ROLLING MILLS

Table of Contents

Page

List of Figures

List of Tables

1.0 SCOPE

This data sheet contains property loss prevention guidance unique to rolling mills processing aluminum, steel, and other metals, and addresses hazards and exposures associated with the mill proper (mill stands), the mill building, and critical mill utilities and support systems.

This data sheet does not cover operations upstream or downstream of the rolling mill. Refer to the applicable data sheets for those operations, such as the following:

- 7-33, *Molten Metals and Other Materials*, for molten metal alloying and casting
- 6-10, *Process Furnaces*, for reheat furnaces (Refer to 5.0 for physical deficiency guidance)
- 7-2, *Waste Solvent Recovery*, for refining used ignitable rolling fluid
- 7-98, *Hydraulic Fluids*, and 13-8, *Power Presses*, for shears and plate stretchers
- 7-104, *Metal Treatment Processes*, for surface treatment (e.g., pickling lines)
- 13-8, *Power Presses, for shears and plate stretchersmed*

This data sheet is a supplement to other data sheets. When evaluating hazards and exposures not addressed in this data sheet (i.e., not unique to rolling mills), adhere to the applicable data sheet, such as the following:

- 5-17, *Motors and Adjustable Speed Drives*
- 5-19, *Switchgear and Circuit Breakers*
- 5-31, *Cables and Bus Bars*
- 5-4, *Transformers*
- 6-10, *Process Furnaces*, for reheat or heat treatment furnace
- 7-110, *Industry Control Systems*, for control equipment and operator control rooms.

1.1 Hazards

1.1.1 Fire

Fire hazards exposing the mill proper often consist of ignitable liquids and combustible deposits or residues. Most mills use high-pressure hydraulic fluid for various functions, and lubricating oil for roll bearings. Some mills also spray ignitable rolling fluid onto work surfaces for lubrication and cooling. Though mill stands and rolls are fairly resilient to the intense thermal exposure posed by an ignitable liquid hazard, damage to power cabling, control wiring, instrumentation, and motors leads to substantial recovery durations. Consistent with most other ignitable liquid spray and pool fire hazards, key fire protection features center upon promptly depressurizing and/or isolating the ignitable liquid supply, and water-based protection systems to limit thermal damage in basements, at the mill level, and/or at ceiling level when appropriate.

Combustible residues and deposits originate from oil spills or leaks, and rolling fluid spray (e.g., dried animal fat). Ignition of residue or deposits on equipment, in ventilation systems, or on interior building surfaces lead to fast fire spread, with the potential to out-run ceiling-level automatic sprinklers and increase the likelihood of igniting more substantial secondary fuel packages capable of overpowering fire protection systems. Source control via exhaust ventilation and housekeeping remain the primary safeguards to limit the release of combustibles, and monitor and remove buildup when it becomes appreciable.

Although not unique to rolling mills, the fire hazards present in electrical or control equipment rooms may constitute a more severe exposure than in other occupancies. These large, expansive equipment rooms often contain a large quantity of equipment that is sensitive to heat, water, and smoke (e.g., rectifiers or variable frequency drives). Electrical fires, such as in cable insulation, may not be intense but can produce significant quantities of corrosive combustion products and generate smoke that can hinder firefighting. This exposure can be mitigated by a combination of fire protection features for power cabling and control wiring, while a sound asset integrity program for electrical equipment can help prevent electrical breakdown that could result in ignition of electrical equipment.

1.1.2 Electrical Breakdown

The electrical breakdown hazards associated with rolling mills are not exclusive to this occupancy; however, the exposures may be more severe given the size and scarceness of equipment used to power working rolls, including several-thousand-horsepower drives. With the criticality of this equipment and long lead times for repairs or replacement, maintenance and protective devices remain key loss prevention safeguards. An equipment contingency plan can also minimize the duration of a forced outage due to an unexpected failure of long-lead-time equipment within the mill drive system such as drive motors, and motor power supplies and transformers. Additionally, many electrical breakdowns have resulted in ensuing fires that exacerbated damage and recovery, making fire protection an important consideration as well.

1.1.3 Mechanical Breakdown

Most of the mechanical breakdown hazards within the rolling mill occupancy are not unique. An exception may be mill stand housings. Cracks can initiate and propagate in mill stand pedestals and housings. Routine visual inspections and other applicable nondestructive examination (NDE) techniques in high-stress areas of the housings can increase the likelihood of detecting cracks in their early stages, improving temporary or permanent repair options. In addition to mill stand housings, interconnected mill equipment such as mill drive spindles, gears and motors are prone to damage during mill stand upsets (e.g., cobble or fold).

1.2 Changes

July 2023. Interim revision. Revised boiler & machinery guidance.

A. Revised mill housing maintenance and mill stand safety devices.

B. Added recommendations for mill operators.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 The loss prevention guidance contained within this data sheet supplements the loss prevention guidance in other data sheets. For anything not covered in Section 2.0 of this data sheet, adhere to the loss prevention recommendations in the relevant data sheet. A list of potentially relevant data sheets is included in Appendix C.

2.1.2 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* listing. Refer to the *Approval Guide*, an online resource of FM Approvals, for a list of FM Approved products and services.

2.1.3 Provide fire protection for ignitable liquid supplies serving the mill in accordance with the following recommendations.

Ignitable liquids may be used in mill support systems such as rolling (fluid), hydraulic, and lubrication systems. These support systems consist of a supply and one or more use points on or near the mill stand. Supplies are often comprised of reservoirs, pumps, accumulators, and/or filters, and should be protected per Section 2.1.3. Fire protection for use points on or adjacent to the mill stand is incorporated into the mill stand protection covered in the following sections.

2.1.3.1 Do not locate supplies of more than 1000 gal (3800 L) of ignitable liquid in basements open to the rolling mill above (i.e., in an oil cellar).

2.1.3.2 If an ignitable rolling fluid (i.e., liquid with a fire point) is used, provide fire protection safeguards for the rolling fluid supply in accordance with either Data Sheet 7-32, *Ignitable Liquid Operations*, or 7-98, *Hydraulic Fluids*, as directed by Figure 1.

2.1.3.3 Whenever feasible, use a hydraulic fluid that either does not have a fire point (i.e., is not an ignitable liquid) or is an FM Approved industrial fluid. When this is not feasible, provide fire protection safeguards in accordance with Data Sheet 7-98, *Hydraulic Fluids*, as directed by Figure 1.

2.1.3.4 Provide fire protection safeguards for lubricating oil supplies in accordance with Data Sheet 7-98, *Hydraulic Fluids*, as directed by Figure 1.

2.1.3.5 When ignitable liquid supplies are located adjacent to the mill and exposed by vehicle traffic or overhead cranes, provide mechanical impact protection.

2.2 Location and Construction

2.2.1 Location

2.2.1.1 Locate mill drive motors, electrical equipment, and control equipment in aboveground rooms cut off from the mill and ignitable liquid supplies such as rolling fluid, hydraulic fluid, and lubricating oil.

