper process plants occupancy corresponding to Ordinary Hazard Group 2 (OH2)”, the ceiling sprinkler design is 7mm/min/ m^2 (0.17gpm/ ft^2) over 279 m^2 (3,000 ft^2) (hose allowance: 250gpm # 1950LPM, duration 60-90min)

B) Provide automatic sprinklers or spray nozzles inside the paper machines and dryers. In case of space limitations between the horizontal passes, a steam suppression fire protection as per NFPA / FM Global Data Sheets 7.4 should be considered. Automatic actuation of steam suppression is recommended for when dryer temperatures exceed normal operating temperatures by 38°C (100°F). Process temperature sensors (if any) may be used to detect fire and actuate the steam suppression system. Manual actuation is only acceptable if a manually actuated steam smothering system is provided. The operators should be instructed and trained to open the steam control valves and shut down the dryer promptly upon recognizing fire in the dryer or associated equipment.

C) Local automatic sprinkler protection should be provided in areas containing combustible constructions or contents beneath the machines (i.e., broke pit, aisle beside the broke pit area, beneath the broke conveyor belts), flammable liquids (i.e., oil or process additives and agents) and for dispensing / storage. Running piping across the machine should be avoided as it could be broken by falling rolls or machine clothing falling down during a fire. This may also cause hang-ups or broke paper.

D) Protection under the machine: provide sidewall sprinklers at the perimeter of the machine and below the machine clothing level. For machines wider than 6m (20ft), provide a fixed spray system (8mm/min/m² # 0.20USGPM/ft²) over the entire area, arranged to wet down the entire broke collection area. The water spray should be automatically activated by any adequate means that can ensure a prompt detection (i.e., of heat, smoke, or flames) within the protected area. Accessible manual trip stations outside the protected area should be provided.

E) For all recommended sprinkler protection systems above, sprinklers should be:
- of the quick response type, including a fusible element to best ensure actuation, and
- of the lowest temperature rated 30°C above the ambient temperature.

F) Hose reels should be provided inside the buildings. (See Table 1 above).

G) Fire protection systems provided below the machine floor should be supplied independently from the above machine floor sprinkler, dryer hood sprinkler, and supply for fire hoses. The control valves should be located outside the protected area and in an easily accessible and safe location.

H) All these installations above should be in accordance with NFPA / FM Global Data Sheets 7.4: “Paper Machines and Pulp Dryers”. All fire alarms, troubles and supervisory signals should be relayed to a constantly attended location. All materials should be FM-approved and/or UL-listed. All project plans should be reviewed by a qualified Fire Protection Engineer familiar with NFPA / FM standards prior to installation.

Airborne Pulp Dryers

I) should be equipped with steam suppression fire protection at a minimum steam application rate of 0.4 kg/m3/min (2.5lbs/100 ft3/min) with steam applied for at least 10 minutes.

Airborne Pulp Dryers

J) should be provided with a spark detection and water spray protection system inside the flash pulp dryer.

Comment:

The installation of a sprinkler system from the press section through to the winders should be seriously considered in order to allow safe and efficient firefighting in this location.

High ceiling conditions (if any) should be considered. These may prevent efficient firefighting due to delays in actuation. For such conditions, installing a noncombustible horizontal barrier may be an option, acting as a false ceiling, with sprinklers beneath the barrier. Another option could consist of providing spray protection which could be manually and/or automatically activated.

Automatic sprinkler protection is needed inside dryer section hoods, exhaust ducts, air plenums, etc. because of deposits of oily lint and paper dust which are generated during the operating of the paper machine. Cleaning some of these enclosures without shutting down the paper machine may be impossible due to high heat and humidity.

For the broke collection pits, sidewall sprinklers may be located under the machine frame so that the piping is not in the way and is protected from mechanical damage.

Note on Pulp Dryer Steam Injection (Point C) (i.e., Steam Smothering / Steam Fire Suppression systems) above: several existing manually activated steam suppression systems are operated through an independent double manual valve located along the dryers in a relatively congested area with difficult access and poor visibility in case of a fire. This is not reliable.

The valves should be motorized and activated from the control room by the operator. The procedure to be followed in case of a fire inside the dryer should be readily available to the operator in the control room (i.e., a formalized procedure). Adequate training in case of emergency should be given to operators so they know how to open the steam control valves and shut down the dryer promptly upon recognizing fire in the dryer or associated equipment.

11.6 STEAM TURBINE GENERATOR

With the invaluable and kind support of Frank Orset, Loss Prevention Engineer:

Inadequate fire protection systems and a lack of proper emergency protocols can lead to serious damage and extended outages in the event of a lube-oil fire at a turbine hall.

Oil releases of pressurized-oil systems used in bearing lubrication, seal oil, hydraulics or control systems are most often caused by electrical failure, fitting failures, operator error, or vibration. This may cause a spray fire, a pool fire, or a three-dimensional spill fire.

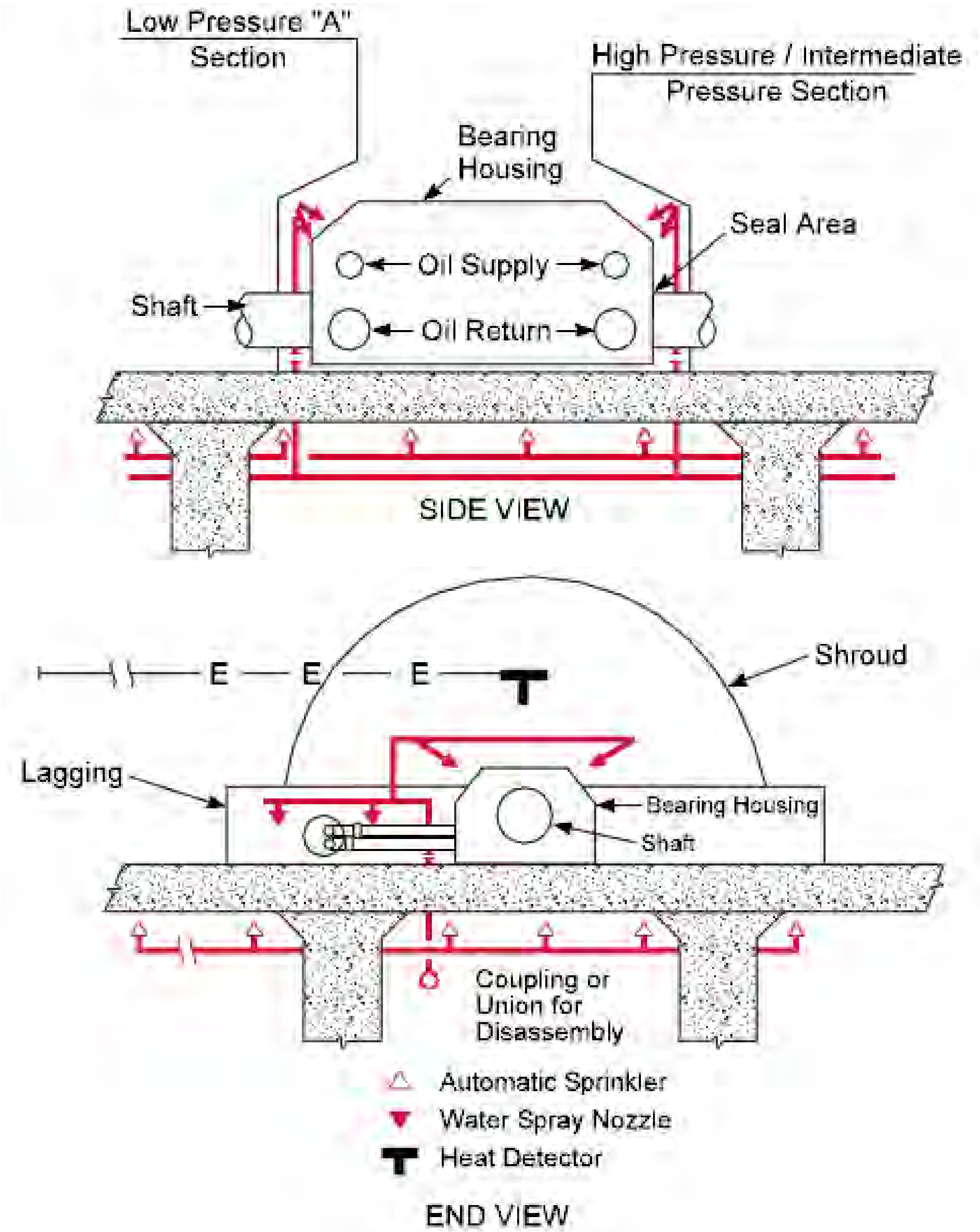
Adequate, reliable and approved fire protection systems should be installed to protect the steam turbine generator as well as the lubrication oil group. The systems should take guidance from the recommended practices of NFPA 850: “Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations”, 2020 Edition, or FM Global Data Sheets 7-101: “Fire Protection for Steam Turbines and Electric Generators”, with some additional remarks:

a) Turbine generator operating floor

Turbine generator bearings should be protected with an automatic closed-head sprinkler system utilizing directional nozzles. Automatic actuation is more reliable than manual action. Fire protection systems for turbine generator bearings should be designed for a density of 10.2mm/min (0.25gpm/ft2) over the protected area of all bearings.

Note that NFPA 804: “Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants” 2020 Edition & 805: “Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants” 2010 Edition, require a density of 12.2 mm/min (0.3gpm/sq ft) and Factory Mutual requires a minimum flow of 113 l/min (30gpm) per nozzle.

This system comprises one to two closed 90° directional spray nozzles over each bearing, directed at the shaft seal. The nozzles should be rated at approximately 83°C (150°F) above the highest ambient temperature.
These nozzles should also be located approximately 60cm (2ft) from the shaft at the 10 and 2 o'clock positions, thus providing the proper spray pattern, as well as cooling and flushing of any oil spray/leak below the turbine deck.
Additionally, one heat detector rated at approximately 30°C (86°F) above the highest ambient temperature should be installed 60cm (2ft) directly above the shaft.
In the case of a fire, the heat released by the fire triggers the heat detectors, which in turn open the valve.



Source: FM Global Data Sheets 7-101 "Fire Protection for Steam Turbines and Electric Generators")

Protection for bearing housing and areas under turbine skirts

Accidental water discharge on bearing points and hot turbine parts should be considered, hence a pre-action system as said above is recommended. If necessary, these areas may, in addition, be protected by shields and encasing insulation with metal covers.

If turbine generator bearings are protected with a manually operated sprinkler system, the following should be provided:

- Manual activation should be from the control room or a readily accessible location not exposing the operator to the fire condition. Plant personnel should be sufficiently trained to promptly handle this function as well as other responsibilities during an emergency of this nature.

- Automatic fire detection should be provided over the area of each bearing and inside the skirting of the turbine where a potential for oil to pool can alert operators to a fire condition.
- Documented procedures should be in place with authority given to operators to activate the system, if necessary, in a fire condition.
- Periodic training should be given to operators regarding the need for prompt operation of the system.
- Regular inspections of the sprinkler & detection system should be conducted to ensure proper functionality at all times.

Automatically actuated systems have proven to actuate properly under fire conditions and are not prone to spurious actuation. If a manually operated water system is installed, consideration should be given to a supplementary automatic gaseous fire extinguishing system.

Accidental water discharge on bearing points and hot turbine parts should be considered. If necessary, these areas may be protected by shields and encasing insulation with metal covers.

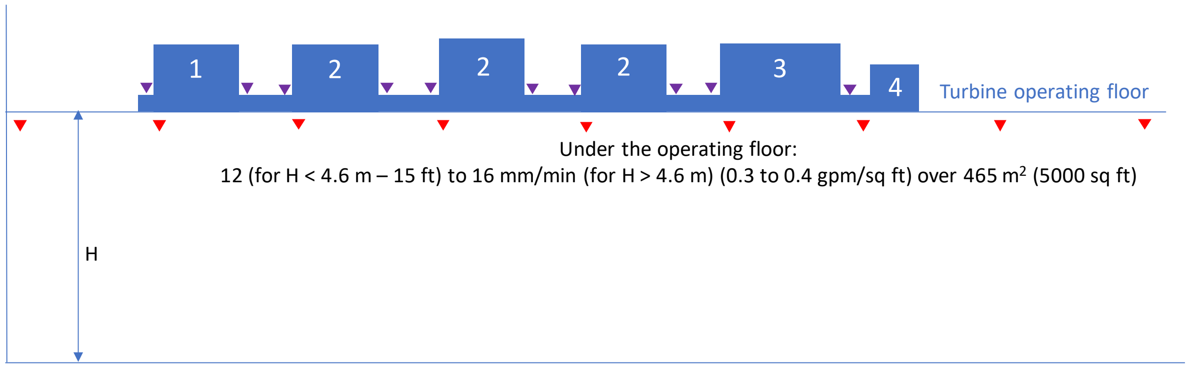
The decision for the installation of fire protection systems, subject to accidental water discharge on the turbine generator bearings and hot turbine parts, must be a local management decision. Alternatives should consist of the use of special fire protection gaseous agents, in accordance with NFPA / FM Standards.

All areas beneath the turbine generator operating floor that are subject to oil flow, oil spray or oil accumulation should be protected by an automatic sprinkler or a foam-water sprinkler system

This coverage normally includes all areas beneath the operating floor in the turbine building.

The sprinkler system beneath the turbine-generator should take into consideration obstructions from structural members and piping and should be designed to deliver a density of 12.2mm/min (0.3gpm/ft²) over a minimum application of 465m² (5000 ft²), with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)) for a roof height up to 4.5m (15ft).

If there is no intermediate protection below the mezzanine or over areas with a pool fire hazard, for a roof height between 4.5 and 9m (15 and 30ft), the sprinkler system should be designed to deliver a density of 16mm/min (0.4gpm/ft²) over a minimum application of 465 m² (5000 ft²) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K160 (K11.2)).



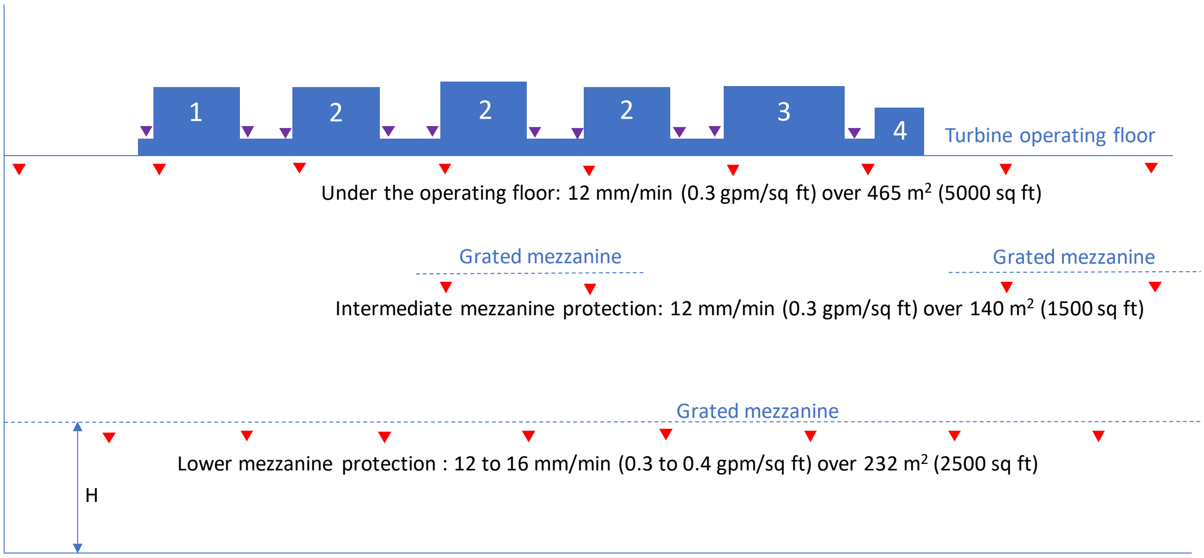
Sprinkler protection with no intermediate levels

When grated mezzanines are provided below the operating floor, additional sprinkler protection should be provided below, as well as at intermediate levels where oil spills may potentially accumulate.

The sprinkler system beneath the turbine generator should take into consideration obstructions from structural members and piping and should be designed to deliver a density of 12.2mm/min (0.3gpm/ft²) over a minimum application of 465m² (5000ft²) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)).

The density below the grated mezzanines should be designed depending on the height between the sprinklers and the ground, so the protection below the operating floor would be over 232m^2 (2500 ft^2) for the lower mezzanine and 12.2mm/min (0.3gpm/ft^2) over 140m^2 (1500 ft^2) for the intermediate levels.

The temperature rating of the sprinkler heads below the mezzanines can be ordinary or high.



Sprinkler protection with grated mezzanines
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Lubricating oil lines above the turbine operating floor should be protected with an automatic sprinkler system covering those areas subject to oil accumulation including the area within the turbine lagging (skirt).

The automatic sprinkler system should be designed to deliver a density of 12.2mm/min (0.3 gpm/ft^2) with standard spray sprinkler heads preferably rated at 141°C 286°F (K115 (K8.0)).

b) The lubrication group

Lubricating oil reservoirs and handling equipment should be protected by an automatic sprinkler or foam-water sprinkler system.

The sprinkler system should take into consideration obstructions from structural members and piping and should be designed to deliver a density of 12.2mm/min (0.3gpm/ft^2) over a minimum application of 465m^2 (5000ft^2) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)).

If the lube oil reservoir is elevated, sprinkler protection should be extended to protect the area beneath the reservoir.

Note:

In some particular circumstances, there is no ceiling above the lube oil tanks and there is no technical possibility of providing a reliable way of collecting the convective heat plume at the sprinkler head position.

In these situations, the above-mentioned protection would not be reliable and should be replaced with the following protection:

The protection on the lube oil tanks should be based on a deluge system with open sprinkler heads and a designed density of 12mm/min (0.3gpm/ft^2) over the entire area of the lube oil tanks.

The system should be activated either by a pilot line (preferably 68°C (154°F)-rated sprinkler heads provided with heat collector plates above the detector heads) or an appropriate fire detection system.

An additional way of manually activating the deluge system from a remote and safe area should be provided (in case the detection system is not working for any reason).
The plant should be designed, and equipment arranged so that lubricating oils are confined to a specified area. The use of trenching, curbs and dikes, plus the utilization of natural holding sumps, such as condenser pits, can serve as an aid in accomplishing this feature.

As a preferred approach, turbine lube oil storage tanks and reservoirs should be cut off from all other areas of the turbine building by fire barriers with a 180-minute fire resistance.

A properly engineered, fixed fire extinguishing system (see above) should be provided throughout all such enclosures.

Where oil storage tanks are not cut off from other areas, they are acceptable provided that:

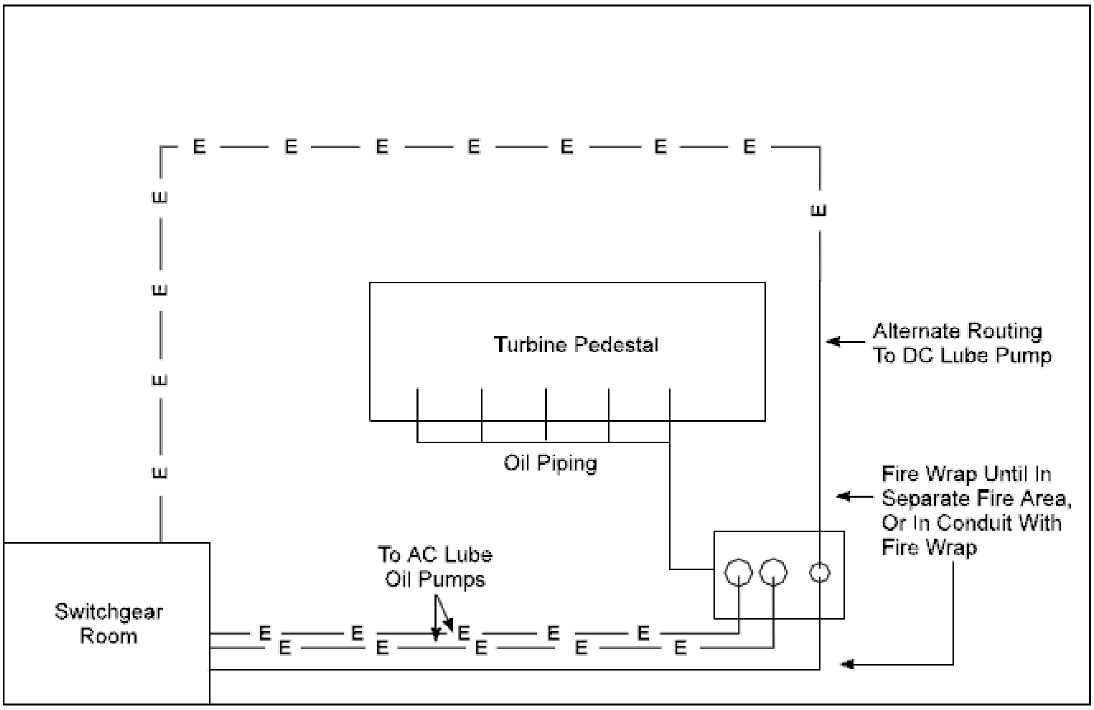
- they are located in areas where the ceiling is protected by an overhead sprinkler system and the sprinkler protection extends sufficiently in the peripheral areas subject to oil spray and oil flow, to control the heat produced by oil fires and maintain building temperatures below those which cause deformation of the structures;
- the tanks are protected by an automatic water spray system;
- an oil containment system is installed in accordance with the Standards.

To prevent potential damage from the effects of water spray, emergency lube oil pumps should be of the enclosed type, with the electrical circuits to the oil pump motors routed and protected so that control will not be impaired by the fire emergency.

Turbine oil reservoirs and lube oil filters equipped with hinged access panels designed to relieve internal pressure should have tamper-resistant devices installed so that pressure relief of the tank is not defeated, e.g., locked cages can be installed over the covers arranged in such a way that the covers can be lifted.
Non-condensable vapor extractors should be vented outside.

Cables for operating the lube oil pumps should be protected from fire exposure. Protection can consist in separating the cables for AC and DC oil pumps or a 1-hour fire-resistive coating (derating of cables should be considered).

If the lubricating oil equipment is in a separate room enclosure, protection can be provided by a total flooding gaseous extinguishing system (e.g., CO_2, designed to deliver a minimum concentration of 34% for at least 20min).



c) Exciter

The area inside a directly connected exciter housing should be protected with a total flooding automatic carbon dioxide system, designed to deliver a minimum concentration of 34% for at least 20min (or during the total coast down period of the machine if longer than 20min). The aim is to protect the bearings inside the exciter housing.

