GLASS MANUFACTURING

Table of Contents

Page

List of Figures

List of Tables

1.0 SCOPE

This data sheet contains property loss prevention guidance unique to glass manufacturing including hot-end operations as well as utility services and support systems associated with hot-end operations. Hot-end operations may include batching, melting/refining, and forming.

Application

For molten glass operations, this data sheet supplements FM Property Loss Prevention Data Sheet 7-33, *Molten Metals and Other Materials*. When not specifically addressed herein, apply the general molten hazard guidance contained in Data Sheet 7-33.

This data sheet focuses on the unique hazards and exposures associated with glass manufacturing. When encountering common hazards and exposures not specifically addressed in this data sheet, apply the relevant data sheet. Examples include the following:

- 5-4, *Transformers*
- 5-19, *Switchgear and Circuit Breakers*
- 5-31, *Cables and Bus Bars*
- 9-0, *Asset Integrity*
- 10-8, *Operators*

Appendix C contains a more comprehensive list of data sheets that may be applicable at glass manufacturing facilities.

1.1 Hazards

1.1.1 Molten Glass Breakout

Regardless of the glass product being produced, breakouts occur from an operating glass furnace due to thinning or glass penetration. Damage mechanisms may include wide-spread wear late in the campaign or corrosion/erosion due to aggressive components in the glass chemistry reducing anticipated campaign life, localized wear at electrodes or bubblers, thermal stresses from poorly controlled temperature swings or elevated operating temperature, temporary interruption of or degrading cooling circuits, poor refractory design or installation practices, or poor refractory quality assurance. Once molten glass passes through the refractory block reaching the fire brick, it becomes a matter of time until the outer brick begins to glow then loses mechanical integrity. Maintenance, operators, and safety devices remain the key factors in preventing a breakout, while containment and steel protection are the critical safeguards for mitigating a breakout.

Released molten glass is likely to damage or destroy anything in sight via thermal radiation and certainly anything the glass touches, which is why breakout containment and steel protection beneath the furnace are so important. Fires have ensued from breakouts, but containment failures, thermal damage to long-lead time equipment, and uncontrolled furnace shutdowns have been the primary negative factors driving long production outages following a breakout.

1.1.2 Equipment Contingency Planning and Service Interruption Planning and Redundancy in Critical Utilities and Support Systems

Although equipment breakdowns or service interruptions in a critical production, utility, and/or support system may not result in direct furnace damage and production downtime, these events have the potential to trigger a glass breakout or uncontrolled cool-down capable of causing significant furnace damage and production downtime. Critical to furnace operations is furnace and forehearth refractory and insulating brick. Critical utilities include natural gas and combustion air/oxygen for fuel-fired furnaces, and electrical power for both fuel-fired and electrically-heated furnaces. Without heat input to the furnace, the tank of molten glass only can maintain furnace temperature for so long before going into an uncontrolled cool-down. In terms of support systems, momentary loss of cooling water or air (wind) has been a key factor in refractory deterioration and glass breakout events.

Loss of utilities and/or and support systems such as these are capable of leading to a breakout or uncontrolled cool-down. A viable equipment contingency plan should be developed to respond to and recover from a sudden equipment failure to limit the exposure from these events. In some critical systems where a matter of minutes may be the difference between a hot-hold verses a breakout or uncontrolled cool-down, installed redundancy should be considered (i.e., high consequence scenarios linked to even short interruptions in service/system). See 2.6.1.

Additionally, a viable service interruption plan should also be developed to respond to loss of critical utilities from off-site or third-party suppliers. Alternative sources with installed infrastructure or on-site emergency supplies should be considered to reduce the exposure of a service interruption leading to an uncontrolled cool-down or glass breakout. See 2.5.9.

1.1.3 Fire Hazards in Forming Operations

Nearly all fires in glass manufacturing have occurred within the forming areas particularly when container or fiberglass is being produced. While most of the glass manufacturing occupancy is noncombustible housed within a noncombustible building, lubricating oil, hydraulic fluid, and release agents and binders and their combustible deposits present sufficient fuel loading to support a large fire within the forming area. Readily available ignition sources such as molten glass (gobs or strands) or broken hot glass increase the likelihood of a fire. When these ignition sources encounter deposits or oil residues, fires start. If not promptly detected and controlled, the fires spread quickly across deposits on equipment and building structures often aided by process ventilation. The fires may spread uncontrolled out of the forming area if secondary fuel packages are present, while if contained within the forming area, damage can still be considerable to forming, and even furnace, power cabling, control wiring, controls, and support systems rendering the subject production line and/or adjacent production line out of service for days to weeks. A combination of housekeeping to manage combustible deposits and automatic fire protection can help limit equipment damage and minimize recovery time following a fire in the forming area.

Poor housekeeping above the forming level on walls, structural members, and ceilings allows for an unprotected fuel package to build over a fire prone area.

1.2 Changes

April 2025. Interim revision. Significant changes include the following:

A. Updated process safety guidance to align with Data Sheet 7-33.

B. Updated guidance on molten equipment cooling system supplies to align with Data Sheet 7-33.

C. Clarified diagrams showing example fire protection nozzle locations.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 Use FM Approved products whenever they are applicable and available, including FM Approved industrial fluids in accordance with Data Sheet 7-33. For a list of FM Approved products, see the *Approval Guide* and/or *RoofNav*, as applicable.

2.1.2 Implement a process safety program for molten glass operations in accordance with FM Global Loss Prevention Data Sheet (DS) 7-33, *Molten Metal and Other Materials*. The program should at a minimum evaluate for and assess the following hazards: molten release with damage to the subject molten equipment as well as thermal damage in the surrounding area and potential for an ensuing fire. It should also include electrical and mechanical breakdown hazards in molten equipment support systems (e.g., cooling systems and heating systems).

2.2 Location and Construction

2.2.1 Locate buildings as well as critical production, utility, or support system equipment in areas not exposed to natural hazards. When unavoidable, refer to relevant data sheet for mitigative solutions. The following natural hazards may expose glass furnaces, while other hazards may be present as well.

- Flood
- Earthquake
- Windstorm including hurricane, typhoon, and cyclone
- Snow loading collapse

- Hail
- Wildland fires

2.2.1.1 When in an earthquake region, design the furnace to resist seismic forces in accordance with Data Sheet 1-2, *Earthquakes* and local codes by an engineer registered to practice structural design in the local jurisdiction.

2.2.2 Construct buildings and process structures using noncombustible building materials. If use of combustible or plastic building materials are unavoidable, use FM Approved building materials. Examples of building construction where FM Approved materials or assemblies are often recommended to address the fire hazard posed by plastic building construction include but are not limited to insulated metal panels installed as a wall or roof assembly, an insulated steel deck roof assembly, and interior plastic wall or ceiling facing such as fiber-reinforced plastic (FRP) panels. Install FM Approved building materials and assemblies in accordance with the manufacturer's guidelines and the FM Approval listing.

2.2.3 For container glass forming operations, install corrugated metal or other smooth-surfaced noncombustible material along roof areas above forming operations extending 20 ft (9 m) beyond where combustible deposits may accumulate. Accumulations are typically found in the cooling wind between forming machines up to the noncombustible roof ventilator over furnace and/or forming machines. A typical roof monitor is shown in Figure 1.

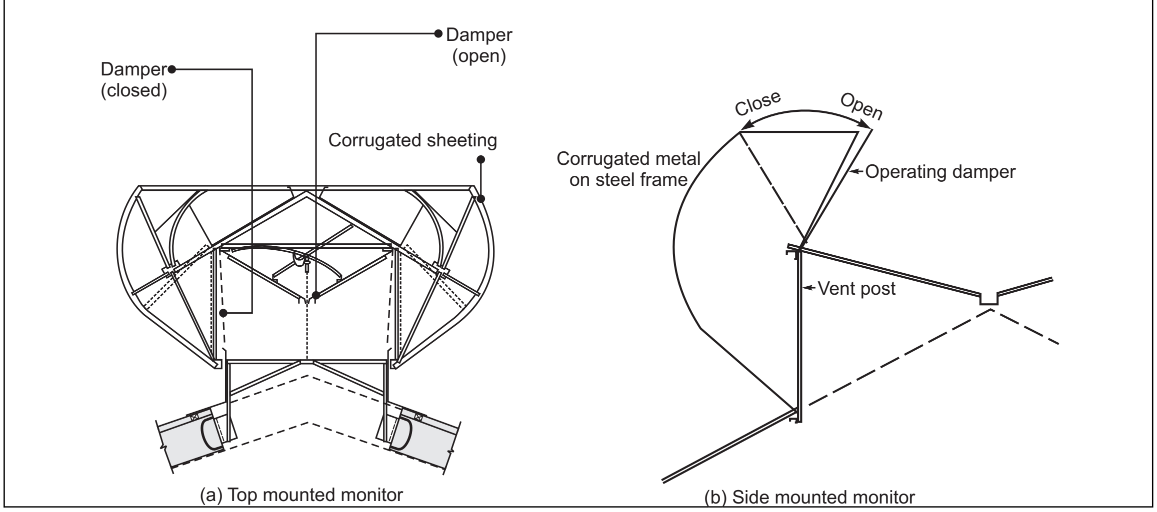

Fig. 1. Example roof monitors (cross section)

2.2.4 For container glass forming operations, provide mezzanines and walkways above forming machines equipment to facilitate housekeeping (i.e., combustible deposit inspection and removal) and firefighting at ceiling-level.

