PAPER MACHINES AND PULP DRYERS

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1.0 SCOPE

This data sheet contains property loss prevention guidance unique to paper, board, tissue, and pulp machines with steam-heated dryer rolls as well as airborne and flash pulp dryers. The machine sections covered include forming, press, drying, and reel as well as operations that may be online or offline such as calendering and coating.

This data sheet focuses on guidance unique to these machines and their utility and support systems, and is intended to supplement the guidance provided in other data sheets. When evaluating hazards not addressed by this data sheet, apply the applicable FM data sheet. A few examples of data sheets offering guidance on hazards found at mills, but outside the scope of this data sheet, include the following:

- 5-4, *Transformers*
- 5-19, *Switchgear and Circuit Breakers*
- 7-98, *Hydraulic Fluids*
- 7-99, *Heat Transfer by Organic and Synthetic Fluids*
- 9-0, *Asset Integrity*
- 10-8, *Operators*

Appendix C contains a more comprehensive list of data sheets that may be applicable at paper, board, tissue, and pulp mills.

1.1 Hazards

1.1.1 Machine Fires

Regardless of product type (board vs. tissue), historically machine fires have primarily occurred in the dryer hood and attached exhaust, and below the machine due to the nature of products being produced. Spilled pulp, fiber, broke, and parent/jumbo reels on the dry-end of machines combined with spilled oil were often the combustibles involved. Automatic sprinklers proved to be effective at managing the risk posed by these combustibles.

Over the last few decades with technological improvements and increased production rates, the combustible loading in and round the machine has changed. Lubrication and hydraulic systems have become larger and more complex, while in some instances oil has entered the footprint of the machine rather than being limited to the ground floor and sides of the machine. The addition of HTF heated rolls in calenders has introduced the potential for a high flow rate, heated oil release.

With these more intense ignitable liquid hazards, automatic sprinklers alone are often not sufficient for reducing fire risk as evident in recent machine fires. Other ignitable liquid safeguards are required to mitigate the oil fire risk at a machine, especially when a large oil release is possible. Safeguards that limit an oil release become more critical as the system size, pressure, and flow rates increase. Such safeguards may include an automatic fire interlock and proper oil-containing equipment (e.g., metallic construction vs. rubber or plastic). These safeguards limit the quantity of oil released thereby the fire intensity and duration by promptly shutting down the machine and depressurizing the release point, while also preventing secondary oil releases and guarding against a sustained gravity release of oil hold-up following depressurization. After taking steps to minimize the release, controlling the flow and pooling of that released oil with containment and drainage, and/or controlling the fire and cooling the fire area with automatic sprinklers become key to further limit fire spread and thermal damage.

Another change in the machine fire risk is the increased amounts of power cabling and control wiring. While adding combustible loading in hard to access areas (e.g., ground floor ceilings), if damaged by a fire, splicing or pulling replacements can significantly increase the downtime of even after a smaller, controlled fire. Routing cabling and wiring runs away from combustibles and providing protection when appropriate reduce the potential for damage.

1.1.2 Roll Failures

The hazards presented by pressurized dryer rolls are well documented. Failure of a bearing, journal, head, or shell can result in roll displacement or rupture releasing a large amount of stored energy in an explosion and also producing projectiles. Recovery times following a dryer roll failure can be substantial. Maintenance, safety devices, and operators are key in managing dryer roll hazards.

While not as dramatic, a functional roll failure or crash or wreck in the forming, press, calender, or reel section can also lead to long recovery times. Failure of roll covers, shells, heads, journals, and bearings can lead to roll displacement or debris damage throughout the section. With few workarounds for damaged functional rolls, maintenance and equipment contingency planning are key to reducing the likelihood and consequences of a functional roll failure.

Refer to the following "Understanding the Hazard" brochures:

- Paper Machine Fires, P0352
- Cracking of Cast Iron Dryers, P0378
- Intermediate Bulk Containers, P0040
- Combustible Dust, P0108
- Hydraulic Fluids, P0031
- Organic/Synthetic Heat Transfer Fluids, P0190

1.2 Changes

October 2024. Interim revision. Updated FM Approved industrial fluid guidance based on a recent fluid approval intended for shoe press applications.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 All Machines

Paper and pulp are produced on various types of machines. Recommendations in this section are applicable to all types of paper machines. Protection for ignitable liquid hazards is provided in two subsections. The introduction section contains protection guidance on ignitable liquid supplies supporting the machine (e.g., lubricating oil reservoir and pumps), while protection for ignitable liquid transfer piping and use-points at or near the machine is provided in the sections that follow (e.g., lubricating oil manifolds and supply/return lines).

2.1.1 Introduction

2.1.1.1 The loss prevention guidance contained in this document is unique to the machines identified within the scope and supplements the guidance contained in other data sheets. For hazards not covered in Section 2.0 of this data sheet, adhere to loss prevention recommendations in the relevant data sheet. A list of data sheets that may be relevant is included in Appendix C.

2.1.1.2 Use FM Approved equipment, building materials, and services whenever applicable and available. Select and install FM Approved products and services in accordance with their *Approval Guide* or Roof*Nav* listing. Refer to the *Approval Guide* and Roof*Nav*, online resources of FM Approvals, for a list of FM Approved products and services.

2.1.1.3 Select a circulating lubrication fluid, hydraulic fluid, and/or heat transfer fluid (HTF) that poses the lowest fire hazard possible; and provide fire protection as discussed below. The oil/fluid options below are listed in order from lowest fire hazard to greatest fire hazard.

2.1.1.3.1 Within hydraulic and HTF systems, use a nonignitable liquid (i.e., liquid that does not have a flash point or fire point). Where a nonignitable liquid is used exclusively, determine the need for fire protection based on the surrounding occupancy.

2.1.1.3.2 Use an FM Approved industrial fluid rather than an ignitable liquid such as mineral oil. Where a FM Approved industrial fluid is used, determine the need for fire protection such as automatic sprinklers and oil fire interlocks based on the surrounding occupancy. FM Approved industrial fluids may be available for the following applications:

A. Shoe press, control crown roll, and/or swimming rolls

The FM Approved industrial fluid should be meet the lubricating requirements for the interface between stationary and rotating surfaces in these nip rolls (e.g., shoe press interface between the sleeve/belt and shoe). Refer to the roll OEM for guidance on the required lubricity and other fluid properties.

B. Hydraulic

C. Circulating lubrication (e.g., roll bearings and gearboxes)

When converting any existing oil system to a FM Approved industrial fluid, refer to the fluid OEM for guidance on compatibility of the outgoing mineral oil and ingoing FM Approved fluid. The OEM should provide guidance on the need to: change out existing hoses, seals, gaskets, filters, and metal components in contact with the fluid; remove residual mineral oil, water, or other contaminants with a flushing procedure; system changes; and/or additional maintenance including sample testing following the initial conversion. Lack of sufficient management of change and fully vetting the conversion can result in damage to system internal surfaces or fouling.

2.1.1.3.3 Use a very high flash point oil meeting the following criteria: operates close to ambient temperature (i.e., not applicable to heated HTF systems) and has a closed cup flash point at or above 414°F (212°C) confirmed by three separate tests at an independent laboratory. Use of very high flash point oil lessens the ignitable liquid protection required for that oil supply.

Per Data Sheet 7-32, the oil supply warrants: (a) a containment curb sized for the expected spill (a minimum of 3 in. [76 mm] in height); (b) ceiling sprinkler protection designed to deliver 0.2 gpm/ft^2 (8 mm/min.) over 2,500 ft^2 (232 m^2) independent of ceiling height with 500 gpm (1,900 L/min) hose stream allowance; and (c) an oil fire interlock.

2.1.1.3.4 When all of the previous options are not feasible, use an oil with the highest flash point possible; and provide fire protection for oil equipment areas per this data sheet.

2.1.1.4 Provide ignitable liquid protection for oil supply equipment areas in accordance with Sections 2.1.1.4.1 through 2.1.1.4.8. Refer to Section 2.1.1.5 when protecting HTF supply and secondary loop equipment areas.

A paper machine will be supported by a number of oil systems including but not limited to circulating lubrication; centralized hydraulic; smaller, dedicated hydraulic; or shoe press. Each of these systems will have an oil supply that may consist of a reservoir, pump(s), filters, heat exchangers and other intermittent or continuous use oil conditioning equipment such as a vacuum dehydrator.

2.1.1.4.1 Locate an oil supply on the ground floor in areas not exposing concentrations of power and control cabling.

2.1.1.4.2 Isolate the oil supply from surrounding areas with minimum one-hour fire-rated walls and ceiling/roof.

2.1.1.4.3 Provide spill containment dedicated to the subject oil supply sized based on the largest expected oil release (e.g., from the reservoir). The containment curb should be of a minimum of 3 in. (76 mm) tall.

2.1.1.4.4 Provide automatic sprinkler protection over the oil supply. Based on ceiling height, hydraulically design protection to provide the following; and install sprinkler protection per Data Sheet 7-98.

A. Under ceiling heights less than or equal to 15 ft (4.6 m), 0.3 gpm. /ft^2 over 4,000 ft^2 (12 mm/min over 370 m^2) with a hose stream allowance of 500 gpm (1,900 L/min) over a 60 minute duration.

B. Under ceiling heights greater than 15 ft (4.6 m), 0.4 gpm/ft^2 over 4,000 ft^2) (16 mm/min over 370 m^2) with a hose stream allowance of 500 gpm (1,900 L/min) over a 60 minute duration.

2.1.1.4.5 Provide an oil fire interlock for the oil supply per Section 2.1.4.3.

2.1.1.4.6 Design and install oil supply equipment (e.g., reservoir) in accordance with the following to minimize pressurized and gravity oil releases. Refer to Data Sheet 7-32 for additional design guidance.

A. Use indirect measurement sensors such as an ultrasonic sensor for reservoir fluid level in place of direct measurement and observation such as reservoir level gauges or sight glass.

B. Provide a safety shutoff valve at discharge ports if the potential exists for a long gravity release from the system (e.g., from the reservoir).

2.1.1.4.7 Use flexible hoses and connections constructed with metal oil-containing components and at least one layer of metal braid reinforcement whenever possible. When rubber hoses and connections are unavoidable, use rubber hoses and connections with one or more layers of metal braid-reinforcement combined with an oil fire interlock per Section 2.1.4.3.

2.1.1.4.8 Provide a means to manually de-energize oil supply pumps from at least one remote location that will remain accessible under anticipated fire conditions.

2.1.1.5 For HTF system supply and secondary loop equipment, provide ignitable liquid protection in accordance with Data Sheet 7-99, *Heat Transfer Fluid Systems*. The HTF system supply may consist of a heater, circulation pump(s), expansion tank, and conditioning equipment.

2.1.1.6 Avoid using ignitable liquid performance and formation additives, and cleaning solvents whenever possible. If unavoidable, select one of the following ignitable liquid protection schemes for machine areas.

A. For low-flash point ignitable liquid additives or solvents, limit the quantity of liquid within the machine room. Provide a dedicated, remote dispensing station. Locate, protect, and arrange the dispensing station in accordance with Data Sheet 7-32. Limit dispensed quantities within the machine room to less than 5 gal. (19 L) contained within FM Approved safety containers.

B. For all pumped/pressurized transfer of ignitable liquid additive or solvent systems, locate the additive/ solvent supply on the ground floor and provide ignitable liquid safeguards in accordance with Data Sheet 7-32.

2.1.2 Location and Construction

2.1.2.1 Use noncombustible building materials and assemblies around the machine including roof, ceiling, flooring/walkways, and wall construction. If plastic building materials are needed, use FM Approved building materials installed in accordance with their listing.

2.1.2.2 Use noncombustible materials to construct dryer hoods and exhaust ventilation systems. If insulated metal panels are used for dryer hood construction, use FM Approved plastic materials installed in accordance with the listing.

2.1.2.3 Locate lubricating and hydraulic oil distribution manifolds such as lubrication metering stations, and hydraulic control valve stations and accumulators on the ground floor. These oil distribution manifolds can contain concentrations of plastic and glass oil-containing components for direct measurement and observation instruments, and/or flexible rubber hoses, which can crack, melt, or otherwise fail in fire, releasing oil.

2.1.2.5 Provide ignitable liquid containment and drainage for HTF use-points, and oil distribution and use points listed in A-D below. When possible, leverage containment to channel the released oil to a trench drain to limit pool size and fire intensity, while also keeping the released oil away from other potential oil release points and thermally sensitive equipment (e.g., power and control cabling).

A. Shoe sleeve or belt within press or calender nips, and flexible supply/return hoses. The potential scenario involves both a sleeve or belt rupture and supply/return hose rupture due to melting (fire) or mechanical impact (drive shaft failure). Shoe presses are afforded substantial process drainage for wet-end dewatering; however, a shoe calender at the machine dry-end may not benefit from the same level of process drainage.

B. HTF heated rolls, specifically the flexible supply and return hoses and rotary joints. The potential scenario involves a rotary joint seal failure or bearing seizure and rupture of the supply/return hoses.

As part of HTF rotary joint containment, provide a sturdy and completely noncombustible enclosure around the joint and flexible hoses that are fixed to the machine or the floor to prevent movement in the event the rotary joint or a flexible hose fails catastrophically. Minimize openings in the enclosure; and for any inspection or access hatches in the enclosure, provide a substantial latch and hinge. Extend ridge supply and return piping into the enclosure. Redirect fluid released within the enclosure into the floor containment and drainage system below.

C. For roll bearing circulating lubrication oil metering stations with plastic or glass variable area flow meter tubes or sight glasses. The potential scenario involves a fire melting or rupturing multiple tubes or sight glasses in the fire area.

D. For individual circulating lubrication oil use points on the operating floor with plastic/glass variable area flow meter tubes or sight glasses, or rubber hose connections such as a drive gear. The potential loss scenario involves a fire melting or mechanical impact (driveshaft failure) rupturing a tube, sight glass or hose in the fire area.

2.1.2.6 Locate dust collectors outdoors in accordance with Data Sheet 7-76, *Combustible Dusts*.

2.1.3 Protection

2.1.3.1 General Machine Areas

2.1.3.1.1 Provide ceiling-level automatic sprinkler protection above and 20 ft (6 m) beyond the machine areas considered as a combustible occupancy. General guidance is provided below to assist defining the combustible occupancy in paper and board machines, and tissue machines.

As an alternative to ceiling-level automatic sprinklers, provide machine-level automatic sprinkler, deluge, or fixed-water spray protection over combustibles in the machine and adjacent areas per this data sheet and other applicable data sheets. In some instances, machine-level protection may be preferred to ceiling-level automatic sprinklers, such as under tall ceilings (e.g., 60 ft or 18 m) and when obstructions such as felts or rolls delay sprinkler response and sprinkler discharge effectiveness. For an example, in a press section, upper felts likely obstruct sprinkler discharge from reaching burning surfaces early in the fire.

A. For paper and board machines, the combustible occupancy can start after the forming section and extend downstream through the dry end of the machine (i.e., press, drying, and reel machine sections).

B. For tissue machines, the combustible occupancy typically starts downstream of Yankee and through-air dryer hoods. Do not provide automatic sprinklers directly over a Yankee dryer hood.

2.1.3.1.2 Provide automatic sprinkler protection within the hood, plenum, economizers, and exhaust system based on the following. Refer to Figures 1 and 2 for example sprinkler locations. As an alternative to automatic sprinklers, automatic deluge or fix-water spray systems are acceptable if designed in accordance with this data sheet and other applicable FM data sheets.

A. Provide automatic sprinklers within concealed air plenums created by any false ceilings.

B. Provide automatic sprinklers inside exhaust ducts in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*.

C. Position sprinklers inside hoods over drive and tending side frames, and beneath every walkway, regardless of flooring (i.e., open-grating or solid).