Although the extension of the bearing pre-action water spray system to the exciter enclosure is an acceptable means of fire protection, the installation of an automatic total flooding carbon dioxide system (CO_2) is preferred over water spray.

When not directly connected, the exciter is not considered as a direct exposure to the turbine generator and protection is not required.

d) Hydrogen seal oil

Hydrogen seal oil units should be protected by an automatic sprinkler or foam-water sprinkler system.
The sprinkler system should take into consideration obstructions from structural members and piping and should be designed to deliver a density of 12.2 mm/min (0.3gpm/ft^2) over a minimum application of 465m^2 (5000ft^2) (or entire area if smaller than 465m^2 (5000ft^2)) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)).

The seal oil units should preferably be located in a fire cut-off area. When these systems are not cut off, the sprinkler protection should extend sufficiently in the peripheral areas subject to oil spray and oil flow, to control the heat produced by oil fires and maintain building temperatures below those which cause deformation of the structures.

e) Feed water pumps

The sprinkler system should be designed to a deliver a density of 12.2 mm/min (0.3 gpm/ ft^2) over a minimum application of 465m^2 (5000ft^2) (or entire area if smaller than 465m^2 (5000 ft^2)) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)).
The feed water pumps should preferably be located in a fire cut-off area or at least provided with fire separation between the different units.

f) Oil storage areas / Discharge tank areas

Clean or dirty oil storage areas should be protected with a density of 12.2 mm/min (0.3 gpm/ft²) over a minimum application of 465m² (5000ft²) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)).
As this area generally represents the largest concentrated oil storage in the plant, separation, ventilation, and drainage should be provided in addition to the automatic protection.
The oil storage tanks should preferably be located in a fire cut-off area.

g) Cable concentrations in the turbine hall

In addition (if not included in the above-mentioned protection), large concentrations of cable trays below the turbine floor should also be protected by an automatic sprinkler system.
The sprinkler system should be designed to deliver a minimum density of 12.2 mm/min (0.3 gpm/ft²) over the entire area (with a maximum operating area of 232m² (2500ft²)).
The sprinkler heads should be rated at 68°C (154°F) (K80 (K5.6)).

h) Hydrogen

Hydrogen cylinders should be stored outside or in a separate well-ventilated enclosure.
Indoor storage of hydrogen cylinders should be protected by a sprinkler or water spray system designed to deliver 12.2 mm/min over 232m2 (0.3gpm/ft² over 2500ft²) with K80 (K5.6) spray sprinklers, preferably rated at 141°C (286°F). [or entire area with water spray systems]

The protection should extend 6m (20ft) beyond the storage area.
An excess flow valve and an emergency shutoff valve should be provided on the supply line where hydrogen is supplied from a large central storage remote from the building. The emergency shutoff valve should be located in readily accessible location and arranged so it can be remotely operated from the control room.

i) Emergency hydrogen drainage valve

The generator hydrogen dump valve and hydrogen draining equipment should be arranged to vent directly to a safe outside location. The dump valve should be remotely operated from the Main Control Room and manually from an area accessible during a machine fire (preferably located outside the main building, in an area not exposed by adjacent equipment, such as transformers).

j) Combustible roof for turbine hall building

If the roof of the turbine hall is of combustible construction (either a combustible insulation material such as polyurethane or expanded polystyrene or a noncombustible insulation such as foam glass, but glued to the roof metal panels with bitumen), it should be replaced with a noncombustible construction system (such as rockwool mechanically fastened on the steel deck assembly) or sprinkler protection should be provided.
The minimum designed density for a sprinkler protection should be 8mm/min (0.2gpm/ft²) over 465m² (5000ft²) (wet system) or 740m² (8000ft²) (dry system) with 141°C (286°F)-rated spray sprinkler heads.

k) Additional specifications

180 m³/h (792gpm) should be provided for manual firefighting needs in the turbine hall area (hydrants and hoses). Note that NFPA recommends 113m³/h (500gpm), which is also acceptable.

Sprinklers also need to be provided under obstructions wider than 1.2m (4ft), such as large piping and valves, and under the condenser as this is an area where burning oil can accumulate. If a mezzanine is present, sprinklers must be provided for each level below the turbine deck.

Lube oil purifiers should be located in an area protected by an overhead sprinkler system and an oil containment system.

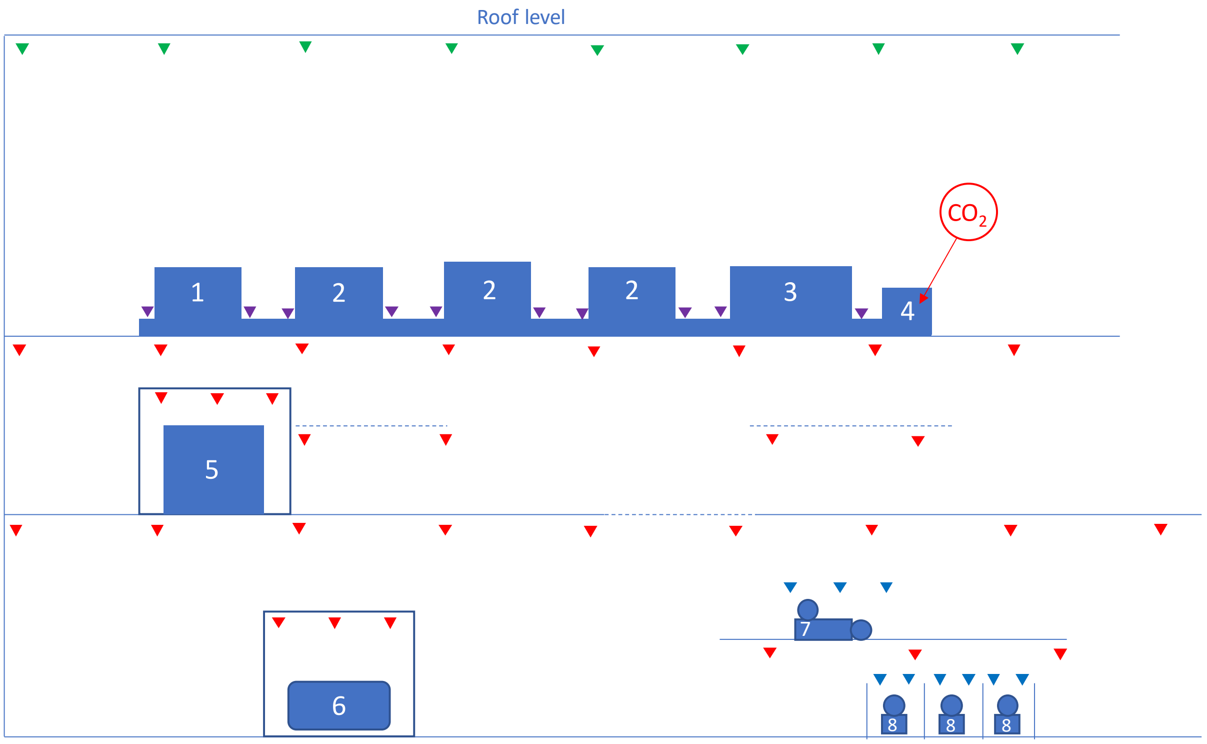
Spill containment curbs prevent the pool fire from spreading outside the sprinkler-protected area. Proper drainage to prevent burning oil from floating to unprotected areas of the plant should be provided for all combustible/flammable type oil hazards.

Electrical equipment in the area covered by a water or foam-water system should be of the enclosed type, or otherwise protected to minimize water damage in the event of the system being triggered.

To extinguish a three-dimensional spray oil fire in the turbine bearing and oil pipe areas, a water spray system with a design water density of 40 to 60mm/min (1 to 1.5gpm/ft²) may be recommended.
Commonly used water spray densities of 12 to 20mm/min (0.3 to 0.5gpm/ft²) will protect and cool machinery and building constructions, but not necessarily extinguish a three-dimensional fire.
The area that should be protected on the operating floor depends on curbing and drainage but should generally be extended to a distance of 6m (20ft) around the turbine generator.

The operating temperature of the sprinkler heads should be set 30°C (86°F) above the highest expected ambient temperature.

l) Sketch for automatic protection location overview in turbine hall



1. High Pressure
2. Low Pressure
3. Generator
4. Exciter
5. Lube oil tank
6. Oil storage/discharge tank
7. Hydrogen seal oil
8. Feedwater pumps

- ▼ (red) Closed sprinkler heads
- ▼ (blue) Deluge nozzles
- ▼ (purple) Closed sprinkler heads or deluge/spray nozzles
- ▼ (green) Sprinkler heads (if necessary at ceiling level)

11.7 STEAM TURBINE

With the invaluable and kind support of Frank Orset, Loss Prevention Engineer:

Inadequate fire-protection systems and a lack of proper emergency protocols can lead to serious damage and extended outages in the event of a lube-oil fire at a steam turbine.

Oil releases of pressurized oil systems used in bearing lubrication, seal oil, hydraulics or control systems are most often caused by electrical failure, fitting failures, operator error or vibration. This may cause a spray fire, a pool fire or a three-dimensional spill fire.

Adequate, reliable and approved fire protection systems should be installed to protect the steam turbine as well as the lubrication oil group. The systems should take guidance from the recommended practices of FM Global Data Sheets 7-101: “Fire Protection for Steam Turbines and Electric Generators”, with some additional remarks:

a) Turbine operating floor

Turbine bearings should be protected with an automatic closed-head sprinkler system utilizing directional nozzles. Automatic actuation is more reliable than manual action. Fire protection systems for turbine bearings should be designed for a density of 10.2mm/min (0.25gpm/ft²) over the protected area of all bearings.

This system comprises one to two closed 90° directional spray nozzles over each bearing and directed at the shaft seal. The nozzles should be rated at approximately 83°C (150°F) above the highest ambient temperature.
These nozzles should also be located approximately 60cm (2ft) from the shaft at the 10 and 2 o'clock positions, thus providing the proper spray pattern, as well as cooling and flushing of any oil spray/leak below the turbine deck.
Additionally, one heat detector, rated at approximately 30°C (86°F) above the highest ambient temperature, should be installed 60cm (2 ft) directly above the shaft.
In the case of a fire, the heat released by the fire triggers the heat detectors, which in turn open the valve.

Protection for bearing housing and areas under turbine skirts

Accidental water discharge on bearing points and hot turbine parts should be considered, hence a pre-action system as said above is recommended. If necessary, these areas may, in addition, be protected by shields and encasing insulation with metal covers.

If turbine bearings are protected with a manually operated sprinkler system, the following should be provided:

- Manual activation should be from the control room or a readily accessible location not exposing the operator to the fire condition. Plant personnel should be sufficiently trained to promptly handle this function as well as other responsibilities during an emergency of this nature.
- Automatic fire detection should be provided over the area of each bearing and inside the skirting of the turbine where a potential for oil to pool can alert operators to a fire condition.
- Documented procedures should be in place with authority given to operators to activate the system, if necessary, in a fire condition.
- Periodic training should be given to operators regarding the need for prompt operation of the system.
- Regular inspections of the sprinkler & detection system should be conducted to ensure proper functionality at all times.

Automatically actuated systems have proven to actuate properly under fire conditions and are not prone to spurious actuation. If a manually operated water system is installed, consideration should be given to a supplementary automatic gaseous fire extinguishing system.

Accidental water discharge on bearing points and hot turbine parts should be considered. If necessary, these areas may be protected by shields and encasing insulation with metal covers. The decision for the installation of fire protection systems, subject to accidental water discharge on the turbine bearings and hot turbine parts, must be a local management decision. Alternatives should consist of the use of special fire protection gaseous agents in accordance with NFPA / FM Standards.

All areas beneath the turbine operating floor that are subject to oil flow, oil spray or oil accumulation should be protected by an automatic sprinkler or a foam-water sprinkler system

This coverage normally includes all areas beneath the operating floor in the turbine building.

The sprinkler system beneath the turbine should take into consideration obstructions from structural members and piping and should be designed to deliver a density of 12.2mm/min (0.3 gpm/ft²) over a minimum application of 465m2 (5000ft²) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)) for a roof height up to 4.5m (15ft).

If there is no intermediate protection below the mezzanine or over areas with a pool fire hazard, for a roof height between 4.5 and 9m (15 and 30ft), the sprinkler system should be designed to deliver a density of 16mm/min (0.4gpm/ft²) over a minimum application of 465m2 (5000ft²) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K160 (K11.2)).

Sprinkler protection with no intermediate levels:

When grated mezzanines are provided below the operating floor, additional sprinkler protection should be provided below, as well as at intermediate levels where oil spills may potentially accumulate.

The sprinkler system beneath the turbine should take into consideration obstructions from structural members and piping and should be designed to deliver a density of 12.2mm/min (0.3 gpm/ft²) over a minimum application of 465m2 (5000ft²) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)).

The density below the grated mezzanines should be designed depending on the height between the sprinklers and the ground, so the protection below the operating floor over 232m2 (2500ft²) for the lower mezzanine and 12.2mm/min (0.3gpm/ft²) over 140m2 (1500ft²) for the intermediate levels.

The temperature rating of the sprinklers heads below the mezzanines can be ordinary or high.

Sprinkler protection with grated mezzanines:

Lubricating oil lines above the turbine operating floor should be protected with an automatic sprinkler system covering those areas subject to oil accumulation including the area within the turbine lagging (skirt).

The automatic sprinkler system should be designed to deliver a density of 12.2mm/min (0.3 gpm/ft²) with standard spray sprinkler heads preferably rated at 141°C 286°F (K115 (K8.0)).

b) The lubrication group

Lubricating oil reservoirs and handling equipment should be protected by an automatic sprinkler or foam-water sprinkler system.

The sprinkler system should take into consideration obstructions from structural members and piping and should be designed to deliver a density of 12.2mm/min (0.3gpm/ft²) over a minimum application of 465m2 (5000ft²) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)).

If the lube oil reservoir is elevated, sprinkler protection should be extended to protect the area beneath the reservoir.

Note:

In some particular circumstances, there is no ceiling above the lube oil tanks and there is no technical possibility to provide a reliable way of collecting the convective heat plume at the sprinkler head position.

In these situations, the above-mentioned protection would not be reliable and should be replaced with the following protection:

The protection on the lube oil tanks should be based on a deluge system with open sprinkler heads and a designed density of 12mm/min (0.3gpm/ft²) over the entire area of the lube oil tanks.

The system should be activated either by a pilot line (preferably 68°C (154°F)-rated sprinkler heads provided with heat collector plates above the detector heads) or an appropriate fire detection system.

An additional way of manually activating the deluge system from a remote and safe area should be provided (in case the detection system is not working for any reason).

The plant should be designed, and equipment arranged so that lubricating oils are confined to a specified area. The use of trenching, curbs, and dikes plus the utilization of natural holding sumps, such as condenser pits, can serve as an aid in accomplishing this feature.

As a preferred approach, turbine lube oil storage tanks and reservoirs should be cut off from all other areas of the turbine building by fire barriers with 180 minutes fire resistance.

A properly engineered, fixed fire extinguishing system (see above) should be provided throughout all such enclosures.

Where oil storage tanks are not cut off from other areas, they are acceptable provided that:

- they are located in areas where the ceiling is protected by an overhead sprinkler system and the sprinkler protection extends sufficiently in the peripheral areas subject to oil spray and oil flow, to control the heat produced by oil fires and maintain building temperatures below those which cause deformation of the structures;
- the tanks are protected by an automatic water spray system;
- an oil containment system is installed in accordance with the Standards.

To prevent potential damage from the effects of water spray, emergency lube oil pumps should be of the enclosed type, with the electrical circuits to the oil pump motors routed and protected so that control will not be impaired by the fire emergency.

Turbine oil reservoirs and lube oil filters equipped with hinged access panels designed to relieve internal pressure should have tamper-resistant devices installed so that pressure relief of the tank is not defeated, e.g., locked cages can be installed over the covers arranged in such a way that the covers can be lifted.

Non-condensable vapor extractors should be vented outside.

Cables for operating the lube oil pumps should be protected from fire exposure. Protection can consist in separating the cables for AC and DC oil pumps or a 1-hour fire-resistive coating (derating of cables should be considered).

If the lubricating oil equipment is in a separate room enclosure, protection can be provided by a total flooding gaseous extinguishing system (e.g., CO_2, designed to deliver a minimum concentration of 34% for at least 10min).

The lubrication pumps should be interlocked with the sprinkler protection in order to enable them to automatically shut down in the case of water discharge (when safe shut down is possible without lubrication), preventing oil from being sprayed on hot parts and from being ignited

or

there should be a low oil pressure switch within each reservoir, arranged to shut down the machine.

To extinguish a three-dimensional spray oil fire in the turbine bearing and oil pipe areas, a water spray system with a design water density of 40 to 60mm/min (1 to 1.5gpm/ft²) may be recommended.
Commonly used water spray densities of 12 to 20mm/min (0.3 to 0.5gpm/ft²) will protect and cool machinery and building constructions, but not necessarily extinguish a three-dimensional fire.
The area that should be protected on the operating floor depends on curbing and drainage but should generally be extended to a distance of 6m (20ft) around the turbine.

The operating temperature of the sprinkler heads should be set 30°C (86°F) above the highest expected ambient temperature.

11.8 STATIONARY COMBUSTION ENGINE

With the invaluable and kind support of Franck Orset, (FPO) Loss Prevention Engineer:

All stationary Combustion Engines such as Diesel Engine-Driven Generators and Diesel Engine- Driven Fire Pumps should be provided with the following fire protection in compliance with NFPA13 and NFPA850.

The preferred choice is a sprinkler system.

Sprinkler and water spray systems:

Sprinkler and water spray protection systems should be designed either:

- for a minimum density of 12.2mm/min (0.3gpm/ft²) over 232m² (2500ft²) with standard spray sprinkler heads preferably rated at 141°C (286°F) (K115 (K8.0)).
- For a minimum density of 10.2mm/min (0.25gpm/ft²) over the entire area for a deluge system.

The maximum area of coverage per sprinkler or nozzle should be 9m² (100ft²).

The sprinkler and water spray system coverage should be extended to all areas in the enclosure located within 6m (20ft) of the engine, the lubricating oil system and the fuel system (i.e., the entire room in most configurations).

Gas protection systems:

For gas protection systems, the designed concentration should be maintained for a minimum duration of 20 minutes, or the rundown time of the turbine, or for the time engine surfaces are above the autoignition temperature of the fluid, whichever is greater.

The agent concentration should be determined for the specific combustible material involved (i.e., 34% for example in the case of a CO_2 gas protection and a fuel/diesel standby generator).

An extended discharge should be provided to compensate for leakage from the compartment and maintain an extinguishing concentration for the rundown time of the engine (or 20 minutes).
For the activation of the gas protection system, heat detectors should be provided at the ceiling level of the diesel generator enclosure. These detectors should alarm in a constantly attended area and should be interlocked to shut off the fuel supply.

The compartment ventilation system should be interlocked to shut off on system discharge. Automatic closing doors or dampers should also be provided for openings not normally closed.

A full discharge test should be conducted to verify that extinguishing concentrations can be maintained for the rundown time of the engine (or 20 minutes minimum). If this test has not been conducted, the system should not be considered reliable.

Gaseous agent fire suppression systems should be designed to have the capacity to supply 2 full discharges to avoid having to keep the engine shut down until the gaseous agent reservoir can be replenished, in particular after a minor fire or accidental discharge.

11.9 TRANSFORMER

Note:

- The following recommendation addresses Polychlorinated Biphenyls (PCB) free oil-filled transformers.
- When PCB-filled transformers exist, it is recommended to replace them with PCB-free transformers. Alternatively, flush and fill the transformers with PCB-free fluid. This should be investigated with the manufacturer.
- Explosion suppression systems are not a substitute for the following recommended protection. Moreover, when such systems do exist they should be FM-approved and UL-listed.

Based on NFPA 850: “Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations”:

1) Indoor oil-filled transformer exposing facilities:

In order to prevent oil-filled transformers from severely exposing facilities inside the site in case of fire or explosion, the following fire protection solutions and their potential alternatives should be considered in detail:

a) The indoor oil-filled transformers should be replaced with dry-type transformers when possible.

   or

b) The indoor oil-filled transformers should be relocated outside the building in compliance with point 2] or attached to the building in an open cell as per Point 3] and well segregated from other oil-filled transformers as per Point 4] below.

   or

c) The following fire separation (i.e., cut-off room) and/or fixed fire protection should be provided:

   i. Oil-insulated transformers of greater than 380L (100 gallons) oil capacity installed indoors should be separated from adjacent areas by fire barriers of a 3-hour fire resistance rating. No fixed fire protection is required, as per NFPA.

   ii. Transformers with a rating greater than 35kV, insulated with a less flammable liquid or nonflammable fluid, and installed indoors should be separated from adjacent areas by fire barriers of a 3-hour fire resistance rating. No fixed fire protection is required, as per NFPA.

   iii. When the transformers are protected by an automatic fire suppression system (see point iv below), the fire barrier fire resistance rating is permitted to be reduced to 1 hour.

   iv. Combustible (mineral) oil-filled transformers, including the adjacent non-absorbing ground areas should be protected with an automatic water-based spray system. The minimum density is 10mm/min (0.25gpm/ft²) for the surface area of the transformers and 6mm/min (0.15gpm/ft²) on the non-absorbing ground areas.

If a wet pipe sprinkler system is installed, the protection should be based on a minimum density of 12.2mm/min (0.30gpm/ft²) over the entire area containing the transformer(s) and extending 6.1m (20ft) beyond (or the entire room housing the transformers up to 232m² [2500ft²]).

Gas protection systems are not recommended as it is difficult to maintain the design concentration for a sufficient amount of time and the fire might start again when the door is opened for final firefighting operations.

Water mist systems are not recommended for reliability reasons.

Adequate oil containment should be provided. (See Point 7]).

v. For transformers with approved, less flammable dielectric fluids:

With approved, less flammable transformer fluids, no fire protection is required when the equipment is located inside a one-hour fire-rated room.

If the transformer is located inside a noncombustible room (but less than one-hour-rated), sprinkler protection should be provided over the entire room with a minimum density of 8mm/min (0.20gpm/ft²) over the entire area

2) Oil-filled transformer in an open front cell attached to the building:

The fire resistance of the existing walls and roof of the open front cells housing the existing oil-filled transformers should be upgraded, when needed, in accordance with the quantity of insulating liquid in the transformer as follows:

a) For 0.38m³ (100USgal) or less, one of the following methods should be used:
   i. Location within a cell of one-hour fire resistance. Moreover, an adequate and approved heat detector should be installed under the roof.
   ii. Location within a cell of less than one-hour fire resistance and provided with automatic adequate and approved sprinkler protection (discharge density of 12.2mm/min [0.30gpm/ft²] over the area of the cell).
b) For more than 0.38m³ (100USgal), one of the following methods should be used:
   i. Location within a cell with a fire resistance rating of 3 hours. Moreover, an adequate and approved heat detector should be installed under the roof.
   ii. Location within a cell of one-hour fire resistance and provided with automatic, adequate and approved sprinkler protection (discharge density of 12.2mm/min [0.30gpm/ft²], over the protected area or over the area of the cell).
c) Adequate oil containment should be provided. (See Point 7]).
d) The project should be reviewed by a qualified Fire Protection Engineer familiar with NFPA standards.