2.2.5 Provide molten breakout containment beneath each melter/furnace in accordance with Data Sheet 7-33 as well as the following:

A. Limit the containment area to a single furnace (i.e., separate containment areas when multiple furnaces are onsite).

B. Size containment to hold the contents of the furnace at operating temperature plus an additional 20% while subtracting the volume of any equipment within the containment area (e.g., furnace exhaust ducts or regenerators constructed of fire brick and refractory).

C. Extend the containment area at least 3 ft (1 m) beyond the footprint of the furnace which includes the throat. Account for ventilation ducts, walkways, or other surfaces that could deflect a molten glass breakout from above outside the containment area.

D. Design containment to be liquid tight.

E. Design containment dike walls to withstand anticipated hydrostatic pressure, velocity pressure, and thermal stress associated with a molten glass breakout. At a minimum, provide a thermal barrier layer over dike wall surfaces expected to be in contact with molten glass such as refractory block or duty brick

F. Prohibit openings within containment dike walls especially hinged openings such as doors.

2.2.6 Provide thermal protection around steel and concrete columns located within the molten breakout containment area in accordance with Data Sheet 7-33 and the following. Design the barrier to the same level of thermal performance as containment dike walls. Extend thermal protection to at least the height of the dike.

2.2.7 Do not locate production critical utility service or support system equipment within the breakout containment area. The intent is to limit the damage to long lead-time equipment and prevent a forced uncontrolled furnace shutdown during a breakout. Examples of production critical systems and equipment may include cooling air motors or blowers, cooling water motors or pumps, and/or critical furnace power cabling or control wiring circuits.

2.3 Protection

2.3.1 For container glass forming operations, provide automatic fire protection for forming areas consisting of the following. Use FM Approved materials, when available.

2.3.1.1 Provide automatic wet sprinkler protection in the basement below the (container) glass forming machine designed and installed as follows.

A. Install automatic sprinklers under the footprint of the forming machine spaced at 6 ft (2.0 m) to 8 ft (2.4 m) When possible, position automatic sprinklers at the ceiling-level gaps between flooring and the machine base. If present, extend protection beyond the machine footprint to cover nearby lubricating and/or hydraulic fluid supply consoles.

B. Position automatic sprinkler thermal elements within 1 in. (25 mm) to 12 in. (300 mm) of the ceiling level.

C. Design automatic sprinkler protection to deliver 0.3 gpm/ft^2 (12 mm/min) using at least a K5.6 (K80) or larger sprinkler rated for quick or standard response with a temperature rating based on the ambient temperature.

D. Provide a manual control valve in the feed main supplying basement sprinklers.

Following a fire, the control valve allows for prompt replacement of fused sprinklers while allowing other fire protection systems to remain in-service.

E. Provide a waterflow alarm in the feed main supplying basement automatic sprinklers to sound at a constantly attended onsite location and perform interlocked functions described in Section 2.4.1.

2.3.1.2 Provide either automatic sprinkler deluge or fixed-water spray protection on the (container glass) forming machine operating level designed and installed as follows:

The intent is to blanket the forming machine in water, including: operating floor from the floor and working space up to the intermediate walkway and drip pan; and walkways above the machine.

A. Install open sprinklers or directional nozzles on the operating floor around the forming machine covering all forming machine and walkway surfaces where deposits may form. Position sprinklers or nozzles in areas limiting their exposure to mechanical impact, while also allowing for riser nipple support leveraging available structural steel. Limit the potential for water spray impinging on forehearths. Example sprinkler and nozzle arrangements are shown in Figures 2 through 7.

1. For deluge applications, space open sprinklers linearly at 7 ft (2.1 m) to 12 ft (3.7 m) with coverage areas of 70 ft^2 (6.5 m^2) to 130 ft^2 (12.1 m^2). Angle open sprinklers, whether sidewall or pendent, to distribute water appropriately. Install piping in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

2. For fixed-water spray applications, arrange and space directional nozzles per the manufacturer's design guidelines and Data Sheet 4-1N, *Fixed Water Spray Systems for Fire Protection*.

When arranging nozzles around the machine, the following factors may influence the design:

- Nozzle characteristics, including K-factor, nozzle spray angle, and spray profile
- Nozzle fixed angle (angle relating nozzle centerline to protected surface)
- Radial offset distance from plane of protection
- Frequent formation of combustible deposits above the machine that are not adequately managed by housekeeping

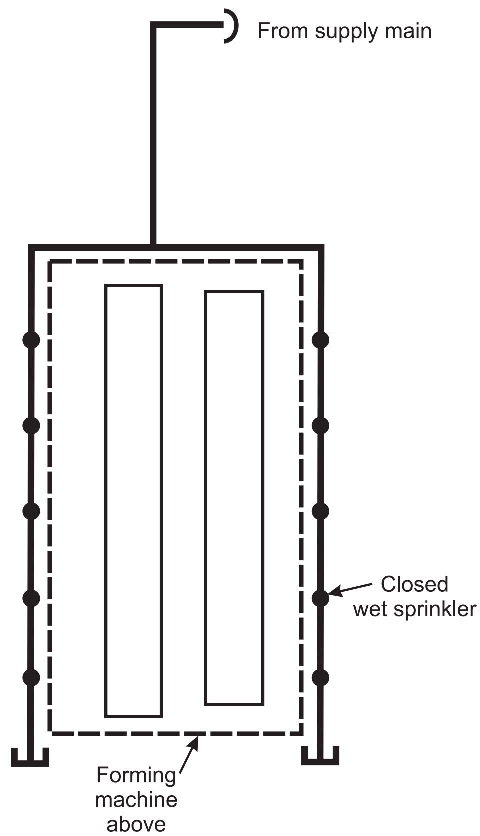

Fig. 2. Example Automatic sprinkler locations in basement (plan view)

B. Design the deluge system or water spray system per the following.

1. Design the deluge sprinkler system to provide 0.30 gpm/ft^2 (12 mm/min) over the protected area with a minimum end head pressure of 7 psi (0.5 bar).

2. Design water spray to provide the equivalent of 0.30 gpm/ft^2 (12 mm/min) over the protected area with a minimum end nozzle pressure of 20 psi (1.4 bar) and in accordance with the manufacturer's design guidance.

C. Provide automatic actuation of the deluge system in accordance with Data Sheet 5-48, *Automatic Fire Detection* and the automatic control valve FM Approval listing. A fire detection option may include linear heat detection positioned within or immediately above combustible deposits. Below are several considerations when selecting the appropriate detection method for a given machine protection application.

Locate linear heat detection within the anticipated fire area in order to function properly, thus will be exposed to process heat, deposits, and housekeeping cleanings. Procedures should be in place to avoid damaging detection when cleaning the machine and appropriately remove deposits on detectors.

As alternative, visual fire detection technology may be the thermal imaging cameras that filter out normal flickers and thermal radiation looking for more indicative flaming combustion.

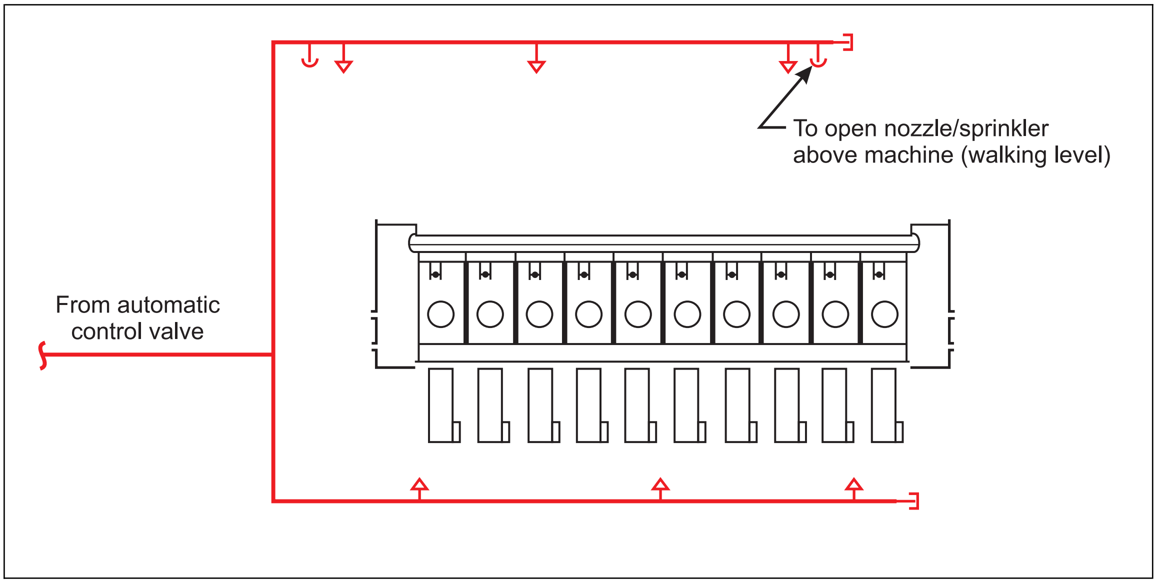

Fig. 3. Example deluge sprinkler/nozzle locations at machine level (plan view)