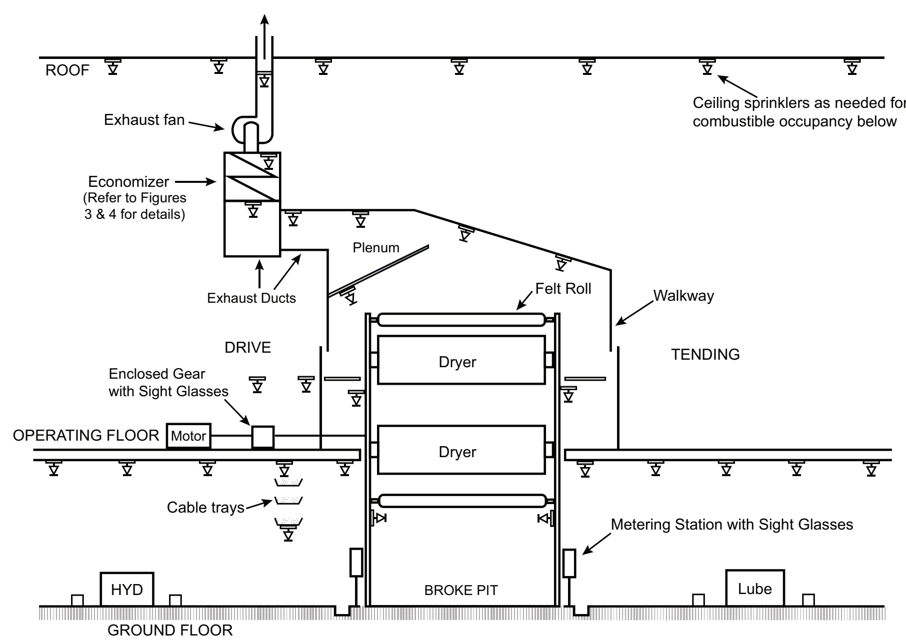


Fig. 1. Example sprinkler coverage in and around dryer hood with partial width concealed plenum

D. Provide automatic sprinklers within an economizer in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*. Refer to Figures 3 and 4 for example sprinkler locations. If HTF is used as the heat transfer media,

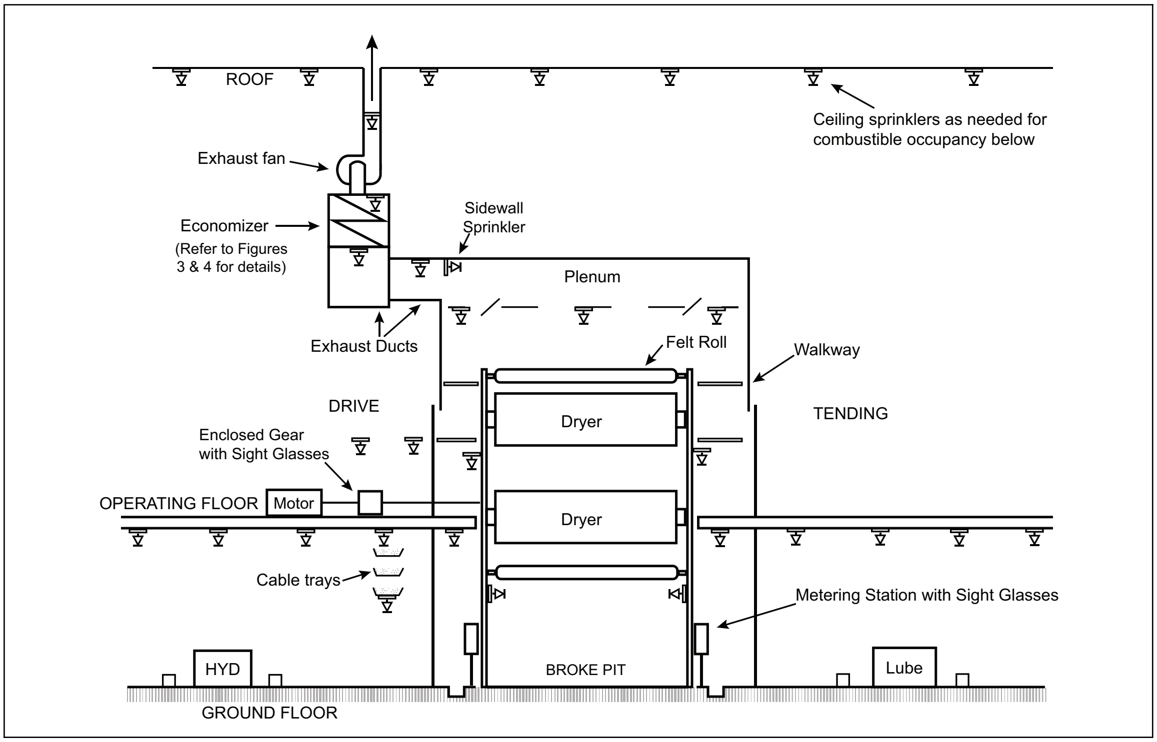


Fig. 2. Example sprinkler coverage in and around dryer hood with full-width concealed plenum

refer to Data Sheet 7-99 for guidance on appropriate ignitable liquid safeguards for the economizer. As an alternative to automatic sprinklers, automatic deluge or fixed water spray systems are acceptable if designed in accordance with this data sheet and other applicable FM data sheets.

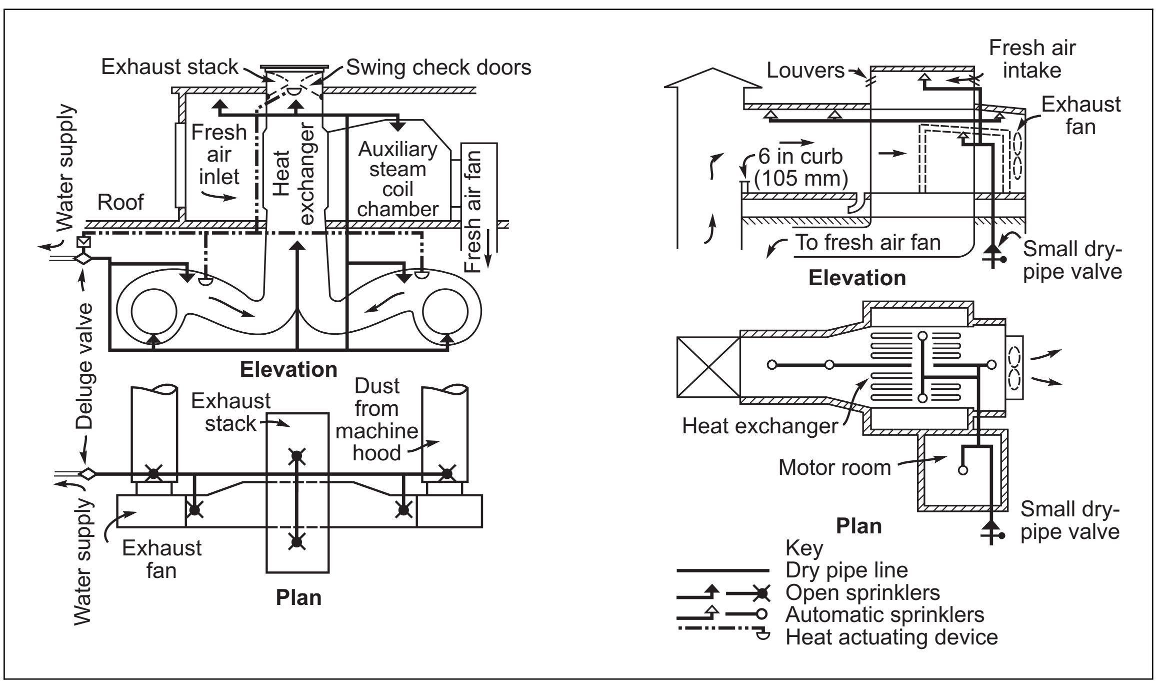


Fig. 3. Example of dry-type economizer automatic sprinkler arrangement

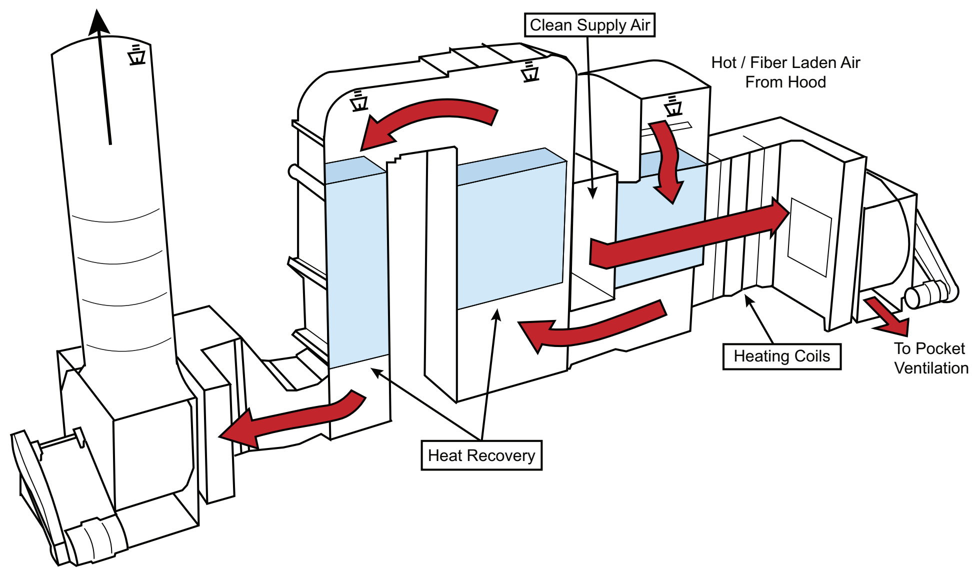


Fig. 4. Example of wet-type economizer automatic sprinkler arrangement

E. Provide drainage for sprinkler and hose stream discharge from within dryer hood plenums, economizers, and exhaust ductwork to prevent collapse from water accumulation.

F. Recirculate air from the economizer to the paper machine room only.

2.1.3.1.3 Provide automatic sprinkler protection in the broke pit and ground floor machine areas containing combustible construction or combustible occupancy and at least 20 ft (6 m) beyond. As an alternative to automatic sprinklers, automatic deluge or fixed water spray systems are acceptable if designed in accordance with this data sheet and other applicable FM data sheets. Typically, the combustible occupancy starts within the broke pit and extends at least 20 ft (6 m) beyond into the aisles on both sides.

2.1.3.1.4 Provide sprinkler protection for trays of power cabling and control wiring in accordance with Data Sheet 5-31, *Cables and Bus Bars*.

2.1.3.1.5 Design ceiling-level, hood, and broke pit sprinkler protection based on Table 1.

Table 1. Automatic Sprinkler Design for Machine Areas

Machine Area	*Density/Operating Area, gpm/ft²/ft² (mm/min/m²)*		*Hose Stream Allowance, gpm (Lpm)*	*Duration, minutes*
	Wet	Dry		
Dryer Hood & Plenum	0.2/3000 (8/279)	0.2/4000 (8/372)	250 (950)	60
Broke Pit	0.2/3000 (8/279)	0.2/4000 (8/372)	500 (1900)	60
Hood Exhaust System (Duct and Economizer)	Data Sheet 7-78[1]			
Machine area (excluding calenders and parent roll Staging/Deck)	Data Sheet 3-26 (HC-2)			
Calenders	Data Sheet 3-26 (HC-3)			
Parent Roll Staging/ Deck	Data Sheet 3-26 (HC-3)			

[1]Hydraulically balance protection in the dryer hood and exhaust system.

2.1.3.1.6 Design and install automatic sprinkler, deluge, and fixed water spray systems in accordance with the respective data sheet along with the following machine-specific design and installation aspects. For automatic sprinkler and deluge systems, refer to Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*. For automatic fixed water spray systems, refer to Data Sheet 4-1N, *Fixed Water Spray System for Fire Protection*. Specific design and installation guidance offered in this data sheet supersedes that of other data sheets.

A. When automatic sprinklers are recommended in this data sheet, automatic deluge or fixed water spray are an acceptable alternative when designed and installed in accordance with this data sheet.

B. Select automatic sprinklers with temperature ratings abased on the maximum ambient temperature at the respective ceiling or hood level in accordance with Data Sheet 2-0.

C. Within broke pits, avoid running fire protection piping in the cross machine direction underneath the machine in the broke pit to protect it against falling rolls, sheet breaks, and felt runoffs. Use sidewall sprinklers located at the perimeter of the machine and below machine clothing. If the machine is wider than 20 ft (6 m), provide an automatic deluge or fixed water spray system arranged to wet down the entire broke collection area.

D. Supply fire protection systems within ground floor areas independently from fire protection systems on the operating floor. Locate the control valves outside the protected area in an easily accessible location.

E. Position sprinklers or nozzles in a manner to limit obstructing discharge in accordance with Data Sheet 2-0. Common obstructions include pipe racks, trays of power cabling and control wiring), and ventilation ducts.

F. Above calenders, locate ceiling sprinklers outside the plan area of individual calender rolls to avoid drips or solid streams from sprinklers striking any heated rolls. Drips and streams can form when the sprinkler system is draining after being shutoff.

G. Use corrosion resistant piping, nozzles/sprinklers, hangers, and other materials when installing ceiling-level and local automatic sprinkler protection in or near wet-end machine areas (e.g., press section).

H. For automatic deluge and fixed water spray systems, apply the following additional design and installation aspects:

1. Provide automatic fire detection within the anticipated fire area to automatically actuate the fire protection system and sound an alarm in a constantly attended location such as a control room. Fire detection options may include optical flame detectors (i.e., UV/IR), video flame detectors (e.g., thermal imaging), and linear or spot heat detection.

   Design and install fire detectors and the detection system in accordance with FM Data Sheet 5-48, *Automatic Fire Detection*, and the applicable FM Approval listing. For additional guidance on detector spacing and layout, refer to Data Sheet 7-98.

2. Provide an operator interface (e.g., push button) to manually actuate the fire protection system from the control room and at least one remote location that will remain accessible under anticipated fire conditions.

3. Install blow-off plugs on open nozzles to prevent moisture and debris (stock or fiber) from clogging piping or discharge orifices.

2.1.3.1.7 Provide automatic fire protection within machine control rooms and rooms containing machine control equipment in accordance with Data Sheet 7-110, *Industrial Control Systems*.

2.1.3.1.8 Provide 1.5 in. (38 mm) hose valves along both sides of the machine, arranged so at least two fire hoses can reach anticipated fire areas containing lubrication oil, hydraulic oil, heat transfer fluid, fiber, fiber dust, and broke. Similarly, provide fire hose stations in ground floor areas to supplement automatic sprinklers.

2.1.3.1.9 Provide combination spray-type nozzles at the hose valves to avoid application of solid stream to a steam or HTF-heated roll or an oil pool fire.

2.1.3.2 Circulating Lubrication Oil at the Machine

2.1.3.2.1 Provide automatic sprinkler protection over circulating lubrication oil metering stations with direct measurement or observation instruments such as glass or plastic variable area flow meter tubes and sight glasses. Extend sprinkler coverage over areas where released oil can flow or pool and at least 20 ft (6 m) beyond. Design and install sprinkler protection in accordance with Data Sheet 7-98.

2.1.3.2.2 Provide automatic sprinkler protection locally over circulating lubrication oil use points on the operating floor such as drive gears with flexible hoses or direct measurement or observation instruments (e.g., glass or plastic variable area flow meter tubes and sight glasses). Extend sprinkler coverage where released oil can free fall to the ground floor or otherwise flow or pool and 20 ft (6 m) beyond. Design and install sprinkler protection in accordance with Data Sheet 7-98.

2.1.3.2.3 In addition to ceiling level sprinkler protection above the machine dry-end, provide automatic sprinklers locally over circulating lubrication oil flexible hoses on each side of a calender. Extend sprinkler coverage where released oil can flow or pool, and at least 20 ft (6 m) beyond. Design and install sprinkler protection in accordance with Data Sheet 7-98. When locating sprinklers, minimize the potential for sprinkler water impacting hot roll surfaces, inducing thermal stresses.

2.1.3.3 Swimming Roll, Control Crown Roll and Shoe Press

The protection recommended below is intended to limit thermal damage to the roll of origin (i.e., swimming, control crown or shoe press) and surrounding parts of the machine and support equipment (e.g., cabling) during an oil fire. Fire can spread to combustible roll covers and clothing depending on oil fire interlock time delays and water spray coverage throughout the machine section.

2.1.3.3.1 Locate automatic deluge or water spray nozzles to provide water spray coverage over and beneath hydraulic and/or high-pressure lubrication oil flexible hoses as specified in A-D below. This protection scheme is intended to address the rupture of supply and/or return flexible hoses serving the roll. Figures 5 and 6 show example nozzle locations for an oil release from a control crown roll or swimming roll flexible hose. Actual nozzle locations will vary depending on machine layout and accessibility for machine maintenance.

A. Operating level, above flexible hoses: Above the full length of the flexible hose and the attaching end of the roll, plus an additional nozzle to either side in the machine direction (e.g., one nozzle above the hoses plus a nozzle spaced 8-10 ft [2.3-3.0 m] on either side directed at the hoses and roll end).

B. Operating level, beneath flexible hoses and other obstructions: Beneath the flexible hoses, driveshafts, suction ducts, and other obstructions to ensure water discharge reaches the operating floor where released oil can flow and/or pool (e.g., one nozzle under flexible hoses, and another two nozzles 8-10 ft or 2.3-3.0 m on either side in the machine direction directed at the operating floor and operating floor edge where oil flows into the pit below).

C. Ground floor, inside the machine footprint: Underneath the rolls over the pit where released oil from the operating floor level can flow and pool, and 20 ft (6 m) beyond the anticipated oil fire area (e.g., a row of four nozzles installed inside the machine pedestal on the hose side of the machine directed across the pit).