3) Outdoor oil-filled transformer exposing facilities:

In order to prevent an oil-filled transformer from severely exposing facilities inside the site in case of fire or explosion, the following fire protection solutions and their potential alternatives should be considered in detail:

a) The oil-filled transformers should be replaced with dry-type transformers when possible.

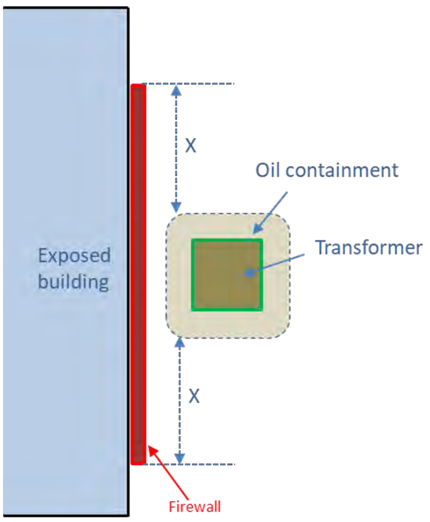
   or
b) Consider any one of the following alternatives to protect the exterior walls of main buildings against exposure to outdoor transformer fires:

i. Provide spatial separation as indicated below (source NFPA850 Table 6.1.4.3):

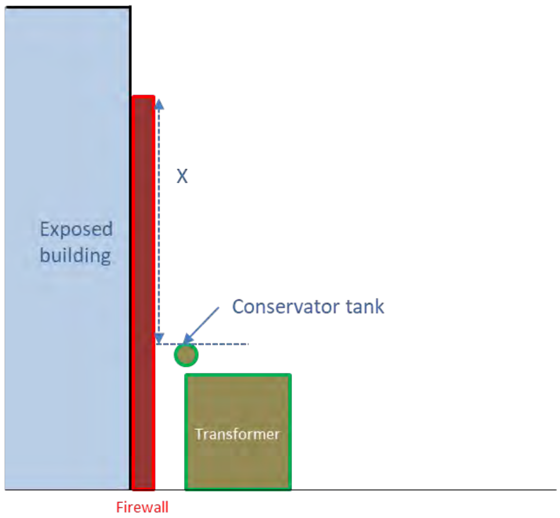
Transformer Oil Capacity		**Minimum (Line-of-Sight) Separation Without Firewall - X**	
Cum	**gal**	**m**	**Ft**
1.9	500	1.5	5
1.9-19	500-5,000	7.6	25
>19	>5,000	15	50

Note: the above spatial separating distances are measured from the edge of the postulated oil spill (i.e., containment basin, if provided).

ii. Provide a 2-hour-rated fire barrier (i.e., concrete block or reinforced concrete) with the same horizontal and vertical extent as in the table above.



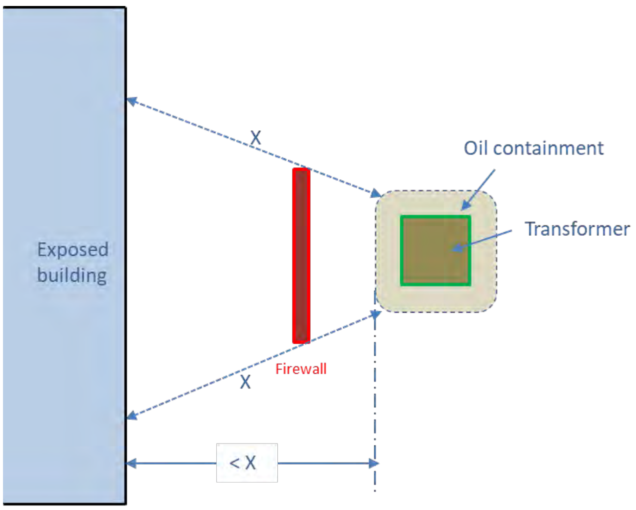
PLAN VIEW



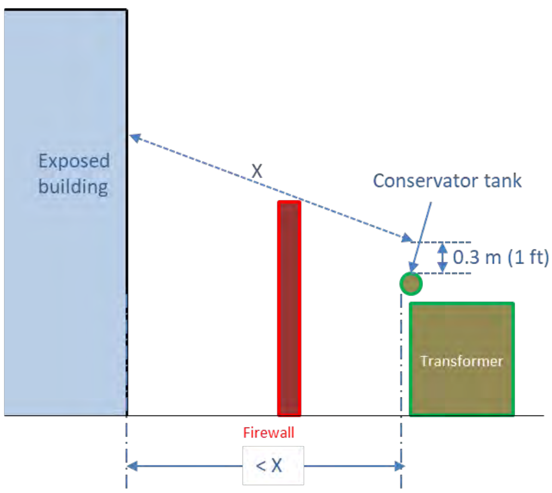
ELEVATION VIEW

Courtesy of FPO. (from NFPA 804 & 850 standards

iii. Where a firewall is provided between structures and a transformer, it should extend vertically and horizontally in accordance with the table above, as follows:



PLAN VIEW



ELEVATION VIEW

Courtesy of FPO. (from NFPA 804 & 850 standards)

Note:

- As a minimum, the firewall should extend at least 0.3m (1ft) above the top of the transformer casing and oil conservator tank and at least 0.6m (2ft) beyond the width of the transformer and cooling radiators.
- The wall should extend up to the limit of the oil containment if its width extends beyond the 0.6m (6ft) indicated above.
- If columns supporting the turbine building roof (if any) at the exterior wall have a 2-hour fire-resistive rating above the operating floor, the firewall need not be higher than required to obtain line-of-sight protection to the height of the operating floor.
- Adequate oil containment should be provided. (See Point 7).

iv. Oil-filled (combustible – mineral oil) mains, service stations, and start-up transformers not meeting the separation or fire barrier recommendations in Table 2] b. i. above should be protected with automatic water spray, systems with water additives, or foam-water spray systems (source NFPA850 9.7.9).

Moreover, exposed facilities (i.e., windows or similar openings, walls not fire-rated or less than 2 hour-fire-rated) should be provided with automatic fixed fire protection.

See section 6] "Automatic Fire Protection for outdoor oil-filled transformers and exposed facilities".

Adequate oil containment should be provided. (See Point 7]).

v. For transformers with approved, less flammable dielectric fluids:

Courtesy of Franck Orset (FPO)

With approved, less flammable transformer fluids, water spray protection and barriers are not needed if the spacing is equal to or greater than that required in the following tables:

Separation from adjacent structures

Fluid capacity in liters	Horizontal distance (m)			Vertical distance (m)
	2 h fire resistant construction	Noncombustible construction	Combustible construction	
< 37 850	1.5	1.5	7.5	7.5
> 37 850	4.5	4.5	15	15

Table 1 – Separation Distances in m between Outdoor Less Flammable Liquid Insulated Transformers and Buildings (from FM Global Data Sheets 5-4)

Fluid capacity in gallons	Horizontal distance (ft)			Vertical distance (ft)
	2 h fire resistant construction	Noncombustible construction	Combustible construction	
< 10 000	5	5	25	25
> 10 000	15	15	50	50

Table 1 – Separation Distances in ft between Outdoor Less Flammable Liquid Insulated Transformers and Buildings (from FM Global Data Sheets 5-4)

This means that if the above-mentioned minimal separation is maintained, neither fire suppression nor barrier walls are required.

When the above-mentioned distances are not respected, a 2-hour firewall should be provided between structures and the transformer. It should extend vertically and horizontally using the distance given in Table 1, as indicated in the diagram of Section iii. above.

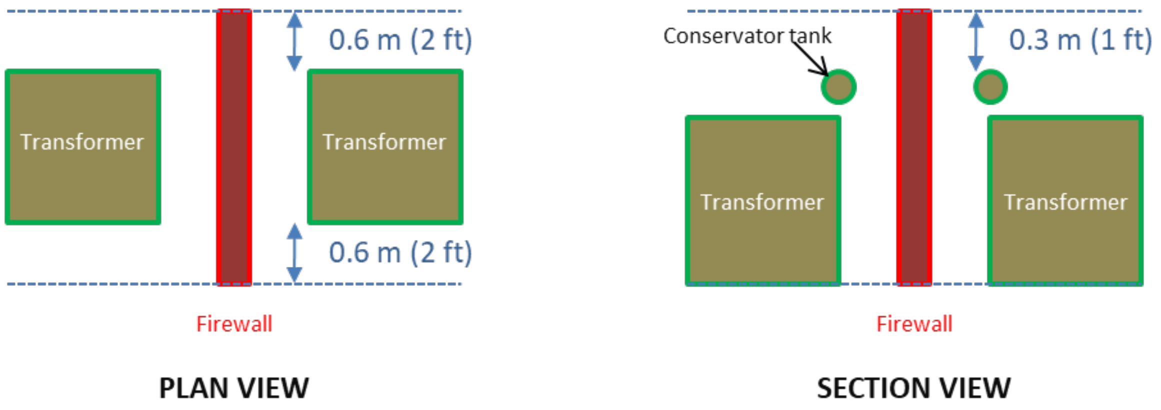
4) Outdoor oil-filled transformers' mutual exposure:

In addition to the passive fire protection for surrounding facilities recommended in Points 1] and 2] above, oil-filled transformers - when not in individual cells - should be separated from the other transformers by:

i. a minimum separating distance, as given in Table 2] b. i. above.

or

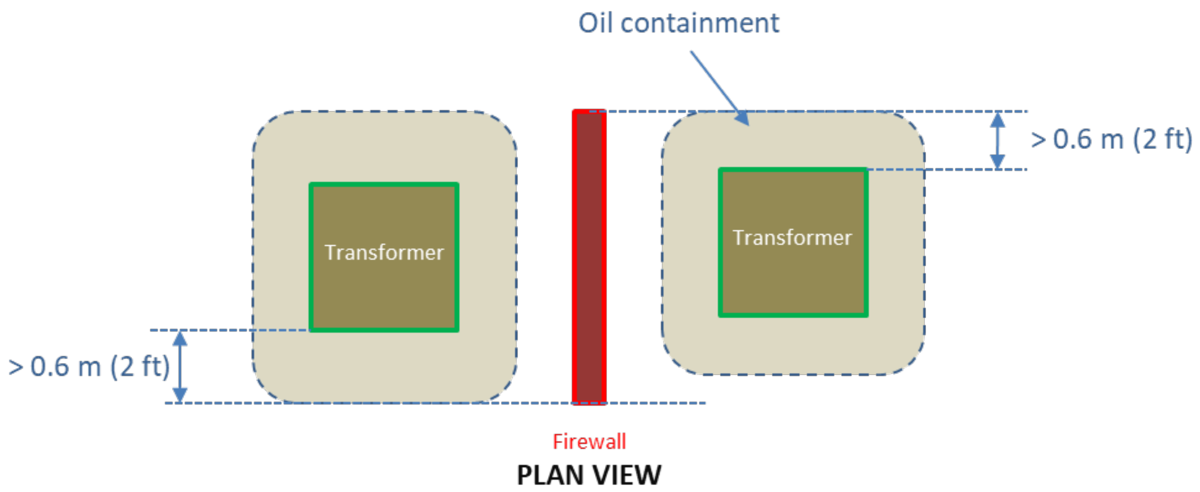
ii. a 2-hour-rated fire barrier extending at least 0.3m (1ft) above the top of the transformer casing and oil conservator tank, and at least 0.6m (2ft) beyond the width of the transformer and cooling radiators as shown below:



Courtesy of FPO. (from NFPA 804 & 850 standards)

Note:

- Where a firewall is provided, it should be designed to withstand the effects of projectiles from exploding transformer bushings or lightning arresters.
- A higher noncombustible shield may be provided to protect against the effects of an exploding transformer bushing.
- The wall should extend up to the limit of the oil containment if its width extends beyond the 0.6m (2ft) indicated above.



Courtesy of FPO. (from NFPA 804 & 850 standards)

- If columns supporting the turbine building roof (if any) at the exterior wall have a 2-hour fire-resistive rating above the operating floor, the firewall need not be higher than required to obtain line-of-sight protection up to the height of the operating floor.
- Fixed fire protection should be considered. (See Point 6] for oil-filled transformers).
- Adequate oil containment should be provided. (See Point 7]).

iii. For Transformers with approved less flammable dielectric fluids

Courtesy of Franck Orset (FPO)

Separation from adjacent transformers is given in Table 2:

Fluid capacity in liters	Min. separation in meters
< 37 850	1.5 m
> 37 850	7.5 m

Table 2 – Outdoor Less Flammable Fluid -Insulated Transformer Equipment Separation Distances in m between adjacent transformers (from FM Global Data Sheets 5-4)

Fluid capacity in gallons	Min. separation in ft
< 10 000	5 ft
> 10 000	25 ft

Table 2 – Outdoor Less Flammable Fluid Insulated Transformer Equipment Separation Distances in ft between adjacent transformers (from FM Global Data Sheets 5-4)

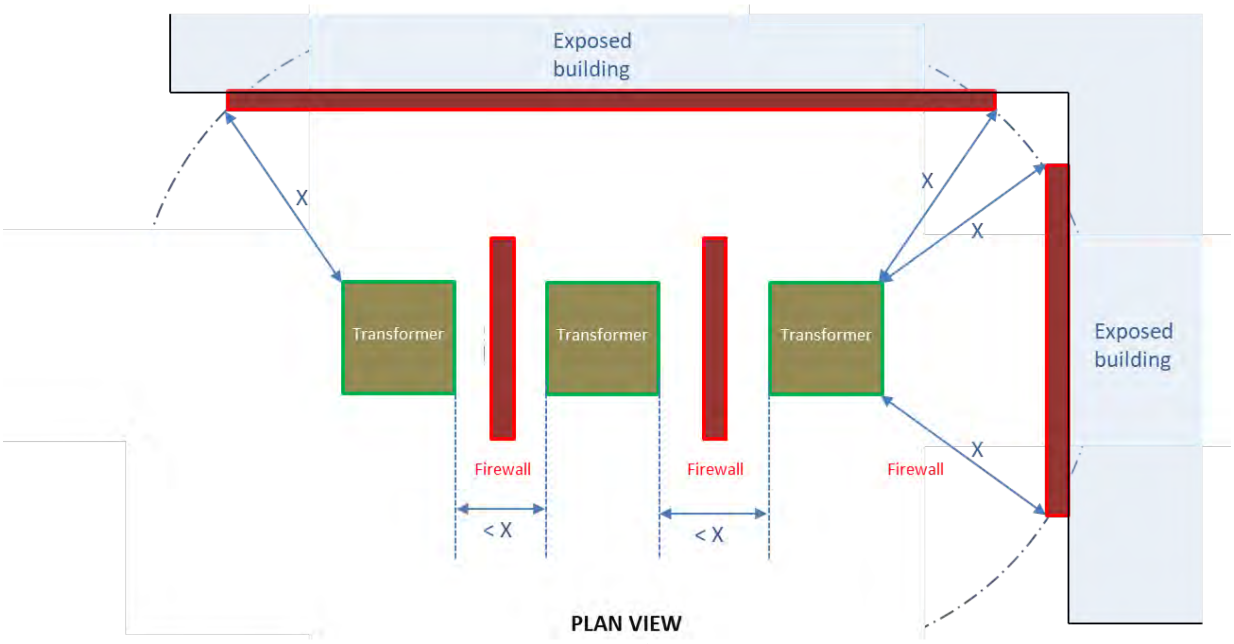
This means that if the above-mentioned minimal separation is maintained, neither fire suppression nor barrier walls are required.

When the above-mentioned distances are not met, a 2-hour firewall should be provided between transformers. It should extend vertically and horizontally as indicated in the section ii. Figure above.

Fixed fire protection should be considered. (See Point 6] for oil-filled transformers).

Adequate oil containment should be provided. (See Point 7]).

5) Illustration of an outdoor oil-insulated transformer exposing facilities and mutual exposure spacing. (See Points 3] and 4] above):



Courtesy of FPO

- Fixed fire protection should be considered. (See Point 6] for oil-filled transformers and exposed facilities).
- Adequate oil containment for oil-filled transformers should be provided. (See Point 7]).

6) Automatic Fire protection for outdoor oil-filled transformers and exposed facilities:

a) Fixed fire protection of outdoor oil-filled transformers:

i. The following fixed fire protection is suitable for:

- Oil-filled (combustible – mineral oil) mains, service stations, and start-up transformers not meeting the separation or fire barrier recommendations in Table 2] b. i. above.
- Reducing the lead time due to the manufacture and shipping of a new transformer by allowing repairs when possible, considering that the fire would be controlled in its early stage of development.

Design density:

- Not less than 10.2L/min/m² (0.25gpm/ft²) of projected area of a rectangular prism envelope for the transformer and its appurtenances, and not less than 6.1L/min/m² (0.15gpm/ft²) on the expected non-absorbing ground surface area of exposure.
- The spray system should be activated by a pilot line or FM-approved fire detection. Note that in recent years some transformers have been designed with relatively high design temperatures. Operation of the cooling fans can release large amounts of heat that can inadvertently trip deluge systems using rate-of-rise or rate-compensated heat detection equipment. To avoid these inadvertent trips, fixed temperature heat detection systems should be used to activate transformer deluge water spray systems.
- Adequate oil containment should be provided. (See Point 7]).
- Nozzles should be positioned so that the water spray does not envelop energized bushings or lightning arresters by direct impingement (unless authorized by the manufacturer).
- Detection of a fire should preferably be undertaken by the use of sprinkler heads, set into a separate air-pressurized line (pilot line).

ii. For Transformers with approved less flammable dielectric fluids:

- When the minimum required distances are not met and/or when the transformers could expose adjacent structures, buildings or major equipment, an automatic water spray system should be installed.
- These transformers should be encased in concrete shields protecting buildings and other transformers from heat and smoke.
- Transformers, including the adjacent non-absorbing ground areas, should be protected with an automatic water-based spray system.
- The minimum density is 10mm/min (0.25gpm/ft²) for the surface area of the transformers and 6mm/min (0.15gpm/ft²) on the non-absorbing ground areas.
- Nozzles should be positioned so that the water spray does not envelop energized bushings or lightning arresters by direct impingement (unless authorized by the manufacturer).
- Detection of a fire should preferably be undertaken by the use of sprinkler heads, set into a separate air-pressurized line (pilot line).

b) Fixed fire protection for exposed facilities:

i. For protection of windows or similar openings, the following design criteria should be considered:

- Sprinkler heads should be positioned within 5cm (2”) of the top of the window and 30cm (12”) from the window surface. For windows up to 1.5m (5ft) wide, only one sprinkler head is required to protect the openings. For windows from 1.5 (5ft) to 3.7m (12ft) wide, 2 sprinklers heads are required.

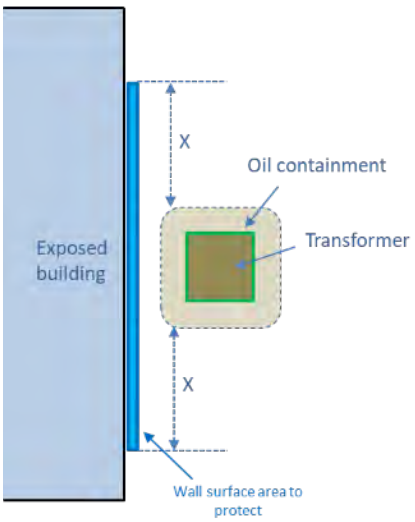
- Sprinkler heads should be positioned so that a certain amount of water discharge could run down the side of the building and cool the exposed surface. Provisions should be made so that the water remains in contact with the wall and/or window surface while running down. Special consideration should be given to potential wind effects, so that the surface can be properly wetted.

ii. For the protection of openings in a fire separation wall, the following design criteria should be considered:

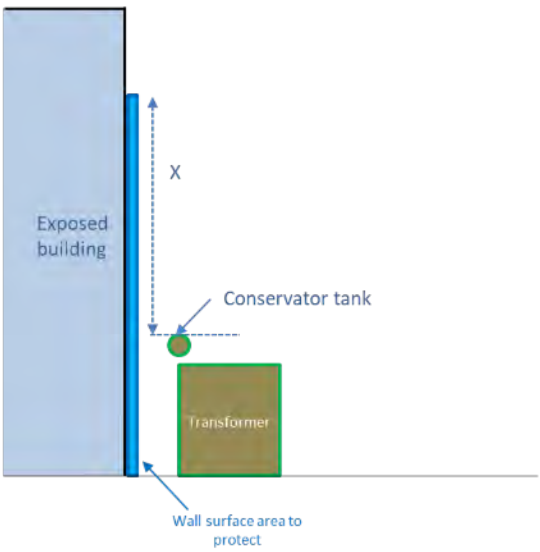
- Water curtain: sprinklers in a water curtain should be hydraulically designed to provide a minimum discharge of 37L/min (10 gallons/min) per lineal meter of water curtain, with no sprinkler head discharging less than 57L/min (15 gallons/min) (minimum operating pressure of 0.5bar (7psi) for K80 (K5.6) sprinkler heads).
- Sprinkler exposure protection (automatic sprinkler or deluge systems)
- Protection should be hydraulically designed to provide a minimum operating pressure of 0.5bar (7psi) with all sprinklers facing the exposure operating (or all of the deluge heads for a deluge system).

iii. For the protection of an exposed wall (not fire-rated or less than 2-h fire-rated), the following design criteria should be considered:

- The protection should be provided to cover the entire surface represented by the minimum distance indicated below:



PLAN VIEW

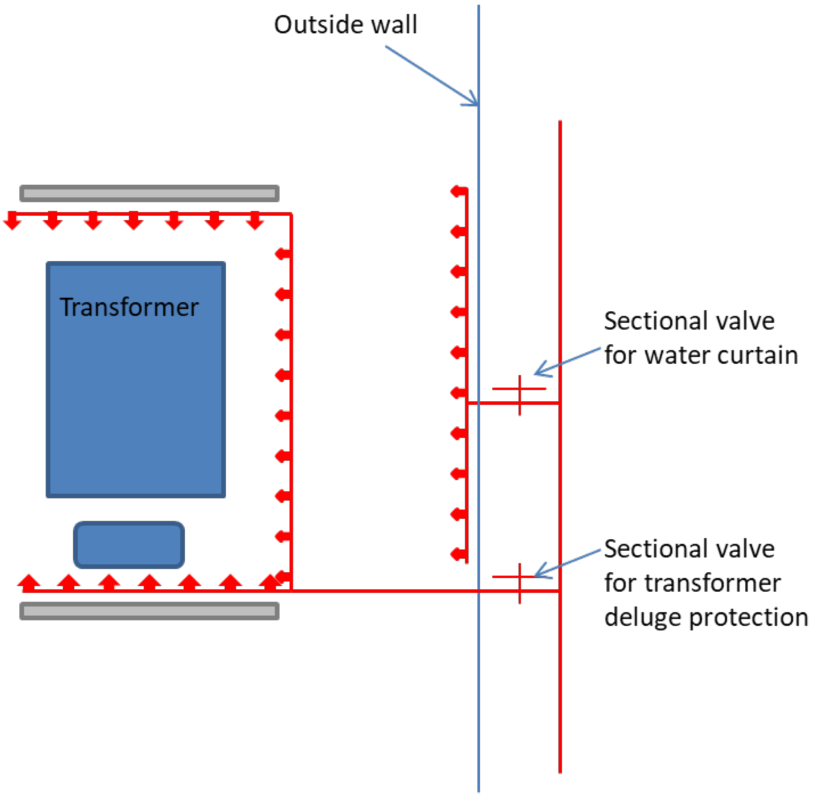


ELEVATION VIEW

With:
x= 7.5m (15ft) if the transformer's oil capacity is < 18 900 l (5000 gallons)
and 15m (50ft) if the transformer's oil capacity is > 18 900 l (5000 gallons).