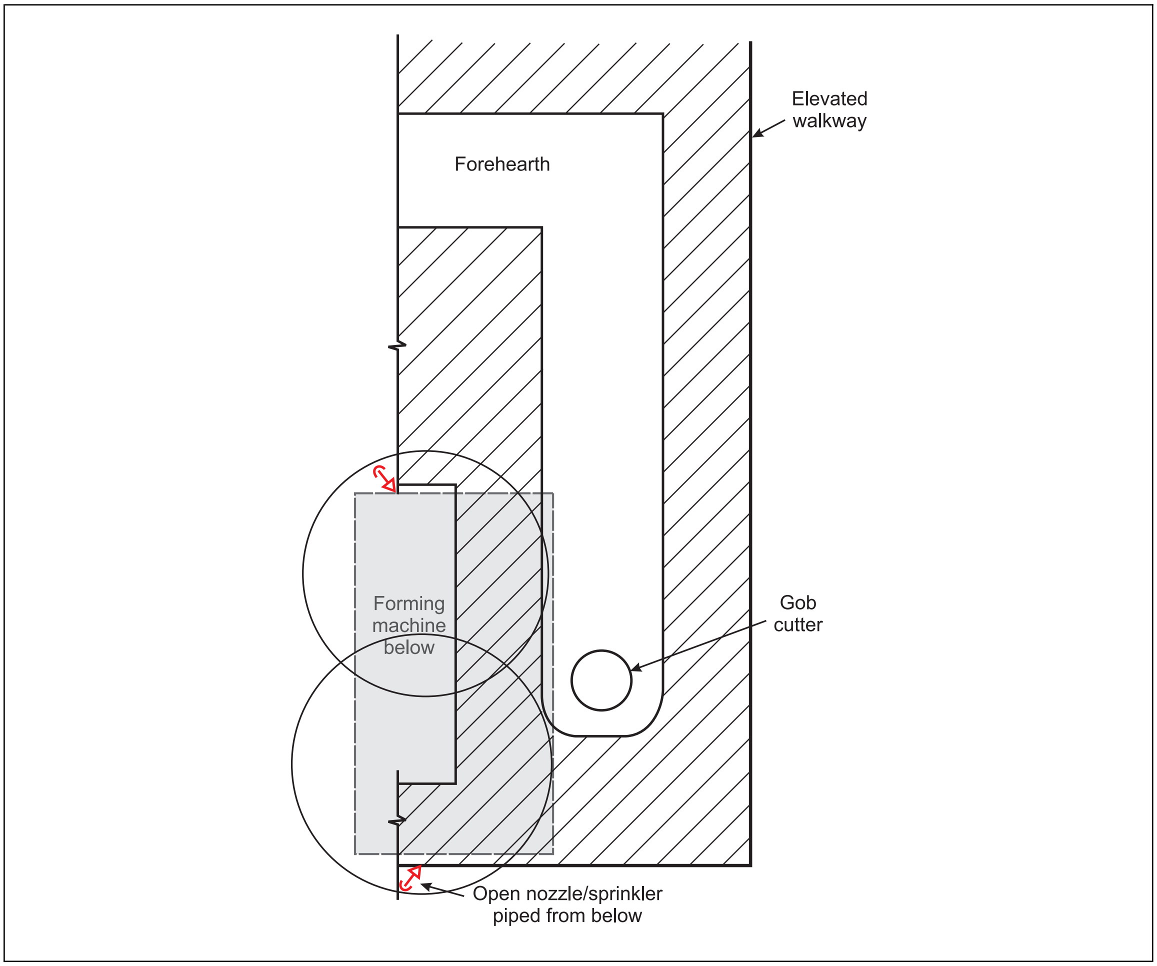

Fig. 4. Example delluge sprinkler/nozzle lodations above the machine (plan view)

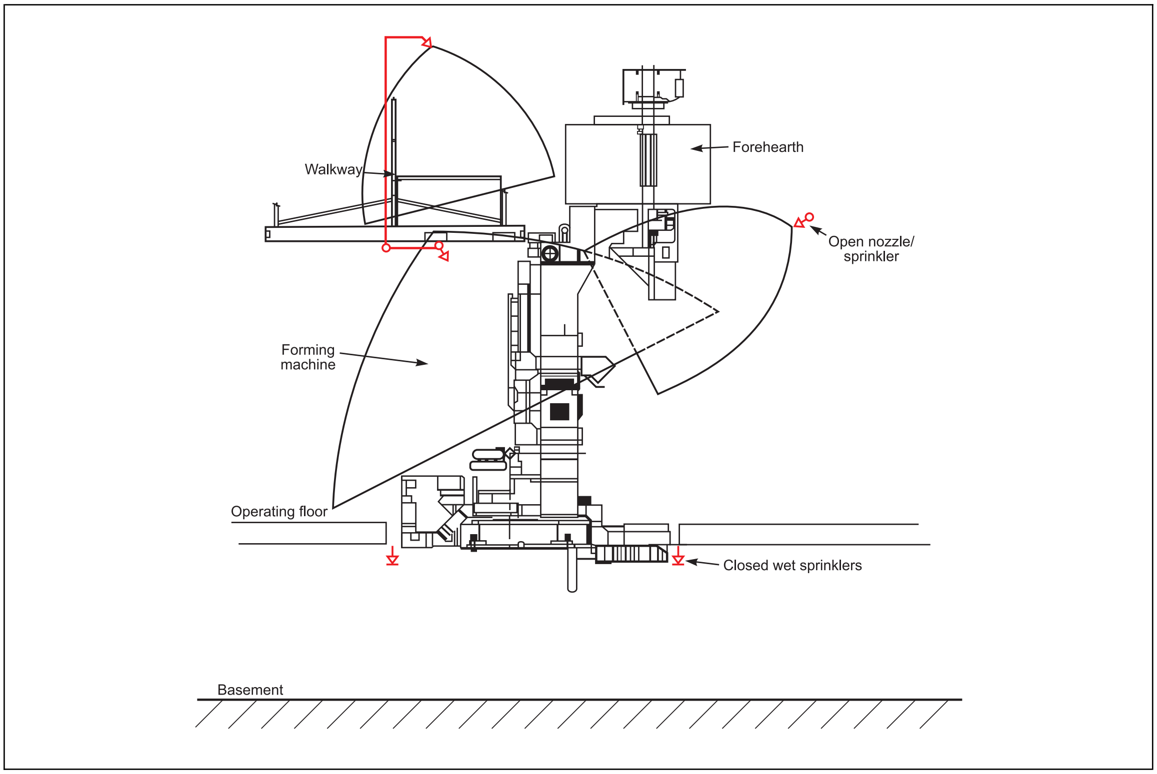

Fig. 5. Example deluge sprinkler/nozzle locations around machine (elevation view 1)

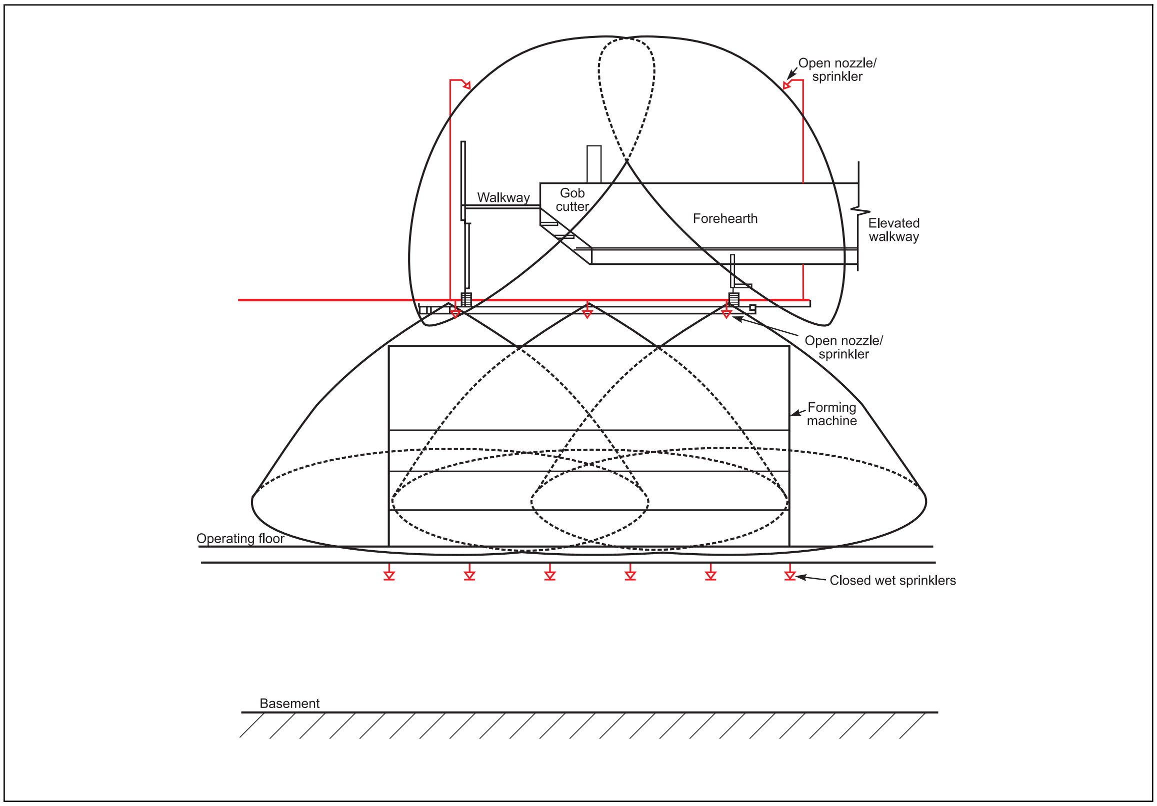

Fig. 6. Example deluge sprinkler/nozzle locations around machine (elevation view 2)

