

Hazards in paper and pulp industries – from an engineering insurance perspective.

IMIA WGP 49 (06)



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Presented at the IMIA Conference in Boston, 12 September 2006.

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1. INTRODUCTION

1.1 General trends in the pulp and paper industry in the world.

The first paper was produced some 2 000 years ago by a Chinese named Tsái Lun, and paper has become one of the most important inventions ever. The production of paper increased by more than 460% between 1961 and 2004, whereby production has increased from 77 000 000 ton/year to 360 000 000 ton/year in the pulp and paper industries. The main paper products are writing and packaging paper representing more than 60% of the total production (Fig.1).The total production of pulp during 2004 was 188 000 000 tons, the main quality being chemical pulp (Fig.2). The amount of paper, which is recycled, is 48% of the paper production in the world. In Germany, Finland, Switzerland, Sweden and Japan more than 70% of the paper is recycled.

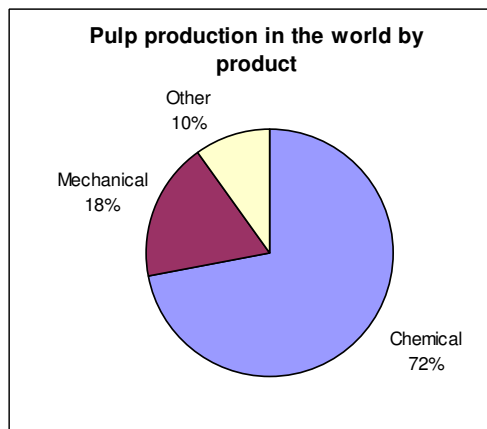
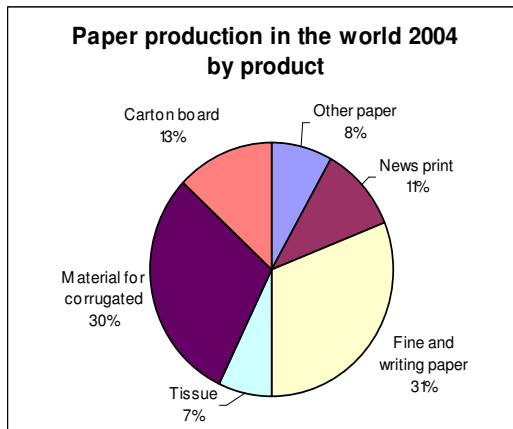


Figure 1. Paper production in the world 2004 by product /1/ Figure 2. Pulp production in the world by product /1/

The demand for paperboard in the world is expected yearly to grow by 2,1% in the long term, reaching 490 million tons by the year 2020. The major part of new paper production capacity has during the last years been built in Asia. There has been an increase of 37 000 000 tons paper production capacity in Asia between 1995 and 2004 /2/.

Between 1990 and 2005 a consolidation within the pulp and paper industry has taken place and is still continuing, so today the ten largest companies represent 27 % of the production capacity in the world (Fig.3) compared with 16% in 1990 (Jaakko Pöyry) /3/. The concentration has been very local and the merges or acquisitions have been with firms working in the same region.

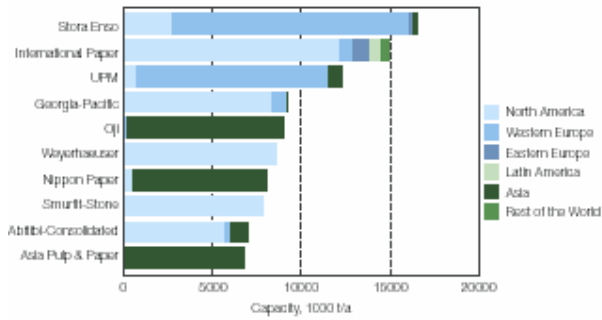


Figure 3. Leading paper companies in the world 2005 /3/

The demand for paper will increase mainly in Asia and Eastern Europe during the next 15 years (Fig. 4). This will imply that the production of paper and pulp will gradually be shifted from today's countries to Asian countries (Fig.5).

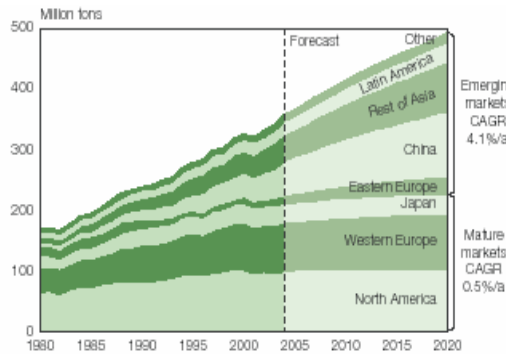


Figure 4. Paper and paperboard demand forecast through 2020 /3/

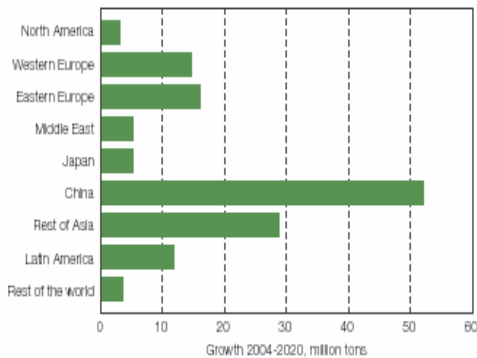


Figure 5. Production prospects 2004-2020 /3/

This will also imply that the majority of all new projects will be started in Asia whereby this will be a new challenge for the EAR/CAR insurer.

1.2 Content of this paper

This paper describes basic characteristics of major production units from a pulp and paper manufacturing plant, focusing on major aspects of risk exposure experienced during construction and operation.

Different types of pulp and paper manufacturing processes are presented with particular consideration of risks pertaining to the production stage and pertaining to new technology.

Turbines and gas turbines are not handled in this paper due to the fact that these have been presented in earlier IMIA papers.

The last chapter is dedicated to some interesting cases of loss.

1.3 References

/1/ Skogsindustrin – En faktasamling 2005, page 44.

/2/ FAOSTAT. (Food and agriculture Organization of the United Nations). FAO Statistical database, <http://faostat.fao.org/faostat/>

/3/ Jakkoo Pöyry. (Pöyry Magazine January 2006, World paper markets, page 6-7).

2 TECHNICAL DESCRIPTIONS AND DEVELOPMENT

2.1 Pulp

Chemical pulp

Chemical pulp can be produced in full mill scale using one of the following production methods or processes:

2.1.1. Sulphate pulping ("Kraft" pulping)

The benefit of sulphate pulping is that almost every kind of wood species can be cooked with the alkaline sulphate process and the process is almost independent of what wood species is used. The cooking yield from especially hard wood is relatively high and the fibre properties are excellent compared with other chemical pulping processes.

These facts have globally made the sulphate pulping to the most popular cooking method. Over 95 % of the chemical pulp in the world are produced with the sulphate pulping process. This fact has also led to guidelines for the future development in process technology, machinery and equipment technological development, safety aspects, energy economy and environmental development as well as in cost engineering. All recently built pulp mills have been equipped with the sulphate pulping process as far as we know, since 1985 when the Biocel green field Mg-sulphite pulp mill started up in the village of Paskov in the Czech Republic.

2.1.1.1 Risks related to chemical pulping

2.1.1.1.1 New chemicals for the bleaching processes

In general, full brightness cannot be achieved in one bleaching stage, instead several consecutive stages must be used. Traditionally, bleaching has been done with chlorine-containing chemicals: with (elemental or gaseous) chlorine (C), hypochlorite (H) or with chlorine dioxide (D). Between stages, the dissolved lignin has been extracted with alkali (E). Typical traditional bleaching sequences were CEHDED and CEDED.

The principle was that the vast majority of the residual lignin was removed with the cheapest chemical i.e. chlorine, and only the final vestiges of lignin were removed with the expensive chlorine dioxide.

When the transition was made to recycle bleach plant filtrates in order to reduce bleach plant wastewater effluent, the temperature of the chlorine stage began to rise, which had a detrimental effect on pulp strength. To prevent this, chlorine dioxide was added to the chlorine stage, i.e. the sequence used became DEDED.

The processes in pressurised reactors or in atmospheric reactors have made it possible to mix oxygen gas into the pulp in the alkali stage, where the oxygen improves delignification. Small amounts of hydrogen peroxide may also be used in the alkali stage to improve delignification. Peroxide does not require pressurised reactors.

Conventional bleaching including an elemental chlorine stage was the dominant method for a long time. Even as recently as 1990 approximately 94% of the bleached pulp were produced by chlorine bleaching. Since then however, the situation has changed, mainly for environmental reasons, as the AOX (Adsorbable organic halogen compounds) and dioxine discharges in wastewater were reduced. Elemental chlorine free bleaching (ECF), where chlorine dioxide is used but no gaseous chlorine, quickly became common. Nordic countries abandoned the use of chlorine gas completely in pulp bleaching in 1994, and the dominant method since then has been ECF bleaching.

Pulp can also be bleached totally without chlorine chemicals. This kind of oxygen chemical bleaching is usually known by the abbreviation TCF (Totally chlorine free). Bleaching chemicals in TCF bleaching are oxygen containing chemicals such as oxygen, hydrogen peroxide and ozone. The latest chemicals to be used are the peracids. These are also oxygen-containing chemicals.