- The transformer should be located at least 1.5m (5ft) from the wall.
- The sprinkler protection should be designed to deliver a minimum density of 8mm/min (0.20gpm/ft^2) over the entire surface, with a design for direct impingement application, or provide rundown application with a maximum distance between levels of 3m (10ft).
- Sprinkler heads' location: for wall protection systems, sprinkler heads should be located 15cm (6") to 30cm (12") from the wall surface and within 15cm (6") from the top of the wall, with a maximum spacing of 2.4m (8ft) between sprinkler heads.

iv. When a water curtain protection is provided against a wall (protection against external exposure) because of the presence of openings (windows, louvers, walls with combustible insulation…), the sectional valve for the supply of the water curtain should be from an independent supply from that of the one used to protect the transformer.



Courtesy of Franck Orset (FPO)

This is to be sure that in case of failure of the deluge protection on the main transformer, it is still possible to isolate the sectional valve controlling the transformer without affecting the water flow on the water curtain.

7) Oil containment:

- Outdoor liquid-filled transformers should be provided with spill containment if the accidental release of transformer fluid could expose a main building or adjacent equipment or storage to fire damage.
- A catch basin should be provided beneath each transformer with sufficient capacity to hold 120% of the oil contents of the transformer, or retention with a drain, leading to an underground tank.
- The area of the bund should be sufficient to be able to capture all oil ejected from pressure relief devices, ruptured bushing turrets, main tanks, oil coolers and the conservator.
- The provision of crushed stones is a good practice to prevent large fires at the transformer location.
- In the event of a transformer failure, the spilling oil will effectively be cooled down by the yard stone to below the combustion temperature. The stones will effectively prevent the oil from burning uncontrolled throughout the containment area.
- Only the area that was exposed to the oil spill will have surface oil that will burn until dry. This will minimize the actual time and severity of the fire due to the limited amount of surface oil and the reduction in oil temperature.
- In passive systems with crushed stone, no less than 300mm (12in.) of stone should be provided to extinguish the oil, if on fire. Smaller stone is more effective, 20mm to 40mm (¾ in. to 1½ in.) is recommended. While larger stone permits quicker penetration by the oil, its size makes it less effective as a quenching stone.
- The volume of the bunding and the rock ballast must be sufficient to hold the total volume of oil from the transformer at 100mm (4in.) below the surface of the rocks to ensure that a pool fire is not sustained.
- Note that rock ballast tends to collect dust and other wind-borne debris over time and may silt up and require cleaning at infrequent intervals.

- A system for removal of rainwater from the containment area should be provided.

11.10 Electrostatic Precipitator (ESP)

The following points should be considered in detail:

1) All oil-filled transformer supports located at the top of ESPs should be provided with adequate stoppers in order to prevent any horizontal and vertical movement in case of earthquake shakes (in regions with EQ exposure).

2) In order to prevent oil-filled transformers from severely exposing the Electrostatic Precipitator in the case of fire or explosion, the following fire protection solutions and their potential alternatives should be considered in detail:

   a) The oil-filled transformers should be replaced with dry-type transformers when possible.

   or

   b) The oil-filled transformers installed above the ESP should be adequately protected as per NFPA850 as follows:

   - Adequate automatic spray (deluge) systems should be installed above the transformers in accordance with NFPA standards. All material and equipment should be FM-approved and/or UL-listed. All alarms should be relayed to a constantly attended location. This protection should be fed by an adequate and reliable Fire Water supply.
   - A catch basin should be provided beneath each transformer with sufficient capacity to hold 120% (oil and fire water) of the oil contents of the transformer, or a retention with a drain, leading to an underground tank.
   - The project should be reviewed by a qualified Fire Protection Engineer familiar with NFPA standards.

Comment:

Oil-filled transformers constitute a severe exposure threat to ESPs which are usually located at elevated levels on top of the ESP. Technically speaking, thermal power generating units, boilers and kilns could operate without an ESP. However, sometimes local environmental regulations stipulate that an ESP is mandatory.

1) In the case of an EQ shake (EQ exposed areas), these transformers may fall out of the rails and be damaged so that the combustible insulating oil is released and may be ignited by a hot surface or by friction resulting in fire and loss.

2) In the case of an explosion and/or a fire involving an oil-filled transformer, oil would spread over the ESP, resulting in severe property damage and potential shutdown. Safe and efficient manual firefighting at such heights would be virtually impossible.

11.11 SUBSTATIONS / MCC ROOMS / SERVER ROOMS / ELECTRIC ROOMS

All Substations / MCC Rooms / Server Rooms / Electric Rooms that have no physical well-segregated backup (located in a different fire / flood / other perils area than the main unit) and that may lead to production disruption in case of total loss should be identified. These facilities are deemed as critical.

The following solutions A), B) and C) and their alternatives should be considered in detail for these critical utilities:

A) Duplication: a full backup should be provided for these rooms. This can consist of duplicating these rooms (so that in case of loss on a hot site, the standby room could immediately take over, or on a cold site there would be a limited switch time for limiting interruption). The main room and the back-up room(s) should be located in different well- separated fire areas consisting of a minimum separating distance (25m for noncombustible construction and 40m for combustible construction) or a physical barrier (at least a 2-hr fire partition without any opening such as a door or even a fire door which risks being left open), false floors / ceiling penetrations or windows. An adequate NFPA and FM-approved automatic fire detection system should be installed in both the main room and the back-up room.

and/or

B) Protection: if a backup or any other redundancies are not available or cannot be fully completed, as detailed in Point A. above, the following fire protection alternatives should be considered:

- Rooms housing electric equipment such as cable vaults, breakers, drivers, PLC cabinets, GIS bay cabinets, etc.:

  For standard-size airtight rooms: Approved and adequate automatic gaseous extinguishing total flooding inside the rooms and inside the cable trenches / false floors / false ceilings should be considered. For reliability, these gaseous extinguishing systems could be of the double-shot type and/or an automatic wet pipe sprinkler protection system under the ceiling could provide an adequate backup in the case of single / double-shot gaseous extinguishing systems. Wet pipe sprinklers for trenches / false floors of at least 80cm deep can also be considered.

  or

  For large-size non-airtight rooms: Approved and adequate automatic wet pipe sprinklers under the ceiling and inside the cable trench / false floors / false ceilings of at least 80cm deep should be considered. Should the site have concerns about electrical shocks and/or accidental water discharge, a pre-action system could be considered for the cabinet rooms. (A wet pipe sprinkler and pre-action - minimum design density should be 6 mm/min (0.15 gpm/ft^2) over 186m^2 (2000 ft^2) with K80 (K5.6) standard spray sprinklers rated at 68°C (165°F) - are suitable for large-size rooms and when it is difficult to make the room airtight for a gaseous extinguishing system)

  or

  For control panels in large-size rooms, high ceilings, relatively low combustible load (i.e., GIS / control bay panels in process areas): Approved and adequate automatic gaseous extinguishing locally discharging inside the cabinets and inside the cable trenches / false floors / false ceilings should be considered. For reliability purposes, these gaseous extinguishing systems could be of the double-shot type and/or an automatic wet pipe sprinkler protection system under the ceiling could provide an adequate backup in the case of single / double-shot gaseous extinguishing systems. Wet pipe sprinklers for false floors of at least 80cm deep can also be considered.

  and

- Cable vaults / tunnels:

  Cable vaults and tunnels should be protected with an approved and adequate automatic wet pipe sprinkler protection system. Moreover, cables in open-side cable vaults exposed to wind should also be coated with adequate and FM-approved intumescent material.

  and

C) Contingency Plan:

A Contingency Plan should be developed in the case of a loss of a Substation / Electric Room, identifying by-pass possibilities, vendors and/or manufacturers or locations where spare cabinets are available. The lead time and installation time should be investigated by specialists. The Contingency Plan should be formalized, regularly reviewed and updated. Ownership and leadership should be clearly defined.

D) Important Note:

The following points regarding the above fire protection solutions and their potential alternatives should be considered:

Gaseous extinguishing agent: carbon dioxide (CO_2) is very dangerous for humans (lethal). As a result, for any normally occupied or occasionally occupied areas, we strongly recommend an automatic system using safe gaseous extinguishing agents for personnel, such as "Inergen" or “Argonite” or approved clean agents such as FE227 and FM200, in accordance with NFPA 2001. The recommended extinguishing agent density should be such that the oxygen concentration in the room does not drop below the safety limit. If a carbon dioxide system is selected for a raised floor, a special low-velocity discharge system should be used so that the carbon dioxide does not rise above knee height in the room. Under-floor halocarbon agent systems (e.g., FE227 and FM200) are not permitted when the space above the raised floor is not equipped with a halocarbon agent system. A fire in the space above the raised floor could draw the discharged halocarbon agent upwards, causing it to decompose and become very toxic. Only equipment tested and approved by a recognized laboratory should be accepted.

Ventilation Interlock: the ventilation system should be interlocked to the fire detection / protection system in order to shut down automatically upon fire detection. Ventilation interlocks should permit ventilation to stop when fire is detected in a room. This is in order to prevent the supply of oxygen to a fire and the escape of gaseous extinguishing agents, when provided.

Ventilation Duct Segregation: fire dampers should be installed in each ventilation system which is common to different rooms. These dampers should be interlocked to their respective fire detection system, to close automatically in case of fire detected in one of these rooms. Some ventilation ducts may be common to at least 2 utility rooms. Without fire dampers closing when fire is detected in a room, smoke may spread to the adjacent rooms and gaseous extinguishing agents may also escape from the room where it has been discharged though the ventilation duct.

Water-Based Fire Protection & Electrical Shocks: regarding sprinkler protection, should the plant have concerns about electric shocks, the mains switch may be interlocked to the sprinkler system in order to de-energize the area in case of sprinkler water discharge.

Fire Water Supply: the above-recommended sprinkler protection should be fed by an adequate and reliable fire water supply in accordance with the latest version of NFPA, as recommended.

Alarms and signals: all fire alarms, supervisory signals and trouble signals should be relayed to a constantly attended location.

Materials and equipment: all fire detection / protection material and equipment should be UL-listed or FM-approved and should be installed by a qualified contractor familiar with NFPA/FM standards.

Plan Review: the project should be reviewed by a qualified Fire Protection Engineer familiar with NFPA standards.

Comment:

Solution A) consisting of adequately-segregated redundancies is the most reliable but also the most expensive.
Solution B) is the most efficient when A) is not possible. Automatic Sprinkler wet pipe or pre-action systems are suitable for large-size rooms and when it is difficult to make the room airtight for a gaseous extinguishing system.

Automatic fire protection systems can fail (i.e., faulty design, lack of maintenance, impairment). Back-up systems (sprinkler and pre-action) for gaseous extinguishing systems are therefore recommended.
Cable coating (2-hour fire-rated maximum) in cable vaults is an acceptable solution for areas handling material that could react with water (i.e., hot molten metal). This should, however, not be a systematic substitute for an automatic sprinkler in other areas. For open-side cable vaults exposed to wind that could divert water discharge, both automatic sprinklers and coatings providing mutual backup are recommended.

Solution C) – the Contingency Plan is not a substitute for either duplication (Point A. above) or automatic fire protection (Point B. above). The main purpose of a Contingency Plan is to limit Business Interruption in case of the loss of a protected room (protection can be impaired) with or without redundancies provided, as per point A. In such cases, the CP aims at ensuring the availability / reliability of the redundancy(ies), if any.

The ultimate goal of this recommendation is to mitigate the impact of Business Interruption. The decision should be based on 'what-ifs' and risk / benefit analysis.

11.12 CABLE OPENINGS / CABLE TRAYS & RUN / CABLE VAULTS / CABLE TUNNEL

The following points should be considered in detail:

A) **All Cable Openings** to substations, electrical rooms, MCC rooms, electric cabinets, control rooms, rack rooms, server rooms and processing areas, should be sealed with an FM-approved fire sealant. If these openings are only temporary, then approved provisional sealing materials should be used. Cable openings could be filled with noncombustible insulation material (glass wool) and sealed with noncombustible gypsum material as an acceptable alternative to an approved fire sealant.

B) **All horizontal Cable Trays** running in processing areas should be provided with large fire breaks, 2m in size, made from FM-approved noncombustible intumescent paint, applied on cables every 30m. As an acceptable alternative to approved intumescent material, noncombustible gypsum material could be applied to cable trays.

C) **In vertical Cable Runs**, the trays should have a fire barrier installed every 10m. The cable openings between the floors of buildings should be sealed with an FM-approved fire-resistant material.

Comment:

A) Some polyurethane foams contain a fire retardant. The retardant allows the flammability of the PU foam to be temporarily reduced by reducing ignition potential and flame spread. However, when exposed to a sustainable fire, the combustible PU foam will burn. Furthermore, the property of the fire retardant may change depending on time and ambient conditions. In order to be approved, fire-retardant material needs to be tested by NFPA 255: "Standard Method of Test of Surface Burning Characteristics of Building Materials*"*. As a result, we strongly recommend the use of approved sealant noncombustible intumescent material.

B), C) Long unprotected cable trays are usually run along the inside of processing areas. A potential fire could spread along the entire length of the cables, from one area to another.

11.13 BATTERY ROOM (ESS)

Courtesy of Franck Orset (FPO), Loss Prevention Engineer:

Based on NFPA855 ed 2020 "Installation of Stationary Energy Storage Systems" and FM Global Data Sheets 5-33 "Electrical Energy Storage System"

Standard:

- Closed hydrogen systems are preferred for Energy Storage Systems (ESS).

Location:

- Batteries should be installed in a separate 1-h fire compartment.
- Energy Storage Systems (ESS) should be arranged in groups with a maximum energy capacity of 250kWh each.
- Each group should be spaced at least 90cm (3ft) from other groups and from walls in the storage room or area.

The maximum rated energy should be 600kWh.

Storage:

- No combustible storage, unrelated to the battery room, should be allowed inside the room.
- Combustible material related to the battery room should be stored at a minimum distance of 90cm (3ft) from the equipment.

Electrical equipment:

- All electrical equipment installed or used in battery rooms should be explosion-proof.

Direct current switchgear and inverters should not be located in the battery rooms.

Ventilation:

1. Battery rooms (flooded lead-acid, flooded Ni-Cd and VRLA batteries) should be provided with natural ventilation to limit the concentration of hydrogen to 1% by volume (25% of the LEL – Lower Explosive Limit) and equipped with a hydrogen detection system. The hydrogen concentrations should be monitored.

   or

2. Mechanical exhaust ventilation should be provided at a rate of not less than 1 cubic foot per minute per square foot ($1ft^3/min/ft^2$) [$0.0051m^3/s / m^2$] of the floor area of the room and should be activated by a hydrogen detection system set to operate the ventilation at 25% of the LEL (1% of H_2 inside the room).

   The hydrogen concentrations should be monitored.
   The mechanical ventilation should remain on until the flammable gas detected is less than 25% of the LEL.

   or

3. Continuous ventilation should be provided at a rate of not less than 1 cubic foot per minute per square foot ($1ft^3/min/ft^2$) [$0.0051\ m^3/s / m^2$] of the floor area of the room.

Excessive concentrations (>1 % vol.) and/or loss of ventilation and/or failure of the gas detection system should sound an alarm signal at a constantly attended location (Main Control Room).

The exhaust ventilation lines should be located at the highest level of the fire compartment.

Exception: Lithium-ion and lithium metal polymer batteries should not require additional ventilation beyond that which would normally be required for human occupancy of the space.

Detection:

- Fire detection should be provided inside the room.

Room protection:

- Battery rooms should preferably be protected by automatic sprinklers designed to deliver a minimum density of 12.2 mm/min ($0.3gpm/ft^2$) over the entire area of the room or $232m^2$ – $2500ft^2$, - whichever is smaller.

- Thermal runaway events create a large amount of heat. The heat, coupled with plastic construction components, can lead to a very large fire. Although sprinkler protection may not be practical in exterior installations, it is the best method of cooling a fire involving an ESS.
- Total flooding gas protection systems could be provided and should be designed to maintain the design concentration within the enclosure for a time sufficient to ensure that the fire is extinguished and that the ESS temperatures have cooled to below the autoignition temperature of combustible material present and the temperature that could cause thermal runaway (with a minimum of 10 minutes).
- The design of the system should be based on:
  - The agent concentrations required for the specific combustible materials involved
  - The specific configuration of the equipment and enclosure.

  Protections by water mist or dry chemical systems are not advised/recommended.

11.14 LIGHTING FIXTURES

The following points should be considered in detail:

a) Metal Halide HID Bulbs: lighting fixtures in both process and storage areas should be provided with borosilicate or tempered soda lime glass external shield enclosures.

b) Florescent light tubes: should be provided with adequate cover and should include an electronic starter designed to start 10 times (maximum) prior to shutdown in case of malfunction. These fluorescent light tubes should be replaced when flicking.

Comment:

a) The lamp containment barrier will prevent fragments of hot glass or quartz from falling and igniting combustible material beneath them.

b) Malfunctioning fluorescent light tubes were responsible for some fires in warehouses. Some Finished Product warehouses made of combustible flexible plastic material are provided with fluorescent light tubes without any cover.

11.15 RUBBER BELT CONVEYOR

The following points should be considered in detail:

A) Identification: All critical rubber belt conveyors should be identified.

B) Contingency Plan: a Contingency Plan should be developed in case of loss of a critical rubber belt conveyor including the belt and its structural support, identifying vendors and/or manufacturers or locations where spare conveyors are available.

or

C) Protection: in case the replacement time is not acceptable from a Business Interruption standpoint, an automatic sprinkler protection, following the requirements of international standards (NFPA / FM Global Data Sheets 7-11: “Conveyor Belts”), should be installed for all critical rubber belt conveyors.
   - The belt drivers should be interlocked to the sprinkler system to enable them to stop automatically in case of water discharge.
   - All fire alarms, troubles and supervisory signals should be relayed to a constantly attended location.
   - All material and equipment should be approved and/or UL-listed.
   - A project plan review of the fire protection systems should be conducted by qualified and recognized fire protection engineers familiar with NFPA / FM standards prior to

installation, and a visit on site should be conducted during and after installation, before acceptance.

- The protection system should be installed by qualified contractors.

Comment:

Although the conveyed product and the structure may be noncombustible, loss history demonstrates that the belt itself presents a sufficient combustible load to spread the fire without any other fuel contribution.

The fire velocity itself would be such that it would not only result in the major loss of a conveyor belt, but also in structural members, such as gantries and legs supporting the overhead conveyor.

Moreover, in certain situations, such as when covered and/or elevated, rubber belt conveyors should be considered inaccessible for manual firefighting. In the case of inclined rubber belt conveyors, a slope greater than 10% facilitates a faster spreading flame front. Underground conveyors are difficult to access.

The conveyors may represent a long downtime in the case of a fire event. The use of a fire-resistant belt may reduce this hazard somewhat, but it will still burn, and a protection system is, therefore, still required.

Because conveyor belts have relatively slow burning characteristics, sprinklers are very effective in gaining early control.

Courtesy Of Franck Orset (FPO) Loss Prevention Engineer:

For closed sprinkler head protection systems, sprinkler heads should preferably be rated at 74°C (165°F) and have a K115 (8.0) orifice size.

If the ambient temperature in the area is above 45°C (113°F), then intermediate or high temperature sprinkler heads can be used - 93°C (100°F) or 141°C (286°F). A minimum of 30°C (86°F) should be maintained between the highest ambient temperature expected and the temperature rating of the sprinklers.

In areas subjected to freezing conditions, dry or preaction systems are preferable options.

The fire protection should be designed in accordance with the following table:

Belt orientation	Sprinkler system type	Sprinkler spacing	Sprinkler demand	
			Number of operating sprinklers	Flow per sprinkler
<10°	Wet, dry or preaction	3.7 m (12 ft)	10	95 lpm (25 gpm)
10-30°	Wet, dry or preaction		15	95 lpm (25 gpm)
>30°	Deluge		All sprinklers on a single system	12 mm/min (0.3 gpm/sq ft) over entire area

Note that NFPA 850 only recommends a design density of 10mm/min (0.25gpm/ft²) over 186m² (2000ft²) of the enclosed area or the most remote linear 30m (100ft) of conveyor structure up to 186m² (2000ft²). This protection is not associated to the belt orientation and is considered insufficient for an orientation above 30°.

Linear heat detection systems should be provided to activate preaction or deluge systems.
The maximum water delivery time should not exceed 60 seconds for dry or preaction systems.

There should be a 60-min water duration for the system.

For conveyors more than 3m (10ft) wide, the maximum sprinkler coverage area should be 100ft² (with a maximum spacing of 3.7m (12ft) between sprinklers).