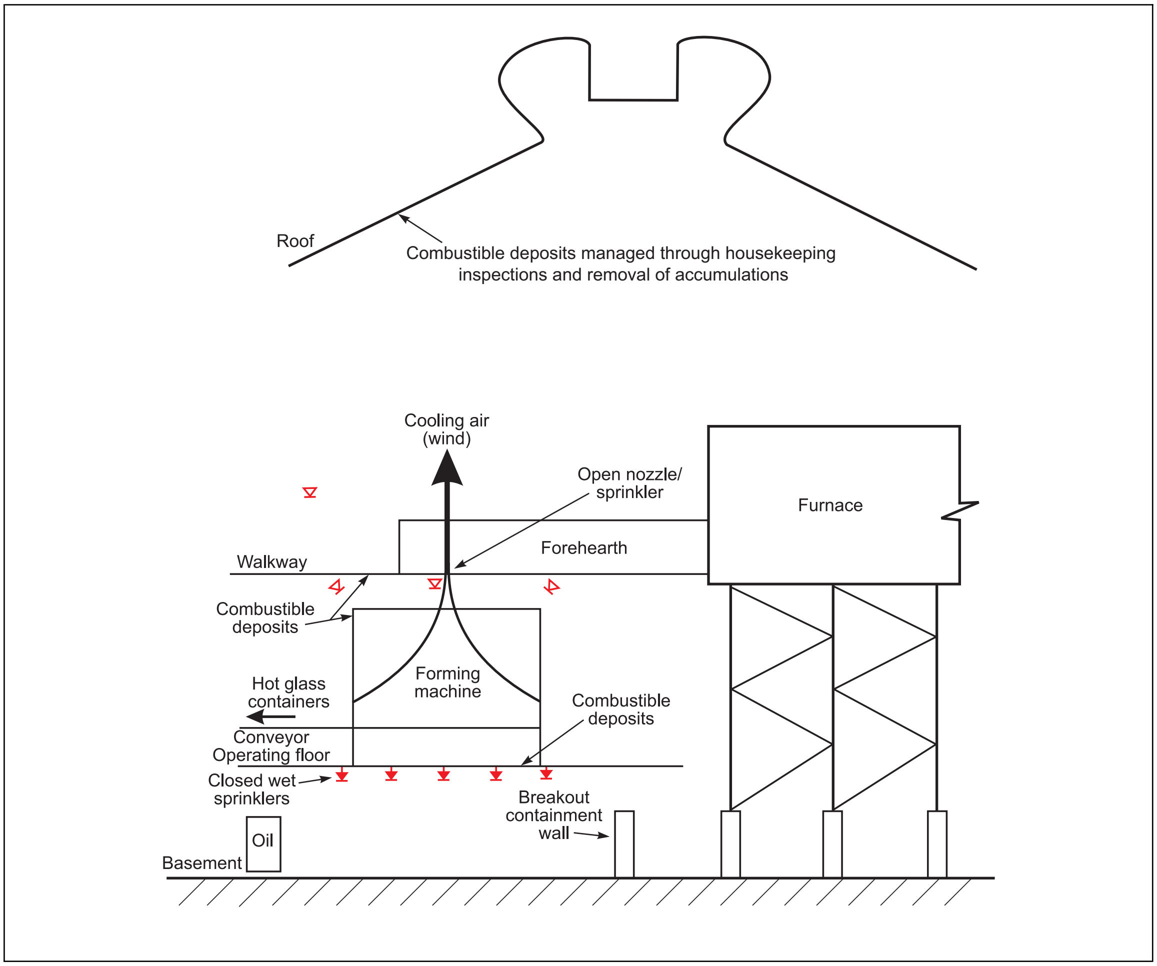

Fig. 7. Overview of fire hazards and fire protection (elevation view)

D. Provide a means to manually actuate the deluge or water spray system from a control room or locally from an area that will remain accessible under anticipated fire conditions.

E. Provide a system trip alarm to sound at a constantly attended onsite location.

F. Provide blow-off plugs or caps on open sprinklers or nozzles to prevent vapor or particulate form entering the system and plugging piping or nozzles.

G. Provide a manual control valve at the base of the system riser.

Following a fire, the control valve allows for prompt isolation of the system while allowing other fire protection systems to remain in-service.

H. Provide a means to trip test the automatic control valve in accordance with Data Sheet 2-81, *Fire Protection System Inspection, Testing, and Maintenance*. One option may be to install a series of manual control valves with an appropriately sized drain-pipe discharging into the basement at a safe location (e.g., one valve in the system riser and another on the drain-pipe which are maintained normally-open and normally-closed, respectively).

2.3.1.3 Hydraulically balance basement and machine protection for simultaneous operation including a 250 gpm (950 L/min) hose stream allowance for a 60 minute duration. When forming machines are located within 25 ft (7.5 m) of each other, consider expanding the hydraulic design operating demand to include the basement and machine protection at fire origin plus machine protection for the adjacent unit (e.g., one basement system plus two machine systems).

2.3.2 For fiberglass forming operations, provide automatic fire protection for forming areas and areas under or adjacent that are prone to combustible accumulations (e.g., spinners, winders, etc.). When combustible deposits are present, refer to Section 2.3.1 for guidance on fixed-water spray or deluge sprinkler protection at the formers, and sprinklers in the surrounding areas (e.g., basements).

2.3.3 Provide a manual firefighting system throughout hot-end operations as specified in any scenarios developed to assess the molten glass breakout or fire hazards (e.g., identified through a hazard assessment), and/or specified in emergency response procedures. Include the following in the system design.

A. Ensure all areas around the furnace and forming machines are accessible from at least two directions (two different stations). Distribute hose stations and equipment within the hot-end to provide access: beneath the furnace (fire and breakout); and within forming areas including below forming level and above forming at the forehearth level (fire).

B. Install hose stations that are a minimum 1-1/2 in. (38 mm) diameter or larger.

C. At each hose station, furnish the necessary length of hose and hose nozzles (both stream and fog). Consider installing permanent oscillating monitor stations at select locations to facilitate a faster response with more water.

D. Include water lances and torpedoes in at least one location for responding to a furnace leak (molten glass) as required by the emergency response procedure.

2.3.4 Provide portable fire extinguishers as recommended in Data Sheet 4-5, *Portable Extinguishers*. A 300 lb (136 kg) capacity wheeled dry-chemical fire extinguisher should be supplied for each furnace supplying forming machines that use combustible release agents.

2.3.5 Provide automatic fire detection in accordance with Data Sheet 5-19, *Switchgear and Circuit Breakers* within critical electrical substations and MCC rooms, that if the equipment within were damaged due to an electrical failure and cable fire, may result in an uncontrolled furnace shut down. Where the potential exists for an ensuing fire involving grouped cables or oil-filled circuit breakers, provide automatic fire protection in accordance with Data Sheet 5-19 and Data Sheet 5-31.

2.3.6 Where the furnace cannot be fired manually by operators, provide automatic fire protection within control equipment rooms and operator control rooms in accordance with Data Sheet 7-110, *Industrial Control Systems*.

2.4 Equipment and Processes

2.4.1 For container and fiberglass forming, provide automatic interlocks to initiate a controlled shutdown of forming operations upon fire protection system actuation and/or independent automatic fire detection. Interlock functions to include the following.

A. Depressurize or isolate any support systems using ignitable liquids such as lubricating oil, hydraulic fluid, binder, or release agent

B. Shutdown cooling air (wind)

C. Shutdown area conveyors

D. Molten glass divert to safe location

2.4.2 Provide a means to manually initiate interlocks per Section 2.4.1. Locate the initiating device (e.g., switch) where it will remain accessible under anticipated fire conditions.

2.4.3 Provide redundancy in the primary cooling supplies serving the molten glass equipment in accordance with Data Sheet 7-33 where loss of cooling can result in refractory damage or molten release.

2.4.4 Provide an emergency cooling water supply independent of the primary cooling water supply in accordance with Data Sheet 7-33.

2.4.5 Arrange the emergency cooling water supply piping to connect as close as practical to the water-cooled molten equipment in accordance with Data Sheet 7-33.

2.4.6 Provide onsite emergency electrical power generation capable of supporting a furnace hot-hold or controlled furnace shutdown during a service interruption (i.e., loss of utility electrical power).

2.4.7 Provide a refractory monitoring system with sensors embedded at various depths in high-risk refractory areas. Concentrate monitoring in high wear areas, which may differ based on furnace design and operating conditions. Design and install the temperature monitoring system for continuous monitoring with data capture for trending in accordance with the OEM. Though different in every furnace, common high wear areas include the throat, and near electrodes or bubblers. Arrange temperature monitoring to signal an alarm in a constantly attended location at an established threshold (e.g., 100°F or 38°C above the normal operating temperature).

2.4.8 Provide remote monitoring of furnace cooling systems used to cool refractory, electrodes, or other furnace equipment. Monitor systems for an upset condition (e.g., low/no flow or pressure, or high temperature on return) rather than blower or pump running.

Position monitoring devices in close proximity to the furnace supply or return connections. Arrange monitoring systems to signal an alarm in a constantly attended location onsite when outside the integrity operating window, and automatically start back-up system capacity to address the upset condition.

2.4.9 Provide furnace burners with fuel-fired combustion controls and safety devices in accordance with Data Sheet 6-10, *Process Furnaces*.

2.4.10 For electrical loads that can't be interrupted during the furnace campaign, provide a means to isolate the equipment allowing for periodic inspection, testing, and maintenance. For example, provide double-ended feeds with normally open tie-breakers.

