HOT WORK MANAGEMENT

Table of Contents

Page

List of Tables

1.0 SCOPE

This document provides recommendations for preventing hot work fires and explosions. The guidance within this document is applicable to all facilities where hot work is conducted on a temporary or routine basis.

Refer to other FM Global data sheets for prevention of hot surface and open-flame ignition source hazards associated with heated processes or utility equipment such as ovens/dryers, furnaces, kilns, and boilers.

1.1 Hazards

1.1.1 Hot Work Fire/Explosion Prevention and Fire Mitigation

All hot work fires and explosions are preventable. A hot work fire or explosion is the result of inadequate hot work management allowing ignition sources to come into contact with combustible, ignitable, or flammable material. The most effective way to prevent a hot work fire or explosion is to aggressively pursue alternative cold work methods. The next best way is to relocate the work to a hot work designated area. If neither option is possible, then removing and/or isolating combustible, ignitable, or flammable materials located within the hot work area or equipment is recommended.

Unfortunately, the implementation of the necessary hot work fire prevention methods are not entirely reliable. To complement prevention efforts, a hot work management program should also contain fire mitigation measures to reduce the consequences of a possible hot work fire. Loss history has shown the vast majority of hot work fires occur during the work or within the first hour following work completion, but more severe hot work fires occur in unprotected areas of the facility where protection systems are either not installed or impaired.

To mitigate the consequences of a hot work fire, a continuous fire watch should be provided in the hot work area during work and immediately following work. Also, hot work that requires a permit should be avoided in unprotected areas whenever possible; otherwise, additional required precautions should be implemented.

1.1.2 Additional Resources

For additional information on the hazards associated with ineffective hot work management, refer to the following FM Global resources:

- Hot Work Management Kit with permit holster, permits, and brochures (P9601)
- *Hot Work Permit System Kit* with permit holster and permits (P9311)
- *Hot Work Permit* (F2630)
- *Hot Work Permit App Brochure* (P12445j)
- *Don't Get Burned By Hot Work* (P9802)
- *Pocket Guide to Hot Work Loss Prevention* (P9602)
- *Understanding the Hazard: Hot Work* (P0032)
- *Understanding the Hazard: Contractor Management* (P0110)
- *Managing Hot Work Online Training Flyer* (P0686a)
- *Advancing Hot Work Skills Online Training Flyer* (P12062)
- *Managing Hot Work Online Training Flyer* (P08109e)

1.2 Changes

July 2018. Interim revision. A sample Hot Work Permit was updated (Appendix D). Construction and occupancy

2.1 Introduction

Improperly managed hot work remains a leading cause of large fires and explosions. Based on a review of FM Global loss history, the following conclusions were drawn regarding key factors in hot work losses:

A. Failing to identify and isolate combustible construction in the hot work area increases the likelihood and severity of a hot work fire.

B. Failing to identify and isolate combustibles in a hot work high-risk area increases the likelihood and severity of a hot work fire.

C. In-service fire protection systems significantly reduce the severity of a hot work fire.

D. The overwhelming majority of hot work fires occur while the work is being done or within 60 minutes of completion, highlighting the importance of a fire watch both during and following hot work.

The primary focus of a hot work management program should be on pursuing cold work alternatives or, failing that, relocating the work to a hot work designated area. If hot work is unavoidable, it is vital to remove or isolate combustible materials. Regardless of size, any hot work fire or explosion should be viewed as a failure of the hot work management program.

The post-work fire watch and/or fire monitoring period should be considered a secondary layer of protection against the uncertainty of identifying and controlling all combustible materials within the hot work area. The appropriate post-work watch and monitoring duration requires judgment based on the factors present within the hot work area, including confidence in being able to identify and remove or isolate combustible materials; the type and quantity of combustible materials present within the hot work area (i.e., combustibles that could be removed and are capable of smoldering or of a sufficient quantity to support a large uncontrolled fire); and the presence of automatic fire protection. If the hot work area is unprotected (e.g., unsprinklered), post-work watch and monitoring along with manual fire-fighting required precautions become more critical.

At no time should any length of post-work watch and monitoring be considered a substitute for properly preparing and maintaining the hot work area or equipment. A hot work management process should always begin with and focus on controlling combustibles in the hot work area.

2.2 Hot Work Management Program

2.2.1 Establish a formal policy statement on hot work management. At a minimum, cover the following in the statement.

A. Identify the program owner.

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H. Define the requirements for auditing the hot work management program, including scope and frequency.