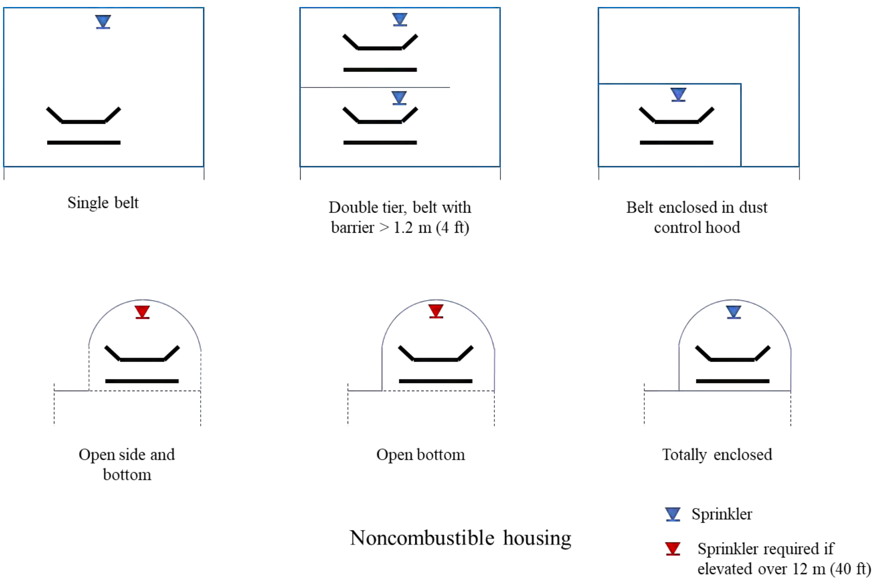
The location of sprinklers over conveyors should comply with the following rules:

For indoor conveyors:

Pendent sprinklers should be provided along the centerline of the belt.
If sidewall sprinklers are provided, there are 2 possibilities, depending on the belt width:
Belt width < 1.8m (6ft): position sidewall sprinklers along one side of the belt.
Belt width > 1.8m (6ft): position sidewall sprinklers staggered along both sides of the belt (i.e.,: sprinkler heads on one side of the belt are spaced 7.4m (24ft) maximum apart).

For outdoor conveyors:

The sprinklers should be located in accordance with the following diagrams for outdoor conveyors (the occupancy is assumed to be noncombustible, apart from the conveyor or conveyed products).



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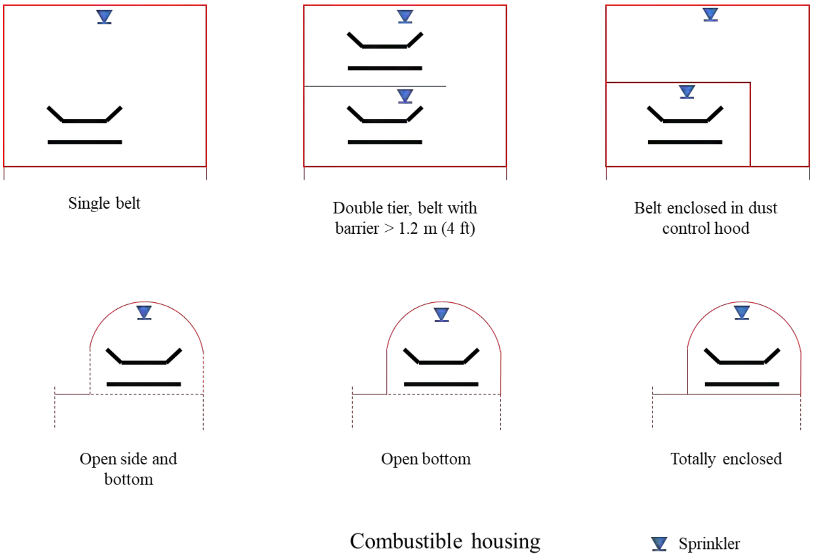
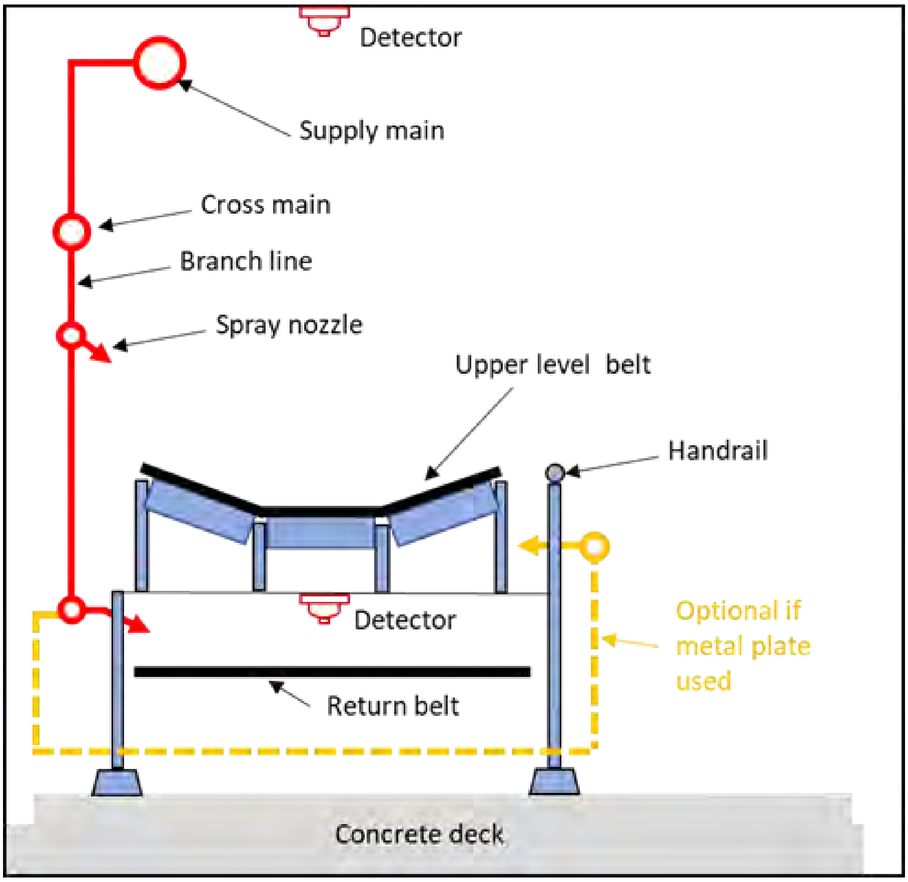
Note that there is a difference between combustible and noncombustible housing. Additional sprinkler heads might be required for the protection of the combustible housing, when provided:

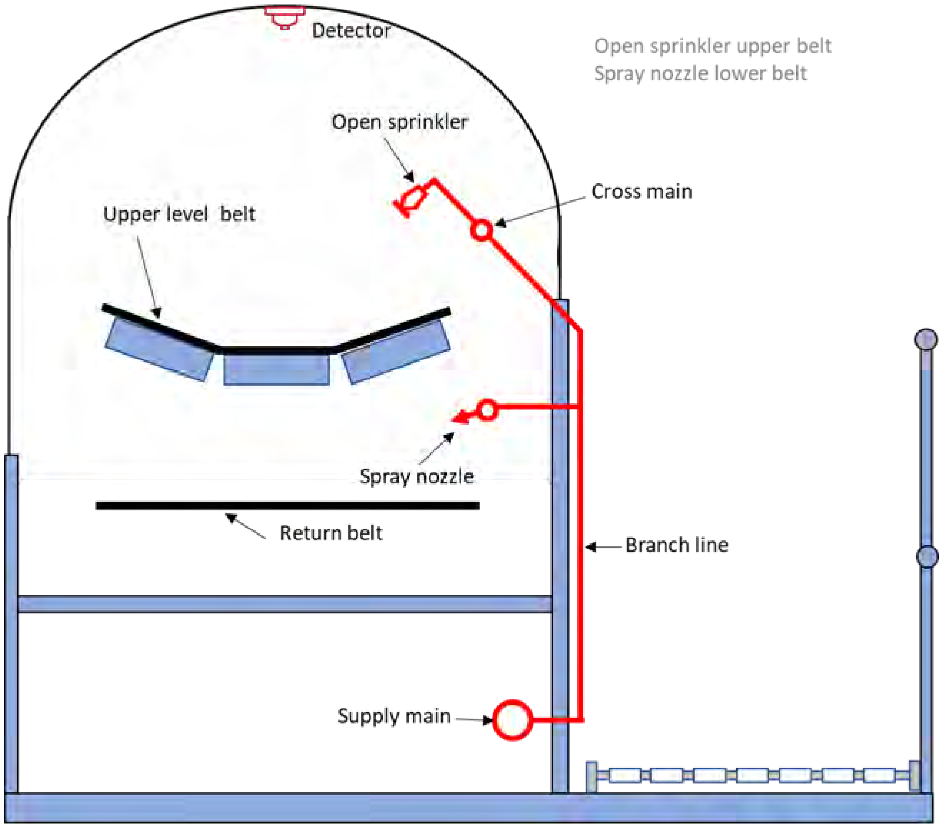


For deluge protection, the discharge pattern of the deluge nozzles should envelop the top and bottom belt surface area, conveyor surfaces where combustible materials are likely to accumulate, structural parts, and the idler rolls supporting the belt.

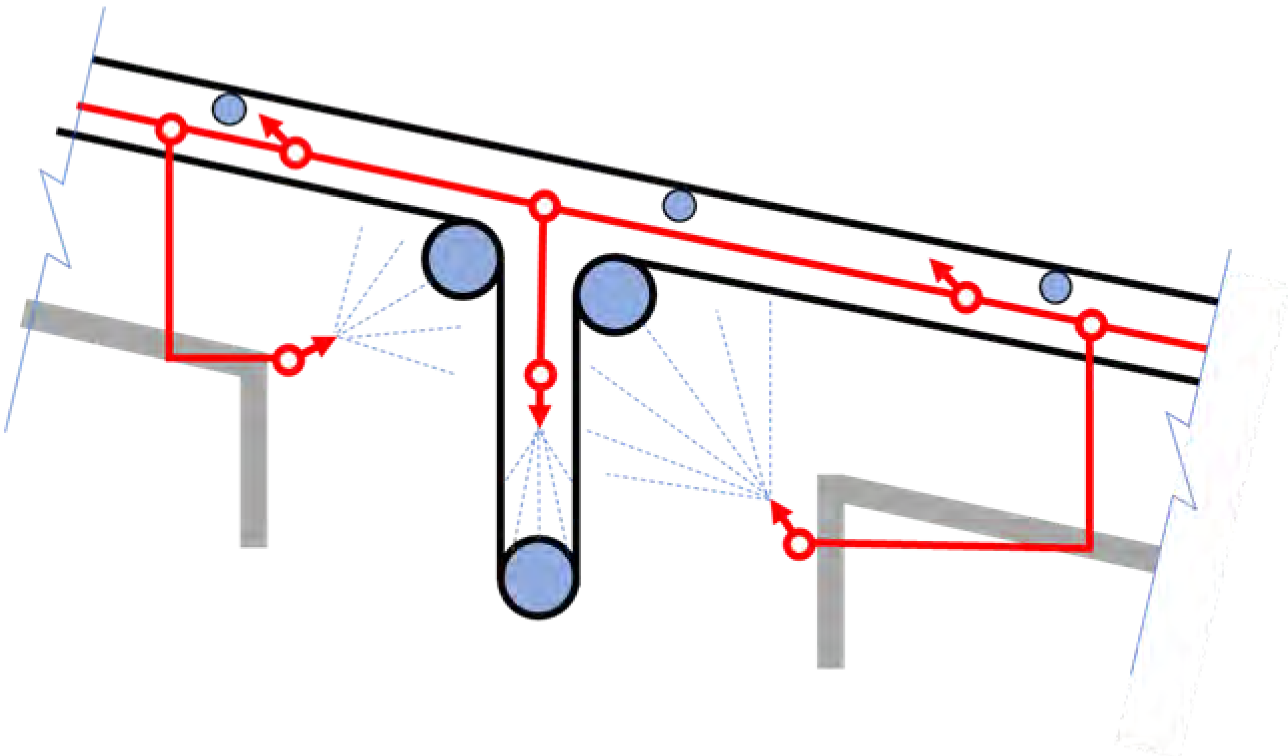
Courtesy of Franck Orset (FPO) Loss Prevention Engineer. (Source NFPA15):



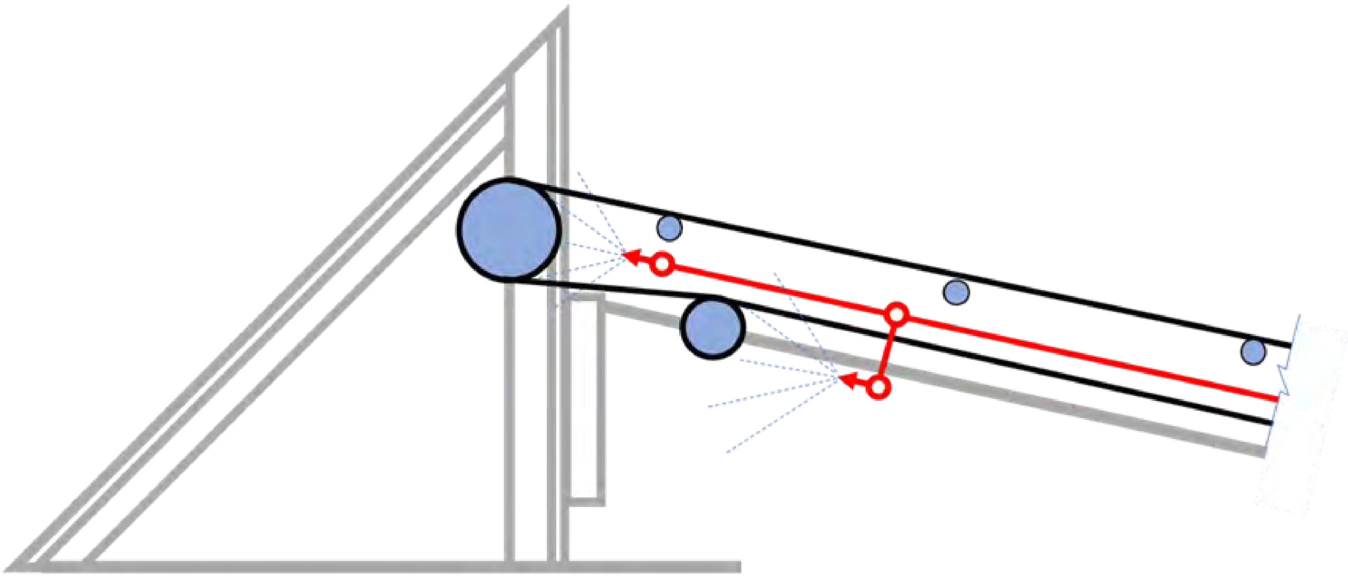
Typical conveyor belt protection (as per NFPA 15)



Typical hooded conveyor belt protection (as per NFPA 15)



Elevation of typical take-up roller protection (as per NFPA 15)



Elevation of typical end roller protection (as per NFPA 15)

11.16 COOLING TOWER

The impact on production of a potential total loss of a cooling tower set should be investigated. The following solutions A) or B) should be considered in detail for mitigating the loss:

A) Contingency Plan: a Contingency Plan should be developed (in case of the loss of a cooling tower set), identifying process-cooling alternatives, vendors and/or manufacturers or locations where entire sets are available.

or

B) Protection: in case the above Contingency Plan is not acceptable from a Business Interruption standpoint, critical cooling towers (having a direct impact on production) should be adequately protected by approved sprinkler protection as per NFPA 214/ FM Global Data Sheets 1.6. All material and equipment should be approved and/or listed. The project should be reviewed by a qualified Fire Protection Engineer familiar with NFPA standards. All alarms should be relayed to a constantly attended location. This protection should be fed from an adequate and reliable Fire Water supply.

Comment:

The study should include the loss of an entire set of cooling towers, comprising several cells without fire separation (i.e., 40m).

Cooling towers are usually made of combustible material such as FRP hoods, shells and packing. If there are multiple cells on the same set, even with a concrete shell and walls, the fire would be able to spread to the hood or to the front or bottom openings.

Several fires during maintenance periods in the cooling tower (dry conditions) are recorded each year. Electrical failure of drivers, overheating, friction of the fan on the hood, and lighting are also serious sources of ignition.

Due to relatively fast fire spread, safe and efficient manual firefighting would be virtually impossible.

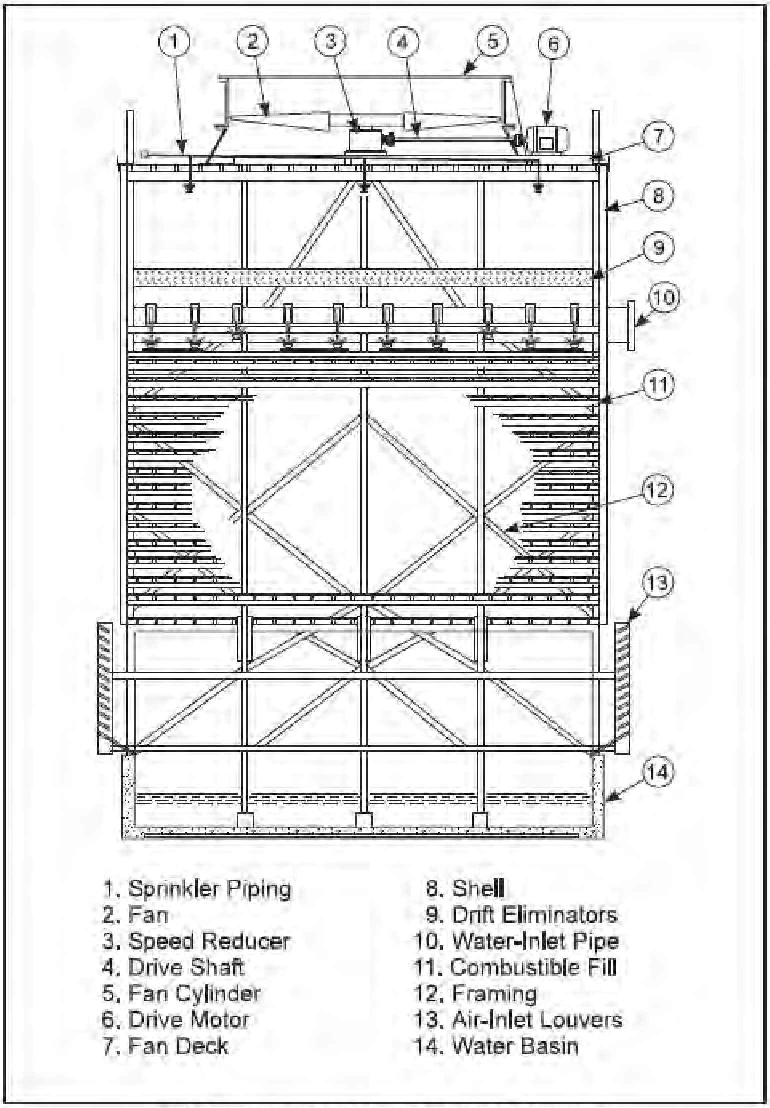


Fig. 1. Typical cross section of a counterflow induced-draft cooling tower

FM Global Data Sheets 1-6 "Cooling Towers". Fig. 1, 2, 3 and 4. Posted and reprinted with permission of FM Global.

Minimum recommended density as per FM Global Data Sheets 1-6:

- For cementitious fill and a combustible fan deck: wet pipe / dry pipe of 6mm/min (0.15gpm/ft²)
- For a combustible fan deck: wet pipe / dry pipe of 14mm/min (0.35gpm/ft²)
- For a combustible fill & fan deck: deluge, 20mm/min (0.50gpm/ft²)

Minimum rate of application as per NFPA214:

- Deluge, under the fan decks, 20.4mm/min (0.50gpm/ft²) including the fan opening.

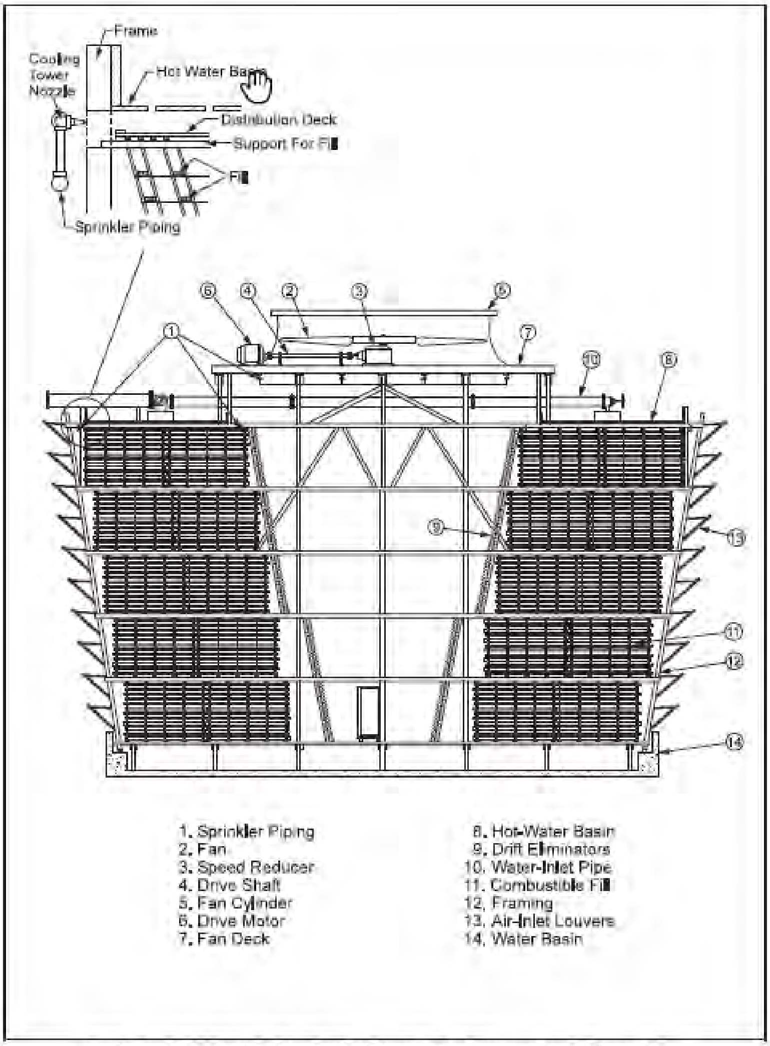


Fig. 2 Typical cross section of a crossflow induced-draft cooling tower (open hot water basin)

Minimum recommended density as per FM Global Data Sheets 1-6:

- For a combustible fan deck and fill: deluge, 14mm/min (0.35gpm/ft²)
- Without a distribution deck below the hot water basin: deluge, 20mm/min (0.50gpm/ft²) with a minimum end-head pressure of 170kPa (25psi).