Typical for the development is that elemental chlorine and chlorine compounds used in pulping has dramatically decreased in 10 - 20 years. The present situation is that practically no elemental chlorine is used in industry today. Chlorine has been replaced by chlorine dioxide in ECF pulping or by non-chlorine compounds like oxygen, hydrogen peroxide, ozone, peracetic acid etc. in TCF pulping (total chlorine free).

The decrease in use of chlorine has decreased the chemical risk of this industry dramatically. On the other hand "new" chemicals have brought additional risks, for example ozone is toxic, peroxide, peracetic acid and chlorine dioxide are hazardous chemicals. Peroxide may in contact with organic substances cause explosions and fires. Oxygen may accelerate the speed of a fire into explosive levels etc.

2.1.1.1.2 Size increase of key machinery

A continuous increase of one single line pulp mill capacity has led into increased machinery and equipment unit sizes. In a similar way as in the case of the recovery boiler, the increased machinery size results in higher EML estimates for property and business interruption risks.

Improved construction materials for the shells of the vessel of the digesters result in lower corrosion risks and lower risks for mechanical breakdowns.

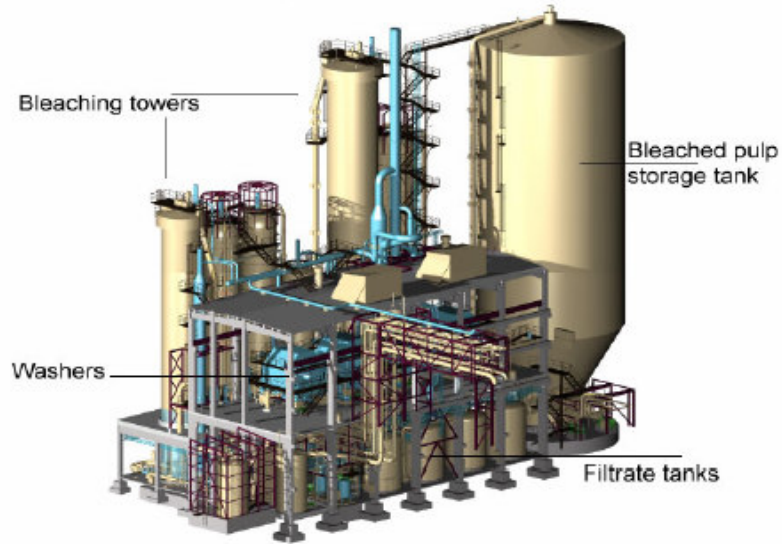


Figure 6. Example of a bleach plant /1/

2.1.2 Sulphite pulping

The pulp from the sulphite process is a proper raw material for several special paper qualities e.g. tissue, wood free printing and writing papers, grease proof papers etc. The raw material especially suitable for sulphite pulping is spruce. Pine and birch as well as other hardwood species are, however, not good for sulphite pulping (especially not for an acid sulphite process). The problem with pine is the fact that the lignin is partly condensing during cooking and it gives a high amount of knots and rejects. The problem with birch and other hard wood species is that they give a low pulp yield.

Sulphite cooking is possible using Ca, Mg, Na or NH₄ as a base chemical in cooking the liquor, and the pH of the liquor divides the method into the acid sulphite process or the bisulphite cooking process.

2.1. 2.1 Special risks of sulphite pulping

The acid sulphite pulping process waste liquor is normally burned in a recovery boiler in an oxidative atmosphere with about a dry solids content of 55-57%. Except for when using a sodium based waste liquor, there is not a chemical smelt layer on the bottom of the boiler and no risk for smelt/water explosions like in the case of a black liquor recovery boiler (combusting sulphate pulp mill black liquor).

The fire risk and the dry boiling risk of the recovery boiler is however similar to that of the black liquor recovery boiler.

Basic processes in the fibre line are quite similar to those in sulphate pulping and the risks for machinery breakdown and fire risks are similar.

The chemical risk may be in some cases be higher in sulphite mills, because quite big amounts of liquid SO₂ are stored and used normally on site as make-up chemicals for the cooking chemicals regeneration cycle (gas emissions into the adjacent areas etc.).

Bleaching chemicals used and risks related with these in sulphite mills are in principle quite similar to those in the sulphate pulp process.

2.1.3. Recycled pulping (RCF) and deinked (DIP) pulps

Risks:

- Similar to other fibre lines (FIRE, MB of key machinery, Chemical risks, EXP of some hazardous chemicals, e.g. peroxide).
- No risks stemming from a recovery boiler.
- The trend to use gigantic electrical motors increases property and business interruptions risks for mechanical breakdowns or fires.

2.1.4. Mechanical pulping (Ground wood (GW), Thermomechanical (TMP), Chemi-Thermo- mechanical (CTMP) and Bleached Chemi- Thermo-Mechanical BCTMP pulps

- -Similar to other fibre lines (FIRE, MB of key machinery, Chemical risks, EXP of some hazardous chemicals, e.g. peroxide)
- No recovery boiler risks (only in case of BCTMP pulping, if there is an adjacent sulphate pulp mill recovery boiler, which may be used in cross recovery for impregnation chemicals regeneration).
- The trend to use gigantic electrical motors increases property and business interruptions risks for mechanical breakdowns or fires.

2.2 Energy and chemical recovery.

A modern chemical pulp plant can produce all steam and electrical energy that is needed for the process. Black liquor, bark and rejects are used as fuel to produce high pressure steam 40-90 Bar. The high-pressure steam is expanded to medium (10 bar) and low (4 bar) pressure steam in a steam turbine. The turbine is connected to a generator which will produce electricity. In integrated mills and in paper mills additional steam and electricity can be produced by a gas turbine or bought from the grid.

To keep a good profitability in a pulp mill is it essential that the main part of the chemicals used in the process is recovered. The recovery of cooking chemicals will take place in the recovery boiler and the lime kiln.

In this section of the paper we will take a closer look at the black liquor recovery boiler. Gas turbines and backpressure turbines have been deeply scrutinised in earlier IMIA papers and will not be handled in this paper.

2.2.1 Kraft recovery boiler

2.2.1.1 General.

The black liquor contains organic compounds as a result of the pulping process and inorganic compounds such as sulphur and sodium which is used in the cooking process.

In the recovery boiler the organics are combusted and the sulphur converted to sodium sulphide. The remaining sodium is converted to carbonate which in the subsequent causticizing process is converted to hydroxide to produce cooking liquor which consists of sulphur sulphide and sodium hydroxide. The released heat is used to support the chemical process of the inorganics which is endothermic (consumes heat) and to produce high-pressure steam. During the last years the size of recovery boilers has increased and today the largest can handle as much as 6 000 tts/d.

2.2.1.2 Description.

Heavy black liquor at a 65-75% dry solid content is sprayed into the lower part of the furnace and mixed with pre-heated primary air. Here the organics are partly burnt and form combustible gases (mainly carbon monoxide) and smelt. The smelt falls to the furnace bottom from where it flows through openings connected to smelt spouts into the dissolving tank.

The distribution of smelt into the green liquor in the tank is enhanced by steam supplied through nozzles located underneath the smelt spouts.

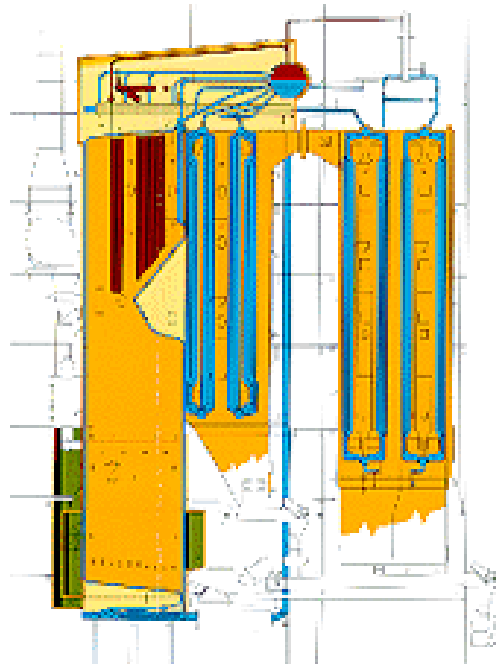


Figure 7. A modern one drum recovery boiler /1/

A separate smelt spout cooling system cools the spouts. This system is supported by an emergency water tank in the case of a failure. The green liquor produced in the dissolving tank is pumped to the causticizing plant and the level in the tank is kept by

adding weak wash from the causticizing plant. Because of the fumes in the dissolving tank it is ventilated separately to the atmosphere through a scrubber.

The combustible gas produced in the lower part of the furnace travels upwards and the final combustion takes place by the addition of secondary and tertiary air. During this process the remaining heat is released and the maximum temperature in the furnace occurs slightly above the secondary air ports. The gas leaving the furnace passes through the super-heater, the boiler-bank and the economiser where the temperature is decreased to 180-200 degree Celsius.

Finally, the fly ash is removed in an electrostatic precipitator before the combustion fumes are exhausted to the atmosphere by an Induced Draught (ID) Fan. Carry-over from the furnace causes deposits in the superheater, the boiler-bank and the economiser.