2.4.11 For fiberglass, provide a thermographic monitoring system to detect globules of molten glass within fiberglass products downstream of forming operations. Arrange detection to signal an alarm in a constantly attended location.

2.4.12 When hydraulic systems are utilized in hot-end operations in proximity to molten glass or hot glass, use FM Approved fluids in the hydraulic system in accordance with the *Approval Guide* listing.

2.5 Operation and Maintenance

2.5.1 Implement a housekeeping program to maintain the breakout containment area free of unnecessary combustibles and/or ignitable liquids. Inspect for combustibles or ignitable liquids at least weekly and document inspection findings including corrective actions taken for review by management.

2.5.2 Implement a housekeeping program to monitor for and remove combustible deposits in forming areas. Include the following within the program.

A. Inspect forming machines, levels below, and ceilings/roofs above prone to accumulating combustible deposits from release agents (container), binders (fiberglass), or hydraulic or lubricating oil residues. Document inspection findings including any corrective actions taken for review by management and trending accumulations.

B. Develop a cleaning plan for forming areas. Define a cleaning schedule based on the rate of deposit accumulation as well as production outages presenting opportunities for inspection and/or removal of deposits. Additionally, define thresholds for regular inspections when emergency action should be taken to remove heavier-than-normal combustible accumulating (thicker or more wide-spread) outside of the normal cleaning schedule. In the plan, list clean methods such as steam, dry-ice (carbon dioxide), or manual scrubbing with solvents that are not ignitable liquids.

C. Inspect and clean fire protection equipment subject to combustible accumulations. Inspect the condition of blow-off plugs (covering open sprinkler and nozzle discharge orifice) to ensure residues cannot enter and plug orifices or piping, the ability of blow-off plugs to move upon system actuation, sprinkler or nozzle deflectors are free of hard accumulations, and condition of fire detectors.

D. For container glass, consider a sooting-release agent system to minimize the rate of combustible deposit accumulation (i.e., hard-piped acetylene system).

Note: Automatic fire protection is not an alternative to a housekeeping program that monitors for and removes heavy combustible accumulations.

2.5.3 Implement an emergency response plan (ERP) for combating fires in forming operations. Key aspects to consider in the plan and operator training include: assessing fire size/intensity for the appropriate action to be taken (e.g., fire extinguisher vs. hose vs. manual actuation of fire protection system); and notification to ensure personnel outside of the forming area are aware of the situation including alerting the fire service. Refer to Data Sheet 10-1, *Pre-Incident Planning* for guidance.

2.5.4 Implement a molten glass breakout emergency response plan. Ensure a glass leak response team is staffed on all shifts, and is provided with procedures, training, and equipment to attempt to stop a glass leak and/or stabilize the damaged refractory until repairs can be completed. Locate response kits at each furnace, and include equipment such as water lances/torpedoes and hoses, fire hoses and nozzles, and personal protective equipment (PPE).

2.5.5 Conduct fire service pre-planning for responses to fire and glass breakout emergencies at least annually in accordance with Data Sheet 10-1, *Pre-Incident Planning*. Involve the fire service in emergency response drills when available.

2.5.6 Develop and maintain standard operating procedures (SOP) for batching, furnace, and forming operations. Of particular concern are procedures covering the following activities:

A. Cold furnace light-off (e.g., following a planned outage, or unscheduled furnace repair/rebuild)

B. Hot furnace re-light (e.g., following a temporary outage due to service interruption of electric power, gas, or oxygen)

C. Furnace startup from cold condition

D. Placing and maintaining the furnace in a hot-hold

E. Controlled furnace shutdown

F. For fiberglass forming operations, response to a thermographic alarm if not an automated process (e.g., identify and segregate suspected hot product)

G. Furnace refractory repairs or alterations typically conducted by onsite operators and maintenance personnel such as electrode installation/replacement or bubbler installation/replacement

2.5.7 Develop and maintain emergency operating procedures (EOP) for responding to the following upset conditions at the furnace.

A. Furnace hot spot detection

B. Furnace breakout (furnace operational aspects)

C. Loss of furnace primary cooling water or wind

D. Loss of primary electrical power

E. Loss of primary fuel supply

F. Loss of primary oxygen supply

G. Loss of furnace control system due to a power supply electrical fault, electronic failure, or fire (at a minimum, the goal is to be able to carry-out a manual controlled furnace shutdown)

H. Upset in downstream operations halting glass production requiring the furnace being placed into a hot hold (e.g., explosion in an annealing furnace, loss of float glass forming, fire at multiple forming machines, or fire in packaging)

Operator familiarity with EOPs becomes more critical during the final stage of the furnace campaign when refractory has thinned making hot spots or glass penetration more likely, and the refractory more susceptible to upset conditions. Ensure these EOPs are readily available to operators in the control room for reference during an emergency.

2.5.8 Implement a hot repair program to manage inservice refractory repairs. Of particular concern are hot repairs conducted below the metal line on an operating furnace or furnace on hot-hold with a significant amount of molten glass remaining in the tank.

A. Conduct a risk assessment on the breakout exposure during the repair and steps in place to reduce the likelihood of that breakout.

B. Contractors available on short-notice to complete the work

C. Repair contingencies and response plans in-place to prevent frozen plugs from thawing, and upon failure, limit thermal damage.

D. Management approval process prior to commencing work.

E. Ensure operating procedures are in place, and contractors and employees involved in the project are trained on those procedures and response procedures.

F. Post-repair inspection and testing.

2.5.9 Develop an service interruption plan (SIP) for loss of primary fuel supply. Assess reliability based on frequency and length of outages and their impact on furnace operations. Upon loss of the primary fuel supply, the goal of the contingency plan is to place the furnace in a hot-hold, or at least allow personnel to conduct a controlled furnace shutdown. Plan options may include installing a permanent onsite back-up fuel supply along with resources, procedures, and training on switching between primary and back-up supplies, or establish a contract with a local energy supplier to promptly configure a temporary onsite fuel supply routed to the furnace through already installed connections.

2.5.10 For furnaces exclusively heated by electrical power, develop an service interruption plan (SIP) for loss of utility power. Upon loss of electrical power, the goal of the contingency plan is to place the furnace in a hot-hold, or at least allow personnel to conduct a controlled furnace shutdown. Plan options may include installing a permanent onsite back-up power generation along with procedures and training on switching between primary and back-up supplies, or establish a contract with a local vendor to promptly configure a temporary, onsite power supply feeding the furnace power system through already installed connections.

2.5.11 For oxy-fuel fired furnaces, develop service interruption plan (SIP) to maintain production or at least a hot-hold upon loss of the oxygen supply. Plan options may include establishing a contractor with a local vendor to truck in oxygen onsite and supply the furnace through already installed connections, and/or temporarily installing air-fuel burners within the furnace.

2.5.12 Implement an operator training program in accordance with Data Sheet 10-8, *Operators*. Include initial and refresher requirements in the program. Train furnace and forming operators on SOP and EOP as well as ERP.

2.5.13 Implement an asset integrity program for the glass furnace. Document the asset integrity program in a furnace campaign management plan. Create the management plan in accordance with OEM guidelines and Data Sheet 9-0, *Asset Integrity*. At a minimum, include the following maintenance, operating, and remaining life assessment activities in the program:

A. Perform routine walkdown inspections, preferably each shift but at least daily for: normal furnace and support system operating conditions; refractory hot spots; containment area for clean, clear, and dry (i.e., free of combustibles, or inert batch ingredients or other contents that may compromise containment capacity); integrity check of containment dike walls and steel protection; and breakout emergency response equipment per Section 2.5.7 is present, serviceable, and accessible.

B. Perform walkdown inspections with thermography at least monthly.

C. Conduct internal inspection of the furnace at least annually. Preferably, this inspection is completed by the audit team or other competent party.

D. Consider employing emerging technologies to help assess refractory health. Radar based technologies have been employed successfully for several years to monitor for thinning and/or glass penetration. If utilized, modify refractory support (steel) during the following rebuild to allow for a complete examination of furnace refractory.

E. Operate the furnace within defined integrity operating window (IOW) provided by the OEM starting with the initial warm-up then throughout the campaign. Document IOW parameters in the furnace SOPs.

Pull rate is a particularly important operating parameter as excessive pull rates may accelerate refractory wear and have been a contributing negative factor in many molten glass breakouts. Additionally, inadequate batch controls can allow furnace contamination to go unnoticed for a period of time. Contaminants need to be flushed from the furnace potentially leading to unnecessary refractory wear.

F. Document findings from inspections, testing, maintenance, and audits including corrective actions taken.

G. Maintain operating and ITM records for management review and trending.

H. Have a competent contractor or corporate representative (offsite personnel) audit the current state of the furnace refractory and campaign management plan at least annually. The audit should review both current and past operating parameters (e.g., pull rates, temperatures, energy performance), hot/cold repairs, operational changes and excursions, and ITM records. The audit should result in a conclusion relative to the original furnace management plan (e.g., on track for the planned rebuild schedule).

I. Conduct a remaining campaign assessment when the furnace nears the end of the designed campaign, and implement additional precautions to prevent and/or mitigate a molten glass breakout during this higher risk portion of the campaign. Document findings from the assessment along with supporting information.