I. Have the program endorsed by facility senior management.

2.2.1.1 When applicable, incorporate standard operating procedures (SOPs) for hot work management into the facility's International Organization for Standardization (ISO) certification. ISO certification requirements often align with administrative controls recommended in Section 2.2, including policy statement, document retention, management of change, and auditing.

A. Avoid hot work. Consider using an alternative cold work method. Refer to Section 3.1.3 for information on alternative cold work methods.

B. Relocate the work to a hot work designated area protected in accordance with Section 2.4.

2.3.2 If hot work that requires a permit is unavoidable, use a hot work permit system meeting the requirements of this data sheet and/or the local authority having jurisdiction, whichever is more stringent.

2.3.3 Maintain hot work equipment in good operation per the equipment manufacturer's guidelines.

2.4.1.4 Install facing materials on walls and ceilings that resist impact damage (e.g., corrugated steel paneling). Limit the use of brittle materials that are prone to mechanical impact damage (e.g., gypsum board).

2.4.1.5 Seal joints between floors, walls, and ceilings/roofs to prevent hot work ignition sources from escaping the designated area. Use FM Approved fire-stop materials.

2.4.2 Occupancy

2.4.2.1 Maintain hot work designated areas free of combustible, ignitable, and flammable materials. If required for work, store combustible materials in metal cabinets, and ignitable and flammable materials in FM Approved storage cabinets for flammable and combustible liquids.

2.4.2.2 Design and install HVAC systems per Data Sheet 7-78, *Industrial Exhaust Systems.* Incorporate the following into the system design:

A. Provide a dedicated HVAC system serving the hot work designated area.

B. Use noncombustible ductwork and insulation.

C. If particulate filtration is required, use an FM Approved Class 1 air filter.

2.4.3 Protection

2.4.3.1 Provide automatic sprinkler protection within hot work designated areas when the cutoff room wall or ceiling/roof assemblies contain combustible construction. Design and install sprinkler protection based on the occupancy within the room.

2.4.3.2 Provide supplemental fire extinguishers within hot work designated area (i.e., in addition to those extinguishers required by local codes). Ensure the extinguishers are rated and sized appropriately for the hazard. Inspect, test, and maintain fire extinguishers per Data Sheet 2-81, *Fire Protection System Inspection, Testing, and Maintenance.*

2.4.4 Operation and Maintenance

2.4.4.1 Conduct inspections of hot work designated areas to maintain the work area free of combustibles per Section 2.4.2.1, and contain hot work ignition sources within the work area per Section 2.4.1. Conduct inspections at least monthly. Maintain records for program auditing per Section 2.2.3.

2.5 Hot Work Permit-Required Areas (Hot Work Permit Required)

2.5.1 Permit Authorization and General Required Precautions

2.5.1.1 Assign the following responsibilities to hot work permit authorizers:

A. Avoid hot work that requires a permit whenever possible. Pursue cold work ai989.97-Psg s5Ena6eo33(those)]TJ 0 -10.976 T

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B. Contain hot work ignition sources using FM Approved welding pads, blankets, or curtains using the appropriate

2.5.2.2.3 Remove combustible accumulations (debris, dust/lint, or residues) and pooling ignitable liquid (due to spills or leaks) from the hot work area. Thoroughly inspect the hot work area for accumulations in spaces hidden from sight such as in trenches or pits, underneath equipment, within partially-enclosed equipment, and atop cable trays, ductwork, or suspended ceilings. Perform the appropriate housekeeping activities to remove combustible accumulations and pooling ignitable liquid. Do not use wet-down as an alternative to removing combustible accumulations.

2.5.2.2.4 Isolate potential sources of flammable gas, ignitable liquid, and/or combustible dust/lint that may be released into the hot work area during work. Conduct a job safety analysis to identify sources of these materials, and to determine the appropriate isolation method. Typically, isolation starts with a minimum of de-energizing the equipment, but may also include blocking, draining, and purging equipment. Consider the following when isolating sources of flammable gas, ignitable liquid, and/or combustible dust/lint:

A. When a more-reliable blocking method is warranted, consider a double-block and vent valve arrangement, or physically disconnecting material sources by temporarily installing a pipe blank, cap, or plug.

B. When a less-reliable blocking method is used due to a lack of available options (e.g., a single-block valve), consider performing frequent checks or constant atmosphere monitoring to verify adequate isolation as discussed in Section 2.5.2.2.5.