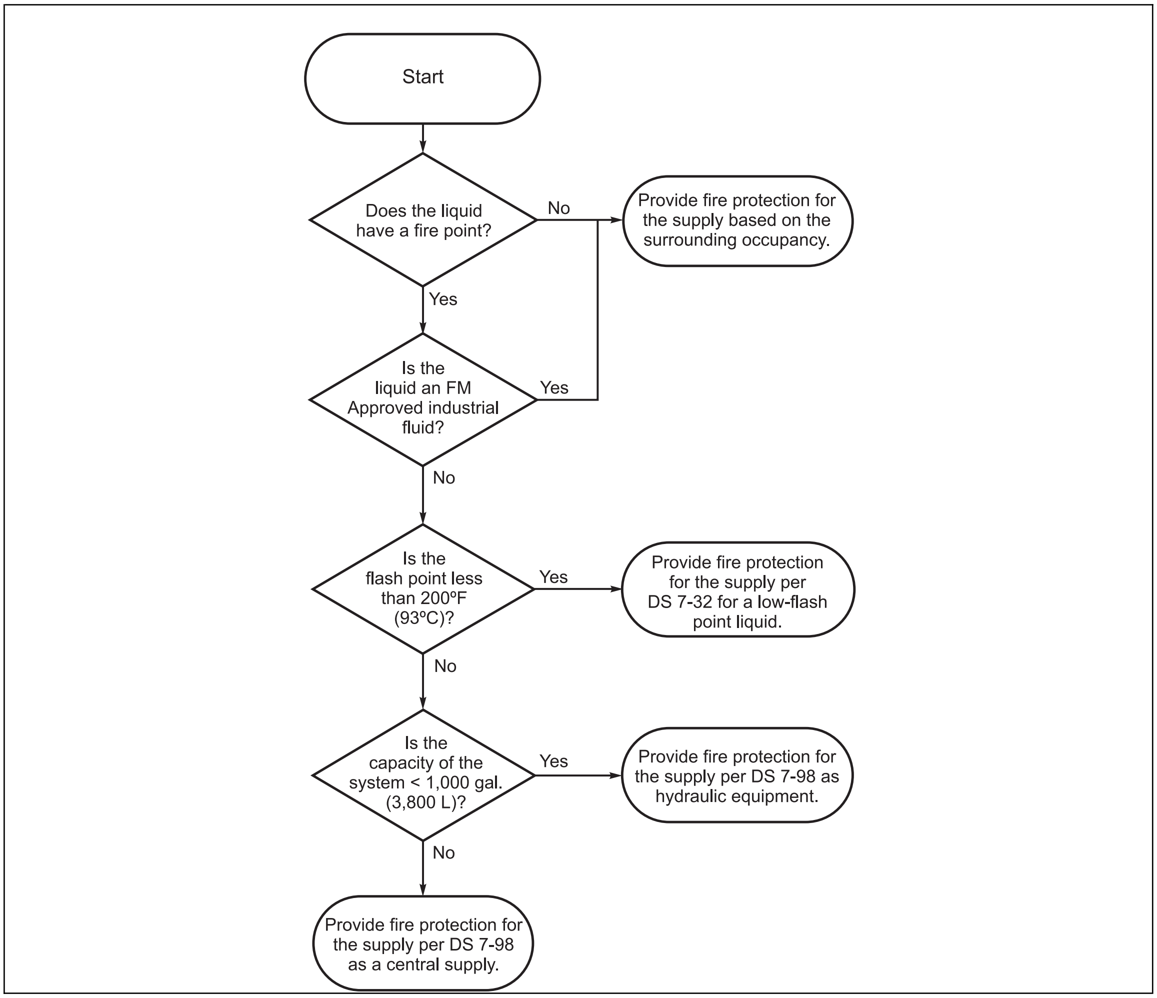


Fig. 1. Flowchart for determining fire protection features for an ignitable liquid supply

2.2.1.2 Draw cooling air for electrical equipment and rooms from areas free of particulate, moisture, and rolling fluid vapor.

2.2.1.3 When multiple rolling mills are installed in close proximity, do not interconnect below-grade spaces beneath multiple mills (i.e., basements, pits, or trenches should not communicate).

2.2.1.4 Route power cabling and control wiring to minimize their exposure to a mill fire as well as the hot surfaces that may be present during normal mill operation. If this is not possible, protect cabling and wiring from exposing fire hazards in accordance with Data Sheet 5-31, *Cables and Bus Bars*, if deemed safety-critical or production-critical with lengthy recovery durations. Examples of safety-critical functions include wiring or cabling serving non-fail-safe final control elements or remotely controlled emergency safety shutoff valves serving itnitable liquid systems. Protect exposed cabling and wiring using a 1-hour fire-rated, FM Approved fire wrap that extends 20 ft (6 m) beyond the fire area.

2.2.1.5 When the mill does not have an exhaust ventilation system with hood or enclosure, install draft curtains to control combustible deposits/residues at ceiling-level per Data Sheet 1-10, *Interaction of Sprinklers, Smoke and Heat Vents and Draft Curtains*. Extend the draft curtains a minimum of 20 ft (6 m) or two ceiling-level sprinklers, whichever is greater, beyond the footprint of the mill proper.

2.2.2 Construction

2.2.2.1 Construct buildings or rooms containing a rolling mill and associated equipment using noncombustible building construction. If combustible or plastic building materials are required, use FM Approved materials. Combustible building construction may include insulated metal panels, insulated steel deck roof assemblies, and interior plastic facings. Install FM Approved building materials in accordance with the manufacturer's guidelines and their FM Approval listing.

2.2.2.2 Protect structural members supporting the building, or elevated equipment that exceeds 3 ft (0.9 m) in width or diameter or 10 ft^2 (0.9 m^2) in cross sectional area, and that could be immersed in a pool fire. Of particular concern is equipment that could collapse, releasing additional ignitable liquid, such as reservoirs/tanks or filter presses containing rolling fluid, hydraulic fluid, or lubrication oil. Provide steel column protection in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*.

2.2.2.3 Construct a 1-hour fire-resistant wall between the mill proper and mill drive motors. Preferably construct the wall of masonry to prevent firefighting hose streams penetrating through the wall. An alternative to a fire-resistant wall is a noncombustible wall (e.g., sheet metal on steel frame) with a line of deluge water spray nozzles along the mill side of the wall arranged to activate automatically on fire detection over the mill.

2.3 Protection

This data sheet contains recommendations for two classes of active fire protection systems: primary and supplementary. Primary protection is water-based (e.g., ceiling-level sprinkler or mill-level deluge system), while supplementary protection may be a fire extinguishing system using a gaseous suppression agent (e.g., local application carbon dioxide system). This terminology may differ from that used in industry as fire extinguishing systems are often viewed as “primary” due to greater frequency of use, while water-based protection systems are viewed as “backup.”

The necessary fire protection for a mill depends on the fire hazards present, the physical arrangement of the mill, and the surrounding building construction and occupancy. When designing and installing fire protection, key aspects to consider are the presence of ignitable liquid use points and supplies, combustible deposits/residues on equipment and building surfaces, combustible construction, and elevated horizontal surfaces that can shield burning combustibles or ignitable liquids from nozzles above.

2.3.1 Ceiling-Level Protection

2.3.1.1 Provide ceiling-level protection over the mill in accordance with the following and Figure 2.

A. When the mill is fully-enclosed or partially-enclosed by an exhaust hood, provide ceiling-level protection outside the enclosure based on the fire hazards present surrounding occupancy and building construction. Additionally, provide mill-level protection in accordance with Section 2.3.2.

B. When the mill does not have an exhaust ventilation system with hood, provide ceiling-level protection within the draft curtained area above the mill.

2.3.1.2 Design and install ceiling-level protection over the mill in accordance with the following recommendations based on mill classification. Refer to Figure 3 for guidance determining the appropriate mill classification based on the ignitable liquid hazards present.

A. Design and install ceiling-level protection over a Type 2 mill (i.e., combustible loading driven by non-FM Approved hydraulic fluid) in accordance with Data Sheet 7-98, *Hydraulic Fluids*. Install automatic sprinklers in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for a nonstorage occupancy.

B. Design ceiling-level protection over a Type 1 mill (i.e., combustible loading limited to lubrication fluid and combustible deposits/residues) in accordance with Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*, for an HC-2 occupancy. Install automatic sprinklers in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for a nonstorage occupancy.