To keep the heating surfaces clean, recovery boilers are equipped with numerous soot blowers. The fly ash separated from the gas is collected in ash-hoppers located underneath the boiler-bank, the economiser and the precipitator. From those, the ash is fed into ash conveyors and transported to the mix tank where it is mixed with black liquor prior to its combustion and thus returned to the process.

During start up, the boiler is heated by oil-fired start burners which also are used during up-set conditions. Some boilers are also equipped with load burners in order to maintain steam production in the event of a shortage of black liquor.

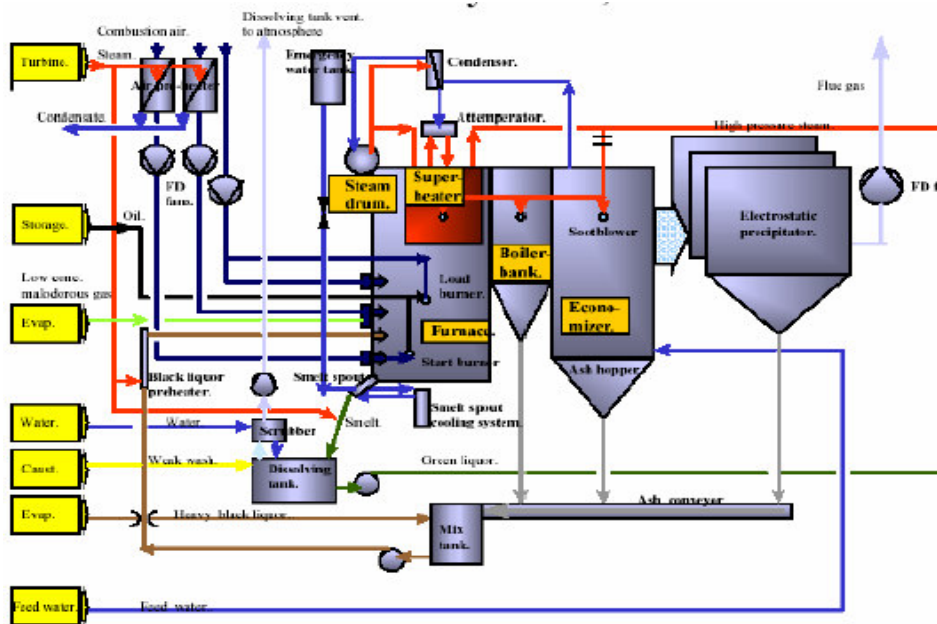


Figure 8. Recovery boiler; Kraft /1/

2.2.1.3 Special considerations.

The lower part of the boiler is subjected to the possibility of getting severe corrosion and is therefore designed and built accordingly. In most cases the lower furnace sidewalls are constructed of tubes and membranes having a corrosion protected layer of stainless steel (composite tubes).

Water must not enter the black liquor causing drops in the dry solid content since this can cause smelt water reactions when the liquor is sprayed into the furnace. Possible sources are water from ash hoppers due to leaking pressure parts, residual water from flushing of liquor piping etc. In the event that water enters the furnace, or is suspected to have entered the furnace, there is an emergency procedure which includes the rapid drain of the pressure parts.

The tubes on the bottom of the furnace are normally covered with a layer of frozen smelt which is maintained by studs welded to the tubes. When this layer is broken the tubes will be subjected to increased heat load and if it happens frequently the tubes will be subjected to a cycling heat load which may cause cracks in the tube shell. To improve the protection of the floor tubes they are normally covered with a thick layer of special cement. During the late eighties and the early nineties some boilers were built with composite bottom tubes. This design turned out to be deficient since the stainless steel layer cracked and most of those furnace bottoms have today been replaced with studded carbon steel tubes.

The tubes around the smelt spout openings are subjected to a large heat load, because of the flow of smelt which prevents the formation of any layer of frozen smelt, and needs particular attention.

The reaction when the smelt hits the green liquor in the dissolving tank is violent and to facilitate the distribution of smelt steam and/or green liquor is sprayed through nozzles located immediately below the smelt spout. If those nozzles fail or if the flow of smelt becomes too large, the reaction in the tank may be so violent that it can cause an explosion that may blow off the lid on the tank. Therefore the dissolving tank must be equipped with a duct that relieves the pressure to a safe location outside the building. The supply of liquid to the dissolving tank must be safe and the level carefully monitored since if the tank runs dry there will be a build up of hot glowing smelt. If this has happened and all of a sudden water enters the tank the reaction will be violent and dangerous.

Special considerations for the pressure parts.

The water, steam/water mixture and the steam are the cooling media in the boiler. Any interruption or restriction in the flow will therefore cause the temperature of the tubes to rise in the area after the restriction. This can cause overheating of the material and the tube to rupture with devastating consequences. Deposits on the inside of the tubes are caused by impurities in the boiler water which in turn enters through the feed water. The most common impurities are calcium, magnesium and silica, which forms chemical compounds which solubility in water decreases with increasing temperature. In a pulp mill where condensate from many sources are returned to the boiler plant there can even be pulp, black liquor or oil present in the

feed water. There are standards for acceptable quality of the feed water and the boiler water based on pressure and temperature. However, the quality of all sources of feed water must be checked regularly based on a schedule and the results must be documented.

Deposits on the gas side in the boiler-bank, superheater or economisers cause restrictions in the flow of the gas in the affected area while it increases in other areas. Since the cooling of the tubes remains the same, while the heat load in these areas increases, the temperature of tubes will increase. At a certain point this causes overheating of the tubes which can result in a tube rupture. The same is true if the mode of firing changes or the fuel changes since it can cause the heat load to increase in certain areas.

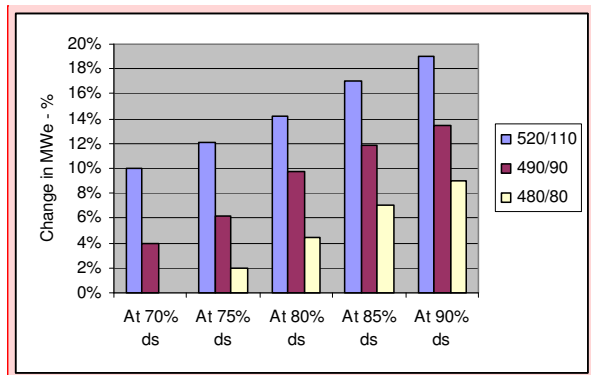
Free oxygen in the boiler water will cause corrosion to the pressure parts. The feed water must therefore be carefully de-aerated before it is fed to the boiler. Certain chemicals are also added to the water in order to consume any remaining oxygen. The soot blowers use high pressure steam to blow off the deposits on the heating surfaces. They are driven by electric motors through a gearbox. If there is a failure in the gearbox the soot blower may come loose and get propelled by the high-pressure steam like a torpedo across the furnace. This will cause damage to the tubes in the pattern of the loose soot blower.

2.2.1.4 Trends in designing new recovery boilers.

The trend for new recovery boilers is that the capacity is increasing. The new recovery at Hainan Jinhai Pulp & Paper Co has a peak capacity of 6 000 ton/day of dry solids. To achieve a higher output from the recovery boilers the dryness of the black liquor has to be increased and also the main steam parameters (temperature and pressure) have usually to be increased. Significantly more power generation can be achieved as presented in Fig. 9. The trend in recent years has definitely been in favour of increased temperatures and pressures.

The current trend within recovery boiler design can be summarised as follows:

- higher design pressure and temperature,
- super-heater materials of high-grade alloys,
- increase in black liquor solids towards 90 %,
- burning of biological effluent treatment,
- installation with CNCG (Concentrated Noncondensable Gases) burners
- dissolving tank vent gases returned to the boiler,
- installation of a fourth air level for NO_x- control



Comment [tå1]:

Comment [tå2]:

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Figure 9, Effect of black liquor dry solids content and main steam parameters on electricity generation from recovery boilers. /2/

2.2.2 Black Liquor Gasification Combined Cycle (developed by Swedish Chemrec AB)

This is still in a development state. For more details see IMIA paper “The Pulp& Paper Industry - technical developments and loss experience. IMIA conference 2002, Zürich”.

2.3 Paper machine

2.3.1 Paper and Board production in general

Paper and board are in principle produced using the same method. It has been this way ever since production became industrialised the main steps being:

- Fibres, fillers and additives in a suspension are transported by water.
- A head-box spreads out the suspension as a homogeneous flow upon the wire.
- Dewatering starts in the wire section.
- The press section then removes a maximum amount of water from the web and compresses the web.
- Finally water is removed from the web through evaporation in the drying section.

This concept has been developed over the years and today there are highly sophisticated paper machines. For example the biggest SC (Supercalendered) paper machine in the world is Stora Enso, Kvarnsveden PM 12 presented in Fig. 10. The machine produces high quality uncoated super calendered paper with a trim width of 1040 cm at a speed of 1550 m/min (design speed 2000 m/min) and a yearly production of 420 000 ton.



Figure 10, PM 12, Stora Enso, Kvarnsveden /3/

An important difference between board and paper is that board is usually made of a multi-layer web and its basis weight is higher than that of paper. But the main technology to produce paper and board is similar even if there are several differences in machine design.