D. Ground floor, outside the machine footprint: At ceiling level over the aisle where released oil from the operating floor level can flow and pool, and 20 ft (6 m) beyond the anticipated oil fire area (e.g., two rows of four nozzles at ceiling level spaced at 8-12 ft [2.3-3.0 m]). Additional nozzles may be needed below obstructions (concentrations of pipe and cabling runs) to ensure water discharge reaches the ground floor.

2.1.3.3.2 In addition to Section 2.1.3.3.1, locate automatic deluge or water spray nozzles to provide water spray coverage over and beneath a shoe press nip as specified in A and B below for the ENP belt or closed shoe sleeve rupture scenario. Figures 7 and 8 show example nozzle locations for an oil release from a shoe belt/sleeve and flexible hoses.

A. Operating level, over the top nip roll: A minimum of two nozzles on each side of the machine (e.g., two nozzles on tending-side and two nozzles on drive-side with overlapping spray directed at the top nip roll and coverage of adjacent machine areas).

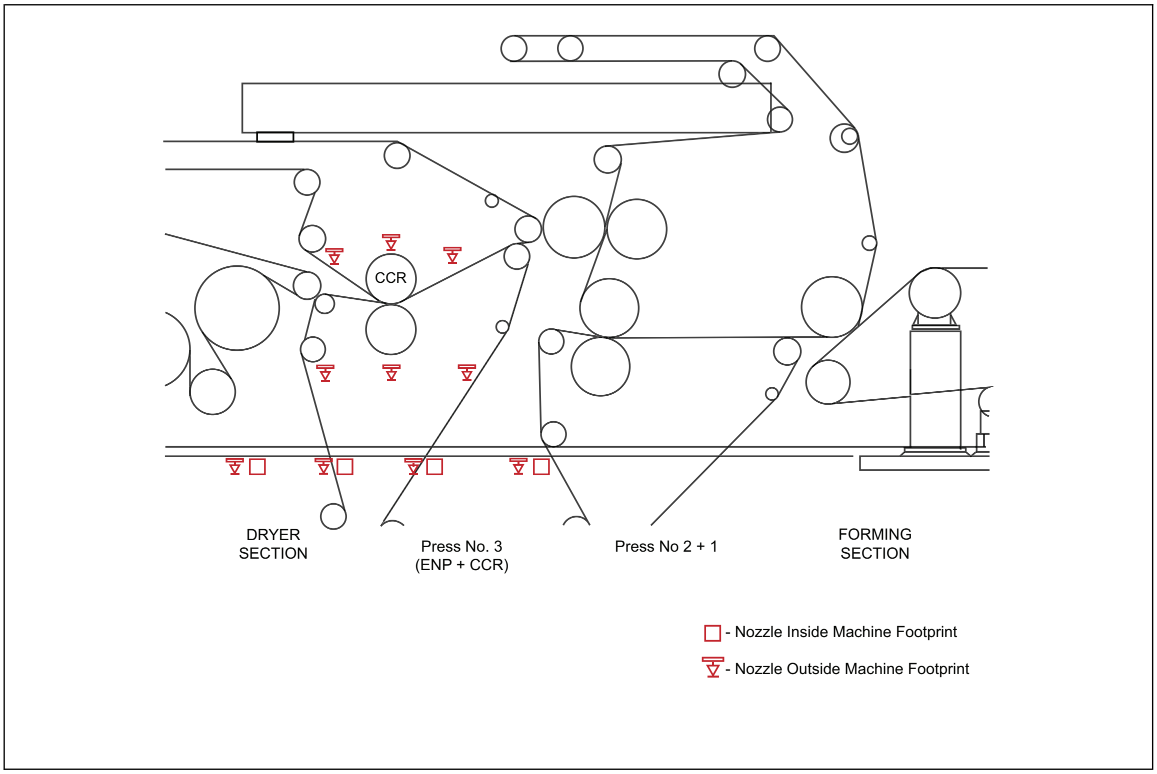


Fig. 5. Example nozzle locations for swimming roll or control crown flexible hose rupture (elevation and machine direction)

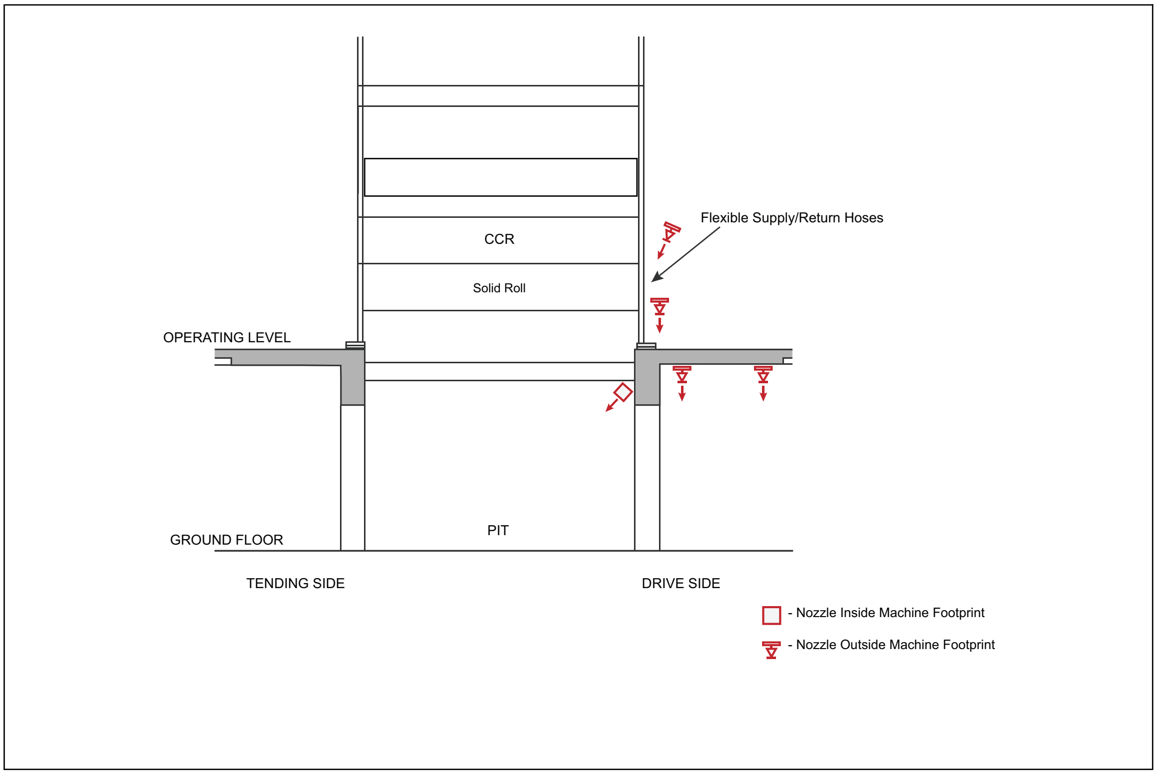


Fig. 6. Example nozzle locations for swimming roll or control crown roll flexible hose rupture (elevation and cross machine direction)

B. Ground floor, inside the machine footprint: Over the pit beneath the nip where oil can accumulate and (if present) felts can runoff, and at least 20 ft (6 m) beyond (e.g., four nozzles on the tending-side and four nozzles on the drive-side, positioned on the machine pedestal under the bottom nip roll and directed across and onto the pit floor).

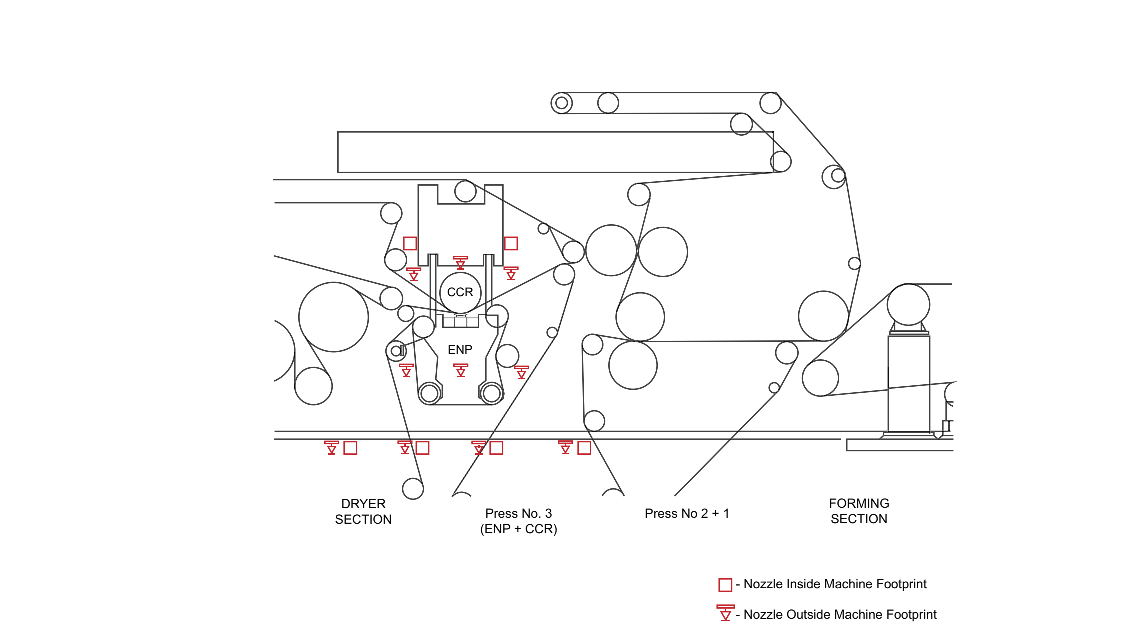


Fig. 7. Example nozzle locations for shoe belt or sleeve and flexible hose ruptures (elevation and machine direction)

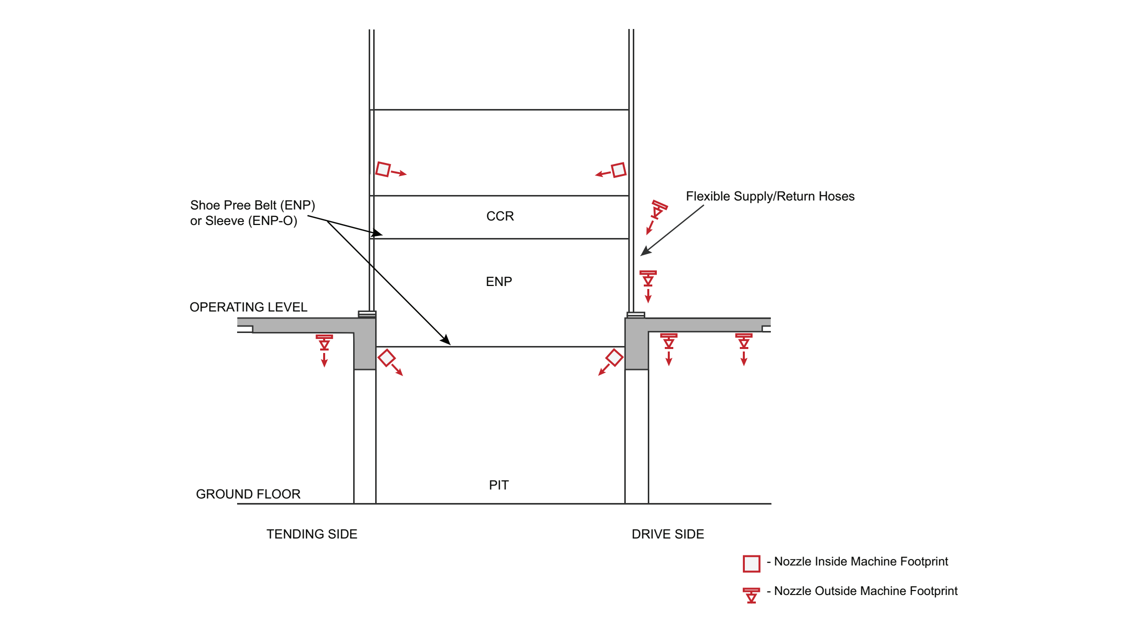


Fig. 8. Example nozzle locations for shoe belt or sleeve and flexible hose ruptures (elevation and cross machine direction)

2.1.3.3.3 Design each nozzle at or above the operating floor level to deliver a minimum of 30 gpm (113 L/min). If an open sprinkler is used for the deluge system, install a minimum K11.2 (K160) sprinkler.

2.1.3.3.4. Design automatic deluge or water spray protection over ground floor areas to deliver 0.3 gpm/ft^2 (12 mm/min) over the protected area.

2.1.3.3.5 Hydraulically design the protection for simultaneous operation of all nozzles on the operating floor and on ground floor plus a 500 gpm (1900 L/min) hose stream allowance for a duration of at least 60 minutes.

2.1.3.4 Calender HTF Heated Rolls

2.1.3.4.1 Locate automatic sprinklers over a calender stack containing a HTF heated rolls as follows.

A. Position sprinklers over the following areas.

1. Full length of HTFl flexible supply and return hoses to the rolls.

2. Under HTF rotary joints.

3. Over and within rotary joint spray shield enclosures

4. Operating floor level beneath the top elevated walkway, intermediate walkways, on the calender sides where clusters of obstructions may be found (e.g., flexible hoses, driveshafts, or piping), and beneath any other shielded areas where released oil may flow and/or accumulate.

5. Ground floor areas or pits beneath the calender where released oil and fluid may flow and accumulate.

B. Design sprinklers at the operating floor level to deliver a minimum of 30 gpm (113 L/min) using K11.2 (K160) sprinklers rated for quick response and appropriate temperature rating based on the maximum ambient temperature (refer to Data Sheet 2-0).

C. Design sprinkler protection over operating floor pits or ground floor areas to deliver 0.3 gpm/ft^2 (12 mm/min) over the protected area.

D. Design the protection at ceiling-level, on the operating floor, and over any ground floor pits for simultaneous operation plus a 500 gpm (1900 L/min) hose stream allowance for a duration of at least 60 minutes.

2.1.4 Equipment and Processes

2.1.4.1 Ensure the machine controls meet the recommendations in Data Sheet 7-110, *Industrial Control Systems*.

2.1.4.2 Avoid leaving ignitable liquid systems, including oil systems, pressurized during machine outages.

2.1.4.3 Automatically de-energize oil supply pumps or isolate the oil supply to the oil equipment areas specified in A-D below in response to a fire involving the subject roll, machine section or oil supply (i.e., oil fire interlock). When necessary, perform a controlled or sequential shut down of supported machine rolls and sections prior to shutting off the oil supply to prevent equipment damage. Design and install the oil fire interlock in accordance with Data Sheet 7-45, *Safety Controls, Alarms, and Interlocks (SCAI)*, and as specified in A-D below.

A. Swimming roll (SR, control crown roll (CRR), and shoe press

B. Hydraulic oil use points at the machine when the system contains an ignitable hydraulic oil (rather than a nonignitable or FM Approved industrial fluid per Section 2.1.1.3)

C. HTF heated rolls

D. Circulating lubrication oil system at the oil supply and release points on the operating floor or mezzanine level. Examples include glass or plastic materials used for direct measurement or observation, and rubber flexible hoses.

Use of indirect measurement and observation and metal braid-reinforced flexible hoses limits fire detection coverage for oil fire interlock to the circulating lubrication oil supply (e.g., only spot heat detectors or linear heat detection over the oil supply).

2.1.4.3.1 Initiate the oil fire interlock automatically based on the following.

1. Design and install fire detectors and fire detection system per Section 2.1.3.1.6.H.1.

2. For closed shoe press (enclosed by a polymer sleeve and rotating heads), the sleeve loss of air pressure protective interlock can be leveraged for isolating the hydraulic and cooling/lubricating oil to roll upon sleeve damage or failure (i.e., in place of fire detection over the shoe press).

3. Provide an oil fire interlock alarm in a constantly attended area (e.g., control room).

4. To alleviate concerns of a false trip leading to a production stoppage, a trip delay of less than 60 seconds with a momentary contact-type abort switch can be installed. Locate the momentary contact switch at the control panel on the operating floor positioned in view of the subject oil use points (e.g., roll or machine section).

2.1.4.3.2 De-energize oil supply pumps and/or isolate the oil supply to the subject oil equipment area in a controlled manner within five minutes of fire detection. When possible, de-energize supply pumps and/or isolate the oil supply to swimming roll, control crown roll, shoe press, and other high pressure or high flow oil use points as soon as possible given the heightened oil fire hazard posed.

2.1.4.4 Provide a means to automatically shut down HTF circulation pumps and isolate HTF from heated rolls promptly in response to a rotary joint failure (i.e., fluid release interlock). This can be accomplished by installing breakaway fittings on the HTF flexible hose connections to the rotary joint, or a position switch on the rotary joint with two safety shutoff valves on the HTF supply and return flexible hose connections. In either case, attach the fittings or valves to the rigid supply and return piping.