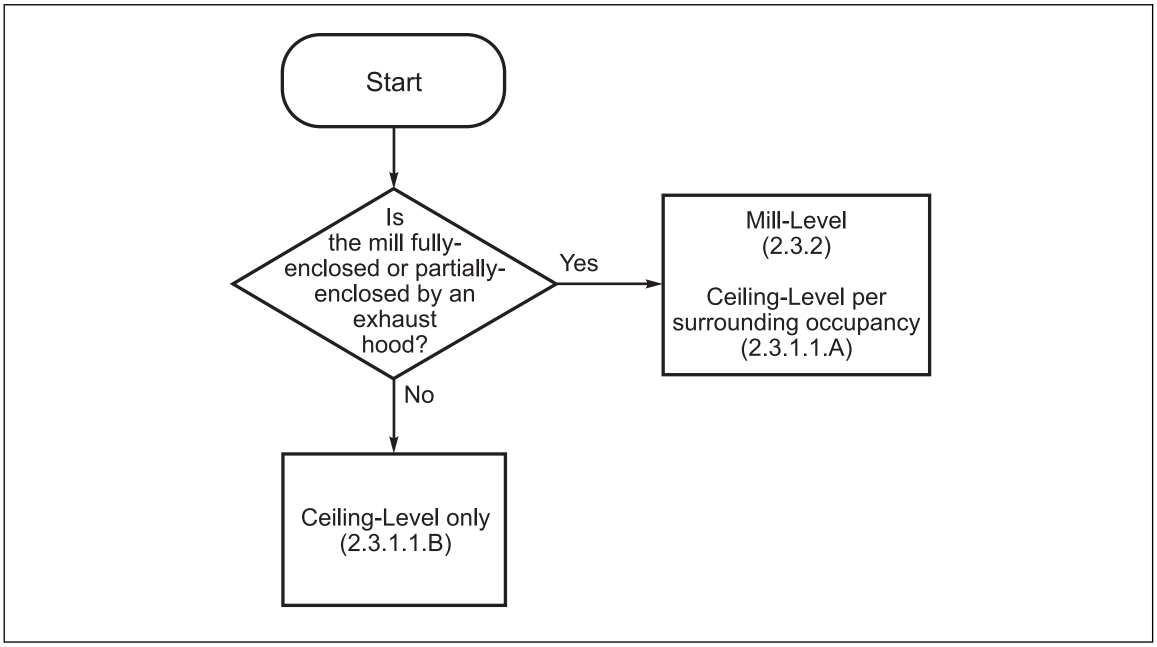


Fig. 2. Flowchart for determining primary fire protection for mills

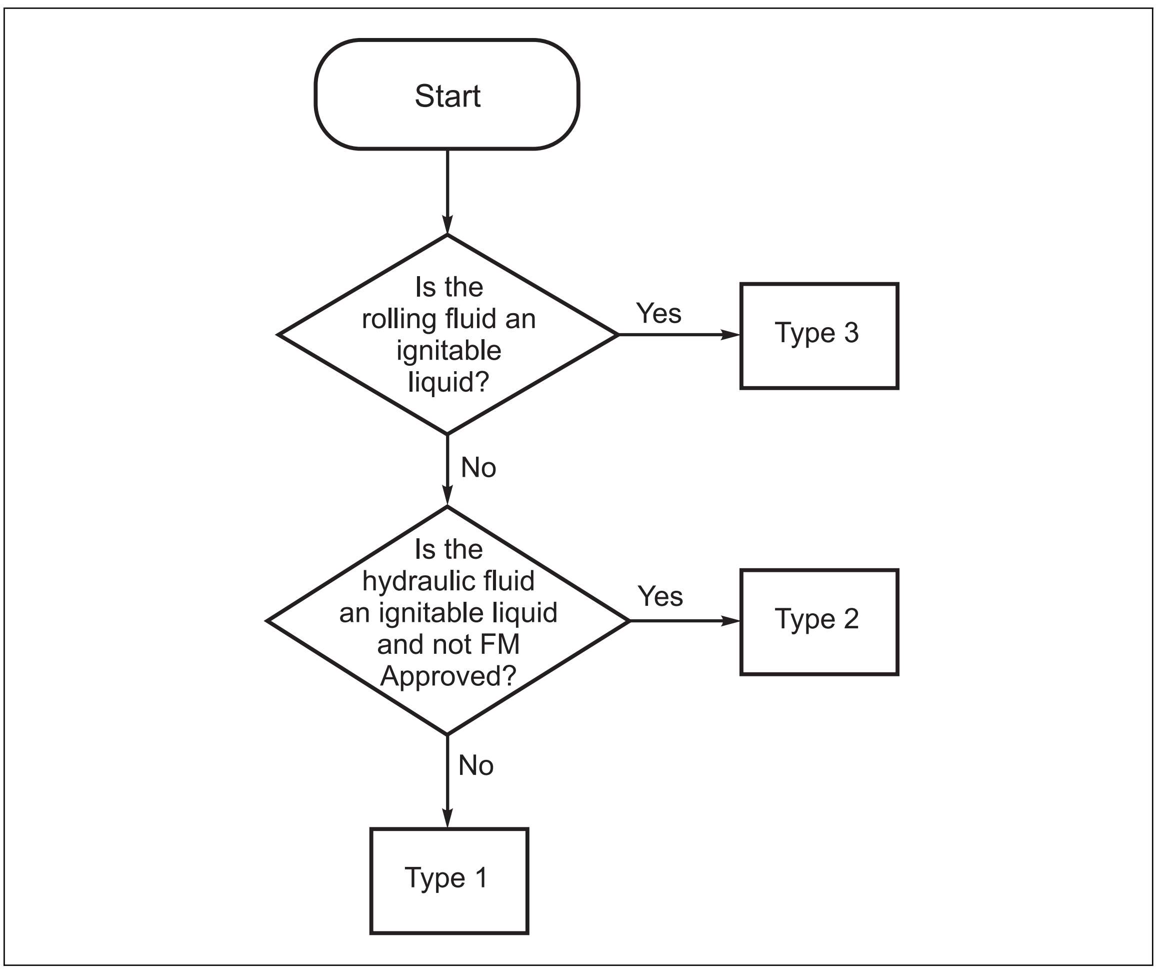


Fig. 3. Flowchart for mill classification (Type 1, 2, or 3)

2.3.2 Mill-Level Protection

2.3.2.1 Provide mill-level automatic deluge protection when the mill is fully-enclosed or partially enclosed under an exhaust ventilation hood as discussed in Figure 2 (note: exhaust ventilation is required for all Type 3 mills). Design and install the automatic deluge system protection in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*, and the following recommendations:

A. Design the deluge system to deliver a density of 0.3 gpm/ft^2 (12 mm/min) over the entire protected area.

B. Install discharge nozzles around the mill proper as follows (refer to Figure 4 and Figure 5 for guidance on deluge nozzle locations:

1. Atop stands on tending/operating and drive sides with coverage outside the stands, and within the roll stack covering the inside of the stands and rolls both above and below the pass line

2. At coiler and recoiler above and below the pass line

3. Above hydraulic cylinders

4. Above roll bearings

5. Under exhaust hood/enclosure

6. Above pits, pipe channels, tunnels, or collection pans extending from the mill where ignitable liquid may collect or combustible deposits may form

7. Above any local ignitable liquid supply located within the mill footprint or immediately adjacent to the mill (i.e., hydraulic fluid or lubricating oil systems)