C. When draining and purging is warranted, ensure all low-points are identified and verified clear prior to work.

D. Use safety programs such as lock-out tag-out, confined space entry, and line-breaking.

2.5.2.2.5 Test the hot work area for flammable vapor/gas prior to work and as-needed during work. When conducting atmosphere monitoring, immediately stop work if the atmosphere exceeds 1% of the lower explosive limit (LEL).

2.5.2.2.6 Protect or shut down ventilation and conveying systems in the hot work area. These systems may contain combustible material or transport hot work ignition sources outside the hot work area to downstream combustible accumulations or filters. If ventilation is needed for an enclosed hot work site, provide the following safeguards:

A. Use a temporary ventilation system constructed of noncombustible components and remove air filters. If particulate filtration is needed, use an FM Approved Class 1 air filter.

B. If negative ventilation is used, extend the hot work area to include the area around the fan discharge.

C. If positive ventilation is used, ensure the airflow does not disperse hot work ignition sources outside the hot work area as discussed in section 2.5.2.2.1 or compromise the arrangement of hot work blankets and curtains as discussed in section 2.5.2.2.2.

2.5.2.2.7 If one of the following conditions exists, extend the hot work area to include the opposite side of a building assembly (i.e., floor, wall, ceiling, or roof):

A. The building assembly has an opening within the hot work area as shown in Figures 4 and 5. Openings may allow hot work ignition sources to pass through, exposing combustible material on the opposite side of the assembly. Examples of openings include: penetrations for cables, piping, conveyors, or ventilation ductwork; stairways; or equipment or personnel doors. Refer to Section 2.5.2.2.1 when defining the hot work area on elevated mezzanines or open process structures.

B. The hot work site is on or near thermally-conductive materials passing through the building assembly. Thermal conduction may ignite combustible material on the opposite side of the assembly. Examples of thermally-conductive materials include metal piping or steel structural members.

2.5.2.2.8 Identify and safeguard any combustible-lined equipment, piping, and/or ducts in the hot work area when the equipment has openings that could allow hot work ignition sources to enter. Refer to Section 2.5.2.2.2 for recommendations on covering openings, or Section 2.5.2.3.6 for recommendations on protecting combustible-lined equipment.