2.1.4.5 Provide a means to automatically shut down ignitable performance and formation additives, or cleaning solvents (e.g., felt cleaners) in response to a fire in the subject machine section (i.e., ignitable additive interlock).

2.1.4.6 Provide a means to automatically shut down exhaust ventilation fans upon sprinkler actuation inside the hood, economizer, over the machine (above the hood), or under the machine (broke pit) to minimize fire spread and thermal damage to the fans (i.e., dryer hood fire interlock). Additionally, either slow down the drying section to a crawl or stop rolls in the section as recommended by the OEM.

2.1.4.7 Provide a means to manually initiate oil fire, ignitable additive, and dryer hood fire interlock functionality. Install manual shut down controls in the control room and in at least one set of controls in a remote location that will remain accessible under anticipated fire conditions. Refer to Section 2.1.5.1 for the human element portion of this manual response.

2.1.4.8 Install indirect measurement and observation instruments to determine or verify conditions of ignitable liquid systems in accordance with Data Sheet 7-32. For example, use flow and level sensors rather than direct measurement, or observation instruments such as variable area flow meters and sight glasses at circulating lubrication oil reservoir and metering stations. When direct observation is unavoidable and FM Approved sight glasses are not available, use a heavy-walled, heat-resistant glass such as fused quartz or borosilicate, and provide ignitable liquid safeguards based on the anticipated oil release and fire scenario.

2.1.4.9 Arrange ignitable liquid transfer piping between supply and use-points to provide the most direct route possible. Additionally, route ignitable liquid transfer piping in a manner that limits fire exposure to utilities and support systems equipment areas, and any concentration of combustibles (e.g., parent reel or roll paper storage).

2.1.4.10 Install ignitable liquid transfer piping in accordance with Data Sheet 7-32.

2.1.4.11 For flexible hydraulic oil connections at the machine, including those that support swimming, control crown, and shoe press rolls, use flexible supply and return hoses constructed from high-strength, noncombustible materials that are resistant to decomposition or melting when exposed to a fire and compatible with the oil used (i.e., all-metal construction and at least one layer of metal braid reinforcement in high pressure supply lines).

2.1.4.12 At circulating lubrication oil use points in the machine, such as roll bearings that are not directly plumbed with ridged tubing or piping, use flexible supply and return hoses constructed with at least one layer of metal-braid reinforcement.

2.1.4.13 At circulating lubrication oil use points on the operating floor, such as drive gears that are not directly plumbed with ridged tubing or piping, use flexible supply and return hoses constructed from high-strength, noncombustible materials that are resistant to decomposition or melting when exposed to a fire and compatible with the oil used. (i.e., all-metal construction).

2.1.4.14 At the circulating lubrication oil supply, use flexible connections or hoses constructed with at least one layer of metal-braid reinforcement.

2.1.4.15 For HTF flexible supply and return hoses and connections, install hoses constructed in accordance with FM Data Sheet 7-99, *Heat Transfer Fluid Systems*.

2.1.4.16 Provide the following condition monitoring for HTF rotary joints with alarms surfacing in constantly attended area (e.g., control room). Establish alarm thresholds derived based on the rotary joint or bearing OEM input.

A. Temperature of the bearing outer race

B. Bearing vibration

C. Both lubricating oil temperature, and the differential between the lubricating oil inlet and outlet temperature

2.1.4.17 Avoid routing hot steam or HTF piping through broke collection areas and other spaces where broke, pulp, or dust may accumulate dry, overheat, and ignite. Alternatively, provide insulation and shielding to prevent materials from accumulating and contacting the hot surfaces.

2.1.4.18 When steam piping is run under or near machine oil use points that can leak oil or oil is released during routine maintenance, use nonabsorbent, noncombustible insulation (e.g., cellular glass). Oil absorbed into insulation can degrade over time and spontaneously combust when exposed to hot surfaces such as steam piping.

2.1.4.19 Equip all machine hoods, plenums, economizers, and exhaust ductwork with openings for cleanout and manual firefighting.

2.1.4.20 Provide dust collection points along the machine to minimize dust accumulation.

2.1.4.21 Provide fuel combustion controls for any gas-or-oil fired heaters on the machine as recommended in Data Sheet 6-9, *Industrial Ovens and Dryers*.

2.1.4.22 Evaluate the machine controls using OS 7-110 to determine the risks associated with connectivity to larger ICS, and if the overall risk of the ICS meets thresholds, perform an ICS assessment. Then we need to renumber after.

2.1.4.23 Provide the following machine permissive-starting and protective-tripping interlocks to prevent equipment damage.

A. Permissive to Start

1. Satisfactory lubrication oil temperature and flow or pressure to engage machine drive
2. Machine at minimum speed to begin warm-up of dryers
3. Machine at minimum speed to start any auxiliary heating equipment on low fire or minimum heat
4. Machine at minimum speed to load any pressure rolls
5. Machine at minimum speed to start any sprays on heated rolls
6. Spray liquids at least 70°F (22°C) to start any sprays on heated rolls
7. Web on dryer(s) to engage high fire or maximum heat for any auxiliary heating equipment

B. Protective Tripping

1. Auxiliary heaters to low fire or minimum heat upon loss of web with possible actions including rotating radiant heaters away from the web or flame sliding shield
2. Sprays stopped if liquid temperature less than 70°F (22°C)
3. Sprays stopped if machine speed below minimum
4. Flame failure of auxiliary heaters

2.1.4.24 Protect all steam-heated dryer rolls from excessive steam pressure with relief valves set at or below the maximum allowable working pressure (MAWP). Provide relieving capacity equal to or greater than the maximum let-through capacity of the pressure reducing station, maximum flow capacity of the thermocompressors or maximum flow capacity of the manual bypass, whichever single source is greatest (Refer to Data Sheet 12-43, *Pressure Relief Devices*).

2.1.4.25 Limit the mean temperature of any pressure-containing part on a non-standard cast iron dryer to the saturated steam temperature coincident with the MAWP.

2.1.4.26 Reevaluate dryer MAWP if the machine speed is to be increased. An increase in machine speed on the order of 10% will significantly increase hoop stresses. This is particularly important if both an increase in MAWP and an increase in operating speed are being considered. In addition, determine that heads, shafts, bearings, and machine frame are suitable for the increased loading. Review all of these items with the paper machine manufacturer or a recognized paper machine consultant.

2.1.4.27 For can-type cast iron dryers, hydrostatically test one dryer of each different design at twice the calculated MAWP if evaluation indicates a MAWP may be increased to 110% or more of a documented MAWP, or if there is no documentation of MAWP (i.e., MAWP is established by evaluation). Support the dryer during the test so as not to subject the bearings, shafts, heads, and shell to the weight of the water. Ensure temperature of the dryer and the water is above the transition temperature prior to applying pressure. Do not perform a pneumatic test on cast iron dryers. Prior to and after hydrostatic test, fully examine the dryer high stress areas by visual inspection (VT) and other NDE methods as described in this data sheet.

2.1.5 Operation and Maintenance

2.1.5.1 Implement an emergency response plan (ERP) for the prompt and effective reaction to a machine fire in accordance with Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*, and the following.

A. Develop a plan addressing the various fire scenarios that involve combustibles (such as pulp, fiber dust, broke, felts/roll covers, and/or power and control cabling) and ignitable liquids present in circulating lubrication oil systems, centralized and small hydraulic oil systems, at a swimming roll, control crown roll, shoe press roll, HTF heated roll, and/or performance/formation additive systems. These fire hazards can be present in the footprint of the machine, in the hood exhaust system, on the operating floor, or on the ground floor. Authorize responders to execute the necessary actions, which may include shutting down the machine and interrupting production.

B. Specify response actions and assign those responsibilities to personnel. Example actions include the following.

1. Confirm automatic interlock initiation and execution of machine responses (e.g., shut down roll or section, or bring the dryer section to a crawl); and if any interlocks fail to do so or are not present, manually initiate those responses.

2. Confirm automatic pump shutdown and/or isolation of ignitable liquid systems such as HTF, hydraulic oil, high-pressure circulating lubrication oil (shoe press), or ignitable additives/cleaners. If any interlocks fail to do so, manually initiate those responses.

3. Confirm automatic circulating lubrication oil pump shutdown; and if the oil fire interlocks fails to do so or has yet to be provided, manually de-energize pumps.

   If an oil fire interlock has yet to be provided, consider installing above the oil equipment area fire detection configured to trigger an alarm in the control room ensuring a prompt manual response. For example, install a heat detector over the oil supply containment area.

4. Confirm automatic isolation of steam supply to dryers, and if any interlocks failed to do so or are not present, manually isolate the steam supply.

5. Confirm fire protection system operation, and if the system failed to operate automatically, manually actuate the system.

6. Manually operate water-based felt showers.

7. Confirm automatic hood and pocket ventilation system response, and if any interlocks failed to do so or are not present, manually initiate the response.

8. Confirm automatic interruption of fuel-fired equipment, and if any interlocks failed to do so or are not present, manually isolate burners.

9. Isolate the fuel supply to the building.

C. Instruct any responders that may use a hose stream to not direct solid, cold-water hose streams in the vicinity of hot rolls whether steam or HTF heated. Such rolls may include dryers, Yankee dryer, MG cylinders, and chilled HTF rolls. Instead use a spray nozzle and ensure the spray or fog is oscillated when near these hot rolls..

2.1.5.2 Conduct pre-incident planning with the public fire service in accordance with Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*. Highlight the importance of controlling hose streams around hot rolls and oil pool fires, and the location of ignitable liquid system supplies and use points.

2.1.5.3 Provide initial and periodic refresher training for the emergency response team on the ERP for prompt and effective reaction to a machine fire.

2.1.5.4 Conduct pre-incident planning with the fire service on fluid fire and explosion scenarios in accordance with Data Sheet 10-1.

2.1.5.5 Conduct exercise drills on machine fire procedures including operators and the emergency response team. When possible, involve the fire service.

2.1.5.6 Test fire interlocks and any HTF leak detection interlocks (e.g., position switch at rotary joint) as follows.

A. Perform a functional test of the interlock at commissioning.

B. Perform a functional test of the interlock impacted by changes as determined through the management of change program. Of concern are changes to any field devices and control equipment or logic.

C. Perform loop testing of the interlock at least annually (i.e., simulated testing).

2.1.5.7 Develop a procedure for interlock testing to verify proper operation, connectivity, and settings of the following interlock hardware and software. Include the following aspects in the test procedure.

A. List the machine equipment involved in interlock testing such as field sensing devices (e.g., instrumentation), operator interfaces (e.g., manual push buttons), controller and logic loops, field control devices (e.g., valves and power disconnect switches).

B. Develop a checklist for documenting interlock testing. At a minimum record: individuals performing the test; date; interlock tested; field devices and equipment involved; type of test; results (e.g., pre-trip conditions, trip point, post-trip conditions, and time required); and as found and as left conditions.

C. Conduct functional testing with equipment in a safe operating condition (e.g., low machine speed).

D. Initiate a functional test using a single field device, while verifying all other field sensing device and operator interfaces separately via loop testing.

2.1.5.8 Test fire detectors and detection systems in accordance with Data Sheet 5-48.

2.1.5.9 Implement a housekeeping program to manage spilled pulp and broke accumulations as well as spilled oil and grease and transient combustibles (empty IBCs). Keep the machine, and utility and support equipment areas clean, orderly, and free from unnecessary combustibles. Establish inspection and cleaning schedules during scheduled shutdowns to clean up spilled oil and grease, and remove pulp, fiber, and broke accumulations before they become excessive. The following are areas of focus:

A. On machine surfaces, in/on hoods, on/in ducts, in plenum spaces, in economizers, on support system equipment (e.g., motors, power cabling, and steam lines), and interior building surfaces (deck above machine, columns, ceiling or bottom of roof deck). Clean up accumulations of broke and spilled pulp promptly.

B. Steam piping near oil systems and all HTF piping for oil-soaked insulation. Promptly replace oil-soaked steam pipe or HTF pipe insulation with clean insulation and repair the oil leak.

C. Unnecessary combustibles near machine equipment and from within electrical, control equipment, and control rooms. Promptly remove combustibles.

2.1.5.10 Implement a housekeeping program to manage combustible dust accumulations in machine equipment areas and within equipment in accordance with Data Sheet 7-76. For removal of dust, wash-down with water hoses or vacuuming are preferred methods.

2.1.5.11 Implement a fire protection system inspection program. During scheduled outages, inspect sprinkler or open-nozzle position, presence of blow-off plugs on open nozzles, sprinkler/nozzle and piping corrosion, condition of any fire detectors, and status of any fire control panels for trouble alarms and automatic mode. At a minimum, inspect fire protection in all machine areas at least annually, while conducting inspections more frequently when fire protection equipment may be exposed to impact during maintenance outages (e.g., clothing changes).

2.1.5.12 Implement a hot work permit program to manage grinding, cutting, welding and similar hot work operations in accordance with Data Sheet 10-3, *Hot Work Management*.

2.1.5.13 Implement a program to reduce fire risk at the wet-end of the machine during outages. Of particular concern are wet-end machine areas where automatic fire protection is not provided. Focus the program on the following: controlling ignition sources (hot work and temporary electrical equipment); removing combustible accumulations such as fiber, dust, and spilled oil; and limit unnecessary combustibles such as packaging and empty IBCs. Additionally, provide fire monitoring of these unprotected machine areas throughout the outage.

2.1.5.14 Inspect, maintain, and rebuild/replace drive shafts for driven rolls, shoe press roll sleeves/belts, and flexible oil hoses per original equipment manufacturer (OEM) guidelines. Of particular importance are equipment failures that could result in an oil release (e.g., shoe sleeve rupture, drive shaft tearing supply and return hoses, or flexible hose abrasion, fatigue, or connection fatigue).

2.1.5.15 Inspect, test, and maintain rotary joints in accordance with OEM guidelines. Instruct operators to isolate calender roll heating if the joint operating parameters exceed established safe operating limits.

2.1.5.16 Establish procedures governing overhead crane positioning/parking when not in-use. Park overhead cranes where they are not subject to fire, will not obstruct ceiling-level sprinkler discharge, or will not alter sprinkler discharge directing streams of water onto hot rolls (steam or HTF heated).

2.1.5.17 Implement a program to inspect structural elements above and around the machine for corrosion. At a minimum, verify the structural integrity of the roof and operating floor, and any false ceiling assemblies as well as supporting columns and load-bearing walls. Of particular concern is the roof and any false ceiling directly above the machine wet-end. Develop the inspection program based on input from a competent structural engineer (e.g., licensed). Have a structural engineer perform a baseline inspection, then follow-up with a visual inspection at a minimum of every 5 years to verify program effectiveness and revise the program as needed. Depending on the inspection findings, more frequent follow-up inspections by a structural engineer or mill personnel may be warranted.

The following are additional measures that may be useful in addressing corrosion. To further monitor active corrosion, have mill personnel perform periodic visual inspections or conduct nondestructive examinations. To slow the rate of corrosion, implement ventilation controls to reduce condensation and humidity in the subject areas, and/or limit use of corrosive agents for cleaning clothing and other machine surfaces. To prevent the onset of corrosion, apply a protective coating structural members.

2.1.5.18 Promptly evaluate the affect of any incident or condition that occurs during dryer roll operation. Examples of such incidents or abnormal conditions include the following:

- Press roll shell, journal, or cover failure
- Objects passing through the nip
- Bearing damage or failure (vibration, sudden stop)
- Unauthorized repairs
- Steam leaks
- Broken head or journal bolts
- Process interlock override or failure such as continued hood or air cap heating after loss of Yankee rotation
- Operating excursion outside of control or operating limits such as steam pressure, temperature, speed, or nip load
- Emergency stops or power failure
- Localized or excessive temperature such as an exposure fire involving fiber, dust, released oil or broke at machine
- Cooling rates quicker than that specified by the OEM
- Application of solid water stream whether for cooling, cleaning, or during a fire response
- Heating rates quicker than that specified by the OEM
- Stationary warm-up
- Increasing differential pressure or steam flow
- Uneven shell wear or doctor blade chatter
- Loss of coating
- Holes or picks in the sheet
- Mechanical noises internal to the dryer
- Loss of dynamic balance

2.1.5.19 Post the manufacturer's operating instructions and precautions at the paper machine.

2.1.5.20 Follow the machine manufacturer's recommendations for startup and shutdown of the machine. Particular concerns are loading and unloading of all pressure rolls; warm-up and cool-down of all dryers; start, stop, and application rate for any cooling or process sprays on dryers and startup, switch to high fire and shutoff of any auxiliary dryer roll heating systems.