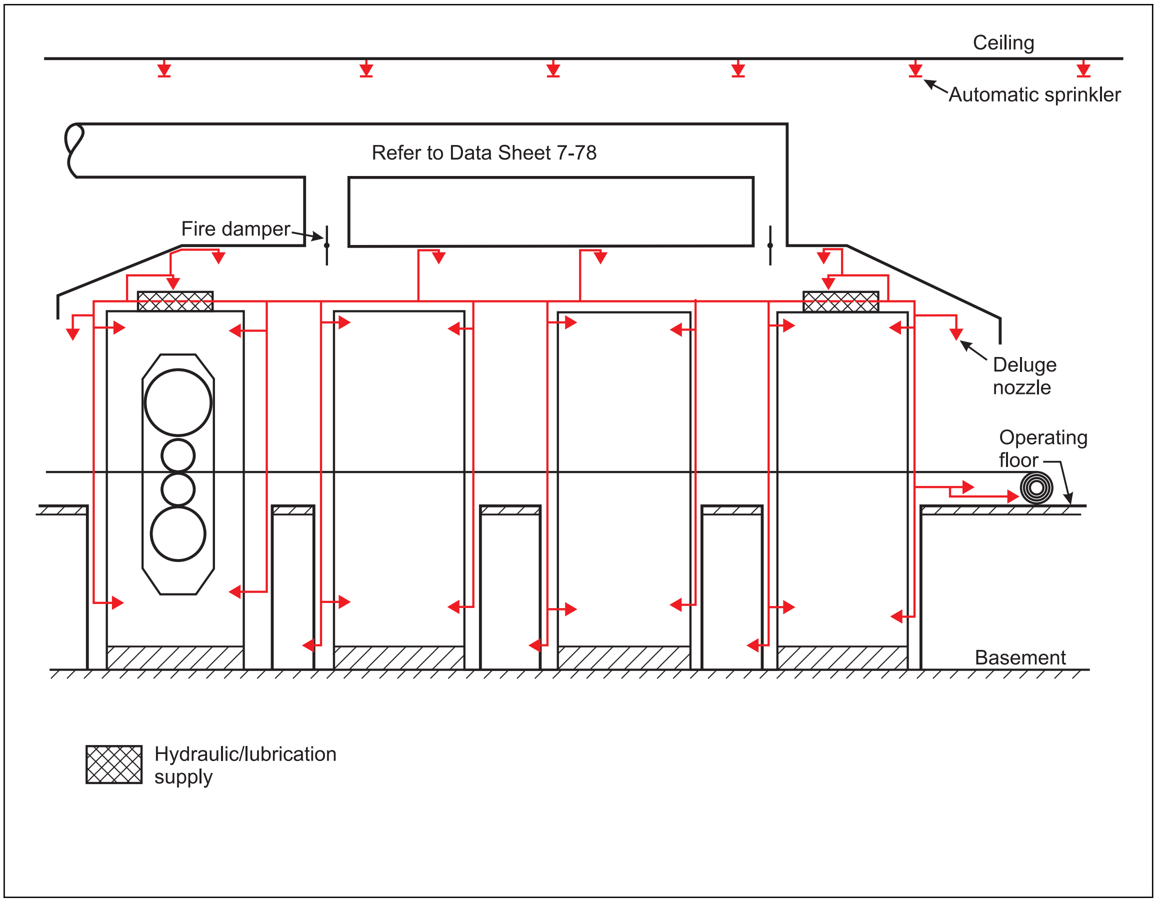


Fig. 4. Mill-level fire protection layout: machine direction

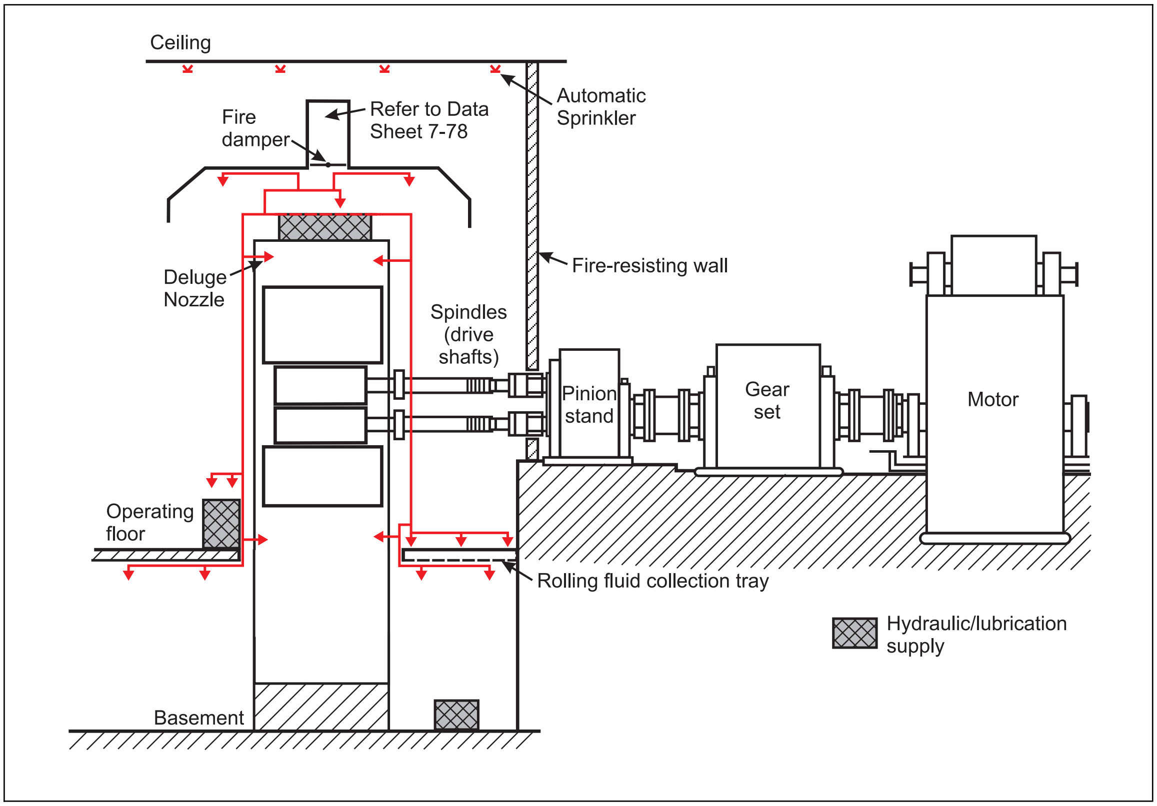


Fig. 5. Mill-Level fire protection layout: cross machine direction

C. When deluge nozzles are used to protect vertical mill surfaces, use the area of the vertical plan being protected to determine the necessary water discharge, and nozzle spacing and coverage requirements.

D. Refer to Data Sheet 7-78, *Industrial Exhaust Systems*, for guidance on protecting exhaust ventilation ductwork and downstream emission control equipment.

E. Provide blow-off caps for deluge nozzles to prevent ingress of solid material or oil that could plug the nozzles.

F. Actuate the deluge system automatically using a crossed-zone fire detection system designed and installed per Data Sheet 5-48, *Automatic Fire Detection*. Use FM Approved fire detectors listed for use with the deluge control panel and automatic deluge valve. Fire detection options may include optical fire, spot heat, and linear heat detectors.

G. Provide at least one manual actuating device (i.e., switch) for the deluge system. Ensure the manual actuation device is installed in a remote location that will remain accessible under the anticipated fire conditions. Provide appropriate labeling for the switch to facilitate identification and use. Preferably, position the actuating switch within the egress path of operators or where the fire service is likely to enter the building.

H. Design mill-level protection for simultaneous operation with ceiling-level protection. Balance the hydraulic demands of both systems at the point of connection.

I. Include a hose stream allowance of 500 gpm (1,900 L/min) in the hydraulic design.

J. Provide a fire protection system activation alarm in the mill control room, and at a remote, constantly attended station (e.g., boiler house or guard house, or offsite alarm monitoring station).