2.3.2 Contemporary technology and trends of paper and board machines

The overall trend is that paper machines will become wider and faster. This is a result of continued research and development work. All parts in the chain from pulp to paper have been developed to support the speed and the demand to reach higher quality. Here three innovations that have supported an increase in speed and/or in quality may be emphasised:

- Dilution controlled head-box.
- Shoe-press.
- Impingement drying.

2.3.2.1 Dilution controlled head-box

The design of the head-box is crucial for the formation of paper (small-scaled basis weight variation) and for the basic weight profile in the cross direction (CD) of the machinery. This has a big impact on paper quality in general and runnability in the paper machine.

For the purpose to improve the formation and CD profile, the dilution-controlled head-box has been developed. A dilution-controlled head-box (Fig.11) has a lot of tubes in 2 or 3 layers across the machine. Every tube has a valve, whereby, it is possible to control the basis weight by varying stock consistency in narrow bands across the paper machine. This has made it possible to speed up the machines. Head-boxes of this design have been on the market for approximately the last 10 years.



Figure 11. SymFlo TIS head box /4/

2.3.2.2 Shoe-press

The introduction of the shoe-press has significantly improved the productivity of both existing and new machines. The shoe-press utilises a long nip, 5-10 times longer than that in a conventional roll press and the dewatering capacity is far higher than that of a roll-press. The typical increase in dryness after the press section has been 3-10% compared to what can be achieved in a roll press, depending on the paper grade being produced. At the same time, a higher dryness facilitates shorter machines and improved runnabilities.

Compared to a standard roll-press the shoe-press gives:

- Higher achieved dryness levels, implying faster speeds and lower drying costs
- The possibility to achieve higher bulk at a given dryness, for better bending stiffness
- More consistent moisture profiles in the cross machine direction
- Decreased two-sidedness and improved printability
- The shoe-press can be used either in the press section or in the calender.

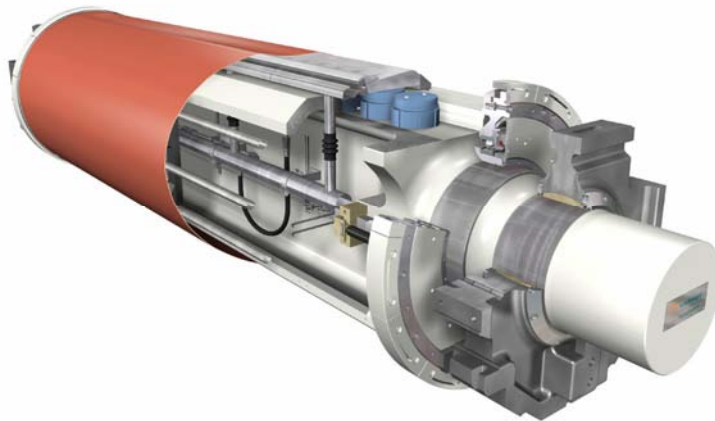


Figure 12. Shoe press, SymBelt™ /5/.

With a construction of a roll, like the one in Fig. 12, it is possible to get a long press nip. Shoe-press rolls are being used successfully at numerous mills around the world.

2.3.2.3 Impingement drying

Impingement drying is a high-efficiency air-drying module intended for new machines as well as for rebuilds. From the impingement hood, hot dry air is blown at a high speed directly onto the paper sheet. Water evaporates from the sheet, and moist air is recirculated back into the exhaust air chamber of the hood. This kind of direct air impingement drying allows drying rates many times higher than those of cylinder drying, the dryer section is about 25...50% shorter than conventional dryer sections /4/.

In the Opti dry concept, high drying capacity is combined with good paper quality. Available diagnostic systems, adjusting different running parameters of the machine, increase moreover the overall performance.



Figure 13. Impingement dryer, OptiDry /6/.

Technical features:

- Hot air is blown at high velocity directly onto the sheet from an impingement hood.

- The sheet is supported opposite the hood by the dryer fabric and a vacuum for optimal runnability.
- Designed using standard components.
- Designed for ropeless and automated tail threading.
- Minimal modifications are required to existing machine structures.
- No separate heaters, air fans, or piping are needed for the recirculation system due to integrated hood technology.
- The hood is equipped with a heat recovery system, which minimises energy consumption.
- The best energy source for heating the impingement air is natural gas.

2.3.3 Tissue paper production

Tissue paper is produced on a paper machine with a Yankee dryer. Yankee cylinders have big diameters and are key units in the production of tissue. Over the years there have been severe cracking and explosions of cylinders leading to long reconstruction times whereby risk prevention of Yankee cylinders is very important.

Also Yankee machines have grown bigger and faster. Today there are 15-20 Yankees in the world in the scale with widths up to 8,5 m and diameters up to 5 m. Steam pressure could be up to 8,6 bar and speeds up to 2 000 metre/min. Discussion is going on to increase the speed up to 2 200 m/min.

Control

After a Yankee cylinder has been moulded, the shell area is nowadays ultrasonically tested volumetrically 100%. The purpose of this is to detect porosities and defects in the shell, that could have influence on the structural strength of the material. The insurer should ask for records of the testing showing that the entire cylinder shell has been ultrasonically tested to a 100% or less and keep that in mind when you calculate the risk.

To achieve better paper quality the machines need more control systems, that even enhance the possibility of increasing the security. The possibility to recognise deviations before we see a breakdown is better.

Special risks and consequences

Moulding a cylinder with the dimension described above is a challenge. Cracking or explosions of Yankee cylinders stop the production for a long time if a spare cylinder is not available. From ordering the production time of a cylinder is 9 months up to a year. The Yankee cylinder itself costs roughly 1.5 M€ and then to get it in place at the mill could cost the same amount. Transportation of the biggest Yankee cylinder could be a huge challenge, the weight being roughly 180 ton. The cost for transportation could be more expensive than the moulding of a new cylinder.

Depending on the consequences of Yankee cylinder breakdown, some companies may have invested in a spare cylinder. This is most common at big companies owning several Yankee machines.

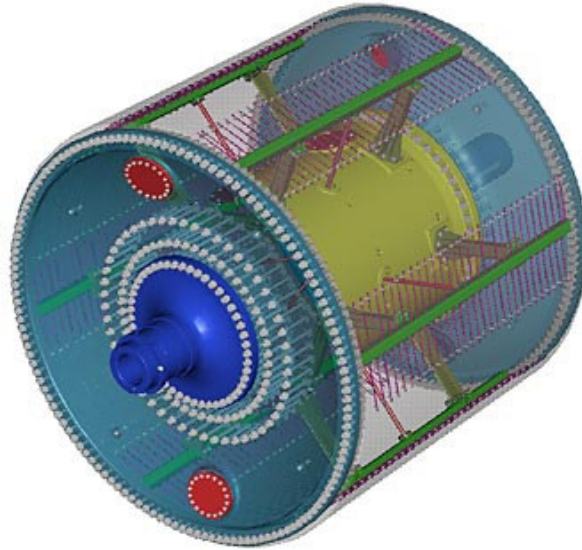


Figure 14. Yankee dryer, Sandusky. /7/

2.3.4 Technical trends and risks in general

Enhancing the machine speed

The new techniques have made it possible to enhance the machine speed. This means more energy in movement and higher damage risks. We also see more sensors and pieces of electronic equipment in the machine; this often implies better control and higher security. But on the other hand there is more hydraulic oil in the machine and fewer people that run the machine.

More of less

In the future the industry needs to produce more paper with less fibre and the fibre has to be recycled even more than today. This will make it more difficult to run the paper machines with high speeds when the fibres are fewer and shorter, leading to higher risks for paper breaks in the machine.

Automation

To get a further increase in efficiency, speed and quality automation is a very important. One example: Honeywell /8/ has developed sensors over some 30 years. They will now use infrared technology to produce sensors that can virtually do the work of the human eye, using a camera for on-line measurement of the sheet formation (small-scaled basis weight variation). Timo Saarelainen, Honeywell/6/, points out that during the past ten years the number of products for industry

measurements has worldwide increased by more than 400 per cent. His opinion is that mills today only have 10 per cent of the sensors that they actually require.

2.4 Environmental aspects

Pulp and paper mills use and generate materials that may be harmful to the air, water, and land, furthermore, pulp and paper processes generate large volumes of wastewater which might adversely affect freshwater or marine ecosystems. Residual wastes from wastewater treatment processes may contribute to existing local and regional disposal problems, and air emissions from pulping processes and power generation facilities may release odours, particulates, or other pollutants. Most of the pollutant releases associated with pulp and paper mills occur at the pulping and bleaching stages where the majority of chemical inputs are performed.

2.4.1 Water treatment

Pulp and paper mill effluent has to be treated to remove particulate and biochemical oxygen demand (BOD), and chemical oxygen demand (COD) produced in the manufacturing processes. A typical conventional end of pipe effluent treatment system for the paper making process involves several treatment steps and generally a large volume of water is discharged from the system. By closing up the water cycle and recovering water from the effluent streams, the amount of fresh water used by the mill can be greatly reduced, to 8-9 m³ per ton of paper produced /9;10 /. There are also examples of completely closed water system in paper mills /11/ that consume only 1 m³ per ton of paper (as water evaporates from the mill's various processes).