2.1.5.21 Calibrate instrumentation, controls, and safety interlocks (pressure, vibration, temperature, speed, fuel combustion controls, oil system shutoffs, etc.) per OEM. Document the calibration and test procedures and maintain records of the results.

2.1.5.22 Monitor, record, and trend bearing vibration levels of all rolls, and open or enclosed drive gears. Perform spot vibration monitoring at least quarterly. Do not overlook abnormal vibration levels. Abnormal vibration indicates increased stress that may damage rolls or the machine frame.

2.1.5.23 Minimize mechanical and thermal stresses on all paper machine rolls by following the manufacturer's recommendations for lubrication of bearings, bearing and shaft tolerances, maintenance of drive gears and clutches, and machine startup and shutdown.

2.1.5.24 Test dryer roll steam supply relief valves by manually lifting or operationally (pressure) testing at least every 12 months.

2.1.5.25 Maintain comprehensive records on all dryer rolls. Include date of manufacture, MAWP, allowable working temperature, operating pressure, operating temperature, results of VT, MT, and UT examinations, and AET location of any indications, and detailed repair history in the records. Maintain records for the life of the roll.

2.1.5.26 Implement a dryer roll operating program covering the following minimum aspects.

A. At least once each shift make an operating inspection of all dryers. Inspect for correct operating temperature, pressure, machine speed, unusual noise (inside dryer, gear, and journal bearing), lube oil pressure, temperature and flow, nip loading pressure, steam or condensate leaks, and condition of the condensate removal system. Look for any unusual movement of rolls or the machine frame. Log this information if it is not automatically recorded. This inspection may be done by the machine operator. Organize the data to permit adverse operating trends to be identified.

B. At least once each week, have the person most knowledgeable in dryer operation conduct a similar operating inspection. As part of this weekly inspection, review the shift inspection logs for adverse trends. Variations in differential pressure, control valve position, steam flow, sheet moisture uniformity, sheet moisture content, machine speed, and steam pressure are indicators of potential adverse conditions needing further investigation.

2.1.5.27 Isolate steam to any dryer roll having cracks or crack indications until an evaluation by a dryer specialist can be completed. If mechanical integrity is in doubt, remove the dryer from service.

2.1.5.28 Confirm that all dryers have functioning condensate removal systems at least weekly. This may be accomplished by measuring dryer temperature by infrared thermometer, surface pyrometer, or contact thermometer on the condensate pipe at the rotary union. A lower temperature for any dryer indicates condensate is not being removed. Excessive condensate (flooding) increases mechanical loads and stress on the dryer.

2.1.5.29 When negative conditions are observed, take appropriate corrective actions which may include isolating steam and possibly by-passing the dryer, and at the next outage, conduct a visual inspection of the subject dryer roll for damage or internal loose parts. Negative conditions may include unusual sounds (e.g., loose balance weights, broken siphon, or loose spoiler bars), or low dryer temperature indicating the condensate removal system may not be functioning properly. During the internal inspection, remove any loose parts from the dryer, and if grooving or other damage has occurred, reevaluate MAWP.

2.1.5.30 Use only nondestructive examination personnel qualified and certified according to the employer's (agency) written practice. Verify that ASNT Recommended Practice SNT-TC-1A or a similar standard has been used as a guideline by the employer (agency) to establish the written practice. Use only nondestructive testing agencies that meet the requirements of ASTM E543-04, Standard Practice for Agencies Performing Nondestructive Testing.

2.1.5.31 For cast iron and steel dryer rolls, perform the following examinations for indications of cracking, thinning, corrosion, or other damage to the pressure boundary.

A. Conduct a visual inspection of the external roll surfaces including shell, heads, journals, and handhole or manhole rims at least every 12 months.

Where accessibility to the drive side head for external visual inspection is impeded by gears and frame, internal surface examination of that head becomes increasingly important.

B. Conduct a visual inspection of internal shell and head surfaces at least every 60 months. Dryers having handhole access only may be examined by remote VT (video camera) combined with UT shell profile.

C. Conduct a volumetric examination (e.g., ultrasonic testing) to examine 20% of head cap screws or head bolts at least annually (i.e., complete examination at least every 60 months). Ensure a different 20% grouping of the head cap screws or head bolts are examined at each test interval (i.e., not the same bolts tested repeatedly).

2.1.5.32 Perform a volumetric examination (e.g., ultrasonic testing) of any head cap screws or head bolts where there are signs of steam leakage. Replace any cracked screws or bolts and stop the steam leakage.

2.1.5.33 In areas of previously identified cracks and damage that are not repaired, re-examine as discussed in Section 2.1.5.30 at least every 12 months until the indications are determined stable or are proven nonrecurring.

2.1.5.34 For cast iron and steel dryer rolls without a center shaft, perform the following additional examinations for indications of cracking, thinning, corrosion, or other damage to the pressure boundary or journal at least every 60 months.

A. Conduct surface examinations of external high stress areas of heads (transitions and reinforcement areas). See Figure 9 for location of high stress areas.

B. Conduct volumetric examinations (e.g., ultrasonic testing). to determine shell profile and thickness. Continuously measure shell thickness starting just inside the shell flange across the length of the shell. Record thickness continuously, or at the minimum thickness within each 12 in. (0.30 m) segment of shell length. Perform four scans, equally spaced around the circumference of the shell. Alternatively for shells with a metalized coating, perform a magnetic lift off (MLO) test to verify a sufficient coating remains.

2.1.5.35 For steel dryer rolls, perform the following additional maintenance activities.

A. On startup, conduct a visual inspection of rolls for evidence of steam leakage. Remove any steel dryer rolls found to have steam leaks or cracking, and replace or repaired as applicable.

B. Conduct applicable surface and volumetric examinations of pressure containing welds per OEM guidelines. However for rolls fabricated with lap joint construction, perform UT to examine the head-shell joint at least every 60 months.

C. Monitor condensate return from steel dryers. Maintain the condensate parameters within the control limits and under the established safe operating limits specified by the OEM.

2.1.5.36 When the opportunity arises, replace any steel dryer roll having the lap joint configuration shown in Figure 10 or Figure 11 with a roll having a butt-type head-to-shell joint.

2.1.5.37 Review repair procedures for all dryers with FM prior to commencing the repair. Repair by welding or brazing is not permitted for cast iron dryer parts.

2.1.5.38 Perform repairs in accordance with the National Board Inspection Code (NBIC). For code constructed dryers, the original construction code, such as ASME Boiler and Pressure Vessel Code, may be used as guide.

2.1.5.39 Apply metalized coatings (a.k.a., thermal spray) by skilled and experienced personnel, for cosmetic surface defect repairs is acceptable and is preferred to plugging of cast iron dryer rolls. However, this is not a strength repair.

2.1.5.40 Complete all repairs expediently and maintain a record of all dryer repairs or repair of other equipment affecting the safety of dryers. Also, maintain a record of any dryer repairs that are deferred, with the reason for the delay.

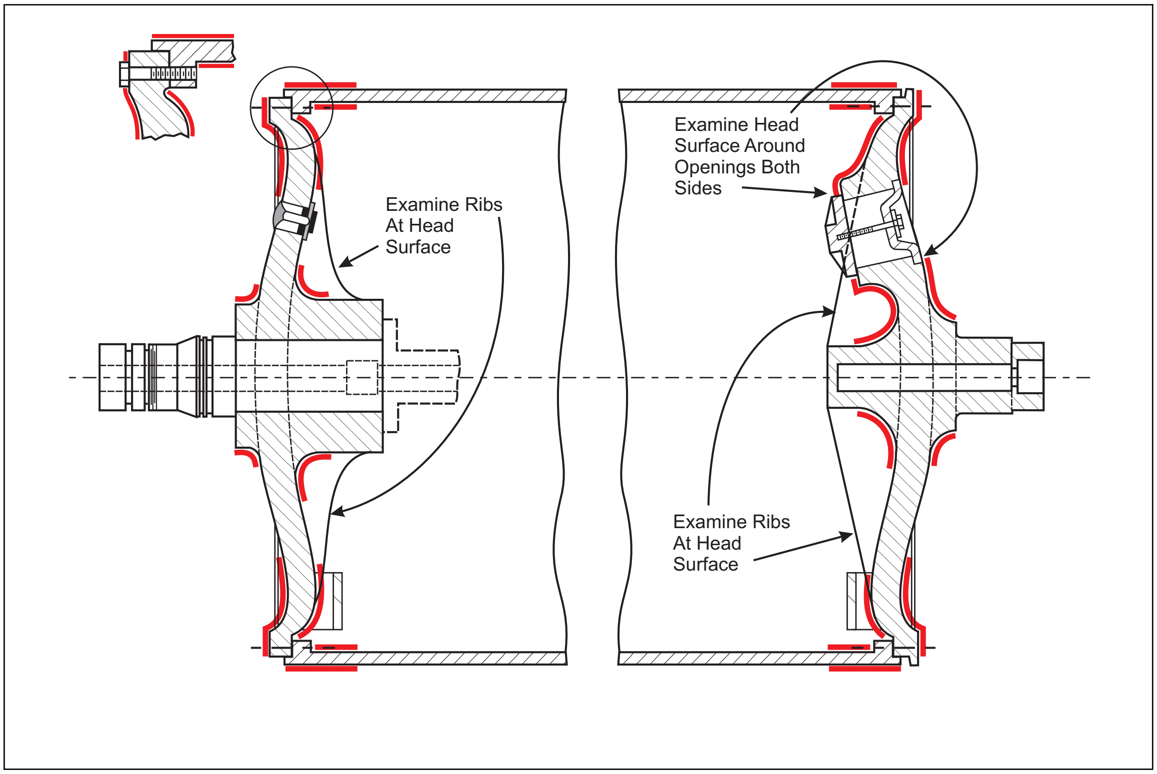


Fig. 9. High stress areas on shell and heads.

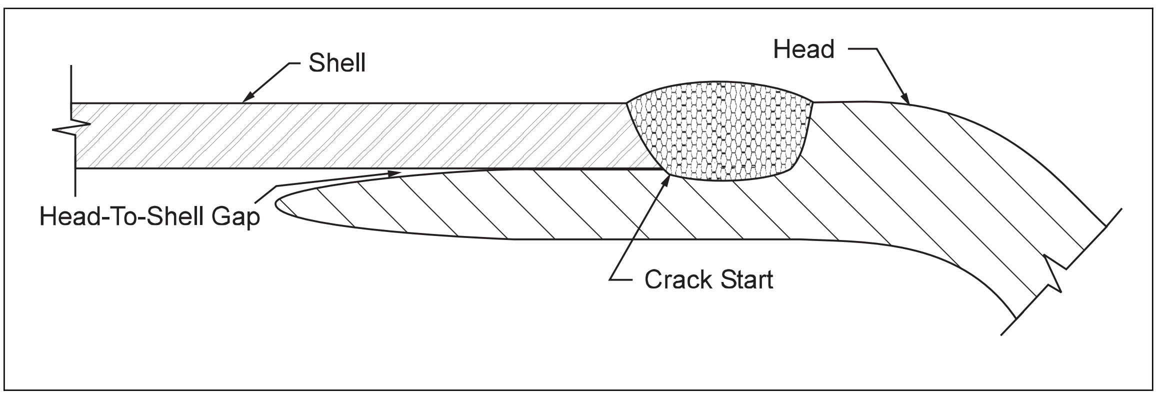


Fig. 10. Head-to-shell joint configuration

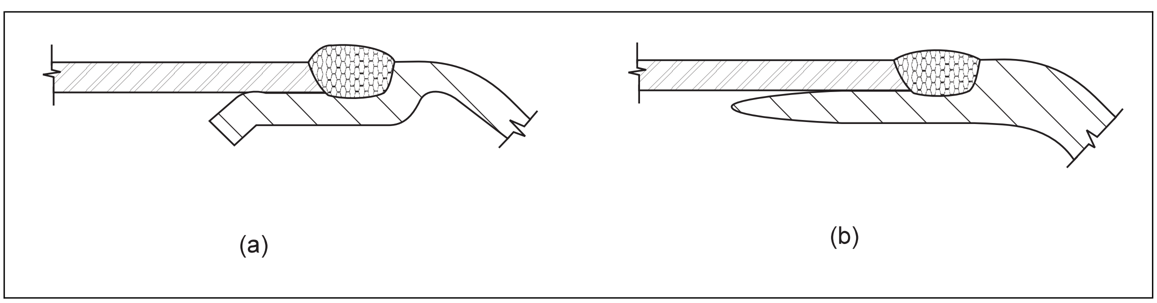


Fig. 11. Head-to-shell lap joint configurations

2.1.5.41 For all suction rolls, conduct a visual inspection of external shell surface and drilled holes at least every 3 years of operation. For additional guidance on suction roll shell inspections, refer to TAPPI TIP 0402-19 Guidelines for Nondestructive examination of suction roll shells.

2.1.5.42 For suction press rolls, conduct an visual inspection of the internal shell surface and drilled holes at least every 2 years of operation. A flashlight can be useful in identifying indications and other damage.

2.1.5.43 For suction press rolls, perform a surface examination of the external shell surface shell at every cover replacement.

2.1.5.44 For all covered functional rolls (e.g., forming, press, and control crown rolls), conduct visual inspection of the cover at every schedule machine outage. A hammer can be useful in assessing cover-roll bonding.

2.1.5.45 For granite rolls, perform volumetric examination (e.g., ultrasonic testing) of center shaft and all tension rods at a minimum of every 2 years of operation.

2.1.5.46 Implement an asset integrity program to manage maintenance examinations of all other machine rolls and roll parts not specifically addressed in this data sheet. Refer to Data Sheet 9-0, *Asset Integrity* for guidance on developing and managing the program, and OEM and industry best practices such as TAPPI for examination guidance. At a minimum, perform routine visual examination of structural roll components (e.g., shell, heads, and journals), coatings (e.g., metalized or ceramic), and attachments (e.g., balance weights) at an established frequency based on operating duration, and scheduled roll and machine maintenance outages. Supplement visual inspections with periodic surface and/or volumetric examinations (e.g., die penetrant and ultrasonic testing), and coating examinations (e.g., magnetic lift off MLO testing) and when VT identifies suspect conditions. Based on loss history, these supplementary examinations may be warranted for shell/roll, heads, journals, and/or suction box small shaft (spigot). Establish a frequency for inspections and examinations, and adjust the frequency based on positive and negative examination results, operating conditions, and history. The following are other roll components and rolls not specifically addressed in this data sheet that warrant routine evaluation mechanical integrity and component attachment based on loss history. The list below is not all-inclusive.

- Other parts of suction roll, suction press roll, granite roll including heads and journals, and suction roll suction boxes.
- Swimming roll, control crown roll, or shoe press
- Felt guide and wire roll
- Ceramic press roll
- Vacuum dryer roll
- Dryer roll with steam isolated
- Calender roll
- Pope Drum
- Spool-Reel

2.1.6 Contingency Planning

2.1.6.1 When a machine breakdown would result in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable equipment contingency plan per Data Sheet 9-0, *Asset Integrity*. See Appendix C of that data sheet for guidance on the process of developing and maintaining a viable equipment contingency plan. Also refer to sparing, rental, and redundant equipment mitigation strategy guidance in that data sheet.

2.1.6.2 Sparing can be a mitigation strategy to reduce the downtime caused by a machine breakdown depending on the type, compatibility, availability, fitness for the intended service, and viability of the sparing. For general sparing guidance, see Data Sheet 9-0, *Asset Integrity*.

2.2 Tissue Machines

2.2.1 Protection

2.2.1.1 For tissue machines with fuel-fired air heating systems, provide explosion vents on the air cap air recirculation systems in accordance with Data Sheet 6-9, *Industrial Ovens and Dryers*.

2.2.1.2 Provide infrared spark detection over the web at the dry end, arranged to sound an alarm when sparks are detected. Burning paper sometimes escapes from the hood or air cap and doctor blades may generate sparks. When sparks are detected, segregate the roll being wound at the time from other storage, preferably to an outside area away from combustibles, or re-pulp the roll.

2.2.1.3 Provide automatic deluge or water spray protection for a shoe press in tissue machines in accordance with Section 2.1.3.3.1. However, when the shoe is pressed against the Yankee, focus water spray under and around the sides of the machine where released oil can flow and pool. Do not direct water spray at the Yankee, and limit the amount of water spray that can impact the Yankee. With the inability to provide full water spray coverage over the shoe press and machine equipment above, place greater emphasis on containing and draining released oil and an oil fire interlock to promptly stop the pressurized oil release and spray fire.

2.2.2 Equipment and Processes

2.2.2.1 Provide a pressure relief device on the supply to the pneumatic or hydraulic loading system for suction press or pressure rolls to prevent damaging the Yankee dryer. The set pressure of this device may be up to 110% of the allowable loading (adjusted for remaining dryer shell thickness) to avoid nuisance operation of the device. Base the capacity of the device on the maximum let-through capacity of the upstream control or pressure reducing valve.