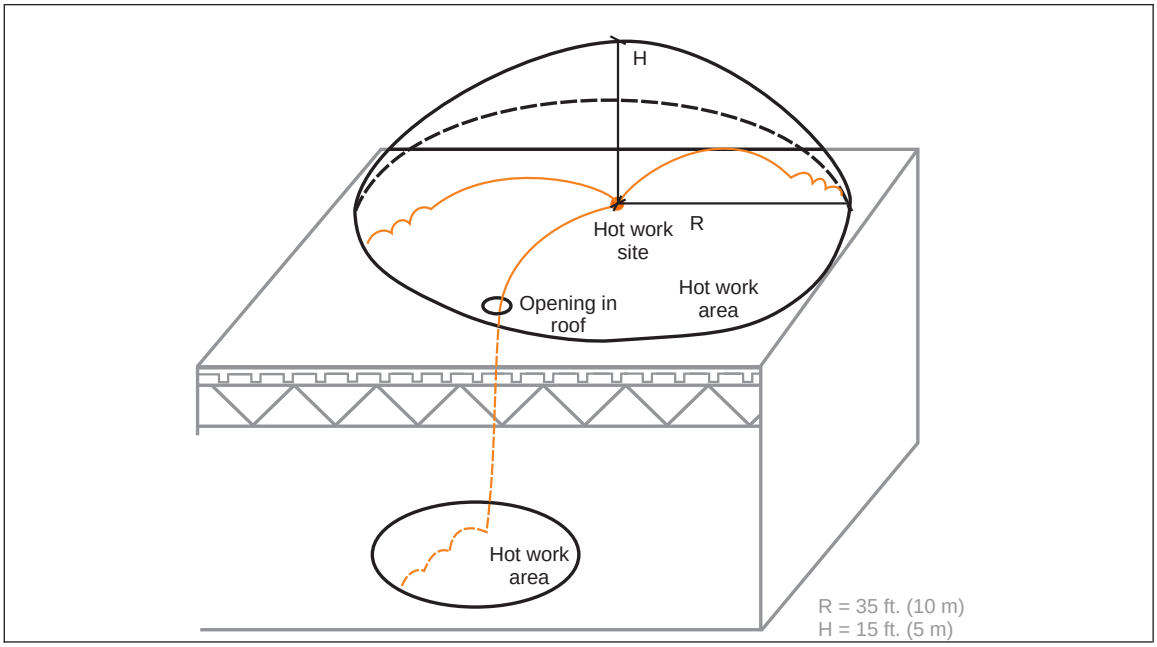


Fig. 4. Rooftop hot work permit-required area

2.5.2.2.9 Treat hot work on thermally-conductive materials at or near penetrations into combustible building assemblies as a hot work high-risk operation. In addition, take the following additional required precautions:

A. Remove portions of the building assembly around the penetration and use suitable noncombustible replacements.

B. Monitor the temperature of the thermally-conductive material before the penetration.

C. Temporarily install a thermal sink on the thermally-conductive material before the penetration.

D. Perform fire watches using an infrared camera to inspect for hot spots. Stop work immediately and initiate emergency action if hot spots are detected.

E. Report all “hot spots” or fires, even if extinguished to the fire service. Smoldering may continue after extinguishment and may take place for hours before flaming begins in areas unsuspected by non-professionals.

2.5.2.2.10 Treat hot work on combustible building assemblies as a hot work high-risk operation. Examples of such hot work may include cutting through a non-FM Approved (Class 2) insulated steel deck roof or insulated metal panel, or welding seams of insulated metal panels. When performing these operations, follow the guidelines of the building system manufacturer, and take the following additional required precautions:

A. Develop a fire emergency response plan that includes conditions under which the fire service should be notified, and verify the fire service has access to the work area.

B. Stop work immediately if material appears to be smoking.

C. Perform fire watches using an infrared camera to inspect for hot spots. Stop work immediately and initiate emergency action if hot spots are detected.

D. Report all “hot spots” or fires, even if extinguished to the fire service. Smoldering may continue after extinguishment and may take place for hours before flaming begins in areas unsuspected by non-professionals.

2.5.2.2.11 Treat work on torch-applied roofing systems as a hot work high-risk operation. Work may include installing, altering, or repairing roof systems. Torch-applied roofing includes modified bitumen roof covers using an open-flame roofer’s torch. When using torch-applied roofing systems, follow the guidelines of the roofing system manufacturer, and take the following additional required precautions:

A. Follow guidelines within FM Global Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installations*.

B. Develop a roof-fire emergency response plan that includes conditions under which the fire service should be notified, and verify the fire service has access to the work area.

C. Stop work immediately if roofing materials appear to be smoking.

D. Conduct a continuous fire watch over the hot work area during torch application.

E. Conduct the post work fire-watch in accordance with Note 1 of Table 1, and adhere to the following:

1. Where thermal imaging such as an infrared camera is used to check all roof areas worked on for

l. Close all valves supplying fuel-fired equipment when unattended.

2.5.2.3 Prepare for Hot Work on/in Equipment and Piping

2.5.2.3.1 Identify and isolate interconnected equipment and piping that contains flammable gas, ignitable liquid, or combustible dust/lint. Refer to Section 2.5.2.2.4 for recommendations on isolating interconnected equipment and piping.

2.5.2.3.2 Drain ignitable liquid and purge flammable gas/vapor from equipment and interconnected piping in accordance with Data Sheet 7-59, *Inerting and Purging.* When draining equipment, identify low-points in equipment and/or (2.5.2.3.1)-333(Identi53(Identi53yl-333(to)-3.Jrapp)-333(piquid)-ng)-333(interconnected)]TJ T*nnectv7d

A. The hot work area and person performing the hot work are not visible from a single vantage point.

B. The hot work area is large, multi-level, and/or congested.

C. The hot work area extends to the other side of a building assembly due to an opening or thermally-conductive penetration.

2.5.3.3 Restrict the scope of a hot work permit to that defined on the authorized permit. Ensure the type of hot work operations and the location of hot work sites do not change once the permit is authorized. Changes may require redefining the hot work area and modifying the required precautions. If conditions do change, stop work and reauthorize the permit before continuing.

2.5.4 Required Precautions After Hot Work

2.5.4.1 After hot work has concluded, perform a continuous fire watch over the entire hot work area (including areas requiring a second fire watch per Section 2.5.3.2). Refer to Section 2.5.3.1 for the responsibilities of the post-work fire watch, and refer to Section 2.5.4.3 for the recommended fire watch period.