2.3.3 Supplementary Mill-Level Protection

2.3.3.1 When an ignitable rolling fluid is used, provide a total flooding (fully-enclosed) or local application carbon dioxide system (exhaust hood) as supplementary protection for the mill to reduce the frequency of a large mill fire and primary fire protection activation. Design and install the carbon dioxide system in accordance with Data Sheet 4-11N, *Carbon Dioxide Extinguishing Systems*, and the following recommendations.

A. Install carbon dioxide discharge nozzles protecting mill areas discussed in Section 2.3.2.1.B.

B. Design the carbon dioxide system for multiple discharges. For high-pressure carbon dioxide systems, design for at least two separate discharges (i.e., double shot with primary and reserve). Size each cylinder bank for the required capacity and, if a local application system, add an additional 40% for shot. For a low-pressure carbon dioxide system, design for at least three full discharges over the most severe hazard or group of hazards simultaneously, plus an extra 10% tank allowance for lost agent.

C. Actuate the carbon dioxide discharge automatically using fire detectors designed and installed in accordance with Data Sheet 5-48, *Automatic Fire Detection*. Arrange the supplementary carbon dioxide system to actuate prior to primary protection (i.e., water-based protection system). Provide a dedicated fire detection zone for each fire area determined by evaluating combustible loading and the likelihood of fire spread between different equipment areas. For example, the zones protecting the roll stack, the mill stand apart from roll stack, the rolling fluid collecting pan/pit, and the hoods plus ducts at least up to the fire damper should discharge simultaneously.

D. Provide at least one manual actuating device (i.e., switch) for the carbon dioxide system. Ensure the manual actuation device is installed in a remote location that will remain accessible under anticipated fire conditions. Provide appropriate labeling for the switch to facilitate identification and use. Preferably, position the actuating switch within the egress path of operators or where the fire service is likely to enter the building.

E. Provide a fire protection system activation alarm in the mill control room, and at a remote, constantly attended location (e.g., boiler house or guard house, or offsite alarm monitoring station).

2.3.3.2 When an ignitable rolling fluid is used, consider providing a local carbon dioxide system at roll bites (i.e., spurt system) as a means of ignition source control where incendiary sparks may occur during normal operations. Design and install the local application system in accordance with Data Sheet 4-11N, *Caron Dioxide Extinguishing Systems*, and the following recommendations.

A. Design the local application carbon dioxide system for a minimum 30 second discharge.

B. Actuate the local application carbon dioxide system automatically using a fire detection system designed and installed per Data Sheet 5-48, *Automatic Fire Detection*. Use FM Approved fire detectors listed for use with the carbon dioxide system.

C. Provide a fire protection system activation alarm in the mill control room.

2.3.4 Manual Firefighting

2.3.4.1 Provide 1.5 in. (38 mm) nominal diameter or larger hose valves spaced to allow coverage around any one point of the mill by at least two separate hose valves. Locate hose valves in areas that will remain safely accessible under anticipated fire conditions.

2.3.4.2 Provide portable fire extinguishers around the mill proper in readily-accessible locations. Use fire extinguishers compatible with the fire hazards present (e.g., combustible deposits/residues or ignitable liquids).

2.4 Equipment and Processes

2.4.1 Provide an exhaust ventilation system over mills that use an ignitable rolling fluid in order to control flammable mist and vapor. Consider installing an exhaust ventilation over mills using an emulsion or other rolling fluid that, if dried, forms a combustible deposit/residue. Design and install the ventilation system in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*.

2.4.2 Use noncombustible materials in the construction of support systems, such as exhaust ventilation ductwork, and emission control devices, such as scrubbers. If combustible or plastic materials are necessary, use FM Approved materials installed in accordance with the manufacturer's guidelines and their FM Approval listing.

2.4.3 Provide fire dampers in the mill exhaust ventilation system designed and installed per the following:

A. Install a fire damper at the inlet to the mill exhaust ventilation system. When multiple mill hoods are present, install one damper at each exhaust hood inlet.

B. Install a fire damper at the entrance to any downstream emissions control equipment (e.g., filters).

C. Arrange the fire dampers to close upon local fire detection upstream of the damper (e.g., heat-actuated device such as a fusible link) and per Section 2.4.5.

D. Install fail-safe dampers that are energized to open, and de-energized to close.

E. Design ductwork and emissions control equipment to withstand vacuum created by induced draft fan operation, or protect against the vacuum created while fans spin-down with closed dampers.

2.4.4 Arrange ignitable rolling fluid returning from the mill (to the supply) to divert to a remote impound pit or reservoir upon actuation of primary fire protection systems (i.e., ceiling sprinklers or mill-level protection). The divert system is intended to prevent the fluid return containing fire water from contaminating the rolling fluid supply, but also not allow ignitable rolling fluid to accumulate within the mill during a fire. Provide the appropriate fire protection over the emergency drainage pit or reservoir.

2.4.5 Provide an interlock to automatically shut down the mill upon activation of fire detection at the mill and/or within support equipment rooms/areas (i.e., rooms containing rolling fluid, hydraulic fluid, or lubricating oil supplies). Initiate the trip upon activation of a primary fire protection system, or an independent fire detection circuit or system. Complete the following actions as part of the sequential, controlled shutdown of the mill:

A. Depressurize ignitable rolling fluid, ignitable hydraulic fluid, and lubricating oil systems promptly. If ignitable liquid systems serve multiple mills, arrange the mills for independent operation. When using remotely-operated emergency safety shutoff valves, do the following, as applicable:

1. Design valves to fail-safe.

2. Locate valves outside but in proximity to the expected fire area in order to protect the valve against thermal damage and limit ignitable liquid holdup.

B. Close emergency fire-safe shutoff valves on the bottom of an ignitable liquid tank/reservoir or liquid filters (e.g., rolling fluid) during a fire.

C. Shut down applicable mill exhaust ventilation fans and close fire dampers.

D. Arrange the ignitable rolling fluid return to divert to a remote emergency drainage pit or reservoir.

Note: Consider initiating several of the above actions upon activation of a supplementary fire protection system (e.g., isolation and depressurization of ignitable rolling fluid supply bringing the mill into a hot standby mode).

2.4.6 Provide at least one emergency shutdown switch for operator or fire service response during a mill fire. Arrange the emergency shutdown switch to perform the interlock trip functionality discussed in Section 2.4.5. Locate the switch in a remote location that will remain accessible under the anticipated fire conditions. Provide appropriate labeling for the switch to facilitate identification and use. Preferably, position the emergency shutdown switch within the egress path of operators or where the fire service is likely to enter the building.

2.4.7 Provide process interlocks requiring primary fire protection system(s) to be in-service (active) in order to start and continue operating the mill (i.e., start permissive and corrective trip). Consider expanding the interlock to include any supplementary fire protection systems as well.

2.4.8 Provide process alarms and interlocks for abnormal operating conditions. Pertinent alarm and interlock conditions are mill dependent, but may include the following parameters:

A. Excessive mill housing strain.

B. Inappropriate gap setting for a given pass.

C. Inappropriate roll rotational direction and speed for a given pass.

D. Inappropriate position of side guides, entry tables and edger rolls.

E. Low circulating lubricating oil pressure or flow, or high oil temperature.

F. High motor temperature.

2.4.9 Provide a mill stand safety device or interlock to limit overload damage to the mill stand and the associated high torque transmitted to interconnected drive equipment.

2.4.10 Use flexible connections and hoses comprised of metallic construction with a braided steel cover (e.g., convoluted or corrugated metal hoses) at ignitable liquid use points such as connections to hydraulic cylinders or roll bearings.

2.4.11 Route and construct ignitable liquid transfer piping extending from an ignitable liquid supply to mill use-points in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*. Construct piping using materials of high resistance to mechanical impact and thermal stresses from an exposing fire (e.g., steel).

2.4.12 When an ignitable rolling fluid is used, arrange the rolling fluid filtration system to prohibit being opened if the filter inlet valve is open in order to prevent a pressurized fluid release.