Recent years have seen remarkable progress in membrane filtration, biofilm processes and thermophilic biological treatment. This makes it possible to use a combination of these processes to build up a modern and efficient water treatment plant, which would achieve low or extremely low fresh water consumption levels.

A modern water treatment plant at a pulp and paper factory consists of several (up to five stages /9/ and includes some of the following stages: pre-treatment or primary clarification where the fibre is recovered, biological treatment with activated sludge or biofilm aerobic method and membrane separation processes.

Biofilm technology implies that the biomass - micro-organisms - grow as a film on a surface in contact with the liquid. The best technical solution has proven to be the use of mobile carriers in the form of small plastic elements, free-floating in the liquid and with a large specific surface. This process requires minimal space and offers many benefits compared with traditional biological treatments as follows:

- increased treatment capacity in existing plants,
- flexible design adaptable to existing basin volumes,
- less sensitivity to load increases and toxic discharges,
- a more stable treatment process,
- unaffected by sludge age.

Membrane separation processes, such as microfiltration, ultrafiltration, nanofiltration and reverse osmosis, are pressure-driven membrane filtration processes. They are

used to separate suspended solids, bacteria, colloids and molecules from liquids. Organic material with a high molecular weight and dissolved solids are removed using microfiltration, while dissolved inorganic material is removed using reverse osmosis.

One of the most recent technologies successfully utilised in the paper industry /12/ is membrane bio-reactor (MBR) technology. In MBR technology, membrane filtration and biotechnology are combined. The MBR receives raw effluent via an inlet pump to a perforated screen. The screened effluent then gravitates to a membrane tank where a series of flat sheet membrane panels are submerged within the activated sludge. The bacteria in the sludge carry out the biological treatment and the membranes allow the treated effluent (permeate) to be discharged while retaining bacteria and other solids in the MBR tank.

Coarse bubble aeration diffusers below the membranes aerate the system, oxidising biochemical oxygen demand (BOD). They also produce a cross-flow effect across the membrane surfaces to prevent fouling and keep the MBR tank completely mixed. Additional oxygen may be provided via fine bubble air diffusers at times of peak organic loading, or continuously for stronger wastewater. The use of a membrane stage to separate biomass from the treated effluent, overcomes several disadvantages experienced with conventional activated sludge systems, e.g., the limitation the settlement process places on the biomass concentration that can be maintained.

The main benefits of MBR technology are:

- process intensification with a smaller footprint than conventional activated sludge,
- non-reliance on sludge settlement properties to separate treated effluents from biomass,
- complete solids removal and effluent disinfection,
- combined COD (chemical oxygen demand), solids and nutrient removal in a single unit,
- low sludge production.

Water after-treatment can be re-used in the manufacturing processes or discharged to the environment. Sludge from the treatment plant is dried and pressed and then burned in the power boiler.

2.4.2 Air purification

The air emission control standards require pulp and paper mills to reduce hazardous air pollutant emissions through the use of thermal oxidisers, boilers, lime kilns, recovery furnaces, caustic scrubbers, or other control devices.

All non-condensable gases from the pulping process are collected in a closed system and burned in the recovery boiler or lime kiln.

The gases from the bleach plant are collected, passed through a caustic scrubber and released.

Dust from the boiler and lime kiln is treated in an electrostatic precipitator before being released.

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3. LOSS PREVENTION

3.1 General considerations

In the pulp and paper industries, as well as in many other industries, working loss prevention requires three main aspects to have been taken care of namely:

- a maintenance philosophy and a system for choosing the risks,
- a pro-active in-service inspection programme and,
- a working and committed maintenance organisation.

The question of what kind of a maintenance philosophy to apply and how to choose the critical objects to be included in the in-service programme, has been dealt with in the former IMIA paper concerning the pulp and paper industries presented in 2002 with the title: The Pulp and paper industry - technical developments and Loss Experience /1/.

Nowadays the word committed is very often used for personnel and for organisations. Earlier people would have performed the work exactly as well for a lot of reasons without knowing this new modern concept. It seemed to be evident in those days that everybody would do their best to keep the machines in a factory running. This is still the fact for maintenance units belonging to the factory but in case of outsourcing, this may not be evident anymore. Furthermore, the BI-losses, stemming from machinery breakdowns, cannot be carried by small maintenance companies taking care of specific functions of the whole programme. For greater maintenance outsourcing the commitment to do one's best, and to keep the wheels running on a longer time scale, can be handled by an agreement between the factory and the maintenance organisation of a guaranteed availability. This availability dependency is apt to apply the best loss prevention methods at hand.

3.2 The most frequently used machine diagnostic methods

Many persons think of vibration measurement or vibration analyses when hearing the words machine diagnostics. This is due to the fact that vibration measurements of rotating equipment have been used for decades in almost all fields of industry.

Vibration measurement is only one of many applicable methods used for the prevention of losses in critical machinery. In fact on the web site one of the authors of this working group paper has presented a paper on 101 different NDT (Non Destructive Testing) and machine diagnostic methods /2/. The most used machine diagnostic methods used in the pulp and paper industries are, however:

- vibration measurements and analyses
- thermography
- oil analysis.

The most used NDT methods and NDE (Non Destructive Evaluation) methods in the pulp and paper field are:

- visual inspection, unaided or aided with the use of e.g. boroscopes or videoscopes,

- ultrasonics (e.g. thickness measurements and search for embedded discontinuities),
- magnetic particle testing (e.g. search for cracks especially fatigue cracks),
- penetrant testing (e.g. search for cracks and pores in non-magnetic materials),
- eddy current testing (e.g. search for cracks and thinning in heat-exchanger tubes),
- hardness measurement (e.g. search for heat induced material softening).

A more detailed description of the most commonly used NDT methods as well as a comparatively comprehensive list of machine diagnostic methods are presented in the IMIA paper concerning the use of NDT in engineering insurance /3/.

3.3 Critical components

In the chapter below altogether twelve components or sub-systems are dealt with, that experience in the insurance world has shown to be critical, and hence require special attention. First the hazards will be mentioned in short and then a checklist presented with some proposals for damage prohibitive measures to look for and proposals for machine diagnostic methods to be recommended. The checklist is not exhaustive but merely gives ideas to be applied from case to case.

3.3.1 Conveyors

In the pulp factory yard there are several long distance conveyors transporting chips in different levels usually utilising rubber belts. The conveyers constitute a major fire risk and should accordingly be fire protected and at least partly sprinkled and equipped with spark detectors. The most probable cause for a fire is a bearing damage whereby the bearing or the belt is finally overheated igniting the chips. A fire in a conveyer can spread into the factory and cause major damage.

Check-list

- **are the critical parts of the conveyers equipped with sprinklers and spark detection devices?**
- **are the bearings of the conveyers incorporated in an in-service programme using vibration measurements of a representative part of the bearings?**
- **are the bearings being tested using thermography on a periodic basis?**
- **are rotation controllers for slippage control on driving rolls utilised as well as indicators for misalignment of the belts?**
- **are the driving motors equipped with over-load warning devices?**

3.3.2 Chippers

First of all the chipper is critical because normally only one chipper is assembled in a pulp factory. Although a chipper could be easily replaced and a new chipper ordered in a short time, it is a piece of expensive machinery equipment, and above all dangerous if damaged. This is due to the great forces involved in the chopping, and if one blade cracks or gets loose and is chiselled in the machine, the machine practically explodes in pieces.

Check-list

- are the bearings in the gear-cases and the axle of the chipper incorporated in a vibration measurement in-service programme?
- is there a system for securing the assembly of the blades?
 - one new sophisticated way of monitoring the structure and the wearing of the blades is to utilise acoustic emission. Is an acoustic emission monitoring equipment installed?
- if the chipper is situated in outside housings, a cold climate requires warmers of the oil for cold-starts or the use of synthetic oil. Are there oil-warmers installed or synthetic oil in use?
- are regular analyses of the gearbox oil performed?

3.3.3 Digesters

The main hazard is constituted by the aggressiveness of the fibre suspension which together with the pressures and temperatures prevailing in the digesters can contribute to increased crack formation in the welds and decreasing wall thickness.

Effective measures of loss prevention are regular non-destructive examinations for crack formation using the ultrasonic (UT) and magnetic particle (MT) methods, and regular measuring of the wall thicknesses /1/.

Check-list

- are the digesters incorporated in the in-service maintenance programme with systematic periodic UT and MT control of representative parts of the digesters?

3.3.4 Diffusors

The most critical component of a diffuser is the huge gearbox situated on the top of the building with an axle turning the dryer around. The gearbox is usually too big to have as a spare, and since many pulp plants utilising diffusors may have more than one, in some cases production can continue perhaps with a reduced capacity at least for a while. Nevertheless, loss preventive precautions should be taken, and most critical spare parts should be available on short notice.

Check-list

- are the gearboxes of the diffusors incorporated in the in-service maintenance programme with systematic periodic vibration measurements of the main bearings?
- if the gearbox of the diffuser is situated in an unheated housing, a cold climate requires warmers of the oil for cold-starts or the use of synthetic oil. Are there oil-warmers installed or synthetic oil in use?
- are the driving motors equipped with over-load warning devices?
- are regular analyses of the gearbox oil performed?