1. At a minimum, factor in the following during the remaining campaign assessment:

- Operating history (e.g., pull rates, total tons pulled, use and quality of cullet, and operating conditions beyond the IOW)
- Current operating conditions (e.g., pull rate, operating temperatures, efficiencies, and product quality)
- Inspection, testing, and maintenance (ITM) records (e.g., localized or wide-spread thinning, glass penetration, and past overcoats or repairs)
- Audit findings

2. Outcomes and additional precautions that may be enacted from this assessment include the following:

- Update the rebuild schedule
- Identify higher risk areas of the furnace warranting increased ITM activities to monitor refractory health, and/or provisions for additional cooling
- Actions to be taken when the operating conditions or refractory deteriorate such as a controlled shutdown or furnace dump
- Increased frequency of refresher training for operators and responders on emergency operating procedures and emergency response plans

2.6 Contingency Planning

2.6.1 Equipment Contingency Planning

When a glass melter furnace 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 glass melter furnace 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.

In addition, include the following elements in the contingency planning process specific to glass melter furnace systems and equipment due to the potential for an uncontrolled cool-down or glass breakout.

• Furnace refractory sources and availability for refractory repairs, including unplanned replacement of large portions of the tank or superstructure, considering custom casting lead times

• Regenerator checker replacement, and/or unplanned replacement of large portions of the walls or dome.

• On site electrical distribution equipment for critical loads such as combustion air/oxygen, cooling air (wind) blowers, cooling water pumps, and controls

• Combustion air system, and/or induced draft system equipment.

• Cooling air (wind) system equipmen.

• Cooling water system equipment

Also consider the following elements in the contingency planning process for the following glass melter furnace support systems and equipment.

- Batch ingredient handling
- Batch mixing and handling.
- Emissions control equipment

2.6.2 Sparing

Sparing can be a mitigation strategy to reduce the downtime caused by a glass melter furnace 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*.

2.6.2.1 Routine Spares

Routine glass melter furnace spares are spares that are considered to be consumables. These spares are expected to be put into service under normal operating conditions over the course of the life of the glass melter furnace, but not reduce equipment downtime in the event of a breakdown. This can include sparing recommended by the original equipment manufacturer. See Section 3.1.5 for routine spare guidance.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Supplemental Information

3.1.1 Fire Hazards in Forming Operations

The principal fire hazard in hot-end glass manufacturing operations is the combustible deposits and oil residues that cover the forming machines, adhere to walkways and equipment above, and collect in the basement. In container glass, the combustible deposits are a product of vaporized hydrocarbon release agents. The container molds are typically swabbed or sprayed with a release agent which is vaporized by the molten gob and released when the mold halves separate from the recently formed hot glass container. The vaporized hydrocarbon is carried upward by the cooling wind, being cooled in the process, and adheres surfaces or is carried out of the ventilator. In addition to the release agent, low-flow oil lubrication systems serve the moving parts on forming machines contributing to combustible deposits and residues at machine level as well as in the basement. To mitigate this fire hazard, a combination of housekeeping to monitor and remove combustible deposits/residues and automatic fire protection systems are relied upon to limit damage to the machine of origin as well as protect the building structure and adjacent machines from fire. Though the surrounding occupancy and construction is generally noncombustible, these combustible deposits on the machine and at the ceiling have fueled substantial fires that caused long production outages for the equipment involved. By limiting fuel loading (thickness at machine level and wide-spread area at ceiling level) and promptly actuating protection systems, the fast vertical fire spread associated with these fires can be impeded and thermal damage to the machine of origin limited to control wiring and power cabling allowing for a short turn-around before restarting the machine.

Fiberglass forming operations have similar problems with housekeeping, but instead of release agent and oil lubrication, combustible deposits form from overspray of the liquid binder. Deposits can accumulate on the surfaces of exhaust ducts, overhead building members and in areas below. Binder may be a hydrocarbon emulsion or contain any ignitable liquid component, but in either case when sprayed and allowed to dry the resulting deposit or residue often is combustible. A fire inside the exhaust duct will usually cause only minor damage if there is a light buildup of overspray; however when allowed to collect for years or following a process upset, substantial deposits may form. Again housekeeping and local fire protection systems are needed to combat the fire hazard posed by these combustible deposits/residues.

3.1.2 Glass Furnace Explosion Hazards

Explosions involving fuel gases in glass furnaces are rare given the operating temperatures, operating schedule, and campaign length; however, cold start is a time when an explosion can occur. Most glass plants rely on outside contractors for cold furnace start-up. The furnace is gradually brought up to operating temperature (usually about 2000°F [1095°]), so as not to damage the refractory. These contractors bring their own mobile equipment with combustion safeguard burner boxes which they connect to the plant's fuel supply piping. They may also use temporary liquid propane gas tanks, which are refilled during operations. Once the furnace has reached operating temperature, the contractor's equipment is removed, and the furnace burners are light-off.

There is no explosion hazard when water-molten glass come into contact. In fact, the first course of action in the event of a molten glass breakout is to insert a water lance into the refractory or direct hose streams at the stream of molten glass in order to freeze the glass solid in hopes to form a frozen glass plug.

3.1.3 Glass Furnace Mechanical Integrity

Glass furnaces and their refractory are a consumable asset. Depending on the glass products being produced, the furnace asset may be run harder (pull rate) and longer (campaign extension) to maximize the investment in that consumable asset. Though molten glass breakouts have occurred throughout the furnace life cycle, loss history has shown the final quarter of the furnace campaign is period of concern. As refractory layers thin, insulation resistance decreases requiring additional heat input to maintain furnace temperatures, which can further deteriorate refractory. Also as the overall furnace thins, the refractory becomes more susceptible to glass penetration and localized high wear zones caused by normal operations at electrodes, bubblers, or doghouses. Further periods where the furnace is thin makes minimizing the potential for furnace upset conditions in undissolved batch, glass currents, or thermal cycling as well as even brief interruptions in cooling wind or water more critical.

Above metal line refractory is also subject to failure including the superstructure and regenerators. Temperature control and age being key factors in many of these refractory failures.

Overcoats applied to the exterior of the furnace or internal coatings such as fused refractory, replace worn thermal barrier layers and in the case of interior coatings replace erosion allowance. Both are applied when inspections reveal damage or thin spots, but are used most often to maintain on the campaign schedule rather than extend the campaign. The furnace design often budgets these normal “repairs” into the furnace management plan.

During breakouts, property damage and business interruption is often driven by the condition of the remaining refractory (around the point of failure), access to replacement refractory, thermal damage sustained below the furnace which can be mitigated by containing the molten glass release, and the ability to maintain the furnace in a hot-hold condition following the breakout. If the furnace is allowed to go through an uncontrolled furnace shutdown with rapid cooling, the refractory is subjected to significant thermal stresses which can lead to wide-spread refractory damage, especially if occurring later in the campaign. Freezing of any residual glass within the furnace is not a loss driver within the glass industry as with other molten metal industries. The frozen glass can be re-melted and discarded. Again the concern upon loss of furnace control is the additional refractory damage resulting from the uncontrolled cool down.

3.1.4 Unique Glass Manufacturing Operations

In the float glass production, maintaining the molten tin bath free of oxidized metal is critical for glass quality (flaw) and downstream operations (Lehr rollers). If oxygen (or water) enter the bath, the tin must be replaced and the contamination purged before sellable glass is again produced. Most often the tin bath is covered by a positive pressure inert gas blanket to prevent oxygen ingress, while other additives may be included to scavenge moisture. Hydrogen can be employed in the float glass process at an atmosphere of 5-10% to scavenge any free-oxygen that diffuses into the float bath atmosphere and keeps the tin from reacting with oxygen.

Note: Molten tin is not very reactive when exposed to water, so the likelihood of an explosion is fairly low.

Nitrogen is also used in other molten glass applications outside of float glass forming. Since nitrogen is virtually inert, it can be used to blanket furnace electrodes to reduce safety hazards and prevent oxidation. Additionally, nitrogen boils at -321oF (-196°C), is well suited for cooling some glass products while being formed. In container glass manufacturing, liquid nitrogen can be injected to cool wind (air) to a temperatures between 10°C and -30°C. This provides the optimum cooling rates needed to simultaneously cool the inside and the outside of a newly formed container. Cooling both surfaces simultaneously stabilizes the container rapidly without inducing excessive stresses in the glass. Quicker stabilization means the next container can be formed quicker, increasing production capacity. By controlling the nitrogen application rate, air temperatures remain constant around the clock, ensuring consistent cooling and glass quality which improves the pack rate as well.

3.1.5 Routine Spares

The following are common routine spares for glass melter furnaces. Store and maintain the routine spares per original equipment manufacturer recommendations to maintain viability. Refer to Data Sheet 9-0, *Asset Integrity*, for additional guidance.

• Refractory for minor leak and/or thinning repairs.

3.2 Loss History

3.2.1 Loss Data

The following loss review is based on 113 FM losses in glass manufacturing focusing on hot-end operations over a recent 20-year period (1999 through 2018). Natural hazard perils were not reviewed, nor were rigging, transportation or similar perils. This loss review aligns with the scope of this standard focusing on fire, and boiler and machinery related perils.

3.2.1.1 Glass Manufacturing Overview

As shown in Table 1, the perils that drive the majority of losses and account for the most gross loss within glass manufacturing are fire, molten glass breakout, and equipment breakdown (electrical and mechanical). Service interruption, which often involves offsite equipment breakdown, and furnace contamination perils account for a number of losses and gross loss cost as well.

Table 1 contains loss data allocated based on the initiating peril only. The following sections dive deeper into some of these losses where the initial event (peril) was followed by a conflagrating event (second peril). Two examples include fire following a breakout or electrical breakdown, and contamination following a mechanical breakdown. As shown in the table, breakout, fire, and mechanical breakdown of refractory (above metal line) were the primary loss drivers in this industry.