2.2.2.2 Provide positive means of preventing a Yankee dryer from exceeding the maximum rotational speed recommended by the manufacturer. This is particularly important for dryers having stay-bar construction. For a turbine-driven machine, the overspeed protection provided on the turbine may be used to prevent overspeed of the Yankee dryer. For an electric motor-driven machine, if the motor can cause the Yankee dryer to exceed the maximum recommended speed, provide a tachometer-type device or other type device on the paper machine, arranged to trip power to the drive motor at or below the maximum allowable speed. For both types of drivers, trip of the driver should also trip any air cap heater, any water sprays, release the pressure roll(s), and trip steam to the Yankee dryer.

2.2.3 Operation and Maintenance

2.2.3.1 Implement an emergency response plan (ERP) for the prompt and effective reaction to a tissue machine fire and acceptable procedures for fighting fires around hot Yankees in accordance with Data Sheet 10-1. For tissue machines, the initial response to a fire near a hot Yankee dryer should be to maintain the Yankee rotating to limit the potential for a cold-water spray or stream stressing the hot cylinder. During the initial response, operators and responders should isolate steam, perform other machine shut down tasks, and attack the fire. However, if the initial fire attack fails to control the fire, procedures should outline conditions when risking damage to the unpressurized, hot Yankee becomes a secondary concern to an escalating fire situation that threatens adjacent equipment or the building. In these instances, the Yankee circulating lubrication oil system should be shut down and Yankee rotation stopped.

2.2.3.2 For cast iron and steel Yankee dryers with through-bolted head construction, perform the following inspections and evaluations at least every 12 months. Runout or head tilt measurements may be done pressurized or cold, but the same condition must be followed each examination, so measurements can be compared.

A. Conduct a visual inspection of the gap in the head to shell joint.

B. Conduct head tilt evaluation. Measure the head tilt at every tenth bolt. Any single measurement 0.030 in. (0.762 mm), or a progressive change in tilt over several bolts, indicates immediate inspection for head-shell cracking is necessary.

C. Conduct shell runout evaluation. Measure the shell runout at 6, 9, 12, 15 in. (150, 230, 300, 380 mm), at quarter shell length from each end, and at the centerline. Radial shell runout that is greatest near the end of the shell and decreases toward the centerline, or that suddenly changes by 0.030 in. (0.762 mm) or more, indicates inspection for impending or existing head-shell cracking is necessary.

2.2.3.3 Perform examinations discussed in Section 2.2.3.2 any time indications are visually detected or either shell runout or head tilt measurements indicate corrosion is present in the head-shell joint.

2.2.3.4 Conduct a visual inspection of internal surfaces of the shell and heads, and center shaft at least every 24 months for indications of cracks or other defects. If indications are found in the cast parts, increase inspection frequency until the indications are determined stable or are proven non-recurring. Check the condensate removal system and balance weights to ensure they are securely fastened and properly positioned. Confirm internal fasteners (i.e., nuts, their tack welds, securing wires, shims, and spacers) are in place and secure.

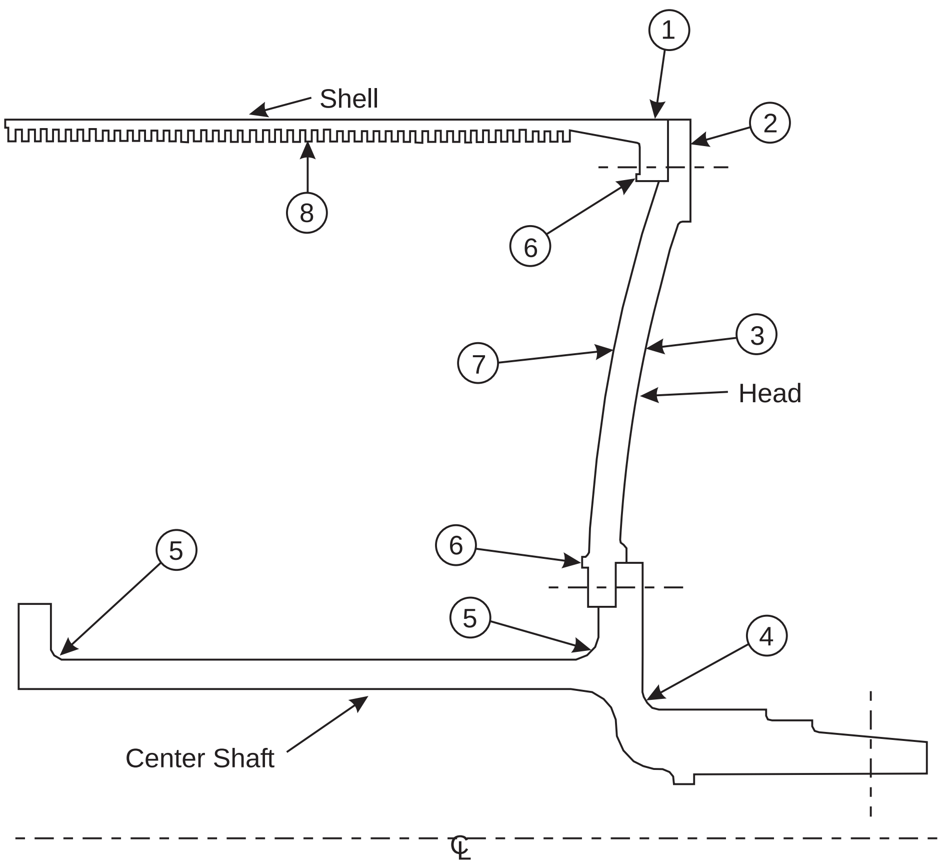
2.2.3.5 For cast iron and steel Yankee dryers, perform surface and volumetric examinations of at least every 72 months of the following susceptible areas as shown in Figure 10. The 72 month frequency assumes baseline data is complete for the dryer. If not, perform a complete examination within 12 months to establish a baseline.

A. Head flanges (through-bolt head only)

B. Shell outside diameter at head joint (cap screw head only)

C. Head-shell and center stay bolts (UT only)

D. Shell or shell ribs where drilled and tapped for bolting of condensate piping supports or spoiler bars.



1. Surface of shell at head bolts (cap screw construction only) for shell cracking
2. External bolting surface on head at OD
3. External surface of head
4. External transition journal to shaft
5. Internal transitions journal to shaft and center shaft to bolting flange
6. Internal nut stop flanges on head
7. Internal surface of head
8. Any drilled and tapped holes in shell

Fig. 12. Common Yankee dryer head and shell areas warranting examination

2.2.3.6 For Yankee shells with a metalized coating, perform a magnetic lift off (MLO) test to verify a sufficient coating remains.

2.2.3.7 In areas of previously identified cracks and damage that is not repaired, re-examine as discussed in 2.2.3.3 at least every 12 months until the indications are determined stable or are proven nonrecurring.

2.2.3.8 Maintain the following baseline data for each Yankee dryer:

- Manufacturer's data sheet
- Chemical and physical tests on heads, shell, and center shaft
- Heat treatment records
- Photomicrographs of the shell, heads, and center shaft castings
- Radiographs of cast iron shell and a radiograph layout chart
- Magnetic particle examination reports for all castings and welded joints
- Chemical and physical test certificates for purchased materials (bolts and nuts, steel plate, and piping)
- Dynamic balancing record
- Nameplate facsimile
- Journal and shell runout, hot and cold
- Shell finished diameter
- Shell thickness, total and root (as applicable)
- Journal bearing taper measurements
- Insulating sleeve test certificate
- Shell crown profile
- Bolt torque requirements (head, journal, center shaft, stay bar)
- Head tilt measurements, hot and cold
- Spigot fit feeler gage measurements (as applicable)
- Cast iron porosity repair record (size, method, and location)
- Cast iron shell thickness derating curve
- Nip load conversion chart
- Engineering drawings
- Design specifications and calculations
- Cast iron grind reports detailing the date of the last grind and remaining shell thickness
- Hydrostatic test certification

2.2.3.9 Maintain dryer operating parameters (pressure, nip load, rotational speed) within the limits of the manufacturer's specifications.

2.2.3.10 Inspect and test the through-air dryer (TAD) cylinder per OEM guidelines.

2.2.3.11Maintain the dryer lubrication oil system as recommended by the machine manufacturer. Conduct oil analysis, and filter as required, to ensure clean, dry oil supply to bearings. For additional guidance on bearing maintenance, refer to TAPPI TIP 0425-03.

2.2.3.12 Provide the following dryer lubrication oil system instrumentation and alarms.

A. Low oil pressure monitor and alarm

B. Low oil pressure trip

When possible, monitor and record discharge oil temperature from bearings. Increasing discharge temperature may indicate incipient bearing failure.

2.2.3.13 For tissue machines with fuel-fired air heating systems, perform frequent blow backs to remove dust from inside the hood or air cap (when the system is provided with a blow back duct) and remove dust from inside the hood or air cap if the system has been running at temperature below 400°F (204°C) for a prolonged period of time before running the system at a temperature above 400°F (204°C).

2.3 Airborne Pulp Dryers

2.3.1 Protection

2.3.1.1 Provide steam suppression fire protection for airborne pulp dryers at a minimum steam application rate of 2.5 lb/100 ft^3/min (0.4 kg/m^3/min) with steam applied for at least 10 minutes. Locate steam injection nozzles on the bottom or sides of the dryer for maximum suppression effectiveness.

Suppression system design may vary depending on dryer size, configuration, and the potential for combustible deposits to collect. The following are general guidelines:

A. Place nozzles (preferably) on the bottom or the sides of the enclosure. Steam supplied to the top of the enclosure may only be effective if the fire is no more than approximately 10 ft (3 m) below the steam injection nozzles.

B. Ensure nozzles are not smaller than 1 in. (25 mm) nominal orifice size to minimize plugging.

C. Install nozzles in the dryer and within ducts, fan housings, and precipitators if dust or broke can accumulate. Provide at least one nozzle per 10 ft (3 m) of enclosure or duct width.

D. Multiple or single steam control valves can be used to supply different parts the system.

E. Preferably provide automatic actuation of steam suppression upon dryer temperature exceeding normal operating temperature by 100°F (38°C). Existing process temperature sensors may be used to detect fire and actuate the steam suppression system. Manual actuation only is acceptable.

F. Shut down process flow and all fans upon fire detection.

G. Ensure the steam suppression system demand is available in addition to the maximum steam supply required for plant operation.

2.3.2 Operation and Maintenance

2.3.2.1 If a manually-actuated steam smothering system is provided, train operators to open the steam control valves and shut down the dryer promptly upon recognizing fire in the dryer or associated equipment.

2.3.2.2 Provide constant operator attendance for observation of the dryer operation during all periods when the dryer contains pulp, particularly during shutdowns.

2.3.2.3 Remove pulp from the dryer during any shutdown (before it is permitted to dry out).

2.3.2.4 Keep lights and other ignition sources out of dryer interiors, particularly when any pulp is present. Ensure lights or any other electrical equipment that must be introduced is suitable for Class II, Division 2 locations in accordance with the National Electrical Code or the equivalent international standard. Ensure high intensity lights mounted outside have prominent flashing signal lights and are on only for brief inspection periods.

2.4 Flash Pulp Dryers

2.4.1 Location and Construction

2.4.1.1 Locate flash pulp dryers outdoors. If weather protection is required, provide a dedicated building for the dryer, separated from the main production building and locate the cyclone collection system outdoors. Extend relief ducts for dryer explosion vents through the roof or walls to safely vent an explosion outdoors.

2.4.2 Protection

2.4.2.1 Provide explosion vents on drying towers, cyclones, bins, and at the inlet and outlet of fans. Vents must be smooth and fitted flush on the inside to minimize accumulation of combustible deposits. Refer to Data Sheet 7-76, *Combustible Dusts*, for venting guidelines.

2.4.2.2 Provide a spark detection and water spray protection system inside a flash pulp dryer as follows:

A. Locate spark detectors in the duct immediately downstream of each drying tower, with the corresponding water spray nozzle located upstream of the inlet to each cyclone (including the cooling duct and cyclone). The water spray system should activate every time a single spark is detected and reset after a few seconds (if no additional sparks have been detected) permitting the dryer to continue operating. The spark-counting feature available in some FM Approved detectors can be used to shut down the dryer when an excessive number of sparks are detected, but this feature should not be used to activate the water spray system.

B. Provide a second “fail-safe” spark detector in the duct between the water spray nozzles and the cyclone inlets. Detection at this location should be interlocked to safely shut down the dryer as follows:

1. Isolate the dryer cyclone outlet ducts to prevent smoldering material from being conveyed into downstream process areas. This may be accomplished by a high speed abort gate.

2. Stop material feed to the dryer and shut off all dryer heating sources.

3. Initiate an automatic deluge water spray system in the drying tower and cyclone. Flush-mounted, spring-loaded “poppet” nozzles (similar to those on the spark extinguishing system) are preferred for resistance to plugging and not protruding into the air flow, potentially accumulating pulp or being damaged.

4. Provide drainage for fire protection water.

5. Continue operating pulp dryer conveying fans to purge the drying system of pulp.

2.4.3 Equipment and Processes

2.4.3.1 Steam heating is preferred over combustion heating. For recommendations on fuel fired safety controls and devices, refer to Data Sheet 6-9, *Industrial Ovens and Dryers*.

2.4.3.2 Provide high temperature limit switches on the dryer duct at the inlet to each drying tower and cyclone. Interlock these limit switches to initiate the same functions as the “fail-safe” spark detector recommended above.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Supplemental Information

3.1.1 All Machines

3.1.1.1 Sprinkler Protection of Dryer Enclosures

Automatic sprinkler protection is needed inside dryer section hoods, exhaust ducts, air plenums, etc., because deposits of oily lint and paper dust are generated during operation of the paper machine. 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. 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.

3.1.1.2 Protection of Broke Collection Pits

Sidewall sprinklers may be located under the machine frame so the piping is not in the way and is protected from mechanical damage. The sprinklers must be located so discharge is not obstructed.

Provision of multiple manual trip stations for an under-machine water spray system at locations readily accessible by operators during a fire in the protected area are important as operator response may be quicker than automatic trip.

3.1.2 Cleaning with Flammable Solvents

Kerosene (flash point 110-162°F [43-72°C]) has been used for many years to clean calender rolls. In the past, and on some existing older machines, the kerosene was applied in small quantities by swabs, watering cans, and spray cans, and the amount stored at the machine has been typically less than 2 gal (7.6 l). Larger kerosene and mineral spirits (flash point 105°F [50°C]) cleaning systems are now being used that present a severe flammable liquid spill fire hazard. Plastic and metal tanks of 50 to 400 gal (190 to 1500 l) capacities, connected by fixed piping and flexible hose to manually controlled shutoff nozzles at the calender stack, are being used. Solvent is discharged as a spray or small stream. Transfer from the tank to the nozzles is by pumping, gravity flow, or, in some cases, by shop air at 20 to 80 psi (1.4 to 5.5 bar).

Flammable liquid transfer methods that maintain constant pressure on combustible flexible hose with the entire tank capacity behind it present the possibility of flammable liquid escape and resultant serious fire. The hose could fail mechanically or fail from exposure to a fire involving sprayed kerosene or burning broke, releasing the contents of the tank. When unavoidable, tanks approved by FM Approvals are preferred, and protection, including confinement and drainage, are needed.

Some pulp and paper mills have recovered fiber (waste paper) pulping operations. These systems repulp and remove ink and other contaminants from waste paper. Flammable solvents may be added to the stock along with other repulping chemicals. A properly designed and operated repulping operation will provide a stock supply to the paper machine free of solid and liquid contaminants. If the repulping operation does not remove all contaminants, flammable solvents, such as naphtha, may be sprayed onto the paper machine forming fabric to control “stickies.” The solvent-laden air may be removed in a ventilation system and recovered by carbon bed adsorption. The practice of spraying low flash point solvents, such as naphtha, directly onto machine clothing is hazardous and should be avoided.

Repulping systems may be installed in areas previously having minimal combustibles and may not be provided with sprinklers or suitable electrical equipment. As an example, a repulping and solvent deinking operation may be installed at the wet end of the paper machine having neither ceiling sprinklers nor electrical equipment suitable for flammable vapors. Fire and possibly equipment or room explosion hazards could exist if low flash point solvents are used, especially if they are heated. Vapors or spilled liquids could enter drainage systems not designed for solvents and find their way to an ignition source.

3.1.3 Oil and HTF Fire Hazards

3.1.3.1 Oil Fire Hazard

Lubrication and hydraulic oil system hazards are inherent to nearly every machine. Lubricating oil is commonly used by roll bearings; however, grease may be used in slower speed or wet applications (e.g., forming sections). Some roll bearing lubrication systems may also supply dryer gears, enclosed reduction gears, and large drive motor bearings.