3.3.5 Black liquor boiler and dissolving tank

One of the prevailing hazards is that of a smelt-water explosion, which can happen if water is able to enter the furnace and come into contact with the hot smelt at the bottom of the boiler. This situation can be caused by the black liquor containing too much water (more than 45 per cent) or by tube leaks in the steam boiler. There is also the hazard of flue gas explosions as a result of the burner failure when unburnt fuel gases and air form an explosive mixture. Burner failures are usually caused by salt deposits from the boiler wall dropping onto the burner or a black liquor jet hitting the burner /4/.

The dissolving tank is a tank situated directly below the recovery boiler to which the molten mass of chemical residue is drained. When the molten chemical mass hits the fluid (a mixture of molten chemical and white liquor called green liquor) in the dissolving tank, an explosive action (steam-water explosion) takes place and during the use of the recovery boiler the molten chemical has to reach the dissolving tank at a moderate rate to keep the turbulence of the tank under control. This control also requires a monitoring of the fluid level in the dissolving tank. During the starting up of the chemical process after a shutdown, the different units of the chemical recovery have to be started at specific moments in order for the process to start in a controlled way. If one unit like the rotary kiln or the causticizing unit has been started and the start of the recovery boiler, for some reason or another, is delayed, the surplus of the chemicals produced have to be taken care of by storing them in special tanks made for this purpose.

Fig. 1 presents a comprehensive statistical review of the down time hours of the Finnish recovery boilers during the fifteen previous years. The figure gives an idea of the problem areas that vary quite considerably from year to year. The statistics are made from 21 boilers, but it is to be noticed that these Finnish boilers are some of the biggest ones in the world, and that at the same time the average age of the boilers is practically the lowest in the world /5/.

Fig. 2 presents a statistical review of smelt water explosions in American and Canadian recovery boilers during the time period 1948-2004 /6/.

Comprehensive automatic safety instrumentation, well trained operating personnel and regular and careful maintenance based on RBMI (Risk Based Maintenance and Inspection) philosophy of the boiler are imperative loss prevention measures for a safe operation of the recovery boilers.

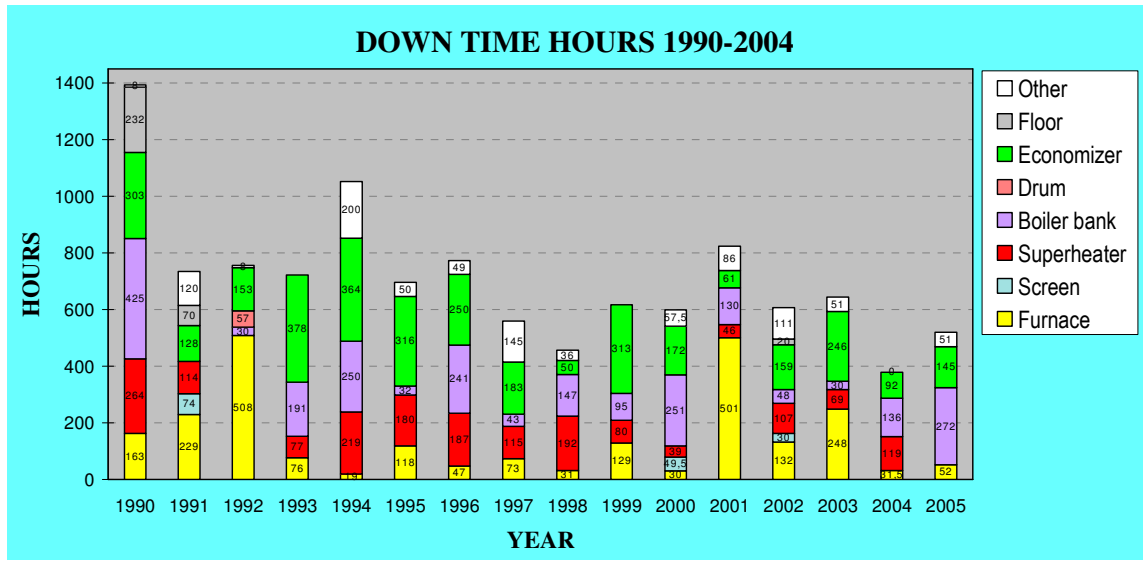


Figure 15. Down time hours versus recovery boiler components in Finnish boilers from 1990 to 2004 /5/.

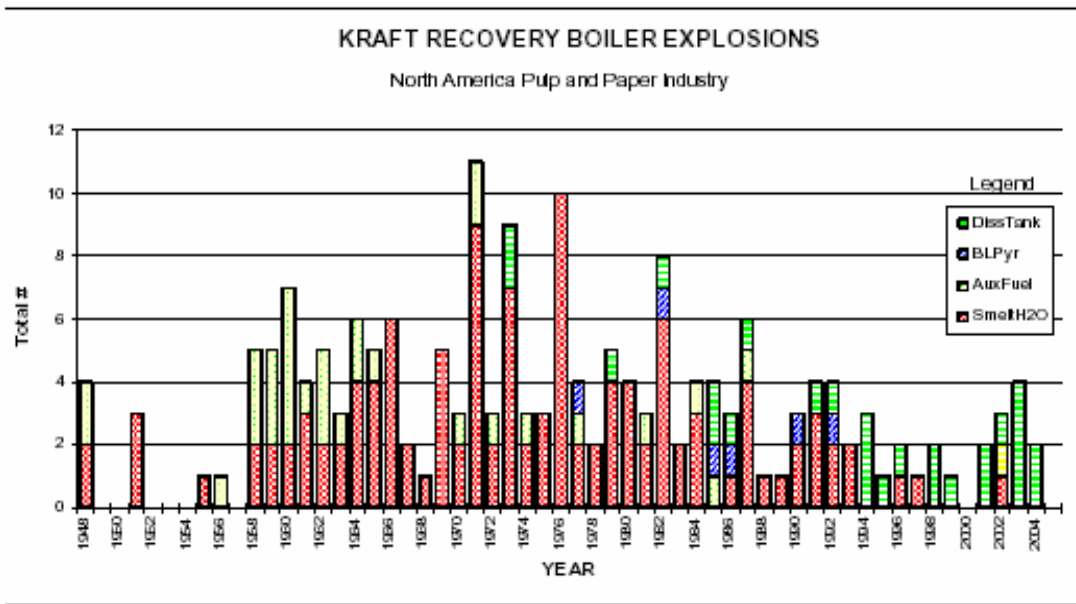


Figure 16. Kraft recovery boiler explosions in North America during the years 1948 - 2004 /6/.

Check-list

- is the combustion process inside the boiler viewed using one or more furnace cameras?
- are there numerous temperature sensors monitoring different parts of the boiler, and are these sensors a part of the safety system and connected to trip the combustion and not only connected to give a warning?
- is the monitoring of the water level of the drum doubled or tripled using different physical measurement systems like a bottom pressure sensor, a float level indicator or a remote glass gauge or a TV-camera following a traditional glass gauge ?
- are there pressure gauges installed in the furnace and are these sensors a part of the safety system and connected to trip the combustion and not only connected to give a warning?
- a deviation in the output of produced steam from a specific amount of used water is usually an indication of a leak. Is there either a manual systematic way for registering this or an on-line system in use for this leak control that may also be a part of the safety system and connected to trip the combustion and not only connected to give a warning?
- for an on-line monitoring of the structural health and for leaks in and outside the boiler, an acoustic emission system can be utilised. Is the boiler fitted with an acoustic emission monitoring system?
- is the monitoring of the green liquor level system in the dissolving tank doubled or tripled using different physical measurement systems like a bottom pressure sensor, a microwave radar from above or a bubble chamber gauge?
- are precautions made for depressurising a part of the lid of the dissolving tank in case of the result of several simultaneous smaller steam water-explosions when the molten mass hits the green liquor?

3.3.6 Boiler fans

A recovery boiler uses huge amounts of air being blown into the boiler at different height levels (primary, secondary, tertiary and even quaternary levels) by heavy blowers with electric motors in the MW range. Except for the burning air blown into the furnace also the combustion fumes have to be transported forward with huge fans. Since the process requires adjustment the whole time these fans have a means of adjusting the air, either using reactor control, turning blade control, hydraulic clutches or inverter control. The fans may show fatigue cracking that is most likely not detectable using only vibration measurement, but also need periodical in-service inspections aided by magnetic particle testing (MT) or penetrant testing (PT).

Check-list

- are the main fans of the boiler equipped with on-line vibration measurements of the main bearings?
- or are the main fans of the boiler incorporated in the in-service maintenance programme with systematic periodic vibration measurements of the main bearings?
- are the bearings of the main fans equipped with on-line temperature measurements?
- are periodic visual inspections aided by MT and PT testing performed at the yearly production shutdowns?
- are the driving motors equipped with over-load warning devices?

3.3.7 Lime kiln

The lime kiln is a typical component that is critical in the chain of producing pulp. The reason for this is that the supporting elements, the riding rings and rolls are heavy cast-steel pieces having an ordering time of around half a year. Also any damage on the unit need the hot kiln to cool down for a couple of days before work on it can start. A pulp factory can only operate a week or two using lime from its own store or transported in from a neighbouring pulp factory.