Table 1. Glass Manufacturing Losses by Peril

Peril	*No. of Losses (%)*	*Gross Loss (%)*	*Gross Property Damage (%)*	*Gross Business Interruption (%)*
Breakout	35	51	51	51
Contamination	2	1	0	1
Electrical Breakdown	12	3	4	3
Fire	23	20	24	17
Mechanical Breakdown	19	22	18	24
Mechanical Impact	1	1	1	0
Service Interruption	8	3	2	4

3.2.1.2 Fire Losses in Glass Manufacturing

Table 2 and Table 3 contain fire losses across the range of glass product types.

Table 2. Fire Losses by Glass Product Group

Glass Product Group	*No. of Losses (%)*	*Gross Loss (%)*	*Gross Property Damage (%)*	*Gross Business Interruption (%)*
Container	69	65	55	75
Flat	0	0	0	0
Fiberglass	27	35	44	25
Specialty	4	0	1	0

Table 3. Fire Ensuing from Initiating Peril

Fire Ensuing From	*No. of Losses (%)*	*Gross Loss (%)*	*Gross Property Damage (%)*	*Gross Business Interruption (%)*
Electrical Breakdown	50	13	12	15
Breakout	50	87	88	85

3.2.1.3 Boiler and Machinery Losses in Glass Manufacturing

Table 1 contains an overview of boiler and machinery losses by peril. The following sections offer a more in-depth review and discussion of these B&M losses.

3.2.1.3.1 Service Interruptions

Table 4 shows the losses attributed to interruption of natural gas, oxygen, and electrical power to melting and forming operations.

Table 4. Service Interruptions to Hot-End Glass Manufacturing Operations

Service	*No. of Losses (%)*	*Gross Loss (%)*	*Gross Property Damage (%)*	*Gross Business Interruption (%)*
Electrical	22	15	5	20
Natural Gas	56	62	74	57
Oxygen	22	23	21	23

3.2.1.3.2 Molten Glass Breakout

Table 5 shows the losses initiated by a molten glass breakout from melting and forming operations. Two notable takeaways from these group of losses are: (1) the chance of a breakout increases threefold during the final quarter of the furnace campaign; and (2) containment should be appropriately designed, installed, and maintained as containment failed in more than a third of these breakouts.

Table 5. Losses Initiated with a Molten Glass Breakout

Equipment	*No. of Losses (%)*	*Gross Loss (%)*	*Gross Property Damage (%)*	*Gross Business Interruption (%)*
Melter/Refiner	82	95	98	94
Forehearth	8	1	0	1
Unknown	10	4	2	5

3.2.1.3.3 Mechanical Breakdown of Refractory

Table 6 contains losses involving mechanical breakdown of refractory above the metal line (i.e., superstructure and regenerator losses). Though not as dramatic as a breakout event, many of these refractory failures ended with similar results including furnaces placed in hot-hold or uncontrolled furnace shutdowns followed by hot or cold repairs.

Table 6. Mechanical Breakdown of Non-Glass Containing Refractory

Equipment	*Component*	*No. of Losses (%)*	*Gross Loss (%)*	*Gross Property Damage (%)*	*Gross Business Interruption (%)*
Furnace	Breast wall	7	2	4	1
	Front wall	20	43	34	48
	Bridge wall	7	0	0	0
	Crown	20	30	27	32
Regen	Dividing wall	13	11	11	11
	Pack	0	0	0	0
	Dome	13	5	13	1
	Port	7	3	8	0
Forehearth	Top	13	5	3	7

3.2.1.3.4 Mechanical Breakdowns of Non-Refractory Equipment

The two traditional mechanical breakdown losses (i.e., do not involve refractory) occurred within batching. One incident involved a recently installed elevated silo that collapsed due to inadequately design. The other losses involved batch metering equipment failures that went undetected for a length of time resulting in furnace contamination.

3.2.1.3.5 Electrical Breakdown

Table 7 contain the electrical breakdown losses interrupting power to hot-end operations including site-wide blackouts or local furnace power interruptions (e.g., electric boost).

Table 7. Electrical Breakdown Effecting Hot-End Operations

Electrical Equipment	*No. of Losses (%)*	*Gross Loss (%)*	*Gross Property Damage (%)*	*Gross Business Interruption (%)*
Transformer	33	42	48	37
Cable	25	18	10	25
Switchgear	25	27	23	31
Bushing	8	3	3	3
UPS	8	10	17	4

3.2.2 Illustrative Losses

3.2.2.1 Fire Losses

3.2.2.1.1 Container Glass-Forming Machine Fire with Adequate Response

A fire started on a container glass-forming machine due to a gob blockage in one section igniting combustible deposits. The machine operator was assisting the adjacent machine operator at the time (another blockage). The fire spread quickly to the roof fueled by combustible deposits from lack of regular housekeeping at machine level and combustible deposits above the machine that accumulated over the furnace campaign. Operators manually actuated emergency machine stops and opened the manual deluge valves for the subject line and the two adjacent lines. With these actions, the gob distributer diverts, and oil lubrication and cooling wind shutdown. The fire service arrived within minutes and was able to knock-down the machine-level and ceiling-level fire were controlled within 30 minutes of ignition.

The fire damaged power cabling serving three lines and a portion of the ceiling. Three lines were stopped following the fire due to the damaged cabling. One line was re-started 3 days later, while the other two within a week.

This incident involved a mostly controlled fire due to the actuated manual deluge system. Poor housekeeping was a key negative factor leading to the shutdown of three lines, while interlocks, deluge protection, and fast fire service response limited thermal damage to the machines and duration of the downtime.

Note: The machine of origin had recently switched to mold sooting (acetylene) from oil swabbing; however, the combustible build-up from the previous several years were not removed.

3.2.2.1.2 Container Glass-Forming Machine Fire with Inadequate Response

A fire started at a container glass-forming machine due to an exit conveyor jam resulting in broken hot glass falling onto basement combustible deposits and pools of leaking oil. Operators responded with fire extinguishers and hose streams but were unsuccessful (rather than actuating the manual deluge system). Operators left the building and the fire service responded quickly controlling the fire in just over an hour.

The fire caused significant thermal damage to both forming machines, but also damaged power cabling and control wiring for the furnace leading to an uncontrolled furnace shutdown that took 9 hours. The furnace was one month away from a schedule rebuild. The furnace rebuild and repairs to the adjacent forming machine were completed in just under 2 mo., while machine of origin required 4 mo. to repair. The fire did not affect the other furnace and forming operations.

This incident involved an uncontrolled fire that consumed most of the available fuel in the fire area. Key negative factors in this incident included poor housekeeping (oil lubrication and machine cleaning intervals) and poor manual intervention resulted in significant thermal damage to the machine of origin and allowed the fire to spread to critical furnace equipment and the adjacent forming machine.

3.2.2.1.3 Fiberglass Forming Area Fire Without Protection

Prior to the incident, a small fire was noted by an operator on the sliver level who attempted to flush the area with a fire hose until the smoke disappeared which is reportedly normal practice. The ignition source was likely molten glass falling into the basement waste bins. The operator went to attend to the bushings. No additional measures were taken.

About 15 minutes later, the same operator returned to the subject area and noted more smoke emanating from the sliver level. The operator left to get help and eventually a manual pull station was tripped. Operators attempted to fight the fire in the basement, but they were unsuccessful and driven out of the area by smoke. The fire service extinguished the fire 2 hours after detection after consuming most of the available fuel.

The basement was gutted including all plastic exhaust ducts and equipment, while half the winders above needed repair/replacement. Operators were able to just place the glass furnace on a hot-hold before the furnace went into an uncontrolled cool down. Operators started a diesel powered air blower (cooling wind) and re-routing power to the electrodes (fuel-fired furnace with boosting).

Several bushings needed to be replaced, while the exhaust system was destroyed along with most of the power cabling and control wiring within the basement feeding the furnace, sliver level, and winder level. Power cabling was the critical path to recovery which took nearly 2 months.

This event resulted in an uncontrolled fire consuming most of the available fuel in the fire area. Key negative factors in this incident were poor housekeeping around and beneath the forming area (binder deposits), poor housekeeping within the exhaust system (binder deposits), lack of protection over plastic/wood equipment along with areas prone to accumulating combustible deposits, and lack of process interlocks and/or manual intervention to isolate exhaust ventilation and cooling wind.

3.2.2.2 Boiler & Machinery Losses

3.2.2.2.1 Breakout With Containment Failure and Ensuing Fire

A container glass forming operator discovered a leak from a furnace. Operators responded with hose streams and water lances, but given the size (greater than a square foot), the glass breakout was not plugged. The fire service responded to assist personnel with hose streams. The contents of the furnace emptied over the course of several hours. During the breakout, the containment wall failed increasing thermal damage to steel columns, services and support equipment outside the containment area. The molten glass ignited deposits under the forming areas igniting a fire that spread to the forming machines. The fire spread up to the roof.

Much of the basement equipment was replaced. The adjacent furnace was placed on hot-hold due to the extensive thermal damage within the basement, but resumed production 2 weeks later. The furnace of origin was repaired (bottom coated) and resumed production 6 weeks later with forming machines being repaired and placed back online over the following weeks. The furnace operated without boost for another 2 weeks. The containment walls beneath both furnaces were reinforced with steel to prevent future failures.