2.4.13 When an ignitable rolling fluid is used, install electrical equipment rated for use in classified/hazardous electrical areas determined using Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*.

2.4.14 When large electric motors are located on or near the mill, use a totally enclosed fan-cooled electric motors.

2.4.15 Design and install de-scale accumulator tanks per the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* or comparable local jurisdictional requirements.

2.5 Operation and Maintenance

2.5.1 Operations

2.5.1.1 Train mill operators on standard and emergency operating procedures in accordance with Data Sheet 10-8, *Operators*. Include the following topics in the operator training:

A. Refresher training that may include what-if scenarios derived from emergency operating procedures and the fire emergency response plan.

B. Operation, location, and emergency shutdown procedures for rolling fluid, hydraulic, and lubricating systems that contain ignitable liquid.

2.5.2 Implement a fire emergency response plan in accordance with Data Sheet 10-1, *Pre-Incident Planning.* Involve mill operators and maintenance personnel in the development of the response plan and include the emergency response team members. Document the response plan and audit it at least annually (e.g., review the plan to ensure it was updated to address facility changes, which may include physical or personnel changes). Include the following topics in the fire emergency response plan and emergency response team training:

A. Overview of the combustible, ignitable, and flammable materials present at the mill

B. Location and functionality of the mill emergency shutdown switch(s)

C. Alternate manual shutdown procedures for the mill (i.e., location of switchgear to isolate electrical power)

D. Verification of ignitable liquid system depressurization or isolation

E. Fire protection system operation

F. Location and procedures for manually actuating the fire protection systems

G. Verification of fire protection system actuation

H. Procedures for isolating fuel supplies to fuel-fired equipment in the mill

I. Fire service pre-plan

2.5.3 Conduct housekeeping inspections for combustible deposits/residues on the mill area, and remove combustible deposits to minimize combustible loading.

A. Inspect the mill, support system equipment, exhaust system, below-grade spaces, and surrounding mill areas at least quarterly; adjust the inspection frequency based on the rate of deposit accumulation documented in previous housekeeping inspections.

B. Remove deposits when accumulations reach a predetermined threshold accounting for deposit thickness and area. Use non-ignitable cleaning agents, such as steam, hot water, or dry-ice (carbon dioxide), to remove deposits.

C. Document housekeeping inspections and cleanings, which may include a description of the extent of accumulations and removal methods.

2.5.4 Test fire interlocks and manual emergency shutdown switches at least annually. Confirm proper position of safety devices prior to and following the trip (e.g., isolation valve position was open in normal operation, then closed after the interlock trip actuation).

2.5.5 Test process alarms and interlocks discussed in Sections 2.4.8 and 2.4.9 at least annually.

2.5.6 Implement a hot work permit system in accordance with Data Sheet 10-3, *Hot Work Management*. Hot work is a leading cause of mill fires. Common scenarios involve clearing cobbles or breaks while in hot standby, or poor recognition of combustibles during planned maintenance outages.

2.5.7 Establish standard (SOP) and emergency (EOP) operating procedures for mill operations as defined by the original equipment manufacturer (OEM) and/or qualified third-party. Define the mill integrity operating windows within the procedures that may include minimum work piece temperature (hot mill), thickness reduction limits for given material and pass, roll speed and direction, circulating lubrication oil operating parameters, and acceptable motor current and temperatures. Also, include actions to be taken when evaluating a mill trip on a safety device or system, including root cause analysis; and provide clear communications distributed to key personnel.

2.5.8 Develop an operator training program in accordance with Data Sheet 10-8, *Operators*. Include refresher training in the program. Train operators on mill SOPs and EOPs.

2.5.9 Establish and implement an asset integrity program for mill stands and utility services and support systems involved with milling operations in accordance with Data Sheet 9-0, *Asset Integrity*. Key elements of the asset integrity program include inspection, testing and maintenance; condition and performance monitoring; unscheduled maintenance following a mill upset condition (e.g., overload), and deficiency management; and conduct remaining useful life assessment of mill equipment where required, which should include replacement plans when equipment nears or surpasses established thresholds.

2.5.10 Conduct walkdowns of the mill at least weekly or during the next available maintenance or production outage cycle. At a minimum, inspect the following during the walkdowns: accessible portions of mill housings and their foundation, gap control system components, and drive system components.

2.5.11 Establish and implement a nondestructive examination (NDE) program for the mill housings in accordance with the original equipment manufacturer and Sections 2.5.11.1 and 2.5.11.2. Ensure mill housings are sufficiently cleaned prior to examination. Document examination results along with any recommendations for corrective action. At a minimum, include the items below in the mill housing examination program.

2.5.11.1 Conduct visual inspection of accessible portions of mill housings and their foundations after the first year of operation and at least every three years thereafter. For inaccessible portions of the mill housing, identify opportunities to conduct visual inspections (e.g., during partial or complete dismantling for mill maintenance or upgrades). Document inspection results along with any corrective actions. If damage is suspected or discovered, conduct additional examinations using appropriate NDE techniques.

2.5.11.2 For older cast housings or housings that are no longer supported by the OEM, conduct additional examinations for surface and/or subsurface defects or indications of such in accessible, high-stress portions of the mill housings starting at a minimum of every five years (i.e., in addition to visual inspections in Section 2.5.10.1). Adjust the examination frequency and scope based on results and site-specific factors. For inaccessible, high-stress portions of the mill housing, identify opportunities to conduct additional examinations, such as during a partial or complete dismantling for maintenance or upgrade. Preferably, leverage a finite-element analysis (FEA) to identify high stress portions of mill housings. Document examination results along with any corrective actions.

2.5.12 Establish and implement a vibration monitoring program for mill stand equipment and mill drive components. When conducting spot vibration surveys (rather than continuous monitoring), conduct a baseline vibration survey. Conduct follow-up surveys at least quarterly (ideally under consistent mill loading and operating conditions) to reduce the influence of mill and plant noise. Adjust the monitoring survey frequency and scope-based survey results and site-specific conditions. Document survey results along with any corrective actions.

2.5.13 When present, conduct evaluations within descale accumulator tanks (a.k.a., bottles) at a minimum of every 5 years. Determine wall thickness in order to assess remaining useful life and examine for indications when damage mechanisms are present (e.g., at the water-air interface).

2.6 Contingency Planning

2.6.1 Equipment Contingency Planning

2.6.1.1 When a mill breakdown results in an unplanned outage to site processes and systems considered key to the continuity of operations, develop and maintain a documented, viable rolling mill 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. Mill equipment with typically long repair or replacement times include the following:

Mill Stand

A. Gap control components such as worm gears for mill screw-downs and hydraulic actuated gap control (HAGC) components.

Mill Drives

B. Spindles (drive shafts), couplings or joints, and reduction gears

C. Motors, DC converters or variable frequency drives, and transformers

Mill Support (upstream, downstream or integrated)

D. Gauge or profile sensors used by the mill control system or for quality control.

E. Edgers, shears and/or coilers.

2.6.1.2 At hot mills, install N+1 redundancy for high-pressure water pumps and accumulator tanks within the descale plant.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Supplemental Information

3.1.1 Ignitable Liquid Hazards at Rolling Mills

3.1.1.1 Lubricating oil is found at mill drive motors, gear boxes, and rolls. The systems vary in oil volume from tens to hundreds of gallons (tens to thousands of liters). Lubricating system operating pressures generally range from 20 to 60 psi (1.4 to 4.1 bar) but occasionally may exceed 100 psi (6.9 bar), while oil flow rates tend to be low, using small diameter supply piping and larger diameter piping for low pressure or gravity return, both presenting more of a pool fire hazard. Lubricating oil supplies may consist of a small console adjacent to the use point or a remote large central supply located in a below-grade space (i.e., oil cellar) for older mills, or in a mill-level cutoff room serving multiple use points. Most lubrication oil systems present a pool fire exposure.