Minimum rate of application as per NFPA 214:

- Deluge, under the fan decks,13.45mm/min (0.33gpm/ft²) including the fan opening
- Deluge, over the fill area, 20.40mm/min (0.50gpm/ft²) including the fan opening

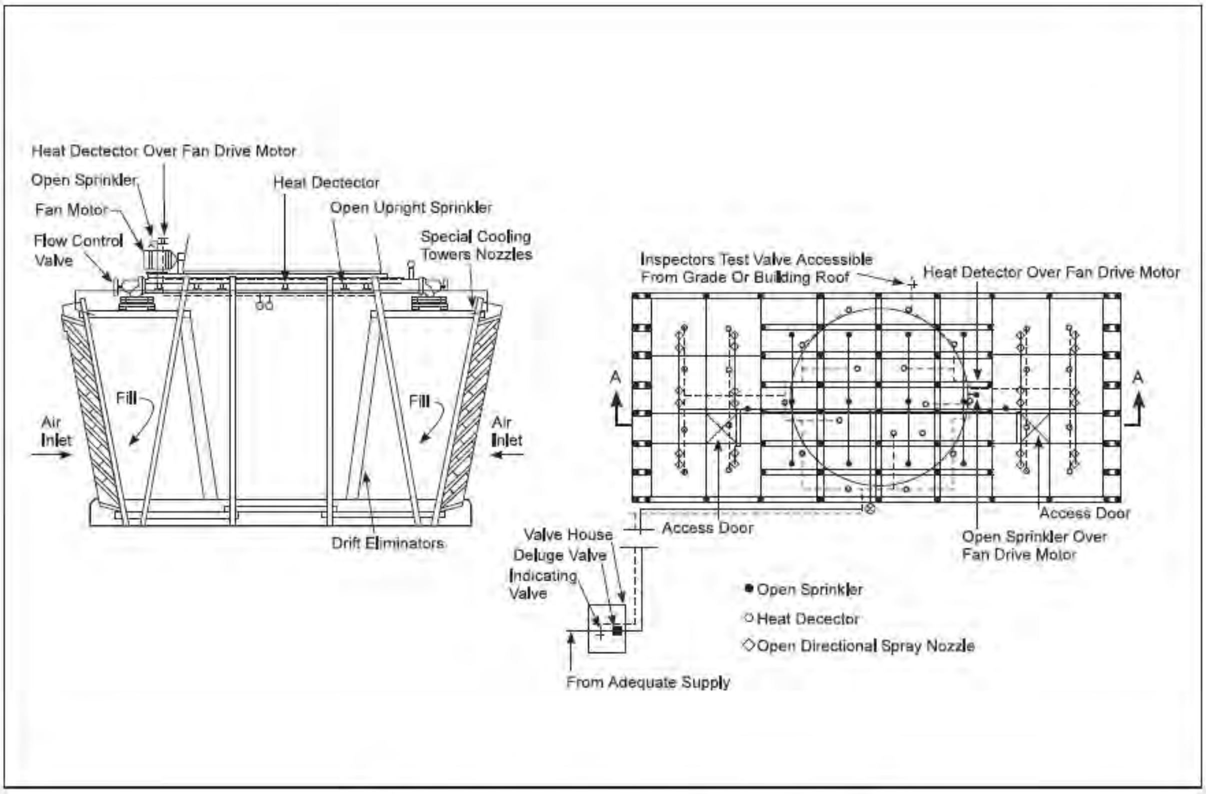


Fig. 3. Typical deluge fire protection arrangement for crossflow cooling towers

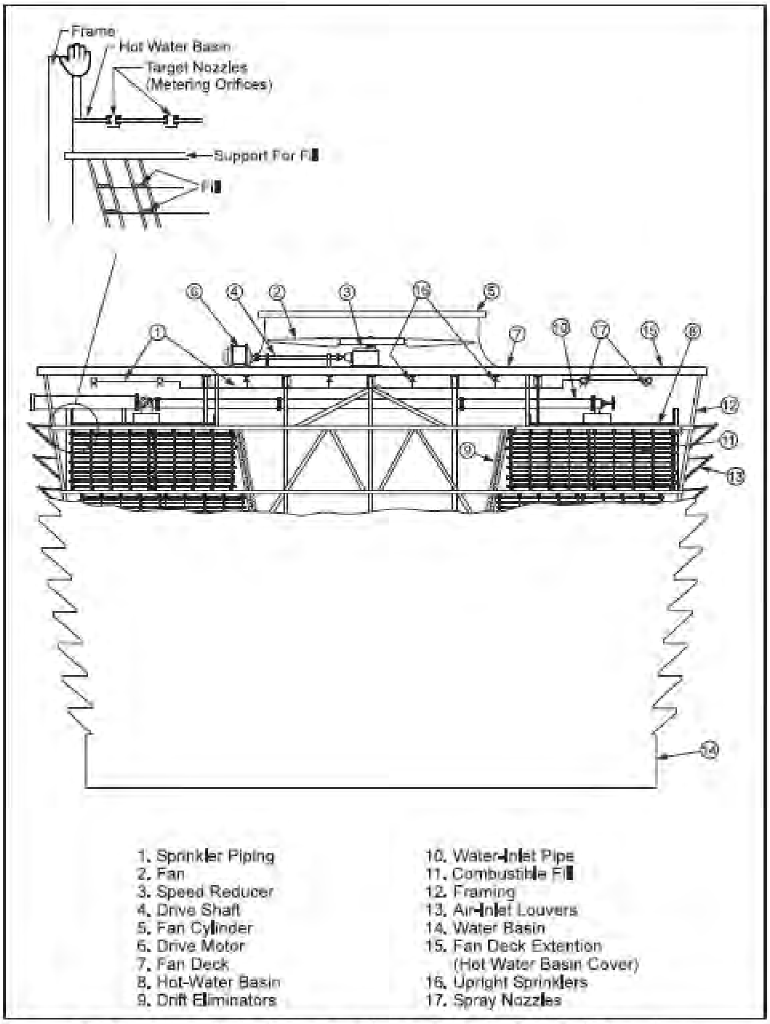


Fig. 4. Typical cross section of a crossflow induced-draft cooling tower (covered hot water basin)

Minimum recommended density as per FM Global Data Sheets 1-6:

- For combustible fill: deluge, 20mm/min (0.50gpm/ft²) with a minimum end-head pressure of 170kPa (25psi)
- For a noncombustible fan deck extension: deluge, wide angle nozzles -180° water spray-20mm/min (0.50gpm/ft²)
- For a combustible fan deck extension: deluge, wide-angle nozzles 16mm/min (0.40gpm/ft²) and additional nozzles on the underside of the fan deck extension 4mm/min (0.1gpm/ft²)
- For noncombustible fill: wet / dry pipe, 8mm/min (0.20gpm/ft²) with a minimum end-head pressure of 170kPa (25psi)

11.17 HYDRAULIC / LUBRICATING GROUPS

Hydraulic oil might very well have a high flashpoint (320°C) but it can definitely burn. Adequate physical protection devices should be provided as follows:

A) All areas housing hydraulic and/or lubrication groups using 380L or more of fluids under pressure should be provided with:

- Sprinkler protection for the areas containing these hydraulic / lubricating groups, installed in accordance with NFPA. All material and equipment should be FM-approved and/or UL-listed. All alarms, troubles and supervisory signals should be relayed to a constantly attended location. This protection should be fed from an adequate and reliable Fire Water supply. The project plans should be reviewed by a qualified Fire Protection Engineer familiar with NFPA standards.

  and

- All hydraulic / lubricating pumps should be interlocked to the sprinkler system in order to automatically shut down all machines operating in the fire area (when a safe shutdown is possible without lubrication).

  or

- A low-oil pressure switch should be located within each reservoir, arranged to shut down the machine.

B) All areas housing hydraulic and lubrication groups using less than 380L of fluid under pressure but still exposing the adjacent facilities should be:

- Sprinkler-protected in accordance with NFPA. This can consist of sprinkler heads installed under a noncombustible canopy above the hydraulic / lubricating group. All material and equipment should be FM-approved and/or UL-listed. All alarms, troubles and supervisory signals should be relayed to a constantly attended location. This protection should be fed from an adequate and reliable Fire Water supply. The project plans should be reviewed by a qualified Fire Protection Engineer familiar with NFPA standards

  and

- The hydraulic / lubricating pumps should be interlocked to the sprinkler system in order to shut down automatically in case of fire water discharge (when a safe shutdown is possible without lubrication).

C) As an alternative to points A & B above:

a. Use a nonignitable liquid that will not sustain combustion *even when in the form of a spray (e.g., water)*.

   or

b. Use FM-approved less combustible fluids when possible. This should be investigated with the equipment manufacturer. FM-approved industrial fluids present a minimal fire hazard and do not, by themselves, necessitate fire protection features for the equipment or building. The need for automatic sprinkler protection should be determined based on the surrounding occupancy's combustible load and the continuity of the combustible (e.g., combustible construction, cable trays, storage of combustible goods).

or

c. When it is not possible to use a nonignitable liquid or an FM-approved industrial fluid, use a fluid with as high a flashpoint as possible and provide additional safeguards to adequately protect the hazard, as recommended in point A and B above (i.e., sprinkler systems and interlocks)

D) Lubricating groups at atmospheric pressure or under low pressure (2-4bar) present a minimal fire hazard and do not, by themselves, necessitate fire protection features for the equipment when enough clearance is provided all around (i.e., 15m radius). If the clearance is less than 15m, the need for automatic sprinkler protection should be determined based on the surrounding occupancy's combustible load, continuity of combustible (e.g., combustible construction, cable trays, storage of combustible goods), exposure to surrounding equipment (e.g., process / utility equipment) and access for manual firefighting (e.g., elevated mezzanines with 3D fire potential, oil cellars).

The sprinkler protection should be in accordance with NFPA. This can consist of sprinkler heads installed under a noncombustible canopy above the hydraulics. All material and equipment should be FM-approved and/or UL-listed. All alarms, troubles and supervisory signals should be relayed to a constantly attended location. This protection should be fed from an adequate and reliable Fire Water supply. The project plans should be reviewed by a qualified Fire Protection Engineer familiar with NFPA standards.

Comment:

In the case of a hose rupture, combustible oil would be sprayed over the area and could easily be ignited by contact with a hot surface or another ignition source. The resulting fire is usually torch-like, with a very high rate of heat release.

Causes of Oil Release: High-pressure pipes with welded and threaded joints, steel and copper tubing, and metal-reinforced rubber hoses are used to conduct oil to the various units under pressure. The failure of piping, failure of valves and gaskets or fittings, pulling out of copper and steel tubing from fittings, and rupture of flexible hoses have been the principal causes of oil release from the system. Lack of adequate support or anchorage, preventing vibration or pipe movement, has been a factor in these failures. Repeated flexing and abrasion of rubber hoses against other hoses or parts of machines have created weak spots, which eventually resulted in rupture. Tubing under pressure has released oil when accidentally cut by welding torches or stepped on during maintenance procedures.

Safe and efficient manual firefighting of oil on fire (especially within confined spaces) will be virtually impossible.

Spray fires cannot be extinguished by automatic sprinklers, so this high-heat release fire will continue until the flow of liquid is shut down. This is the most efficient way of preventing the release of combustible fluid a (fuel source for the fire) and then sprinklers may be used for controlling the fire in its early stages of development.

FM-approved industrial fluids have been developed to replace petroleum-based oils in all types of hydraulic systems. FM-approved industrial fluids present a minimal fire hazard and do not, by themselves, necessitate fire protection features for the equipment or building. These fluids, if sprayed onto very hot surfaces, can result in a flaring fire. However, these fluids should stop burning when they flow away from the hot surface. Loss experience indicates that properly maintained systems with FM-approved hydraulic fluids significantly reduce the extent of damage caused by a fire as compared to systems with petroleum-based oils.

Follow procedures recommended by the manufacturers of the FM-approved fluid and of the hydraulic equipment when converting machines from ignitable liquids such as mineral oil. Consult the manufacturers to address issues such as draining the old fluid from the system;

replacing seals, gaskets, packing, and filters; filling the system with the new fluid and monitoring equipment and operating conditions (e.g., temperatures, inlet and outlet pressures, flow rates, fluid viscosity and stability, corrosion, etc.).

Warning: some hydraulic fluids are available that are designated as “less flammable.” These fluids are not considered to be equivalent to FM-approved industrial fluids in terms of the fire hazard they present. The methodologies used in validating these other fluids as “less flammable” are inconsistent and not fully understood. The actual fire hazard that these liquids present is unknown, and they may still sustain a high-heat release rate spray fire despite their designation.

An Ignitable Liquid comprises any liquid or liquid mixture that is capable of fueling a fire, including flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn. An ignitable liquid is one that has a fire point.

High-water content fluids may not exhibit a fire point. However, high-water content fluids can still burn in the form of an atomized spray. FM-approval Standard 6930 also includes criteria to evaluate fluids without a fire point for approval. Please refer to FM Global Data Sheets 7.98 “Hydraulic Fluids”, Appendix C2 for more details.

11.18 HEAT TRANSFER FLUID / MEDIA (HTF/HTM)

The following points should be investigated in detail:

A) Construction & Location: Ensure construction (including electric equipment classification) and space separation of the detached building is in accordance with Data Sheet 7-32, “Flammable Liquid Operations”.

B) Provide automatic sprinkler protection (EH2*) throughout all building areas subject to a heat transfer fluid spill fire. This includes the vaporizer or heater room, user room, and areas containing heat transfer fluid piping. An automatically actuated deluge sprinkler system is an acceptable alternative to an automatic sprinkler system.
(*) There is no dedicated NFPA standard for HTF. As a result, if we consider NFPA13, Occupancy Class EH2 refers to the use of HTH heated above its flashpoint, or it refers to the vaporizer (i.e., Flammable liquid spraying"). Occupancy Class EH1 could also be considered for HTF that is NOT heated above its flashpoint or if the vaporizer is not taken into consideration (i.e., "Combustible hydraulic fluid use areas"). For fine tuning the required density and surface of application, please refer to FM Global data sheet 7-99: “Heat Transfer by Organic and Synthetic Fluids”.

C) System Instrumentation & Interlocks: Ensure that measuring instrumentation and interlocks are provided to sound an alarm and automatically shut down the fuel source to the HTF heater or vaporizer when any of the following conditions are detected:

1) Low HTF flow through the heat exchange tubes of the heater, measured at discharge (i.e., when flow velocity is below that required for turbulent flow).
2) High HTF temperature or pressure at the heater or vaporizer outlet. (Note: ensure the high temperature interlock is set at or below the HTF manufacturer’s maximum recommended bulk fluid temperature).
3) Low pressure at the heater or vaporizer outlet or elsewhere in the system. (Note: this interlock may require a by-pass to allow for conditions at startup).
4) High heat exchanger tube temperature or high film temperature, as measured by thermocouples at the surface of the tubes (optional). (Note: ensure the set point is at or below the HTF manufacturer’s maximum recommended film temperature).
5) Low fluid level in the expansion tank.
6) Low vaporizer liquid level.
7) High temperature of liquid entering the heater or vaporizer (optional if 2. is provided).

8) Sprinkler system flow in any area containing HTF equipment or piping.

9) High temperature at bridge wall (optional).

D) Fire Interlock & Isolation: Interlock the heat transfer system to stop the circulation of fluid throughout the system and to isolate major piping segments in the event of a fire. To accomplish this, provide the following, arranged to actuate either in the event of sprinkler system operations, or an abnormally low pressure in the heat transfer system, or upon operation of a heat-detection system using FM-approved and/or UL-listed detectors.

Comment:

Heat Transfer systems using organic and synthetic fluid are responsible for numerous losses in the industry. As a result, adequate safeguards and fire protection should be provided.

HTM boilers and loops may contain several cubic meters of oil.

Note that some Heat Transfer Fluids (i.e., Therminol 66, Fp°170-184) are operated with a flashpoint at about 200°C max 250°C. Areas such as boiler rooms should be equipped with intrinsically safe electrics (ATEX).
Emergency drain tanks designed to contain the entire content of the loop should be provided and adequately protected with sprinklers. A secondary containment designed to contain 120% of the full content of the tank (20% is for fire water) should be provided.

11.19 AIR COMPRESSOR

Courtesy of Franck Orset (FPO) Loss prevention Engineer:

The Hazard

Many air compressor explosions and fires originate from oil and carbon deposits in the compressor systems.

Excessive deposits in the system are the result of over-lubrication, use of unsuitable lubricants or dirty and/or chemically contaminated suction air.

Under conditions of high temperature and pressure, contaminants and oily carbon deposits may oxidize and ignite spontaneously, creating an ignition source for vapors and residues. Glowing particles may be carried to a point in this system where there is a combustible or explosive mixture. Localized heating may weaken the equipment walls to the point of failure.

Another important cause of air compressor fires and explosions is excessively high discharge temperatures.

Abnormal temperatures are caused by recompression due to leakage through faulty valves or to blow-by in double-acting cylinders, by inadequate cooling water jackets and after-coolers, caused by high cylinder pressure due to severe restriction of discharge lines by deposits, or by mechanical friction or broken compressor parts.

Other air compressor fires and explosions have originated in the compressor drive motor, controls, or associated electrical equipment. A few fires have been caused by friction due to slippage of drive belts or pulleys; by external ignition sources that involved oily residues; by solvent cleaners or combustibles in the vicinity of the compressor that in some cases heated the compressor system to a point where internal carbon deposits ignited; and by oily lint or other combustibles in contact with outside surfaces of hot compressor parts.

The frequency of fires in oil-flooded rotary-screw compressors is much greater than other air compressors.

STANDARD

Location

Air compressors should be located in noncombustible buildings or cut-off rooms. No other equipment or storage should be located in the same room.

Ventilation

Rotary-screw compressor air-receiver vents should discharge to a safe location because the vented air/oil mixture may be flammable.

Air intakes should be located away from sources of flammable vapors, gas, steam, dust or other contaminants. Intake-air filters should be provided to remove suspended solids.

Fire protection

Sprinkler protection is only required if one of the following conditions exists:

- The room or building is of combustible construction
- An adjacent occupancy is combustible or represents a fire hazard
- Compressors have an external lubrication system with a capacity above 380L (100gal.) or a flow rate exceeding 95L/min (25gpm). If there are multiple compressors, the capacity should be considered as the aggregate total for all compressors within 8m (25ft).

The sprinkler protection should be designed to deliver a minimum density of 8mm/min (0.2 gpm/ft^2) over the postulated oil spill, or compressed air foam, with a maximum area of application of 280m^2 (3000 ft^2), with K80 (K5.6) spray sprinklers rated at 141°C (286°F) - or a higher density if the adjacent occupancy/storage within the room requires it.

If the protection is only over the units (no need to protect the rest of the room), then the sprinkler protection should extend at least 6m (20ft) beyond the units (the compressor and any part of the oil system).

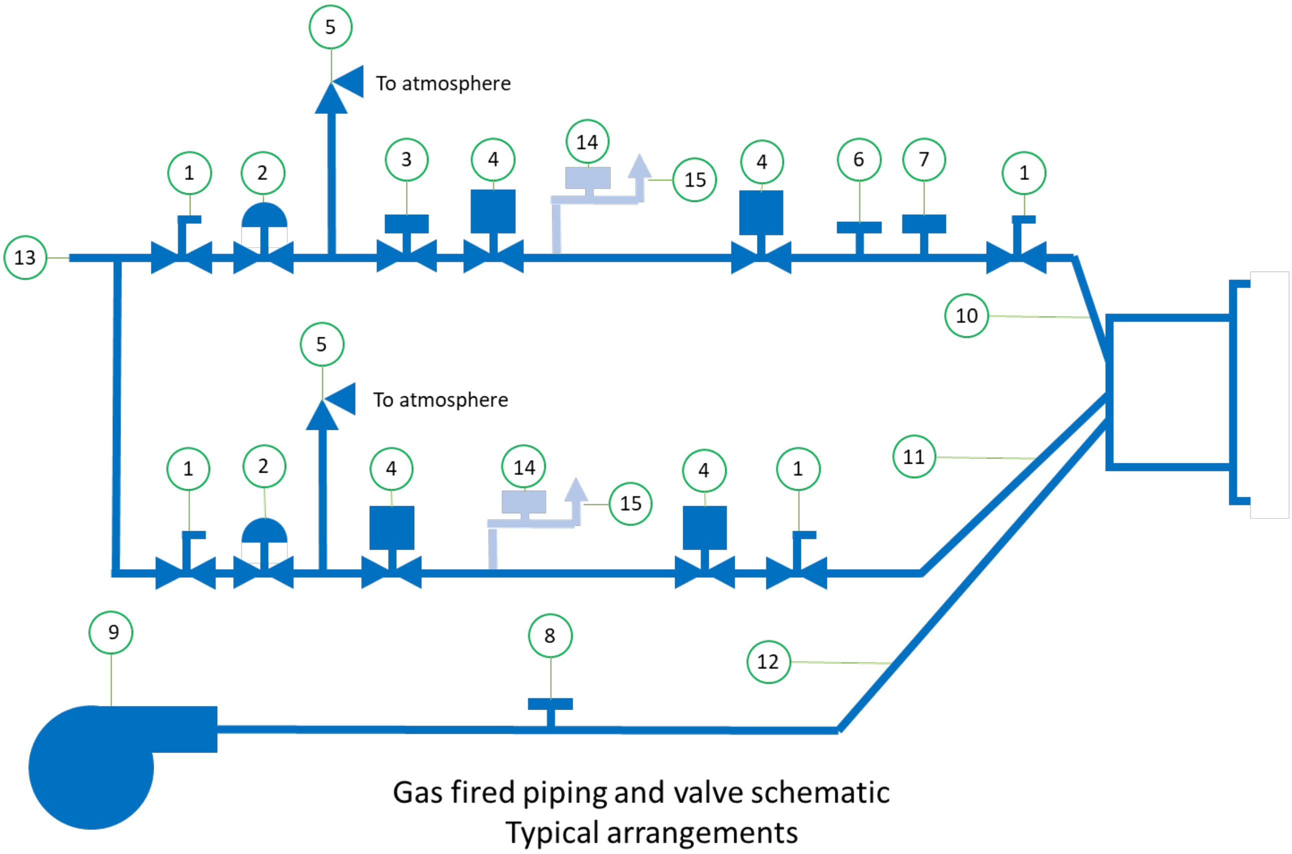
If sprinkler protection is omitted, consideration should be given to providing heat-actuated detectors interlocked to an automatic shutdown for high-value units or areas.

11.20 FUEL LINE SAFETY COMBUSTION CONTROL

An automatic starting sequence including a purging cycle, and inerting of the combustion chamber and ignition interlock should be provided.