Hydraulic oil can be found at many nips in press and calender sections, while compressed air may be substituted at some nips (e.g., Yankee dryer press rolls). Hydraulics (or pneumatics) may also be used for roll movements, felt stretching, and articulate the headbox.

3.1.3.2 HTF Fire Hazard

HTF heated roll operating temperature may be up to 500°F (260°C). Thermal oil may be circulated at more than 500 gpm (1900 L/min) at a pressure of about 60 psi (400 kPa). Rotary joints are required to circulate thermal oil through a thermo-roll. Rotary joints require frequent servicing to avoid failure. Thermal oil is typically piped to a point near the rotary joint and then connected to the joint with 3 in. (75 mm) or 4 in. (100 mm) steel reinforced flexible hose. Failure of a rotary joint typically results in tearing the hoses apart, releasing the thermal oil at operating temperature and pressure. Under operating conditions, the thermal oil is easily ignited.

3.1.4 Suction Rolls and Pressure Rolls

Suction rolls and pressure rolls are machine elements with a finite life. Unlike cast iron dryer rolls, the combinations of roll loading, limited shell thickness, and, for suction rolls, the multitude of drainage holes, limits the useful life of these rolls. Suction couch rolls, while not nip loaded, do have a multitude of drainage holes and are driven to transport the forming wire. Pressure rolls do not have drainage holes but are nip loaded and are usually driven. Suction press rolls have the combination of a multitude of drainage holes, nip loading and drive loading.

For all three roll types, the roll supplier works with the machine owner to design the roll for the characteristics desired for a particular machine. The supplier can calculate the number of cycles (revolutions) the roll can endure before cracking will likely begin. Some suppliers will guarantee this life while others will only provide a limited warranty. In either case, the roll has a limited service life that can be adversely impacted by operation at load greater than original design or operating in a chemical environment differing from the original design. These rolls have bonded resilient covers that require surface restoration and replacement. A second roll is generally maintained to exchange rolls during this routine maintenance. The roll supplier typically advises the operator on type and frequency of roll examination to coincide with the routine maintenance. This permits detection of impending failure so the roll may be removed from service prior to failure in the machine.

3.1.5 Cast Iron Dryer Rolls

Can-type cast iron roll shells range anywhere from 0.5 to 2.0 inches (12.5 to 50 mm) in thickness, from 24 to 72 inches (610 to 1830 mm) in diameter, and length may exceed 30 ft (9.1 m). The cylindrical face of each roll is ground to a smooth finish. The rolls are supported by trunnion shafts. The trunnion shafts are often cast integrally with the head and rotate in bearing housings. The bearing housings may be cast integral with, or bolted to, the frame of the paper machine. The dryers are driven by electric motors or steam turbines through open or enclosed gear sets. Modern dryer sections typically are two high but older machines may have dryer stacks up to twelve high.

3.1.6 Shoe Press

Shoe press popularity has been growing since the late 1990s given their improved dewatering capabilities. The fire hazard posed by the shoe presses is much greater than that of the conventional solid roll press. Shoe presses use significantly more hydraulic and lubricating oil than conventional press sections, and that oil is no longer limited to the machine frame (sides) but rather spans across the press section. Belt or sleeve failure (e.g., delamination) as well as mechanical impact to supply or return flexible hoses (e.g., drive shaft failure) can release tremendous amounts of oil into the press section.In addition to press nips, a closed shoe nip can also be employed in the calender section.

3.1.7 Yankee Dryers and MG Cylinders

Creping dryers used in tissue machines are commonly referred to as Yankee dryers. Similar dryers used in production of other paper types are commonly referred to as MG cylinders, as most of these cylinders apply a smooth or “glazed” surface on one side of the paper (machine glazed). These dryers differ from can-type paper machine dryers in size and in having a center shaft that both supports the dryer and serves as stay-bar (pressure containing element). Modern Yankee dryers and MG cylinders are unique rotating pressure vessels, which are constructed of high-strength cast iron. When fully pressurized and at operating speed, the dryer contains a tremendous amount of energy. Knowledge of fracture toughness, crack growth rate, and critical crack size is comparatively limited for high alloy gray cast iron, necessitating frequent inspection. Operating experience has not shown any uniform life cycle limitation, and the safe operating service life for modern, high-strength cast iron is not well defined.

Compared to creping dryers, non-creping Yankee or MG dryers typically operate at lower steam pressures, have significantly lower or no nip loading, do not have a creping doctor, and do not have any process sprays. The process sprays on creping dryers are a factor in head joint corrosion, and nip loading produces alternating stress, introducing a fatigue factor. Several creping dryer incidents (damage to the shell) resulted from objects (bolt, tool, torn rubber cover, torn machine clothing) passing through the nip. Non-creping dryers generally do not have the air cap or hood common to high speed creping dryers, eliminating a significant thermal stress.

Compared to creping dryers, there are relatively few non-creping Yankee or MG dryers in service. As machines are updated or replaced, non-creping Yankee or MG dryers are being replaced by calenders. Of the seven incidents involving non-creped Yankee or MG paper production reported to FM for the ten-year period 1993-2004, none involved a Yankee or MG dryer.

The significant safety concern for these dryers is the devastation that may accompany a catastrophic failure. Since 1970, twelve explosions of creping Yankee dryers have been reported to the TAPPI Yankee Dryer Safety Subcommittee. Of these twelve, two occurred in North America. These resulted in extensive property damage and long production interruption with substantial associated costs. Causes were various: improper repair, improper operation, joint corrosion, stationary warm-up, inadequate overpressure protection, and application of solid water streams.

3.1.8 Creping Machines

3.1.8.1 Spark Detection on Tissue Machines

Fires have occurred in warehouse storage of tissue paper. The paper was produced on Yankee dryers equipped with fuel-fired aircaps or hoods. It is believed that tissue dust, lint, and pieces of tissue from waste paper stock enter either the recirculating air system or the air inlets of the Yankee dryer aircaps. This material may be ignited by a burner in a direct fuel-fired hood, the hot-wire grid, or by autoignition in the indirect fuel-fired hood. Burning sparks or embers are then expelled onto the tissue paper, which is wound and stored without rewinding. It has been documented that burning embers were produced when the temperature of the drying air was raised shortly after the Yankee dryer hood had been running at a lower temperature (below the autoignition temperature of paper) for a prolonged period of time. Burning embers may also occur from dust or lint accumulations on top of the aircap hood that auto-ignite and fall onto the web. Another possible ignition source is sparks from doctor or cleaning blades contacting the Yankee.

Whatever the source, these burning embers smolder inside the rolled tissue for several days before bursting into flame. Good housekeeping in and around the aircap or hood recirculation system, and frequent blow backs will help prevent embers from developing. Vacuum cleaning of the aircap is preferred over blowdown to prevent suspension of a dust cloud that may contain embers. In the event that a spark or ember is expelled onto the web, a spark detection system will alert operators so the roll can be segregated from other storage or repulped.

3.1.9 Airborne Pulp Dryers

3.1.9.1 Steam Protection

Airborne pulp dryers are large, costly pieces of equipment that are vital to production. A severe fire could cause warping of the blow boxes. Steam extinguishing is being recommended for these dryers in lieu of more conventional means of fire protection for the following reasons:

- Automatic sprinklers or spray nozzles cannot be installed inside the dryers due to space limitations between the horizontal passes, making inerting of the dryer atmosphere the next best alternative.
- Access for manual firefighting is limited.
- The relatively closed configuration and elevated temperature of the dryers make them suitable for steam extinguishing.
- Most mills have adequate steam supplies, making steam an economical inerting agent.

3.1.10 Flash Pulp Dryers

3.1.10.1 Protection

Flash pulp dryers are expensive pieces of vital production equipment. The design of these dryers presents all the conditions necessary for an explosion or severe fire: large amounts of combustible fibers are in suspension in an enclosed space and a continuous ignition source is present. Wet fiber can impact and stick to duct walls where changes in direction occur. This is likely to occur upon initial startup when the consistency of the pulp may be variable or overly wet. The deposits dry out and may reach autoignition temperature. Spark detection and automatic extinguishing, abort gates, and other protection are recommended to prevent burning embers being conveyed to process equipment further downstream and possibly causing a fire or explosion. Explosion venting in the dryer towers and cyclones is needed, particularly in the second stage and cooling tower.

3.1.11 Fire Causes at Paper Machines

Overheated bearing fires occur primarily with manually lubricated sliding-element bearings that are not readily accessible with the machine in operation. Other ignition sources are friction of paper chokes between rolls, friction at belts, brakes, gears, and clutches. Mechanical sparks may be generated by metal contacts from excessive end play of rolls, broken shafts, gears, and doctor blades.

The surface temperature of exposed steam pipes, dryer hoods and ductwork, de-superheater valves, infrared radiant heaters, and steam turbines are often near or above the autoignition temperature of paper dust and oil. The autoignition temperature of paper dust and oils will decrease over a period of time when exposed to heat, and the autoignition temperature of oily dust similarly exposed to heating will be even lower. These deposits may rest on the hot surfaces for days or weeks before igniting. Oil-soaked insulation on steam and HTF pipes is particularly susceptible to autoignition.

Electrical fires result from improper maintenance, overloading of cable trays, poor housekeeping, short circuits, and static discharge. Over-lubrication of motors results in breakdown of oil-soaked insulation and accumulations of dust and fiber, which can cause overheating and short circuits. Spliced cables are susceptible to attack by the constant moisture and dirt commonly found in and beneath the paper machine, and can lead to arcing. Paper scraps or dust that obstructs motor vents can cause overheating of the motor and ignition of the paper or dust.

Hot work fires result from carelessness and failure to adopt proper safeguards, including a hot work permit system. Once ignition occurs, the presence of grease, oil-covered open gears, oily fibers, paper dust, paper scraps, rags, rope, machine clothing, or other combustibles can cause a hot, rapidly spreading fire. A fire starting at or below the operating level often is transported into exhaust ducts and economizers by the ventilation system. Prompt shutdown of ventilation will help limit the amount of fire spread.

All paper machines are subject to fire, justifying installation of automatic sprinkler protection where combustibles normally are or are likely to accumulate. FM experience demonstrates the likelihood of severe damage to the paper machine and extended business interruption is much greater in the absence of automatic sprinklers. Within dryer hoods, experience has shown that sprinkler discharge has not caused cracking, distortion, or other damage to the dryer rolls.

3.2 Loss History

Tables 2 through 5 show the results of a study of FM client machine losses (concentrated on fire and boiler & machinery hazards) spanning a period of over 22 years (1998 through mid-2020).

Table 2. Machine Losses By Peril

Peril	*No. of Losses*	*Gross Loss (US$M)*
Electric Breakdown	7	8.22
Ensuing Fire	1	1.93
Explosion	3	10.60
Fire Following	1	0.46
Fire	87	282.14
Mechanical Breakdown	163	204.09
Mechanical Impact	1	0.69
Pressure Part Breakdown	24	118.55
Rigging	3	1.26
Service Interruption	3	21.00
Total(s)	295	660.48

Table 3. Paper/Board Machine Losses by Section and Peril

Peril	*No. of Losses*	*Gross Loss (US$M)*
Forming	24	39.36
Collapse	4	11.54
Electrical Breakdown	1	2.53
Mechanical Breakdown	18	17.82
Press	76	123.01
Electrical Breakdown	3	3.50
Fire	6	43.70
Mechanical Breakdown	65	74.55
Dryer	77	162.55
Fire	32	53.45
Mechanical Breakdown	33	57.58
Pressure Part Breakdown	12	51.52
Reel	9	16.20
Fire	6	10.64
Mechanical Breakdown	2	5.20
Calender	12	77.00
Fire	9	69.88
Mechanical Breakdown	2	6.80
Utility System	2	19.45
Service Interruption	2	19.45
Support System	7	63.12
Fire	4	57.98
Electrical Breakdown	2	1.32
Mechanical Breakdown	1	3.82
Total(s)	207	500.68

Table 4. Tissue Machine Losses by Section and Peril

Peril	*No. of Losses*	*Gross Loss (US$M)*
Forming	1	0.26
Press	26	14.50
Fire	3	1.32
Mechanical Breakdown	23	13.18
Dryer	36	79.76
Fire	14	26.64
Mechanical Breakdown	10	6.51
Pressure Part Breakdown	11	42.44
Reel	6	3.05
Utility System	1	1.55
Support System	4	2.20
Total(s)	74	101.32

Table 5. Pulp Machine Losses by Section

Peril	*No. of Losses*	*Gross Loss (US$M)*
Press	3	15.72
Drying	2	30.56
Total(s)	5	46.28

4.0 REFERENCES

4.1 FM

4.1.1 FM References

Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*
Data Sheet 4-1N, *Fixed Water Spray System for Fire Protection*
Data Sheet 5-4, *Transformers*
Data Sheet 5-19, *Switchgear and Circuit Breakers*
Data Sheet 5-31, *Cables and Bus Bars*
Data Sheet 5-48 *Automatic Fire Detection*
Data Sheet 6-9, *Industrial Ovens and Dryers*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-45, *Safety Controls, Alarms, and Interlocks*
Data Sheet 7-76, *Combustible Dusts*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-83, *Drainage Systems for Ignitable Liquids*
Data Sheet 7-98, *Hydraulic Fluids*
Data Sheet 7-99, *Heat Transfer Fluid Systems*
Data Sheet 7-110, *Industrial Control Systems*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*
Data Sheet 10-3, *Hot Work Management*
Data Sheet 10-8, *Operators*
Data Sheet 12-43, *Pressure Relief Devices*

4.2 Others

American Society for Nondestructive Testing (ASNT). ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*.

American Society of Mechanical Engineers (ASME). *Boiler and Pressure Vessel Code*.

ASTM International (ASTM). ASTM A247, *Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings*.

ASTM International (ASTM). ASTM E8, *Test Methods for Tension Testing of Metallic Materials*.

ASTM International (ASTM). ASTM E10, *Standard Test Method for Brinell Hardness of Metallic Materials*.

ASTM International (ASTM). ASTM E110, *Standard Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers*.

ASTM International (ASTM). ASTM E543, *Standard Practice for Agencies Performing Nondestructive Testing*.

International Organization for Standardization (ISO). EN 9712, *Qualification and Certification of NDT Personnel*.

International Organization for Standardization (ISO). EN 14584, *Examination of Metallic Pressure Equipment - Planar Location of AE Sources*.

National Board of Boiler and Pressure Vessel Inspectors (NBBI). *National Board Inspection Code*.

National Fire Protection Association (NFPA). NFPA 70, *National Electrical Code*.

Technical Association of the Pulp and Paper Industry (TAPPI). TAPPI TIP 0402-19, *Guidelines for Nondestructive examination of suction roll shells*.

Technical Association of the Pulp and Paper Industry (TAPPI). TAPPI TIP 0402-34, *Paper Machine Reel-Spool Journals: Guidelines for Crack Testing and repair or replacement*.

Technical Association of the Pulp and Paper Industry (TAPPI). TAPPI TIP 0425-01, *Guidelines for Routine Periodic Inspection and Testing of Cast Iron Yankee and MG Dryers*.

Technical Association of the Pulp and Paper Industry (TAPPI). TAPPI TIP 0425-02, *Inspection Guidelines for Yankee Hood Systems*.

Technical Association of the Pulp and Paper Industry (TAPPI). TAPPI TIP 0425-03, *Design, Monitoring, and Maintenance Guidelines for Yankee Dryer Bearings*.

APPENDIX A GLOSSARY OF TERMS

Allowable Stress: some fraction of the ultimate tensile stress of a material. The fraction selected is generally based on knowledge of the particular material and operating experience. In the case of cast iron typically used for dryers, the fraction is 1/10, or the allowable stress is one-tenth of the material ultimate tensile stress.

Chaplet: metal support for holding casting cores in place within sand molds.

Control crown roll: A deflection compensated roll that adjusts crown (and thus nip loading uniformity) by modulating oil pressure in one or more zones via hydraulic cylinders supported by a stationary beam. The cylinders apply force to the rotating shell through attached shoes. The hydraulic oil used to control nip uniformity is also employed to lubricate the shoe-shell interface. These rolls can be used in press or calender nips.

Deflection compensated roll: A nip roll that operates using a stationary beam to support and load a rotating shell against an opposing roll. Manipulation of the shell by modulating hydraulic oil pressure in one or more loading zones achieves more uniform loading across the nip. Deflection compensated rolls include control crown roll (CCR) with a metal rotating shell, and swimming roll (SR) with metal rotating shell. These rolls are found in nip applications, mostly in press and calender machine sections.

FM Approved: references to “FM Approved” in this data sheet means the product or service has satisfied the criteria for Approval by FM Approvals. Refer to the *Approval Guide*, a publication of FM Approvals, for a complete list of products and services that are FM Approved.