3.1.1.2 Hydraulic systems may be present in various mill operations such as roll balance, backup roll pressure, automatic gauge control, tension rolls, coilers, or coil cars. Similar to lubrication systems, the supplies range in size and location from small local consoles to large remote supplies. System pressures may range from hundreds to thousands of psi (tens to hundreds of bar) presenting primarily a spray fire exposure with the potential for a pool fire once depressurized. Interlock trips to depressurize and/or isolate the hydraulic supply to the mill remain a critical fire protection feature, while larger hydraulic supplies often warrant additional fire protection features.

3.1.1.3 FM Approved industrial fluid used in hydraulic systems is designed and tested to present a less intense spray fire hazard. FM Approved industrial fluids present a minimal spray fire hazard and do not by themselves drive a need for fire protection features. When these fluids are sprayed on a hot surface, a flaring fire can result producing a significantly reduced heat release rate as compared to a similar mineral oil spray fire; however, upon removal of the ignition source, the flaring fire will self-extinguish.

Other “less flammable” hydraulic fluids have been evaluated and tested per various industry or national standards. These fluids are not considered equivalent to FM Approved industrial fluids in terms of the fire hazard they present. The methodologies used in validating these other fluids as “less flammable” are inconsistent and not fully understood. The actual fire hazard that these liquids present is unknown and may sustain a high heat release rate as a spray fire.

When retrofitting a system to use a FM Approved industrial fluid, refer to original equipment manufacturer (OEM) guidance on the compatibility of the Approved fluid with the existing equipment seals, gaskets, and other components in contact with the fluid.

3.1.1.4 Rolling fluids vary depending on the metals processed and operating conditions (e.g., hot or cold mill). In general, hot mills use water or water-based emulsions (oil or animal fat/tallow). Cold steel tandem mills may also use a rolling fluid emulsion. Emulsions are often a mixture of 5%-10% oil or tallow mixed with 90%-95% water, which are not ignitable liquids. However, this does not eliminate the potential to form combustible deposits when the rolling fluid dries on mill equipment or building surfaces. Even water rolling fluids can have trace contamination (e.g., lubrication or hydraulic oil) that when dry will form a combustible deposit/residue.

Cold rolling mills may use a light petroleum-based rolling fluid similar to kerosene. Again, combustible deposit/residues may accumulate on mill equipment and building surfaces. However, the open-handling of ignitable liquid (often low flash point) poses a heightened fire hazard at the mill requiring a hood or enclosure to control flammable mist and vapor, and robust fire protection at the mill consisting of fire detection and protection systems, process interlocks to depressurize or shut down rolling fluid supply to the mills, and thermally-resistant metallic fluid-containing components for rolling fluid, hydraulic fluid, and lubrication oil.

3.1.2 Mill Fire Protection

3.1.2.1 Mills using ignitable rolling fluid may be protected by several different forms of fire protection systems, including a carbon dioxide system at the roll bite, a carbon dioxide total flooding or local application system, and mill-level deluge system. The two carbon dioxide systems are supplemental protection, while the deluge system is primary protection.

The spray application of an ignitable liquid on the work surfaces likely produces in an ignition sensitive, flammable atmosphere in proximity to potential ignition sources such as hot surfaces or sparks (i.e., hot surfaces or sparks generated by misalignment, strip break, or roll bite). Given the higher likelihood of fuel and ignition sources coming together, these operations often warrant additional fire protection to reduce the severity of the ensuing fire. Roll bite protection (i.e., puff or snuffing) at may be used to react quickly to a flash consisting of a small carbon dioxide release actuated based on UV/IR detection. Roll bite protection is considered ignition source control.

A total flooding or large local-application carbon dioxide system may be present in case the fire is not quickly snuffed out by the roll bite. This supplementary protection may be actuated by heat detection and involves a much larger release of carbon dioxide across most of the mill and intercommunicating spaces. This form of protection reduces the frequency of a large, sustained fire.

Mill-level deluge protection is intended to be primary protection to control a large fire not extinguished by the carbon dioxide systems. The deluge systems tend to be more reliable and more effective at fighting larger fires that may be sustained due to a delay in ignitable liquid system shutdown or excessive combustible deposits. Deluge protection is installed to be the last line of defense against an uncontrolled mill fire.

3.1.2.2 As with most ignitable liquid exposures, fire protection at use-points should start with fire interlocks to depressurize and/or isolate the ignitable liquid supply. Depressurizing the release reduces the liquid flow rate from the release point and for high pressure systems the potential to atomize the liquid posing a spray fire. After depressurization, a gravity release of the available liquid hold-up will follow.

As with most complex manufacturing operations and equipment, the ignitable liquid systems are critical components, which often cannot be shutoff immediately upon fire detection as equipment damage may occur. When a fire is detected, a sequential controlled shutdown of the mill should be initiated and completed within a reasonable amount of time. With an ignitable liquid fire, delays in depressurization will often result in a larger, longer duration fire, thus the controlled shutdown should be initiated and executed promptly.

3.1.2.3 At open mills (no hood or enclosure), draft curtains installed around rolling mills are intended to limit the ceiling area containing combustible deposits/residues and not limit sprinkler operation. If the mill uses an ignitable rolling fluid, the mills are often fully or partially enclosed by a hood with exhaust ventilation to control flammable mist and vapor.

3.1.3 Combustible Dust Hazards

At aluminum rolling mills, aluminum chips and turnings generated by scalping ingots or trimming rolled material tend to produce larger, coarse particle with some fines. The larger waste generated by these operations is collected for recycling. Collection systems may be as simple as gravity fed refuse bins, or more complex conveying systems including belt conveyors. These operations may pose a dust explosion hazard if the overall particle distribution is sufficiently small, or aluminum fines separate out from the coarser particulate (e.g., in a dust control system filter).

3.1.4 Controlling Ignition Sources

Many fires involving rolling mills have occurred during maintenance operations. During such operations, carbon dioxide protection is taken out of service due to life safety concerns, yet ignition sources may be present such as hot work (any operation involving open flames or producing heat or sparks) or portable lamps of inappropriate type. A very strictly enforced, well defined Hot Work permit is needed to help minimize such hazards. For all types of mills, but particularly for Type 3, the use of a maintenance work permit, addressing hazards and precautions similar to a hot work permit, is highly encouraged.

Fires during maintenance operations (when the mill and rolling fluid spraying system are out of service) have frequently been caused by cutting and welding operations. Despite all precautions taken prior to authorizing such work, it should be recognized that it is extremely difficult to ensure complete cleaning of deposits in some areas that can be reached by hot metal particles, thus primary mill protection should remain in-service.

3.2 Loss History

3.2.1 Loss Data

3.2.1.1 All Perils

A group of rolling mill losses that occurred over a roughly 25-year period were reviewed. Losses occurred primarily at mills processing either aluminum or steel, while one mill was processing brass. Table 1 contains a breakdown of the losses by initiating peril.

Table 1. Rolling Mill Losses by Initiating Peril

Peril	*No. of Losses*	*Total Gross Loss, US$ Million*
Electrical Breakdown	15	83.14
Ensuing Fire	4	33.06
Fire	59	287.03
Liquid Release	1	0.49
Mechanical Breakdown	18	70.88
Mechanical Impact	2	0.32
Totals	95	441.86

3.2.1.2 Fire

In the larger fire losses, one or more of the following negative factors was present:

A. Inability to promptly depressurize ignitable hydraulic fluid systems.

B. Inability to promptly isolate ignitable rolling fluid.

C. Significant delay or failure of mill-level carbon dioxide system combined with lack of or inadequate primary protection (ceiling-level or mill-level sprinklers or deluge).