This incident started with a breakout with an ensuing fire following. Key negative factors included furnace history (late in the campaign with known hot spots), poor maintenance of the containment walls, poor housekeeping around the forming machines, and lack of automatic fire protection over the forming machines.

3.2.2.2.2 Breakout With Containment and No Ensuing Fire

A container glass furnace began leaking from a bubbler. Operators were able to stop the leak limiting the breakout to several tons of molten glass. To permanently repair the leak, the contractor and corporate furnace management team decided to remove the damaged refractory using a water-cooled hole saw, and install a plug. During the repair, the saw malfunctioned and the furnace contents drained into the containment area. Steel protection was not provided high enough on the columns, but hose streams cooled the columns immersed in the molten glass. The furnace was placed on a hot-hold for repair.

The furnace bottom was repaired using mortar and the booster cables and electrodes were replaced. The furnace was restarted and 1 month after the breakout, the furnace resumed production.

This incident was limited to a breakout into the containment area. Key negative factor was the poor planning (contingencies) during a hot repair.

3.2.2.2.3 Regenerator Packing Collapse With Planned Outage for Repair

An operator noted a spike in furnace temperature and drop in combustion air pressure. Upon investigation, the operator heard packing (checkers) within a regenerator collapsing. The operator responded by adjusting damper positioning and notified management and the corporate furnace management team. While awaiting furnace specialists to arrive onsite, additional packing collapsed. The furnace continued to operate while clean-outs were made to remove broken checkers allowing airflow through the regenerator. Refractory was ordered to completely rebuild both regenerators, and the furnace continued to operator at a reduced pull rate (due to lower efficiencies). Six months later the refractory arrived onsite, the furnace was placed in a hot-hold, and both regenerators were rebuilt within four weeks. Production resumed a week after warm-up.

This incident resulted in a series of partial collapses of packing within a regenerator. There weren't any negative factors associated with this incident. Though a history of failures and repairs within the regenerator during the several years leading up to this incident while the companion regenerator has suffered no damage (rebuilt 15 years prior at the same time).

4.0 REFERENCES

4.1 FM

Data Sheet 1-2, *Earthquakes*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 2-81, *Fire Protection System Inspection, Testing, and Maintenance*
Data Sheet 4-1N, *Fixed Water Spray System for Fire Protection*
Data Sheet 4-5, *Portable Extinguishers*
Data Sheet 5-4, *Transformers*
Data Sheet 5-19, *Switchgear and Circuit Breakers*
Data Sheet 5-23, *Design and Protection for Emergency and Standby Power Systems*
Data Sheet 5-48, *Automatic Fire Detection*
Data Sheet 6-10, *Process Furnaces*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-43, *Process Safety*
Data Sheet 7-98, *Hydraulic Fluids*
Data Sheet 7-110, *Industrial Control Systems*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-1, *Pre-Incident Planning*
Data Sheet 10-8, *Operators*

APPENDIX A GLOSSARY OF TERMS

Boost transformer: Step-down transformers providing power to furnace electrodes.

Cold-end: Glass manufacturing operations downstream of forming operations such as annealing and packaging.

Electrodes: Electric heating elements used to add thermal energy and stir furnace contents.

Hot-end: Glass manufacturing operations that process or handle molten glass or recently formed hot glass often prior to annealing.

Hot-hold: A condition where the furnace production is shutdown as furnace temperatures are lowered but maintained sufficiently high to reduce thermal stress on refractory. For example, a furnace may be placed in a hot-hold upon a emergency conditions such as a glass breakout until a repair plan can be devised.

Hot repairs: Maintenance activities able to be conducted with the furnace at least in a hot-hold if not in full production. Examples of hot repair works may include ceramic welding and overcoating.

Lehr: Annealing furnace for glass to remove mechanical/thermal stresses from forming.

Major rebuild: At the end of the campaign, complete disassembly of existing blocks and bricks, and installation of replacement blocks and bricks from doghouse through the furnace to regenerator (when installed).

Melter: Part of the glass melter furnace in which glass batch is added, melted, and the molten glass is made free of undissolved solid batch (a.k.a., scum).

Metal-line: The level of molten glass in the furnace which may also be known as the flux-line.

Minor rebuild: Partial disassembly of damaged or high wear areas in the tank, superstructure, or regenerator during the campaign. Minor rebuilds may also include application of interior coatings.

Refiner: Part of the glass furnace where the molten glass starts to be conditioned for forming including removing dissolved gases.

Regenerators: Refractory block heat exchangers used to capture heat from the hot flue gas existing the furnace to pre-heat combustion air entering the furnace. Often regenerators are built in pairs and cycle between heating and cooling operations (a.k.a., reversal).

Superstructure: Components of the furnace above the metal line, which may include breast walls, crown, front wall, and back wall (gable wall).

Throat: A channel through which molten glass is forced to pass upon exiting the furnace before reaching the forehearths. Throats may be submerged or sunken where the bottom is lower than the furnace bottom (e.g., container glass), or straight where the bottom is level with the furnace bottom (e.g., float glass).

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).

April 2025. Interim revision. Significant changes include the following:

A. Updated process safety guidance to align with Data Sheet 7-33.

B. Updated guidance on molten equipment cooling system supplies to align with Data Sheet 7-33.

C. Clarified diagrams showing example fire protection nozzle locations.

July 2023. Interim revision. Minor editorial changes were made.

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

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

July 2021. Interim revision. Minor editorial changes were made.

July 2020. Interim revision. Updated contingency planning, service interruption planning, and sparing guidance. Added process safety guidance.

January 2020. This document has been completely revised to address changes within the industry and update loss experience. Major changes include the following:

A. Revised breakout containment guidance beneath glass furnaces.

B. Revised fire protection guidance for container glass-forming areas.

C. Added fire protection guidance for fiberglass forming areas.

D. Removed the alternate ceiling design (draft curtain) to separate forming operations from the furnace.

E. Added guidance on process interlocks to address fire hazards in container glass and fiberglass forming.

F. Expanded guidance on furnace refractory inspection, testing, and maintenance.

G. Added guidance on standard and emergency operating procedures.

H. Expanded guidance on contingency planning and redundancy for utility services and support systems critical to furnace operations and preservation.

I. Added guidance on a hot furnace repair program.

J. Added new and revised existing guidance on asset integrity and furnace maintenance.

K. Added guidance for arranging electrical distribution to facilitate testing of equipment serving critical, non-interruptible loads.

L. Revised the Supplemental Information section to clarify hazards present in hot-end operations.

M. Updated loss history.

N. Removed training material (Appendix C).

January 2013 (Interim revision). Terminology and guidance related to ignitable liquids has been revised to provide clarity and consistency with FM Global's loss prevention recommendations for ignitable liquid hazards. The following changes have been made:

A. Replaced references to "flammable" and "combustible" liquids with "ignitable liquids" throughout the document.

B. Added recommendation to see Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers,* for guidance on the storage of ignitable liquids (e.g., lubrication oils, hydraulic oils, etc.).

C. Added recommendation to see Data Sheet 7-7/17-12, *Semiconductor Fabrication Facilities,* for guidance on storage and handling of gaseous silane.

D. Added recommendation to see Data Sheet 7-35, *Air Separation Processes,* for guidance on oxygen generation plants.

E. Revised the contingency planning recommendations (Section 2.6).

F. Reworded a number of recommendations to improve clarity.

G. Revised the recommendation for portable fire extinguishers to accommodate a change in the available types of extinguishers (Section 2.3).

H. Updated the loss history (Section 3.1).

May 2010. Minor editorial changes were made for this revision.

January 2000. This revision of the document has been reorganized to provide a consistent format.

APPENDIX C RELEVANT FM DATA SHEET REFERENCES

This data sheet contains unique loss prevention guidance tailored specifically for glass manufacturing along with their support systems. For brevity, general loss prevention guidance contained within other FM data sheets (i.e., not unique to hot-end glass processing) was not duplicated within this data sheet, but may be applicable at a mine. For example, Data Sheet 5-4, *Transformers* contains inspection, testing, and maintenance guidance that is applicable to step-down transformers and rectiformer group transformers. Below is a list of other FM data sheets that may be applicable at a glass manufacturing facility. This list is not intended to be an 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 3-10, *Installation/Maintenance of Private Service Mains and Their Appurtenances*
Data Sheet 3-26, *Fire Protection for Nonstorage Occupancies*
Data Sheet 4-1N, *Fixed Water Spray System for Fire Protection*

D. Systems and Equipment

Data Sheet 1-6, *Cooling Towers*
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 5-48, *Automatic Fire Detection*
Data Sheet 6-10, *Process Furnaces*
Data Sheet 7-11, *Conveyors*
Data Sheet 7-29, *Ignitable Liquid in Portable Storage Containers*
Data Sheet 7-32,*Ignitable Liquid Operations*
Data Sheet 7-35, *Air Separation Processes*
Data Sheet 7-43, *Process Safety*
Data Sheet 7-76, *Combustible Dusts*
Data Sheet 7-91, *Hydrogen*
Data Sheet 7-95, *Compressors*
Data Sheet 7-98, *Hydraulic Fluids*
Data Sheet 7-108, *Silane*
Data Sheet 13-7, *Gears*

E. Human Element

Data Sheet 2-81, *Fire Protection System Inspection, Test, and Maintenance and Other Fire Loss Prevention Inspections*
Data Sheet 7-43, *Process Safety*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-1, *Pre-Incident Planning*
Data Sheet 10-3, *Hot Work Management*
Data Sheet 10-4, *Contractor Management*
Data Sheet 10-8, *Operators*