The safety combustion controls on the fuel line should include modern safety devices such as (but not limited to): high-and low-pressure switches, Safety Shut-Off Valves (SSOV) and Valve Seal Over Travel Interlocks (VSOI). This should be in accordance with NFPA85: “Boiler and Combustion Systems Hazards Code” as summarized below:

Courtesy of Franck Orset (FPO) Loss Prevention Engineer:



Gas fired piping and valve schematic
Typical arrangements

Legend

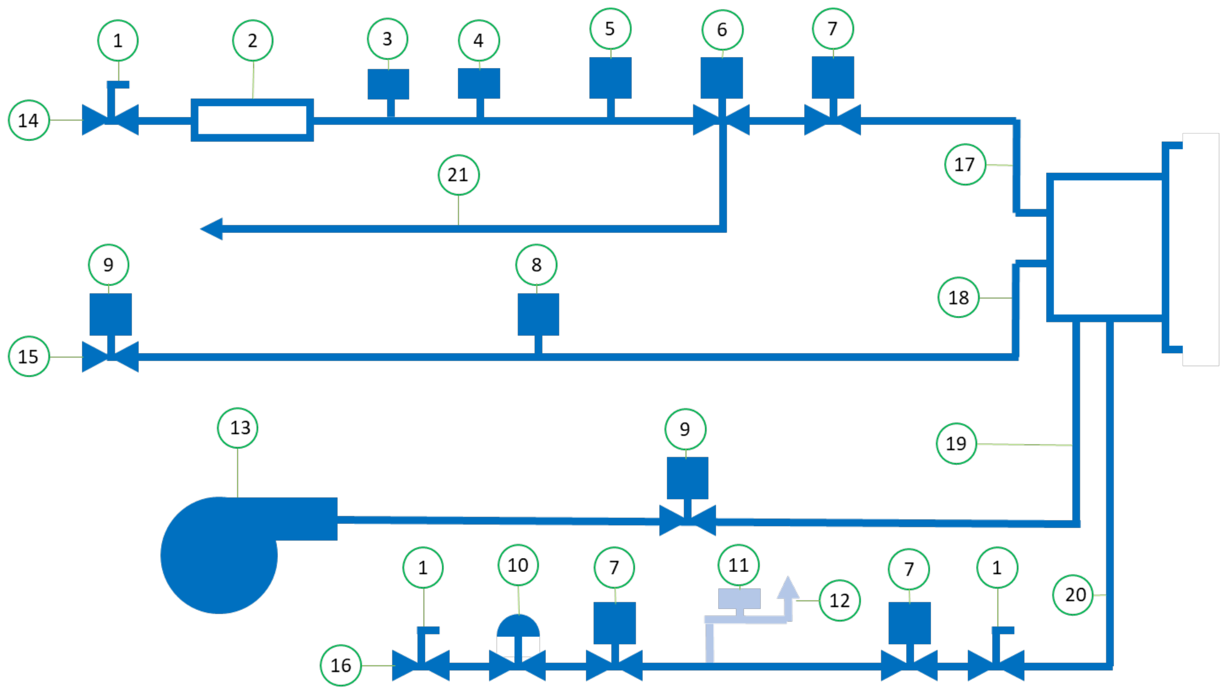
1. Manual cock
2. Pressure regulator
3. Low gas pressure switch
4. Safety shutoff valve
5. Relief valve (if required)
6. Test connection
7. High pressure gas switch
8. Combustion air pressure switch
9. Combustion air blower
10. Main burner
11. Igniter
12. Combustion air
13. Gas supply
14. Normally open valve (see note)
15. Vent line to atmosphere (see note)

Note: the vent valve and vent line to atmosphere are required by NFPA on units greater than 3.7 MW (12.5 mBtu/h) input

Note 1: when a modulating valve is provided on the main gas line, it should be located between the second safety shutoff valve and the manual cock at the burner. An alternate location is between the gas pressure regulator and the first safety shutoff valve.

Note 2: igniters of 75kW (250,000Btu/h) input or greater, having gas pressure regulated separately from the main burner gas supply, should be provided with high-and low-gas pressure switches located on the same relative positions as on the main gas line.

Note 3: the vent valve with vent line to atmosphere is an additional safety feature providing increased protection.



Oil fired piping and valve schematic
Typical arrangements

Legend

1. Manual cock
2. Preheater
3. Low oil temperature switch
4. High oil temperature switch
5. Low oil pressure switch
6. Circulating oil valve
7. Safety shutoff valve
8. Atomizing medium pressure switch
9. Combustion air pressure switch
10. Pressure regulator
11. Normally open vent valve (see note)
12. Vent to atmosphere (see note)
13. Combustion air blower
14. Oil supply
15. Atomizing steam/air
16. Igniter gas supply
17. Main burner
18. Atomizing medium
19. Combustion air
20. Igniter
21. Oil return to supply

Note: the vent valve and vent line to atmosphere are required by NFPA on units greater than 3.7 MW (12.5 mBtu/h) input.

Suggested Testing Schedule

This proposed testing schedule emphasizes preventive maintenance, which is imperative for continuous safe operations. As equipment and devices age, the need for testing becomes more important.

Equipment	Hourly	8-hourly	Daily	Weekly	Monthly	Semi-annual	Annual
Blow down low-water control		X					
Clean out low-water control						X	
Test and recalibrate boiler gauges							X
Check water column	X						
Blow down water column		X					
Test CO_2 or O_2				X			
Clean out stack							X
Flame condition	X						
Flame-supervisory control			X				
Gas-pressure switch				X			
Oil-pressure switch				X			
Oil-temperature switch				X			
Excess-steam-pressure switch					X		
Atomizing-steam air switch				X			
Forced-draft-air switch				X			
Induced-draft-air switch				X			
Gas safety shutoff valves				X			
Gas vent valves				X			
Oil safety shutoff valves				X			
Purge timing				X			
Damper limit controls				X			
Modular limit controls				X			
Fuel and air linkage					X		

11.21 HAZMAT & AEROSOLS & COMPRESSED GAS CYLINDERS

- Chemicals should be stored in a dedicated, adequately sprinkler-protected building, with retention and/or drainage to a tank. The use of approved and adequate safety cabinets inside the building dedicated to some hazmat (i.e., separation of acid and base solutions, oxidizers and flammables) is also good practice.
- Flammable liquid room requirements:
  - A. The room should be cut off from other areas by a 90min. (F90)-rated wall and ceiling. The door opening should be protected with a 90min.-rated self-closing door (T90).
  - B. All electrical equipment and wiring should be explosion-proof.
  - C. Grounding and bonding facilities should be provided.
  - D. The walls should be liquid-tight where they meet the floor. A 100mm curb should be provided at the doorway. Special drains or trenches should be provided to remove liquids to a safe location under emergency conditions. The system should have sufficient capacity to remove the expected discharge from the sprinkler system (if installed) and hose streams.
  - E. Low-point continuous mechanical ventilation should be provided with the suction inlet within 0.3m of the floor. It should be designed to exhaust a minimum of 0.3m³/min per m² of floor area.
- Aerosols should be stored in metal cabinets or be fenced in. In case of fire, the exposed aerosols would explode and would allow the fire to spread into the building.

- Compressed gas cylinders should be chained (or otherwise restrained) upright to a wall, cylinder truck, cylinder rack or other substantial structure.
- Acetylene cylinders should be stored away from oxygen cylinders. Oxygen cylinders should be separated from fuel gas cylinders or other combustible materials by a minimum distance of 6m or by a barrier of noncombustible material at least 1.5m high with a fire resistance of at least ½ hour.

11.22 COMBUSTIBLE OIL STORAGE & HANDLING

Combustible oil (FP>38°C) storage is considered a serious exposure to the plant. Oil leakage and spillage should be considered as a fire hazard and as a cause of pollution which could lead to severe losses to the plant. It is, therefore, recommended to segregate it from the rest of the activity.

In order to provide adequate protection:

A) Adequate segregation should be foreseen. This can consist of:
   - storing it outside in a dedicated area not exposing the buildings

   or
   - storing it inside the buildings in a dedicated room with a fire resistance of at least 2 hours (walls, roof and fire doors). The rooms should be equipped with a sill at the entrance to prevent escape of liquids (+/- 10cm). Natural ventilation should be provided.

B) The quantity of drums stored inside the process areas should be limited to the need for 1 shift maximum. Moreover, these oil barrels should be provided with a non-combustible dike capable of containing the entire contents of the barrels, to prevent the spread of oil through the facility should leakage occur.

C) All drums used for dispensing oil should be provided with approved, self-closing faucets, or positive displacement hand pumps should be provided. When faucets are used, they should be provided with retention pans underneath to collect dripping liquid. Moreover, the dispensing oil barrels should be provided with a dike capable of containing the entire content of the barrels, to prevent the spread of oil through the facility should leakage occur.

D) Noncombustible materials (such as mineral clay pellets) should be used to absorb any potential combustible liquid spillage. The use of a combustible absorber, such as sawdust or wood particles, should be avoided.

11.23 OVERHEAD CRANES

Courtesy of Franck Orset (FPO) Loss Prevention Engineer:

Overhead cranes should not be positioned above critical equipment (GIS, turbine) when not in operation.

Smoke detection systems, as well as portable fire extinguishers, should be provided for the electric cabinets of the main overhead cranes (turbine hall and reactor building as a minimum).

Smoke detection should be provided in the battery room, machinery room, elevator shaft, elevator machine room, transformer room, transformer blower room, near main electrical disconnects and group cable trays, and in any similar areas without fixed protection.

The alarm must sound in the control cab and at the base of the crane.
The alarm should also be transmitted to the Main Control Room.

Upon activation of the fire detection system, the procedure should include positioning the crane in a safe area (not above critical equipment such as the fuel pool or the turbine equipment), accessible for manual firefighting. Then, the electrical supply should be shut down to limit fire activation on electrical equipment.

The need to provide an automatic fixed gas-protection system should be considered if, in case of fire, the access is deemed too difficult (or delayed) for manual firefighting means.

In that case, an automatic gaseous fire protection system should be provided in the control room, cable room and cabinets, switchgear cabinets and other similar areas where combustibles are present.

If a time-delay interlock needs to be provided on the system, set it to the minimum required for the safe evacuation of personnel.

Note that situations where electrical cabinets are located inside the beam of the crane (bridge beam) are more problematic than when the electrical cabinets are located outside (in terms of fire damages).

There are further disadvantages to having electrical cabinets located inside:

- Smoke is difficult to detect by operators (it remains inside the beam).
- Even with a limited amount of combustible material involved in a fire inside the beam, the heat released can have serious adverse effects on the steel structure of the crane (a phenomenon similar to a "pizza stove" effect).

11.24 CONTROL ROOM

Courtesy of Franck Orset (FPO) Loss Prevention Engineer:

Construction/Safe separation

The Control Room should be separated from adjacent areas of the plant by floors, walls, ceilings and roof assemblies with a minimum fire resistance of 3 hours.

Peripheral rooms in the control room should be equipped with a water-based fixed fire protection system and separated from the main control room by a noncombustible construction with a minimum fire rating of 1h.

There should be no kitchen in the same fire area of the Main Control Room (if a kitchen is directly accessible from the Main Control Room, it should be fire-separated, equipped with a self-closing fire door, and with a smoke or thermal fire detection system).

Combustible construction materials should not be used in the Control Room. The use of decorative wood paneling and plastic grid ceilings should be avoided.

Raised floors and suspended ceilings should be avoided, or the smoke detection system should be extended to these areas.

When raised floors are present, access to the space under raised floors should not be restricted, and tools necessary for access (such as suction cups) must be clearly marked and readily available in the computer room.

Fire detection

A smoke detection system should be provided in the Control Room to detect fires at their incipient stage. Air sampling-type detection systems are recommended.

Smoke detection systems should be provided in the Control Room complex, and the electrical cabinets and consoles (and under raised floors or above false ceilings, if provided and if cables are present). Cabinets containing electric and electronic equipment should have detectors installed inside.

Fire protection

Automatic fire protection is not necessary in a Control Room that is constantly attended (24/7).

Automatic fire protection systems might be recommended for adjacent rooms such as the computer room or adjacent electrical and relay rooms.

Automatic fire protection might also be recommended under raised floors or above false ceilings when large concentrations of cables are present.

Ventilation

Automatic fire dampers that close when the smoke detection system is operating, and fire suppression systems should be provided for ventilation system openings between the Control Room and peripheral rooms.

The outside air intakes for the Control Room ventilation system should be provided with smoke detection capabilities to trigger the alarm in the control room and enable manual isolation of the control room ventilation system (to prevent smoke from entering).

Venting of smoke produced by a fire in the Control Room, by means of a normal ventilation system, is acceptable if provision is made for isolating the recirculation portion of the normal ventilation system.

Manually operated venting of the Control Room should be available to the operators.

Cables

All cables entering the Control Room should terminate inside the Control Room.

No cabling should be routed through the Control Room from one area to the other.

Cable openings, through walls or floors, should be adequately sealed to avoid a fire spread from one side to the other.

Breathing apparatus

Breathing apparatus should be available with sufficient capacity to achieve a safe shutdown.

Emergency Control Area

A separate Emergency Control Area (ECA) should be available should the Control Room be unavailable. The ECA should be situated in a fire compartment separate from the Control Room.

There should be a safe access route from the Control Room to the ECA.

The smoke management system should ensure a habitable environment for the operators to safely transfer the Control Room to the ECA.

The ECA should contain all instrumentation and control equipment needed to achieve and maintain a hot shutdown. There should be full electrical isolation and fire separation from the MCRC.

Manual firefighting

There should be easy access to individual cabinets to facilitate the use of portable hand-held extinguishers.

Manual firefighting capabilities should be provided for fires originating within a cabinet, console or connecting cable, as well as for exposure fires involving combustible materials in the room area.

A suction cup to lift false floor tiles should be provided inside the Control Room if raised floors are located within the main Control Room and/or adjacent control computer room & electrical room.

Nonsmoking policy

The Main Control Room should be a strictly non-smoking area.

A smoking corner, even well arranged, should NOT be allowed inside the Main Control Room.

11.25 WAREHOUSE

Commodity Class II (i.e., large metal parts in wooden crates or on wooden pallets) in noncombustible construction warehouses (i.e., single metal sheets, mineral wool-insulated panels) should be provided with adequate and approved Automatic Fire Alarm systems (i.e., smoke detectors, laser beams) as per NFPA. All alarms, troubles and supervisory signals should be relayed to a constant attended location (even when manned 24/7).

Adequate sprinkler protection, as per NFPA13, should be provided for the following cases:

- Warehouses made of combustible construction material (e.g., PUR, PIR panels. Note that the use of EPS panels under the ceiling should be prohibited as there is no automatic fire protection solution).
- Spares and consumables exceeding Commodity Class II, as per NFPA (e.g., cables and PVC insulation on wooden spools, rubber hoses, open-top plastic containers, PE wrapping rolls).

11.26 FORKLIFT BATTERY CHARGERS

Forklift battery chargers should preferably be relocated outside under a canopy.

When located indoors, the forklift battery charging area should be located in a cut-off room made of noncombustible construction material. All electrics should be intrinsically safe. Continuous mechanical ventilation should be provided. Hydrogen detectors should be provided. Alarms should be relayed to a constantly attended location. Adequate and reliable automatic sprinkler protection should be provided at the ceiling, in accordance with NFPA / FM Global Data Sheets.

Comment:

Small quantities of hydrogen are emitted from a charged battery and can represent a fire and explosion hazard. An electrical disturbance may cause a fire in the grease and/or dirt on the truck, insulation or charging equipment.

Most batteries have a polypropylene case and, if stored empty, should be treated as a Group A plastic, as per NFPA.

11.27 GAS-DRIVEN FORKLIFTS

The LPG-driven forklift, used for loading and unloading operations inside the storage areas, should have minimum acceptable safeguards against inherent fire hazards for exhaust gas and electrical systems in order to prevent any goods from igniting. This should be investigated by the Plant Management.

Comment:

In warehouses or general storage without hazardous fibers in the air, (such as sawdust and wood chips), the following power-operated trucks can be used: any LP gas-powered unit which has minimum acceptable safeguards against inherent fire hazard-approved, power-operated industrial trucks, designated as Type LP, or trucks which conform to the requirements for the specified types, as per NFPA 505. In locations where easily ignitable fibers are stored or handled, (such as wood chips and sawdust - including external storage), but where such fibers are not processed or manufactured, Class III, Division 2 power-operated industrial trucks, designated as type LPS, or trucks which conform to the requirements for the specified types as per NFPA 505, should be used. These LPS-gas-powered units have been provided with additional safeguards to their exhaust, fuel, and electrical systems in addition to meeting the requirements for Type LP units.

11.28 LARGE DRIVERS STORAGE

Large drivers that are stored for a relatively long time without any regular rotation of the rotor could lead to a major failure when installed and operated. The following points should be considered in detail

a) Procedure: a procedure should be established and strictly enforced in order to ensure the regular rotation of the rotor of large, stored drivers. The schedule and the rotation degree (270° every month) should be clearly indicated.

b) Indicator: visible markers should be provided on large, stored drivers showing the position and the date of the rotations.

11.29 DUCT SPRINKLER PROTECTION

Courtesy of Franck Orset (FPO) Loss Prevention Engineer

STANDARD

Any portion of a piping/exhaust system with the potential for a combustible residue buildup on the inside, where the duct sectional area is greater than or equal to 480cm^2 (75in.^{2}) - i.e., for pipes with a 250mm (10in.) diameter or larger - should be provided with an automatic extinguishing system **inside** the duct.

Sprinkler protection should also be provided in ductworks (for combustible ductworks of a sectional cross diameter of 250mm (10in.) or larger, and for smaller diameters whenever practical).

A separate indicating control valve should be provided for the sprinklers installed in the ductworks.

The sprinkler protection inside the exhaust ducts/pipes should meet the following requirements:

- The sprinkler protection should be designed over a maximum length of 30m (100ft), with a minimum flow of 114L/min (30gpm/min) per head at a minimum of 1bar (15psi) pressure, over the 30m (100ft) of duct (horizontal or vertical).
- Use 74°C (165°F)-rated sprinkler heads (or heads with a temperature rating at least 30°C (86°F) above the temperature of the environment inside the duct).

- One sprinkler should be located at the top of each vertical riser and at the midpoint of each offset. Additional sprinklers should be spaced on 7.3m (24ft) centers if the rise is greater than 7.3m.
- Maximum spacing between sprinkler heads should be 3.7m (12ft) for horizontal ducts. The first sprinkler should be located no more than 1.7m (6ft) from the duct entrance.
- Sprinklers heads should be arranged in exhaust ducts containing baffles in such a way that the sprinkler distribution pattern is not obstructed.
- To prevent the collection of paint on the sprinkler heads (which would delay activation), the heads should be covered with a cellophane bag up to 0.076mm (0.003in.) thick, or with a thin paper bag. This covering should be replaced frequently so that heavy deposits of residue do not accumulate.
- Sprinkler piping should be installed outside the ductwork and supported independently from the ductwork system.
- Access to the piping system should be provided to enable a regular check of the sprinkler heads. Flexible sprinkler fittings allow for easier inspection. *See Figure 2 below*.
- Automatic drains should be provided to eliminate extinguishing water and to prevent water accumulation in the duct or flow of water back to a process subject that could be damaged by water.
- If duct width or diameter is larger than 3.7m (12ft), an additional line of sprinklers, with the same spacing, should be provided inside the duct. For rounded ducts, the sprinkler lines should be positioned at 2 o'clock and 10 o'clock.

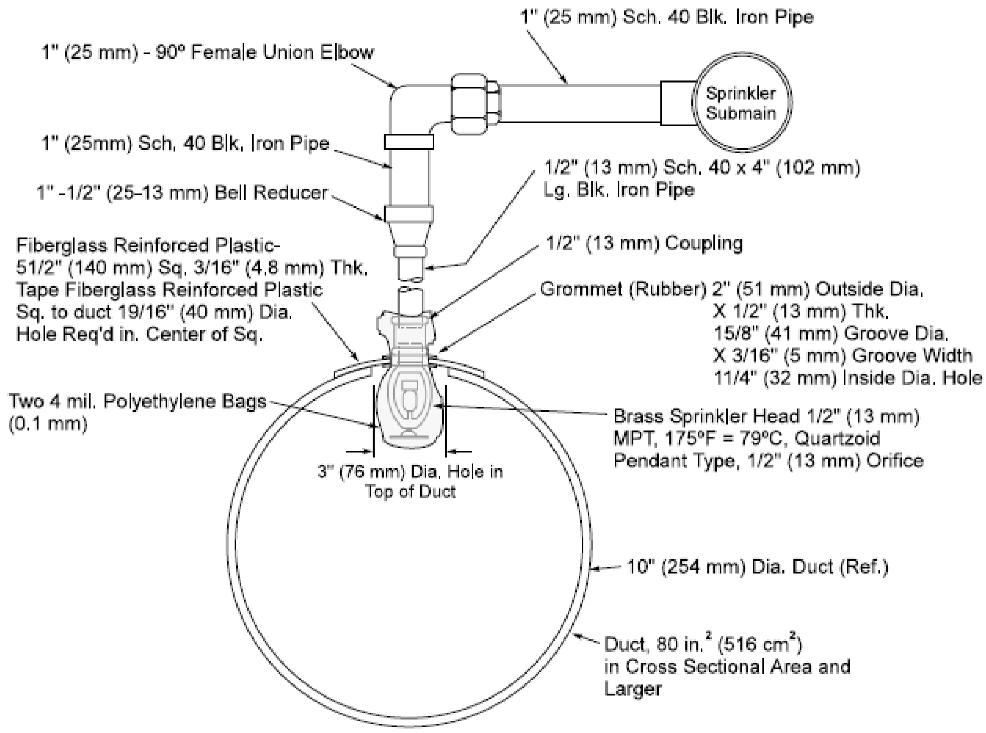


Fig. 1 - Typical sprinkler installation within a duct (Factory Mutual)

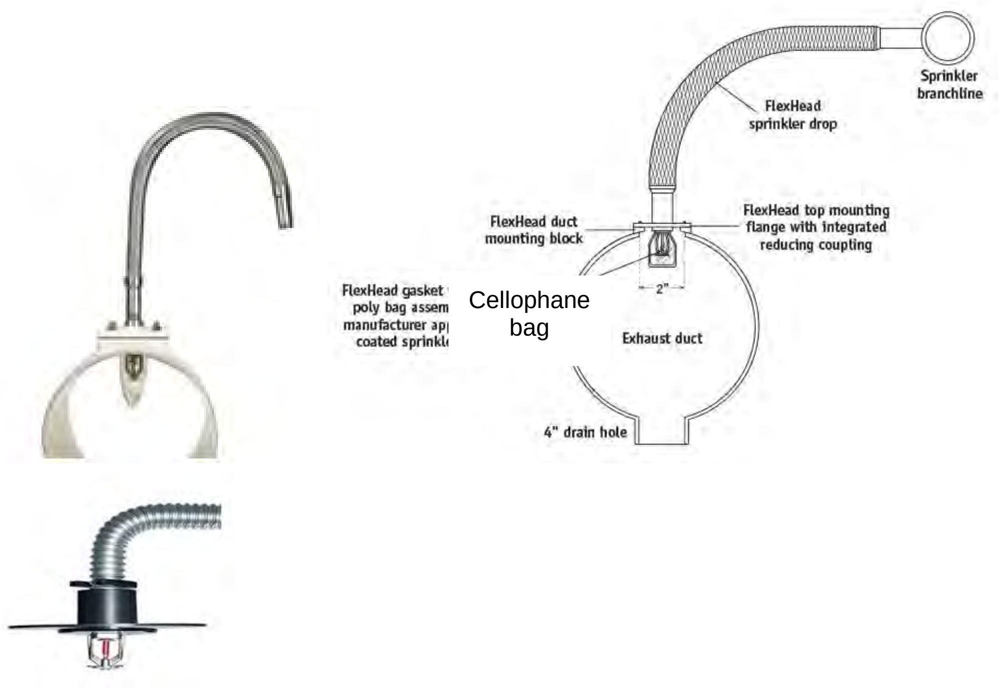


Fig. 2 - Examples of flexible sprinkler connections
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Notes:

Reference documents:

- NFPA 13: "Standard for the Installation of Sprinkler Systems"
- Factory Mutual Data Sheet 7.78: "Industrial Exhaust Systems"

11.30 IGNITABLE LIQUID STORAGE TANK

When spacing between adjacent tanks, or tanks and other facilities, is inadequate, as per Table 2 below (see FM 7-88: "Ignitable Liquid Storage Tanks"), provide a deluge water spray (installed in accordance with DS 4-1N) on all exposed tanks at a rate of 0.3gpm/ft² (12mm/min) of the tank surface. Include a water supply duration of 2 hours and at least 500gpm (1,900L/min) for hose streams.