Check-list

- **is the temperature of the kiln not only monitored by several temperature gauges, but also by using an on-line thermography unit measuring the temperature of the kiln along the centre line of the kiln?**
- **are regular thickness measurements of the brick lining being performed at shutdowns utilising ultrasonic, eddy-current or mechanical inside diameter measurements?**
- **is the gearbox (or are the gearboxes) of the lime kiln incorporated in the in-service maintenance programme with systematic periodic (like monthly) vibration measurements of the main bearings?**
- **is the gearbox of the lime kiln incorporated in the in-service maintenance programme with systematic periodic (e.g. yearly) visual inspections of the internal components of the gearbox?**
- **if the gearbox is situated in an unheated housing, a cold climate requires warmers of the oil for cold-starts or the use of synthetic oil. Are there oil-warmers installed or synthetic oil in use?**
- **are the driving motors equipped with over-load warning devices?**
- **are regular analyses of the gearbox oil performed?**
- **one new sophisticated way of monitoring the structure integrity of both the rolls of the kiln and the bearings of the gearbox is to utilise acoustic emission. Is an acoustic emission monitoring equipment installed?**
- **is there a way or plan of turning the kiln if not only the power from the grid is out and the uninterruptible power system is working, but the gearbox is broken?**

3.3.8 Steam turbo-sets

When one studies damage statistics like the ones we make in IMIA /7/, it is quite evident that the turbo-set in a pulp and paper plant is highly critical due to the fact that the components are heavy and complicated and require cumbersome dismantling in order to be repaired. There are numerous safety provisions provided for and devices mantled in both the steam and gas turbine as well as in the generator.

A comprehensive presentation of the safety systems and diagnostic monitoring systems utilised for steam turbines was presented at last year's IMIA conference in Moscow /8/ and questions adhering to gas turbines have been presented earlier and are to found at IMIA web site /7 /9/ and /10/

Check-list

- are all the safety devices on the turbo-set incorporated in the in-service maintenance programme with systematic periodic function checks?
- are there several sensors for temperature, oil and steam pressure, and also for vibration that are connected to trip the turbine and not only connected to give a warning?
- do the drivers of the turbo-set know why the parameters are connected to safety functions and why they are just given as warnings?
- are the maintenance overhauls in accordance with the recommendations of the manufacturer?
- has the maintenance programme been adjusted according to earlier findings at the overhauls?
- are the maintenance tasks and objects prioritised towards the highest prevailing risks?
- is the turbine equipped with holes for endoscopy and is endoscopy performed regularly like yearly, every second year or every third year?
- are regular analyses of both the hydraulic and the lubricating oil in the turbine and the lubricating oil in the generator performed?
- one new sophisticated way of monitoring the ageing of the insulation used in the stator of the generator, is to use a Partial Discharge system. The PD-system may work on an on-line basis or a periodic basis utilising a bank of capacitors that are beforehand installed during a non-voltage outage period. Are PD measurements being performed on the stator of the generator?

3.3.9 Main transformers

The availability of electrical power is crucial for the different part-factories at a pulp and paper plant and the biggest transformers cannot be stored as spare components. Furthermore, transformer damage may lead into ardent fires and therefore the transformers should be fire protected using sprinklers and they should be incorporated into the in-service inspection programme giving scheduled inspection intervals. The probability of damages is clearly a function of age, and this has to be taken into consideration when applying testing methods.

Check-list

- are there numerous temperature sensors monitoring different parts of the transformer for overheating and are these sensors a part of the safety system and connected to trip the unit and not only connected to give a warning?
- are regular periodic electrical controls like over-voltage tests performed?
- are regular, visual controls of the oil-level performed?
- are regular, visual controls of the silicate elements for drying performed?
- are regular analyses of the transformer oil, including its ability to withstand electrical perforations, performed?
- are regular analyses of the transformer gas performed?
- are regular infrared thermography of different parts of the transformer and the connection plates or bars performed?
- are regular tests performed on Bucholtz relays and differential relays?

- one new sophisticated way of monitoring the ageing of the insulation used in the transformer, is to use a Partial Discharge system. The PD system may work on an on-line basis or a periodic basis utilising a bank of capacitors that are beforehand installed during a non-voltage outage period. Are PD measurements being performed on the transformer?

3.3.10 Paper machine

Hazards on and consideration for loss prevention of paper machines has been dealt with in part 2 of this paper. Below a list of some important aspects to be considered are presented.

Check-list

- are all the safety devices incorporated in the in-service maintenance programme with systematic periodic function checks?
- are the maintenance overhauls in accordance with the recommendations of the manufacturer?
- has the maintenance programme been adjusted pro-actively according to earlier findings at the overhauls?
- are the maintenance tasks and objects prioritised towards the highest prevailing risks?
- are spare parts like critical rolls available at the site, and if not due to the complexity or unique construction of the components, like compensated shoe-rolls, are provisions made for their fast repairs?
- are the main bearings in the gear-cases and the rolls of the machine either equipped with on-line measurement or incorporated in a vibration measurement in-service programme?
- are regular analyses of both the hydraulic and the lubricating oil performed?
- are certain critical areas and components like bearings not monitored by vibration measurements, electrical motors and hydraulic units of the machine incorporated in an in-service thermography measuring programme?

3.3.11 Yankee dryers

Hazards of and considerations for loss prevention of yankee dryers have as well been dealt with in part 2 of this paper. Below a list of some important aspects to be considered is presented.

Check-list

- is there a clear in-service testing programme for the most critical areas of the dryer. The methods used should be visual inspection outside and inside, magnetic particle testing for the most restrained areas and ultrasonic testing of the bolts?
- is there a system of recording and measuring the material thicknesses after possible grinding operations?
- is there an accredited calibration system for the instrumentation?

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4. MPL / PML estimation in the pulp and paper industry

4.1 Loss scenarios

The major hazard areas in a pulp and paper mill are: log and chip piles; black liquor recovery boilers; paper machines and roll paper storage. From a machinery breakdown viewpoint, exposure is inherent in the large, fast-rotating, steam-pressurised dryer cylinders. There have been devastating explosions of yankee dryers in the past. In the case of an integrated pulp and paper mill, the highest concentration of values is represented by the largest paper machine. Quite often, more than one paper machine is housed under the same roof without adequate fire barriers for separation. What is more, paper machines have extensive replacement times – in excess of 18 months; added to this is an additional start-up time of three months to reach full production capacity.

4.2 MPL scenario

The maximum possible loss (MPL) is the maximum loss amount possible for a single risk from a single event. In the case of a pulp and paper mill, we assume a worst-case scenario resulting in a total loss (property damage (PD) + business interruption (BI)). The MPL scenario is usually based on a major fire in the paper production facility originating in the dryer section of a paper machine. Extensive damage to a large part of the machine has to be anticipated. The paper section is often not housed in a fire-resistant construction. In this case, building collapse and extensive damage have to be expected.

In terms of possible BI implications, the entire paper production of the affected machine(s) would be lost for a period of 18-24 months under the worst-case scenario. An integrated pulp and paper mill could consider mitigating the loss amount by selling the extra pulp on the market, but only if the plant has enough capacity to dry the pulp.

4.3 PML scenario

The probable maximum loss (PML) is based on a credible large-loss scenario. This normally involves the criterion of “first line of defence failure”. In other words, it is assumed that the first mechanism of intervention (e.g. automatic sprinkler system) will fail. However, the risk assessment gives credit for subsequent protective measures.

A credible PML scenario for a paper mill is a partial loss in the dryer section of a paper machine. Large paper machines can be up to 300m in length. The fire hazard is greater in the dryer end of the machine because highly combustible materials, such as lint deposits, oily residues and paper scraps, are combined with the presence of ignition sources such as hot bearings, friction or electrical equipment. A typical PD PML would be in the range of 50%-80% of the dryer section. Secondary losses in the adjacent area may have to be taken into account depending on the individual situation.




For the consequent BI loss under the PML scenario, a loss in paper production by the affected machine could be expected to last for 12-18 months. As in the case of the MPL scenario, it may be possible to mitigate the loss amount by selling the extra pulp on the market.



An alternative PML scenario that may be considered for an integrated pulp and paper mill is a smelt/water explosion in the black liquor recovery boiler (BLRB). This scenario is based on the loss history of the pulp and paper industry. A devastating smelt/water explosion could lead to a total BLRB loss. Although a pulp plant may have more than one BLRB, there is normally no make-up capacity available for the chemical recycling of the black liquor. Thus, pulp production will either be interrupted completely or, if more than one BLRB is available, in proportion to the combustion capacity of the BLRB affected. For the consequent BI loss, the period until start-up of a new BLRB is estimated at 18 months. Paper production can be sustained by imported pulp. However, expenses arising from the price difference between the internal cost and market price of pulp have to be added. Further additional expenses may arise from the purchase of fuel oil for the auxiliary boiler and for the purchase of electricity should power be produced on site by steam turbines.