Ignition sources for these fires often included hot surfaces/sparks associated with cobbles (steel) and breaks (aluminum), and poorly managed hot work during forced or scheduled outages.

3.2.1.3 Electrical Breakdown

The majority of electrical breakdowns involved mill drive motors and their upstream power supply components (drive, transformer, or switchgear).

3.2.1.4 Mechanical Breakdown

Mechanical breakdowns involved a number of mill drive gears and rolls, as well as coiler stand, coiler gear, crop shears, spindles, screw-down gears and descale pumps.

4.0 REFERENCES

4.1 FM

Data Sheet 1-10, *Interaction of Sprinklers, Smoke and Heat Vents and Draft Curtains*
Data Sheet 1-20, *Protection Against Exterior Fire Exposure*
Data Sheet 1-57, *Plastics in Construction*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*
Data Sheet 4-11N, *Carbon Dioxide Extinguishing Systems*
Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*
Data Sheet 5-4, *Transformers*
Data Sheet 5-17, *Motors and Adjustable Speed Drives*
Data Sheet 5-19, *Switchgear and Circuit Breakers*
Data Sheet 5-31, *Cables and Bus Bars*
Data Sheet 5-32, *Data Centers and Related Facilities*
Data Sheet *5-48, Automatic Fire Detection*
Data Sheet 6-10, *Process Furnaces*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-33, *Molten Metals and Materials*
Data Sheet 7-45, *Instrumentation and Control in Safety Applications*
Data Sheet 7-76, *Combustible Dusts*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-98, *Hydraulic Fluids*
Data Sheet 7-99, *Heat Transfer by Organic and Synthetic Fluids*
Data Sheet 7-104, *Metal Treatment Processes*
Data Sheet 7-110, *Industrial Control Systems*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-1, *Pre-Incident Planning*
Data Sheet 10-3, *Hot Work Management*
Data Sheet 10-8, *Operators*
Data Sheet 13-7, *Gears*
Data Sheet 13-8, *Power Presses*

4.2 Other

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

APPENDIX A GLOSSARY OF TERMS

Cobble stop: A controlled stop on a hot rolling mill.

Continuous mill: The product passes only once through the mill.

Edging mill: The edging mill (or edger) shapes the sides of the slab or rolled-product often using two vertical rolls. The edger rolls and sizes the side face of the slab and breaks loose scale from the edges.

Finishing mill: Takes the rough shape and turns it into a finished hot rolled product. This product can either leave the plant at this stage or continue to be further reduced using cold rolling processes.

FM Approved: Products and services that have satisfied the criteria for Approval by FM Approvals. Refer to the *Approval Guide* for a complete list of products and services that are FM Approved.

Ignitable liquid supply: Tanks/reservoirs, pumps, filtration, and ancillary equipment supporting use-point(s), in this case on the mill, typically containing much more fluid hold-up capacity than the use point(s). Supplies can range in volumetric size from tens of gallons to thousands of gallons of fluid.

Mill stand: A section of the mill housing set(s) of rolls.

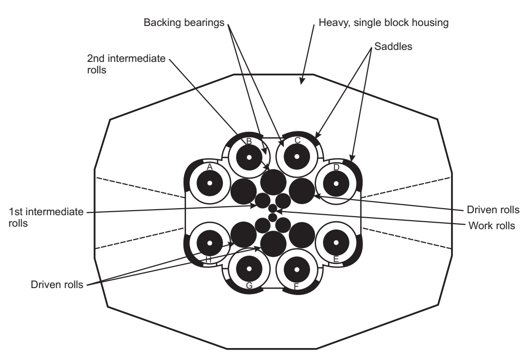
Plate mill: These mills produce plate products. Plate mills can be either universal mills or sheared plate mills (discreet or individual plates).

Primary mill: A mill that handles ingots only.

Reversing mill: The product is passed back and forth through the same mill. Reversing mills can be used to work slabs, heavy plate, or finished products.

Roughing mill: The first operation in the hot milling process. The roughing mill (or rougher) takes the ingot or cast product and further reduces it into the “rough” shape of the product via vertical force. These mills are usually reversing mills.

Sendzimir mill (Z-Mill): A cold rolling mill used in the processing of specialty metals such as stainless steel, silicon steel, titanium, zirconium and beryllium. The rolls on a Z-mill are arranged in a cluster as shown in Figure 6. Z-mills can be arranged to be single pass or reversing mills.



PRINCIPLE OF ROLL ARRANGEMENT AND SUPPORT IN A SENDZIMIR MILL

Fig. 6. Sendzimir Mill (Z-Mill)

Steckel mill: Uses two coils of sheet steel to feed the sheet back and forth through the mill, rather than driving it through with the rollers. If a Steckel mill is being used in hot rolling, a furnace is located at each end to help maintain the steel at the desired temperature. There are no furnaces present if the Steckel mill is being used for cold rolling. Steckel mills are commonly used for stainless or acid-resistant grade steel, nickel and cobalt alloys, or titanium alloys.

Strip mill: Produces hot rolled sheet. In general, these mills consist of a reversing rougher and multiple finishing mill stands. Upon exiting the last finishing mill stand, the sheet is wound into coils. A strip mill can also be arranged so the metal passes only one way through the mill. If this arrangement is being used there are normally multiple stands arranged far apart for the metal to pass through. This type of arrangement was very popular in the 1970s.

Types of fluid: The industry classifies mills based on the properties of the fluids used in rolling fluid and hydraulic systems. The following are the mill classifications.

Type 1: Rolling mills using oil-in-water emulsion rolling fluid (i.e., non-ignitable rolling fluid), and either a FM Approved industrial fluid, non-ignitable hydraulic fluid, or no hydraulic systems present.

Type 2: Rolling mills using oil-in-water emulsion rolling fluid (i.e., non-ignitable rolling fluid), and an ignitable hydraulic fluid (e.g., mineral oil).

Type 3: Rolling mills using a petroleum-based ignitable rolling fluid (i.e., high or low flash point) regardless of hydraulic fluid present.

Tandem mill: The metal passes through the mill only one way. As the metal passes from one mill stand to the next, the thickness of the metal is incrementally reduced. The number of stands in a tandem mill can range from 2 to 18. A tandem mill can be used in both hot and cold rolling.

Universal mill: A mill with horizontal and vertical rolls used to shape the metal on multiple axes such as structural mills.

Wreck: A controlled stop on a cold rolling mill.

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).

July 2023. Interim revision. Revised boiler & machinery guidance.

A. Revised mill housing maintenance and mill stand safety devices.

B. Added recommendations for mill operators.

January 2021. Interim revision. Updated contingency planning and sparing guidance.

January 2019. This data sheet has been completely revised. The following major changes were made:

A. Incorporated guidance on aluminum rolling mills from OS 7-64, *Aluminum Smelting*, and expanded the scope to include mills processing any metal.

B. Reorganized the standard in accordance with current OS development guidelines.

C. Revised the guidance on primary mill protection and ignitable liquid interlocks. An automatic carbon dioxide fire protection system with a manually-actuated water-based backup system is no longer an adequate fire protection scheme.

D. Revised ceiling-level and mill-level primary protection design to be consistent with other standards (7-98 and 3-26). The level of protection is contingent upon the type and size of fuel packages present (e.g., ignitable rolling fluid vs. ignitable hydraulic fluid).

E. Added an exception for mill-level only protection (no ceiling-level required).

F. Added supplemental fire protection system guidance for roll bites in mills using ignitable rolling fluid.

G. Consolidated fire protection guidance for ignitable liquid supplies.

H. As part of the asset integrity program, clarified that inspections (NDE) should be conducted on all mill stands regardless of the material being processed.

I. Replaced sparing recommendations with recommendations for equipment contingency planning.

January 2013. This is the first publication of this document.