Table 2. Spacing for Ignitable Liquid Storage Tanks and Loading/Unloading Stations

Liquid, Arrangement	*Liquid Flash Point* (1)(2)	
	≤ 140°F (60°C)	> 140°F (60°C)
Stable liquids, tank to bldgs of non combustible or better construction (See Appendix A) or open process structures (3)	1 D (min. 75 ft, 23 m)	0.5 D (min. 50 ft, 15 m)
Stable liquids, tank to buildings of combustible construction (See Appendix A)	2 D (min. 125 ft, 38 m)	1 D (min. 75 ft, 23 m)
Stable liquids in listed UL 2080 or 2085 containers	See Section 2.2.2.6	
Unstable liquids, tank to bldgs of any construction	2 D (min. 125 ft, 38 m)	1 D (min 75 ft, 23 m)
Stable liquids, tank to tank	0.5 D (min. 3 ft, 0.9 m)	0.5 D (min. 3 ft, 0.9 m)
Unstable liquids, tank to tank	1 D (min. 5 ft, 1.5 m)	1 D (min. 5 ft, 1.5 m)
Tank truck and railcar loading/unloading to tank, (4)	75 ft (23 m)	50 (15 m)
Tanks (single or multiple) to LPG storage	Minimum 100 ft (30 m) or 1 D	

Notes

[1] Where tanks are equipped with internal heating systems and store liquids subject to boil over, froth over, or slop over, evaluate as if containing liquids with flash points ≤ 140°F (60°C), regardless of their flashpoint.

[2] D refers to the diameter of the largest flammable liquid tank.

[3] Open process structure refers to areas of one or multiple levels used to manufacture chemicals. Intermediate tanks considered part of the process are excluded from this spacing requirement.

[4] For separation between loading/unloading facilities and buildings, see DS 7-32, *Ignitable Liquid Operations*.

Source: FM Global Property Loss Prevention Data Sheet 7-88 (04/20) Used with permission. © 2020 Factory Mutual Insurance Company.

Comments:
This should be investigated for all ignitable liquid storage tanks.

11.31 LIQUEFIED PETROLEUM GAS (LPG) STORAGE TANKS AND UNLOADING STATIONS

All LPG facilities should be arranged and protected with at least (but not limited to) the minimum requirements of FM Global Data Sheets 7-55: “Liquefied Petroleum Gas (LPG) Storage in Stationary Installations” as summarized below. (Please refer to FM Global Data Sheets 7-55 for details):

1) Location:
- Avoid locating underground tanks in areas exposed to high groundwater or possible flooding.
- LPG installations should be located on elevations that are at least 0.6m (2ft) higher than the predicted 500-year flood elevation, and at least 152m (500ft) from direct wave impacts and/or high flood-flow velocities (i.e., river beds). Where above-ground tanks are located in flood-prone areas, provide anchorage and foundations to resist the forces of buoyancy, moving water and wave impact (assume storage tanks are empty when determining buoyancy and overturning forces, and full when designing supports and foundations to resist maximum gravity loads).
- LPG storage and unloading stations should be located in areas accessible to emergency response equipment and responders.
- Railcar sidings and truck access routes should be arranged in order to minimize exposure to plant buildings.
- LPG storage tanks and unloading stations should be separated from important buildings and operations by a minimum of 61m (200ft) clearance (no material / storage in between).
- In case a 61m (200ft) separation distance is not feasible due to site constraints, provide (at least) the distances shown in Figure 1 and Table 1 below:

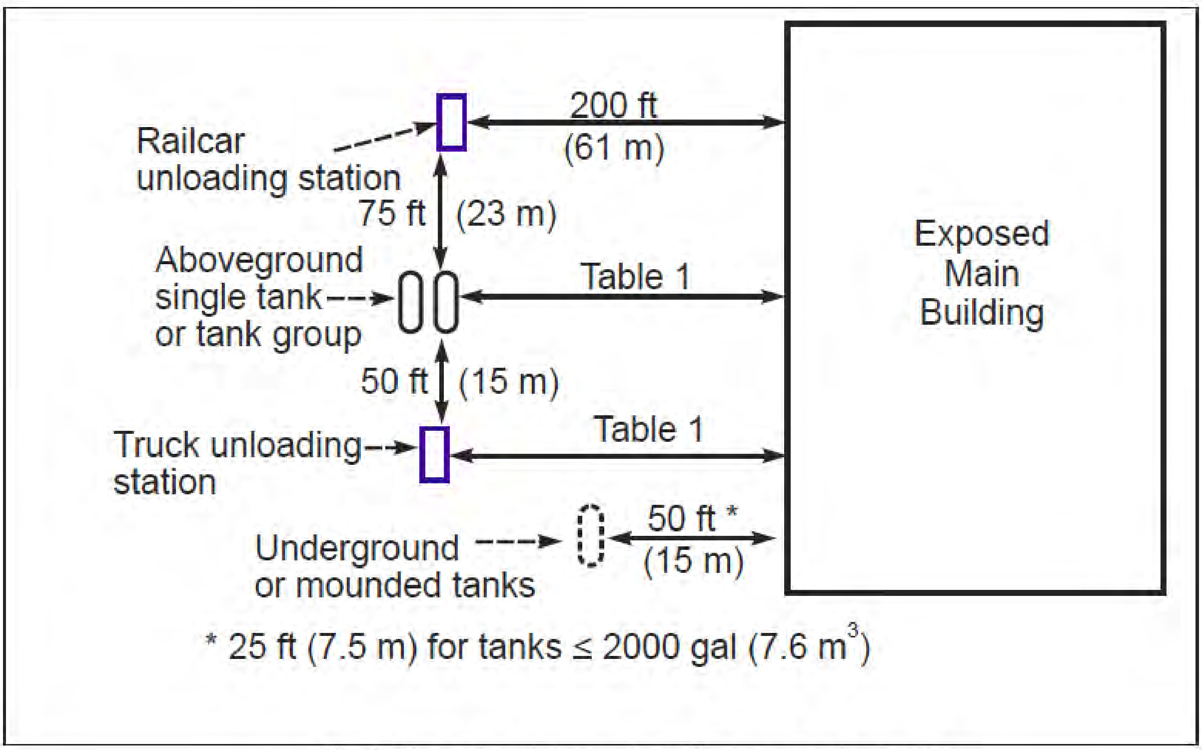

Fig. 1. Separation distances for LPG storage and unloading

Table 1. Separation Distances to Main Buildings for Aboveground Stationary LPG Tanks and Unloading Stations

Tank Capacity[2], gal (m^3)	*Single Tank, ft (m)*	*Tank Group,[1] ft (m)*
500 - 2000 (1.9 - 7.6)	25 (7.5)	Aggregate Capacity not exceeding 2,000 gal (7.6 m^3) 25 (7.5)
> 2000 - 60,000 (7.6 - 230) [4.1 - 124]	75 (23)	Aggregate Capacity not exceeding 180,000 gal(680 m^3) 200 (61)
> 60,000 - 100,000 (230 - 340)	150 (46)	
Unloading station	Same discance as tank or tank groupbeing filled	

[1]Provide at least 5 ft (1.5 m) horizontal separation between tanks in the same group. Separate tank groups from other tank groups by at least 75 ft (23 m).
[2]Tank water capacity.

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- Moreover, LPG tanks should be located at least 15m (50ft) away from exposures created by buildings of combustible construction or outdoor storage of combustible commodities.

If LPG tanks and unloading stations do not meet the spacing recommended above, please proceed to Point 3] "Protection", below.

- Locate vaporizers outdoors in open areas and away from tanks, main buildings, courtyards and unloading stations. Provide at least the separation distances in accordance with Table 2.

Table 2. Separation Distances[1] for Outdoor LPG Vaporizers

Exposure	*Direct-Fired[2]*	*Indirect-Fired*
Main building, blank noncombustible wall	Any	Any
Opening in main building wall	50 ft (15 m)	20 ft (6.1 m)
Storage tank	15 ft (4.6 m)	5 ft (1.5 m)
Relief valve discharge	75 ft (23 m)	Any
Unloading station	75 ft (23 m)	Any

[1]These distances will not protect against severe damage to main buildings in the event of a large accidental release of LPG occurring at the vaporizer or piping.
[2]Including gas-fired water bath units and boilers for indirect-fired units.

Source: FM Global's Property Loss Prevention Data Sheet 7-55: "Liquified Petroleum Gas (LPG) Storage in Stationary Installations" (rev. 10/13). Posted and reprinted with permission of FM Global. ©2013 Factory Mutual Insurance Company. All rights reserved.

2) <u>Arrangement</u>:

- Tanks, tank trucks, and railcars should be oriented so the longitudinal center line axis does not point towards important buildings, equipment or fixed storage tanks.
- Fencing around above-ground tanks or buried installations should be provided if located in areas accessible to public walkways or adjoining properties.
- Above-ground tanks, tank groups or mounded tanks should be provided with barriers, posts, curbing or other positive means to prevent public or plant vehicles from passing over or impacting the tank(s).
- Separate above-ground tanks from overhead power lines so that a break in the line will not allow the exposed ends to come into contact with the tank.
- Prevent overgrown vegetation, and control ignition sources within the perimeter of the LPG bullet tanks.

3) Protection:

- If LPG tanks and unloading stations do not meet the spacing recommended in Table 1 of Point 1] “Location” above, and/or if the separation between LPG tanks and exposures created by buildings of combustible construction or outdoor storage of combustible commodities is less than 15m (50ft), provide:
  - **Either** an automatic emergency isolation system for above-ground tanks with a water capacity greater than 15m³ (4000gal), in accordance with section 2.5.5.5 of FM Global Data Sheets 7-55, **or** water spray protection on the exposed building walls. The design of the water spray protection should be based on construction and occupancy, in accordance with FM Global Data Sheets 1-20: “Protection Against Exterior Fire Exposure”.

    And
  - Water spray on above-ground storage tanks and unloading stations. These automatic fixed systems should have a minimum application rate of 12mm/min (0.3gpm/ft²) of the external tank surface (water spray) or over the pad area (deluge). The water-spray system should be activated using automatic fire detectors or sprinkler pilot lines, located to ensure prompt activation..

- Yard hydrants and/or monitor nozzles should be provided for emergency manual fire protection of storage, unloading and vaporizer equipment, as per “FM Global Data Sheets 7-55: “Liquefied Petroleum Gas (LPG) Storage in Stationary Installations”, Table 3 below:

Table 3. Hose Stream Demand for Outdoor LPG Tanks

Hose Stream Demand		
Single Tanks	GPM	M³/min
≤30000	250	.95
> 30000	500	1.9
Tank Groups (largest tank)		
≤30000	500	1.9
> 30000	1000	3.8
Half the above demand is acceptable if water spray or insulation is provided on the tank.		
Minimum duration: 2 hours		

Source: FM Global’s Property Loss Prevention Data Sheet 7-55: “Liquified Petroleum Gas (LPG) Storage in Stationary Installations” (rev. 10/13). Posted and reprinted with permission of FM Global.

Hydrants should be located in a way that allows for hose application under varying wind conditions, with a separation space of at least 23m (75ft) and not more than 60m (200ft) from the storage tanks.

When provided, the monitor manual or automatic oscillating nozzles should be FM-approved. The discharge pattern should be set so that all portions of the tank or tank group are wetted. Nozzles should be located at least 23m (75ft) from the tanks to allow for effective manual operations regardless of wind direction.

12 ANNEX

12.1 ANNEX A: TECHNICAL REFERENCES

- NFPA 1 Fire Code
- NFPA 13 ed. 2019 and previous “Standard for the Installation of Sprinkler Systems”
- NFPA 25 ed. 2020 “Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems”
- NFPA 30 Flammable and Combustible Liquids Code
- NFPA 58 Liquefied Petroleum Gas Code
- NFPA 214 “Standard on Water Cooling Towers”
- NFPA 664 “Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities”
- NFPA 855 ed. 2020 “Installation of Stationary Energy Storage Systems”
- NFPA 901 “Standard Classifications for Incident Reporting and Fire Protection Data”
- NFPA 2001 “Standard on Clean Agent Fire Extinguishing Systems”
- NFPA 1143 “Standard for Wildland Fire Management”

- FM Global Data Sheets 1-4 “Fire Tests”
- FM Global Data Sheets 1-6 “Cooling towers”
- FM Global Data Sheets 1-20 “Protection Against Exterior Fire Exposure”
- FM Global Data Sheets 1-57 “Plastic in Construction”
- FM Global Data Sheets 5-4 “Transformers”
- FM Global Data Sheets 5-19 “Switchgear and Circuit Breakers”
- FM Global Data Sheets 5-33 “Electrical Energy Storage Systems”
- FM Global Data Sheets 6-6 “Boiler Furnace Implosions”
- FM Global Data Sheets 6-9 “Industrial Ovens and Dryers”.
- FM Global Data Sheets 6-11 “Thermal and Regenerative Catalytic Oxidizers”
- FM Global Data Sheets 6-17 “Rotary Kilns and Dryers”
- FM Global Data Sheets 6-21 “Chemical Recovery Boilers”
- FM Global Data Sheets 7-2 “Waste Solvent Recovery”
- FM Global Data Sheets 7-29 “Ignitable Liquid Storage in Portable Containers”
- FM Global Data Sheets 7-32 “Ignitable Liquid Operations”
- FM Global Data Sheets 7-4 “Paper Machines and Pulp Dryers”
- FM Global Data Sheets 7-9 “Dip Tanks, Flow and Roll Coaters and Oil Cookers”
- FM Global Data Sheets 7-10 “Wood Processing and Woodworking Facilities”
- FM Global Data Sheets 7-11 “Conveyor Belts”
- FM Global Data Sheets7-27 “Spray Application of Flammable and Combustible Materials”
- FM Global Data Sheets 7-32 “Flammable Liquid Operations”.
- FM Global Data Sheets 7-35 “Air Separation Processes“
- FM Global Data Sheets 7-35R “Air Separation Processes“
- FM Global Data Sheets 7-52 “Oxygen”
- FM Global Data Sheets 7-55 “Liquefied Petroleum Gas (LPG) Storage in Stationary Installations”
- FM Global Data Sheets 7-57 “Pulp and Paper Mills”
- FM Global Data Sheets 7-58 “Chlorine Dioxide”
- FM Global Data Sheets 7-73 “Dust Collectors and Collection Systems”
- FM Global Data Sheets 7-78 “Industrial Exhaust Systems”
- FM Global Data Sheets 7-80 “Organic Peroxides and Oxidizing Materials”

- FM Global Data Sheets 7-83 “Drainage and Containment for Ignitable Liquids”
- FM Global Data Sheets 7-88 “Outdoor Ignitable Liquid Storage Tanks”
- FM Global Data Sheets 7-96 “Printing Plants”
- FM Global Data Sheets 7-98 “Hydraulic Fluids”
- FM Global Data Sheets 7-101 “Fire Protection for Steam Turbines and Electric Generators”
- FM Global Data Sheets 7-103 “Turpentine Recovery in Pulp and Paper Mills”
- FM Global Data Sheets 8-21 “Roll Paper Storage”
- FM Global Data Sheets 8-27 “Storage of Wood Chips”
- FM Global Data Sheets 8-28 “Pulpwood and Outdoor Log Storage”
- FM Global Data Sheets 9-19 “Wildland Fire”

This list is not exhaustive.

12.2 ANNEX B: "FOREST STEWARDSHIP COUNCIL" (FSC)

Courtesy of Michael Rüegger, Senior Underwriter and Rene Kunz, Chief Underwriting Officer – both SCOR Agriculture, Global Lines.

FSC is the abbreviation of "Forest Stewardship Council" (Home Page | Forest Stewardship Council (fsc.org)) and is one of many labels (see list & link below) in the context of forestry and wood-based production and products. The label was established after the Rio UN Sustainability Conference in 1992 ("Earth Summit") to foster sustainable forestry management and insure traceability of wood-based products.

One of FSC's leitmotifs is "how do our efforts improve the environmental, social and economic management of forests?" Or, in other words, how should we organise the criteria, measures and supervision of "sustainable forestry" implementation? 10 basic principles were established (leading to 70 concrete criteria):

- Principle #1: Compliance with laws: The Organization shall comply with all applicable laws, regulations and nationally-ratified international treaties, conventions and agreements.
- Principle #2: Workers' rights and employment conditions: The Organization shall maintain or enhance the social and economic well-being of workers.
- Principle #3: Indigenous peoples' rights: The Organization shall identify and uphold indigenous peoples' legal and customary rights of ownership, use and management of land, territories and resources affected by management activities.
- Principle #4: Community relations: The Organization shall contribute to maintaining or enhancing the social and economic well-being of local communities.
- Principle #5: Benefits from the forest: The Organization shall efficiently manage the range of multiple products and services of the Management Unit to maintain or enhance long term economic viability and the range of environmental and social benefits.
- Principle #6: Environmental values and impact: The Organization shall maintain, conserve and/or restore ecosystem services and environmental values of the Management Unit, and shall avoid, repair, or mitigate negative environmental impacts.
- Principle #7: Management planning: The Organization shall have a management plan consistent with its policies and objectives and proportionate to the scale, intensity and risks of its management activities. The management plan shall be implemented and kept up to date based on monitoring information, in order to promote adaptive management. The associated planning and procedural documentation shall be sufficient to guide staff, inform affected stakeholders and interested stakeholders and to justify management decisions.
- Principle #8: Monitoring and assessment: The Organization shall demonstrate that progress towards achieving the management objectives, the impacts of management activities and the condition of the Management Unit, are monitored and evaluated proportionate to the scale, intensity, and risk of management activities, in order to implement adaptive management.
- Principle #9: High conservation values: The Organization shall maintain and/or enhance the high conservation values in the Management Unit through applying the precautionary approach.
- Principle #10: Implementation of management activities: Management activities conducted by or for the Organization for the Management Unit shall be selected and implemented consistent with the Organization's economic, environmental, and social policies and objectives, and in compliance with the Principles and Criteria collectively.

According to FSC's own declaration, their approach was, and is, to provide a governance structure balancing both societal interests as well as North-South perspectives to:

- develop a consensus-based set of global responsible forest management Principles and Criteria (P&C)

- encourage national multi-stakeholder initiatives to agree on nationally appropriate indicators to adapt the FSC P&C to national circumstances
- accredit independent bodies to audit forestry operations for compliance with nationally adapted standards, and
- certify those who demonstrate compliance, granting a certificate that allows certified operations to market the FSC-certified status of products and thereby gain market advantages vis-à-vis uncertified competitors.

As the structure is consensus-based, multi-stakeholder and organised as an assembly of country units, it is obvious that FSC may be exposed to "dilution of purpose" risks. At the time the label was established, it was a very innovative approach and a huge step towards improving minimal standards. In the early 2000's, many forest owners (state, private or corporate) were only moderately interested in the label, but from 2010 to 2020, most bigger retailers worldwide began to demand the label, or else not use wood products anymore, This led to the situation where most of the larger forest producers have an FSC or similar label, at least in OECD countries and throughout LATAM (where SCOR Agriculture is most active and, as standard procedure, asks for an FSC or equivalent label).

Taking 2 examples from the principles above, we may perceive the complexity in establishing sustainable resource management, be it in forestry or any other sector:

- Principle 1: Compliance with law: as laws are the result of a political process, a given situation in a country may lead to laws which do not, per se, foster sustainability. Hence, complying with laws, per se, does not necessarily advance sustainability.
- Principle 6: Environmental values and impacts: research into the ecosystem has proved that careful management of that same said ecosystem (i.e., human activity) may increase biodiversity. However, as the population of cities increases every day, the demand for "wilderness" has become the ultimate goal of sustainability. This may be very conflictual for local populations on the one hand and counterproductive in terms of biodiversity on the other.

This shows that the discussion as to how to achieve sustainability will ultimately require stakeholders with a high capacity for understanding the importance of differentiation, accepting complexity, and knowing how to manage it.

It will need an interdisciplinary approach consisting of political discussion, scientific and traditional knowledge, economic mechanisms and good governance.

Ecolabels on forest products / paper (Alphabetical index of 89 ecolabels) can be found at www.ecolabelindex.com (the "Website").

Other publications in this series:

- RISK CONTROL PRACTICE: CONSTRUCTION MATERIAL
  Wall Assembly Classification Handbook

- RISK CONTROL PRACTICE: EXPOSURE
  Falling Aircraft Handbook

- RISK CONTROL PRACTICE: SPECIAL HAZARDS
  - Embankment Dams Handbook
  - Tailings & Tailings Management Facilities Handbook
  - Stationary Battery Handbook

- RISK CONTROL PRACTICE: OCCUPANCY
  - Renewable Energy Handbook
  - Aluminium Handbook
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- RISK CONTROL PRACTICE: LOST ESTIMATE
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