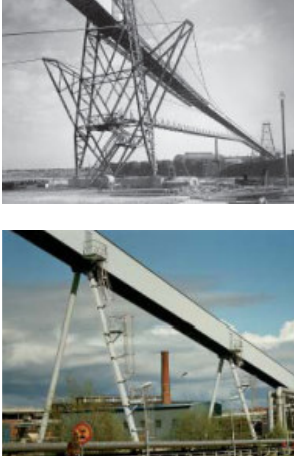
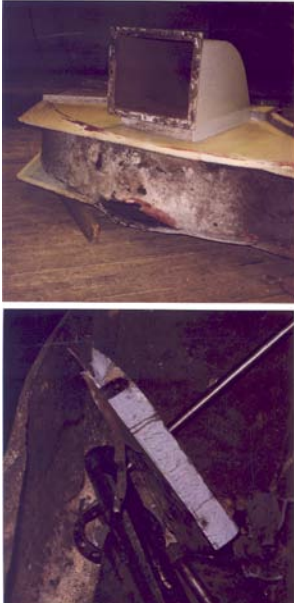
4.4 Additional helpful information

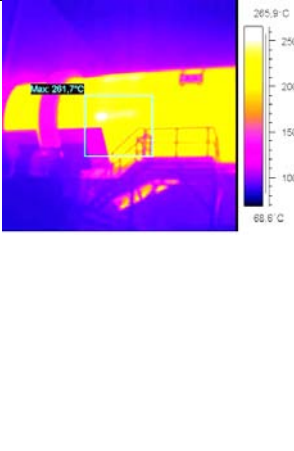
- The trend in the paper industry is towards larger paper machines to take advantage of economies of scale. However, this leads to increased vulnerability to BI.
- A critical aspect in the assessment of the risk quality is the age of the BLRB. Loss statistics indicate that BLRBs older than 25 years are more prone to losses. In these cases maintenance and inspection are of utmost importance. BLRBs over 40 years old are considered problematic for underwriting.
- The yankee cylinders used in some paper mills, e.g. in the dryer section of a tissue plant, raise similar issues. These are huge cylinders which operate under steam pressure, thus having an inherent explosion risk. The usual life expectancy of such a yankee dryer is about 40 years.
- Paper mills are usually located on river banks. The possibility of flooding must therefore be considered.
- A paper machine essentially consists of a large number of heavy rolls of the same width as the paper produced, which are used to form the paper product very precisely. Due to their elevated centre of gravity, paper machines are vulnerable to the horizontal acceleration of an earthquake in areas where this is a factor.



5 Description of Losses. Below a list is presented of loss examples from Pulp and Paper Industries gathered by the working group from IMIA member countries.




	Type of equipment/ construction	Cause	Country of Loss	Conclusion/ Loss amount
	Description of Loss			
	<p>Lime Kiln</p> <p>Failure of casing to lime kiln, which has suffered plastic deformations in "screw" form.</p>	<p>The brick lining had become detached in the combustion zone of the kiln, in a ring-form around the casing. Rapid heating of the casing material (steel 30-500mm) had taken place locally, until it had been plasticized, after which warping had occurred.</p>	<p>Sweden</p>	<p>Replacement of a 4,2 m long casing part, which was welded to the existing part. The thermographic heat scanner should cover the whole lime kiln.</p> <p>Loss amount 1,5 M US\$.</p>
	<p>Bearing failure on a drying cylinder in a paper machine.</p> <p>Failure in a bearing which caused damage to gearwheels in the same group of drying cylinders.</p>	<p>Why the bearing failed is not clarified. The vibration of the bearings was measured five weeks before the failure and the results showed no deviations from normal levels.</p>	<p>Sweden</p>	<p>The damaged parts were changed.</p> <p>There should be an on-line measuring of bearing vibrations also indicating the successful working of the lubrication.</p> <p>Loss amount 3,5 M US\$.</p>
	<p>Recovery boiler</p> <p>A catastrophic explosion followed after water came in contact with the smelt. The shock wave caused the boiler to deform and burst open in one corner. A fire developed after the explosion due to red-hot smelt spreading into the area.</p>	<p>A water tube fractured under pressure allowing water to leak into the combustion chamber. The cause of the fracture of the tube is not determined.</p>	<p>Sweden</p>	<p>It was possible to salvage the steam drum of the boiler, which meant that the plant was back in operation after a downtime of only four months.</p> <p>Loss amount 57 M US\$.</p>

	<p>Paper machine A guide roll in the drying section of the paper machine broke and caused severe damage to five drying cylinders, twenty other guide rolls and the frame of the paper machine.</p>	<p>The failure of the guide roll was caused by a small hole which was used for fixing the weights which balanced the guide roll.</p>	<p>Sweden</p>	<p>The paper machine was not working for eight days directly after the loss and an additional seven days were needed for installing the new drying cylinders and guide rolls.</p> <p>Loss amount 6,5 M US\$.</p>
	<p>Steam turbine A welded heat protection shield in a steam turbine (approx. 100 MW) at a P&P factory was found broken and had injured the Curtis wheel and both stator and rotor blades.</p>	<p>The breaking of the shield was caused by fatigue of the fillet weld.</p>	<p>Finland</p>	<p>The failure was found during a major overhaul of the machine. The failure must have occurred in the very early use of the machine, because for years the vibration level, efficiency and oil analyses had been good. Now a complete damage was very close.</p> <p>Loss amount 1 M €.</p>
	<p>Dissolving tank A problem with a frozen pipe led to a delay in starting up the process after a planned shutdown. The black liquor drain openings in the boiler were first stuck and then burst open leading to an explosion in the dissolving tank and this again lead to a fire.</p>	<p>The delay of the starting up of the boiler lead to a surplus of white liquor and an unusually high level of green liquor in the dissolving tank. The drainage of this tank was partly out of order due to the frozen pipe, and a sudden burst open of the smelt spouts of the boiler lead to the explosion when the tank was overfilled.</p>	<p>Finland</p>	<p>The damage was primarily caused by a frozen pipe and secondarily by the fact that the level of the dissolving tank was driven too high. This highest level has now been lowered giving more expansion air in the dissolving tank should the bursting of the drain openings again happen abruptly.</p> <p>Loss amount 0.8 M €.</p>

	<p>Chip belt conveyor Fire in a chip belt conveyor bridge connecting a sawmill and a pulp mill.</p>	<p>Probable overheating of a conveyor bearing.</p>	<p>Finland</p>	<p>The transportation of wood chips and bark was organized by car transport during the rebuild of a new conveyor. A completely new 300 m long conveyor bridge was built including a sprinkler system, partition into four spaces with smoke venting and emergency exits through the support legs. Loss amount 5 M US \$.</p>
	<p>Chipper The blade of a chipper got loose, was chiselled in between the blade holder and the flywheel and broke, flew through the casing and at the same time the gear-case practically exploded due to the immense inertia forces of the flywheel.</p>	<p>The blade loosened most probably due to freezing of the chipper after frozen big sizes logs had been chopped for a long period without pauses. The torque of the fastening bolts probably was too small due to material contraction.</p>	<p>Finland</p>	<p>It is imperative to check the fastening torque of the bolts periodically, especially if extremely low or high temperatures are present. Unnatural cutting circumstances may also be monitored using on-line acoustic emission for process control. Loss amount 1 M €.</p>

	<p>Lime Kiln Failure first on the brick lining. This had been diagnosed using on-line thermography (like in the picture to the left, although it is not the same failure as the picture below). After relining and starting up, the riding ring got stuck due to an unnoticed dent in the casing.</p>	<p>The lining fell down due to overheating of the oven. The overheating caused a dent. When the riding ring is not properly riding and carrying the load on most of the connecting surface, it will start cracking.</p>	<p>Finland</p>	<p>Replacement of a 6m long casing part with the reinforced part for the riding ring. The part with the riding ring on was welded to the casing. The replacement could be made after postponing the change to the scheduled summer production stop by intensively testing the ring at all production stops using</p>
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	<p>Gear case of lime kiln</p> <p>Failure on gear case. The acoustic emission monitoring system showed activation on one of the two gear cases rotating the lime kiln. Preparations for a fast shift from having used two to using one gear case could be made. At the same time the lime kiln production rate was slowed down to cope for the reduced rotation force.</p>	<p>The cause for the breakage of gear teeth and bearings is not clear. It might be a clear under-dimensioning of the components in the gear case.</p>	<p>Finland</p>	<p>The damaged gear-case was pulled back and a new assembled on a very short notice. The remedy is to more closely monitor the case using vibration measurements and acoustic emission. A spare gear case is also now at hand.</p> <p>Loss amount 1,3 M €.</p>

	<p>Fire in Tissue plant A total loss of the entire storage area and part of the production facilities.</p>	<p>The fire was caused by a short circuit in an electrical switchboard.</p>	<p>Switzerland</p>	<p>Loss amount 128 M US\$.</p>
	<p>Yankee dryer A 1050 mm crack in the surface of the Yankee dryer.</p>	<p>At the start up of the paper machine, cold water was sprayed on the surface of the Yankee dryer, which caused thermal tension resulting in the crack.</p>	<p>Sweden</p>	<p>The Yankee dryer was temporarily fixed and replaced after 6 months. Loss amount 3 M US\$.</p>
	<p>Odorous gas collection system An explosion in a blower in a malodorous gas collection system in a pulp mill.</p>	<p>Possible exceeding of the lower explosion limit of the turpentine gas concentration in the air due to problems in the cooling system.</p>	<p>Finland</p>	<p>The reconstruction of the system was done in about two weeks including technical improvements and changes to prevent turpentine vents enter into the weak odorous gas collection system.</p>