Ground Floor: Level below the machine operating floor also known as the ″basement.″

HTF: Heat transfer fluid. An organic or inorganic fluid, usually flammable, used to transfer heat to a process.

Journal: As used in this data sheet, that portion of a dryer head having a shape and increased cross-sectional area to accept a press-fit shaft or create a transition from the head shape to an integral shaft

MAWP: maximum allowable working pressure. As used in this data sheet, is the maximum pressure to which a dryer may be subjected during operation. It is code limited and determined by either the manufacturer or by analysis.

Non-standard dryers: Dryers neither constructed to a manufacturer's standard nor having stamping or other documentation sufficient to ensure construction is standard.

Paper machine dryer (dryer): assembly consisting of shell, heads, shafts, and head bolts. Dryers typically have internal balance weights, siphons, and may have spoiler bars.

Process drains: Trenches around or under the machine intended to capture and control process water from de-watering or use of hose for machine clean-up. Drains may be referred to as ″sewers.″

Responsible Person: The individual selected and trained to fill the duties of a "Responsible Person" should be technically qualified, have some degree of expertise with Yankee drying equipment and systems, and, using the five stages of mastery (beginner, apprentice, journeyman, artisan, and expert) have attained, at a minimum, the level of journeyman. It is highly recommended that the company establish or sanction a training certification program for the Responsible Person at each papermaking facility.

Shoe press, open: A stationary nip roll consisting of a beam-supported, hydraulically loaded concave plate (shoe) not enclosed by a rotating belt that passes over shoe with the assistance of lubrication. These shoe presses are typically installed as the bottom roll in the nip and may be opposed by a controlled-crown roll or solid roll. The open shoe press was the original design also known as the extended nip press (ENP).

Shoe press, closed: A stationary nip roll consisting of a beam-supported, hydraulically loaded concave plate (shoe) enclosed by a rotating sleeve that passes over shoe with the assistance of 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.

Standard dryer: "Standard," as used in this context, is a manufacturer's standard. That is, a dryer appearing to be consistent in construction to "code" constructed dryers from the same manufacturer. A "recognized code or standard" is one that is acceptable to FM. Nearly all pressure vessel construction codes are acceptable to FM for the purpose of evaluating dryer rolls. Stamping on a head may not be sufficient assurance that the entire dryer is standard construction since heads are replaced and stamping may only be indicative of the replacement head. Manufacturer's data reports, certificates, or similar documentation that can be traced to individual dryers, in addition to stamping on dryers, is good indication the dryer is actually of standard construction.

Swimming roll: A deflection compensated roll that adjusts crown (and thus nip loading uniformity) by modulating oil pressure within an internal fluid chamber. The chamber is formed by the two seals that travel spanthe width of the roll in the cross-machine direction between the stationary beam and the rotating shell. Hydraulic oil used to control nip uniformity is often "lower pressure hydraulic oil" (e.g., 100 psi or 6.6 bar instead of 1,000 psi or 66 bar), while higher pressure hydraulic oil is used to position and load the nip at each end. These rolls can be used in press or calender nips.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

October 2024. Interim revision. Updated FM Approved industrial fluid guidance based on a recent fluid approval intended for shoe press applications.

January 2024. Interim revision. Minor editorial changes were made.

January 2023. Interim revision. Significant changes include the following:

A. Revised oil and fluid selection for machine oil systems.

B. Replaced bulk oil release concept with specific oil hazard protection methodologies along with associated scenario and LE guidance for machine oil supplies, circulating lubrication oil distribution and use points, centralized hydraulic oil use points, and small hydraulic oil systems.

C. Expanded shoe press and control crown roll protection methodology to include swimming rolls.

D. Clarified deluge/water spray nozzle location guidance for oil releases at shoe, control crown, and swimming roll flexible hoses and shoe belt/sleeve.

E. Added allowance for loss of compressed air interlock for a closed shoe press.

January 2022. Interim revision. Minor editorial changes were made.

April 2021. Interim revision. Significant changes include the following:

A. Reorganized the document to be consistent with current data sheet requirements.

B. Revised guidance on machine oil hazards.

C. Revised guidance on machine HTF hazards.

D. Revised automatic fire protection guidance for machine areas.

E. Clarified guidance on automatic fire protection coverage within dryer hood plenums and exhaust ducts.

F. Added guidance on roof inspections for corrosion.

G. Revised guidance on maintenance of cast iron and steel dryer rolls.

H. Added guidance on maintenance of other key machine rolls.

I. Revised equipment contingency plan (ECP) guidance.

J. Updated loss history.

K. Added a roll maintenance job aid.

October 2019. Interim revision. Fire protection guidance for shoe presses was added to this data sheet (Sections 2.7, 3.17, Appendix A, Glossary of Terms).

April 2010. Clarification was made on differentiating the recommended inspection practices for Yankee dryers of welded steel construction from those of bolted cast iron construction.

January 2009. Recommendation 2.1.6.13, ″d″ was revised to reduce the scope of recommended inspection.

September 2007. Minor editorial changes were made for this revision.

September 2006. Minor editorial changes were made for this revision.

January 2006. Corrected data sheet number in Section 1.1 (DS 12-30 was incorrectly given as DS 12-24).

June 2005. This data sheet consolidates material formerly contained in Data Sheets 7-4, *Paper Machines and Pulp Dryers;* 7-102/12-29, *Yankee Dryers*; 12-25, *Cast Iron Paper Machine Dryers*; 12-30, *Weld Fabricated Paper Machine Dryers*; and 12-60, *Suction Press Rolls*.

2.1.4.4 New recommendation to perform an oil fire hazard assessment for lubrication, hydraulic, and heat transfer fluid (HTF) oil systems.

2.1.6 Recommended inspection for Yankee or MG cylinder not in creping service is now the same as recommended inspection for can-type dryers.

2.1.6.2 New recommendation to follow machine manufacturer's recommendations for startup and shutdown of paper machine.

2.1.6.6 Testing of paper machine steam relief valves (all types of machines) now set at 12-month intervals.

2.1.7.1 New recommendation to improve operator awareness and response to oil fires.

2.3.6.1 Revised recommendation limiting examination of Yankee head joint for corrosion to dryers in creping service with through-bolt head construction.

2.3.6.3 Revised recommendation limiting examination of head or shell of creping dryer for cracking based on type of head bolt (cap screw or through-bolt).

2.5.1.1 Revised steam suppression protection for airborne pulp dryers.

May 2005. This data sheet consolidates material formerly contained in Data Sheets 7-4, Paper Machines and Pulp Dryers; 7-102/12-29, Yankee Dryers; 12-24, Weld Fabricated Paper Machine Dryers; 12-25, Cast Iron Paper Machine Dryers; and 12-60, Suction Press Rolls.

APPENDIX C RELEVANT FM DATA SHEET REFERENCES

This data sheet contains unique loss prevention guidance tailored specifically for paper, board, pulp, and tissue production along with their utility and support systems. For brevity, general loss prevention guidance contained within these other FM data sheets was not duplicated within this data sheet, but may be applicable at a mill. For example, Data Sheet 5-4, *Transformers*, contains fire protection as well as inspection, testing, and maintenance guidance that is applicable to power transformers, however this guidance is not customized for application at a mill. Below is a list of other FM data sheets that may be applicable at mills. This list is not intended to be all-inclusive.

A. Site Selection (Buildings and Utility Services)

- Data Sheet 1-2, *Earthquakes*
- Data Sheet 1-27, *Windstorm*
- Data Sheet 1-34, *Hail Damage*
- Data Sheet 1-40, Flood

B. Building Construction

- Data Sheet 1-11, *Fire Following Earthquake*
- Data Sheet 1-28, *Wind Design*
- Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*
- Data Sheet 1-54, *Roof Loads for New Construction*
- Data Sheet 1-57, *Plastics in Construction*

C. Fire Protection

- Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
- Data Sheet 2-8, *Earthquake Protection for Water-based Fire Protection Systems*
- Data Sheet 3-10, *Private Fire Service Mains and Connections*
- Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*
- Data Sheet 4-1N, *Fixed Water Spray System for Fire Protection*
- Data Sheet 4-9, *Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems*
- Data Sheet 4-12, *Foam-Water Sprinkler Systems*
- Data Sheet 5-48, *Automatic Fire Detection*

D. Systems and Equipment

- Data Sheet 5-4, *Transformers*
- Data Sheet 5-11, *Lightning and Surge Protection for Electrical Systems*
- Data Sheet 5-17, *Motors and Adjustable Speed Drives*
- Data Sheet 5-19, *Switchgear and Circuit Breakers*
- Data Sheet 5-20, *Electrical Testing*
- Data Sheet 5-23, *Design and Protection for Emergency and Standby Power Systems*
- Data Sheet 5-31, *Cables and Bus Bars*
- Data Sheet 6-9, *Industrial Dryers and Ovens*
- Data Sheet 7-29, *Ignitable Liquid in Portable Storage Containers*
- Data Sheet 7-32, *Ignitable Liquid Operations*
- Data Sheet 7-76, *Combustible Dusts*
- Data Sheet 7-78, *Industrial Exhaust Systems*
- Data Sheet 7-83, *Drainage Systems for Ignitable Liquids*
- Data Sheet 7-98, *Hydraulic Fluids*
- Data Sheet 7-99, *Heat Transfer by Organic and Synthetic Fluids*
- Data Sheet 7-110, *Industrial Control Systems*
- Data Sheet 12-2, *Vessels and Piping*
- Data Sheet 12-43, *Pressure Relief Devices*
- Data Sheet 13-3, *Steam Turbines*
- Data Sheet 13-7, *Gears*
- Data Sheet 13-24, *Fans and Blowers*

E. Human Element

- Data Sheet 2-81, *Fire Protection System Inspection, Test, and Maintenance and Other Fire Loss Prevention Inspections*

- Data Sheet 9-0, *Asset Integrity*
- Data Sheet 10-1, *Pre-Incident and Emergency Response Planning*
- Data Sheet 10-3, *Hot Work Management*
- Data Sheet 10-4, *Contractor Management*
- Data Sheet 10-7, *Fire Protection Impairment Management*
- Data Sheet 10-8, *Operators*

APPENDIX D BOILER AND MACHINERY MACHINE ROLL MAINTENANCE JOB AID

Table 6 contains an overview of roll maintenance activities recommended for specific machine rolls per this data sheet. The table also includes examples of maintenance activities that should be considered within the asset integrity program for other machine rolls.

Table 6. Machine Roll Maintenance Guide

Roll	*Part*	*Scope*	*Frequency*
Couch and Pick-up	Heads	Magnetic particle (MT) or liquid penetrant (PT)	Each roll maintenance
	Shell, External	Visual (VT).	36 months of operationor at each roll maintenance
	Suction box	Visual inspection (VT) of the box.	Each roll maintenance
		Ultrasonic (UT) and magnetic particle (MT) of the suction box small shaft (spigot).	Each roll maintenance
Suction Press	Heads	Magnetic particle (MT) or liquid penetrant (PT) in high stress and transition area.	Each roll maintenance
	Shell, Internal	Visual (VT).	24 months of operation or at each roll maintenance
	Shell, External	Liquid penetrant (PT).	Every roll cover replacement
	Roll Cover	Visual (VT).	Every scheduled machine maintenance
	Suction box	Visual inspection (VT) of the box.	Each roll maintenance
		Ultrasonic (UT) and magnetic particle (MT) of the suction box small shaft (spigot).	Each roll maintenance
Grooved Press	Heads/Journals	Magnetic particle (MT) or liquid penetrant (PT) in high stress and transition area including bearing journal (axial UT as an option).	Each roll maintenance
	Roll Cover	Visual (VT) of roll covers.	Every scheduled machine maintenance
Granite Press	Heads/Journals	Magnetic particle (MT) or liquid penetrant (PT) in high stress and transition area including bearing journal.	Each roll maintenance
	Central shaft	Ultrasonic (UT).	12 months of operation
	Tension rod	Ultrasonic (UT) of all rods.	18 months of operation
Ceramic Press	Heads/Journals	Magnetic particle (MT) or liquid penetrant (PT) in high stress and transition area including bearing journal (axial UT as an option).	Each roll maintenance
	Roll Coating	Visual (VT).	Each roll maintenance
Felt, Wire, Guide	Journals	Ultrasonic (UT).	Depending on material
	Heads	Magnetic particle (MT) or liquid penetrant (PT) in high stress and transition area including bearing journal.	Each roll maintenance or by vast campaign if never done
	Roll	Remove all felt rolls in operation that have been balanced with welded balancing weight in the center	

Table 6. Machine Roll Maintenance Guide (continued)

Roll	*Part*	*Scope*	*Frequency*
Cast Iron and Steel Dryer	Heads, External	Visual (VT) in operation.	Daily
		Visual (VT).	12 months
		Magnetic particle (MT) or liquid penetrant (PT) in high stress area in Fig. 9.	60 months
	Heads, Internal	Visual (VT).	60 months
		Magnetic particle (MT), as needed.	60 months
	Head-Shell Joint, Bolted	Ultrasonic (UT) to examine head screws or bolts.	60 months (incrementally at 20% annually)
	Head-Shell Joint, Welded	NDE of circumferential weld per OEM.	
	Shell, External	Visual (VT).	12 months
	Shell, External Non-Metalized	Ultrasound (UT) to profile the shell thickness.	60 months
	Shell, External Metalized	Magnetic lift off (MLO).	60 months
	Shell, Internal	Visual (VT).	60 months
Cast Iron Yankee Dryer	Heads, External	Visual (VT) in operation.	Daily
		Visual (VT).	12 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 12.	72 months (Up to 144 months)
	Heads, Internal	Visual (VT).	24 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 12.	72 months (Up to 144 months)
	Journal/Center Stay, External	Visual (VT).	12 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 12.	72 months (Up to 144 months)
	Ultrasonic (UT) to examine bolts. Alternatively, AET.	72 months (Up to 144 months)	
	Journal/Center Stay, Internal	Visual (VT).	24 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 12.	72 months (Up to 144 months)
	Head-Shell Joint, Bolted	Visually (VT) the head to shell joint.	12 months
		Perform head tilt.	12 months (Up to 72 months)
		Shell Runout.	12 months
		Ultrasonic (UT) to examine head screws or bolts.	72 months (Up to 144 months)
	Shell, Internal	Visual (VT).	24 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 12.	72 months (Up to 144 months)
	Shell, Metalized	Magnetic lift off (MLO).	72 months (Up to 144 months)

Table 6. Machine Roll Maintenance Guide (continued)

Roll	*Part*	*Scope*	*Frequency*
Steel Yankee Dryer	Heads, External	Visual (VT) in operation.	Daily
		Visual (VT).	12 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 12.	72 months (Up to 144 months)
	Heads, Internal	Visual (VT).	24 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig.12.	72 months (Up to 144 months)
	Journal/Center Stay, External	Visual (VT).12 months	72 months (Up to 144 months)
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 6.	
		Ultrasonic (UT) to examine bolts.	72 months (Up to 144 months)
	Journal/Center Stay, Internal	Visual (VT).	24 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 12.	72 months (Up to 144 months)
		NDE on structural and pressure welds per OEM.	
	Head-Shell Joint, Bolted	Visually (VT) the head to shell joint.	12 months
		Perform head tilt.	12 months (Up to 60 months)
		Shell Runout.	12 months (Up to 60 months)
		Ultrasonic (UT) to examine head screws or bolts.	72 months (Up to 144 months)
	Head-Shell Joint, Welded	External visually (VT) the head to shell joint.	12 months
		Internal visually (VT) the head to shell joint.	24 months
		NDE of circumferential weld per OEM.	
	Shell	NDE on longitudinal weld per OEM.	
	Shell, External Metalized	Magnetic lift off (MLO).	72 months (Up to 144 months)
	Shell, Internal	Visual (VT).	24 months
		Magnetic particle (MT) or liquid penetrant (PT) of high stress areas defined in Fig. 12.	72 months (Up to 144 months)
Cast Iron MG Cylinder	Refer to Cast Iron Dryers.		
Steel MG Cylinder	Refer to Steel Dryers.		
Through-Air Dryer	Refer to OEM inspection and testing guidelines.		
Vacuum Dryer (Steam-Isolated Dryer)	Heads, External	Visual (VT).	12 months
	Head-Shell Joint, Bolted	Ultrasonic (UT) to examine head screws or bolts.	60 months (up to 120 months)
Calender	Roll	Visual (VT).	12 months
	Heads	Magnetic particle (MT) or liquid penetrant (PT) in high stress and transition area.	3 to 5 years
Spool-Reel and Winder Drum	Roll	Visual (VT).	12 months
	Heads/ Journals	Magnetic particle (MT) or liquid penetrant (PT) in high stress and transition area.	3 years (Up to 10 years)