2.5.4.2 After the post-work fire watch has concluded, perform fire monitoring within the hot work area. Use one of the fire monitoring methods listed below and refer to Section 2.5.4.3 for the recommended fire monitoring period:

A. Automatic smoke detection system with remote alarm that sounds in a constantly-attended location.

B. Security video cameras with clear coverage of the hot work area. Locate camera displays in a constantly-attended location. Cameras with infrared capability are preferred.

C. Operators routinely present in the hot work area. Train operators to monitor for fire-safe conditions, maintain required precautions in place, and notify emergency contacts before making any attempt to extinguish the fire.

D. Personnel to intermittently patrol the hot work area for fire-safe conditions. At a minimum, patrol the hot work area at least every 15 minutes. Train personnel to monitor for fire-safe conditions, maintain required precautions in place, and notify emergency contacts prior to attempting to extinguish a fire, regardless of size.

2.5.4.3 Provide post-work fire watch and fire monitoring periods as follows:

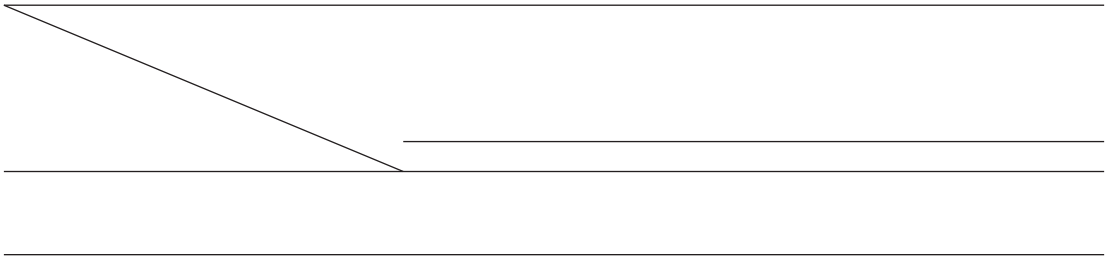
A. Provide a 1 hr post-work fire watch and a 3 hr fire monitoring period.

B. If combustible construction with unprotected concealed cavities are present or torch applied roofing is being conducted, use Table 1 to determine post-work fire watch and monitoring periods.

C. If favorable factors are present, use Table 1 to determine reduced post-work fire watch and monitoring periods. Clients of FM Global should not modify post-work fire watch and monitoring periods from Table 1 without first discussing the modifications with their FM Global field engineer or client service team.

2.5.4.4 When conducting hot work in unprotected areas (e.g., unsprinklered), fire monitoring becomes more critical as a primary means of protecting against hot work fires. Treat unprotected areas as hot work high-risk areas and refer to Section 2.5.2.1.3 for additional required precautions.

Table 1. Construction and Occupancy Factors for Determining Post-Work Fire Watch and Fire Monitoring Periods [1, 2]



2.6.6 Provide fire extinguishers within the low-energy hot work area per local codes. Inspect, test, and maintain fire extinguishers per Data Sheet 2-81, *Fire Protection System Inspection, Testing, and Maintenance.*

2.6.7 Conduct inspections of low-energy hot work areas to ensure required precautions are maintained. Inspect work areas at least weekly.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Supplemental Information

3.1.1 Hot Work Operations

3.1.1.1 High-Energy Hot Work Operations

Examples of high-energy hot work operations include the following:

A. Field (Infrequent)

1. Metal-working that involves radial-mechanical or torch cutting, grinding, welding, and heat treating
2. Pipe assembly and installation, including radial saw cutting, wheel grinding, and soldering, brazing, and welding joints
3. Installation of powder-driven fasteners
4. Thawing ice plugs in piping (in place)
5. Torch-applied roofing

B. Production (Routine)

1. Metal-working that involves radial-mechanical or torch cutting, grinding, and welding or hot riveting
2. Pipe fabrication producing ERW or helical pipe
3. Thermal spraying
4. Shrink wrapping using fuel-fired burners (e.g., hand-held weed burners)

Figure 6 compares common hot work ignition source temperatures to the ignition temperatures of several solid materials.

3.1.1.2 Low-Energy Hot Work Operations

Examples of low-energy hot work operations include the following:

A. Field (Infrequent)

1. Heat welding single-ply membrane joint using an electric welding iron.
2. Soldering repair or alteration within installed electrical/electronic equipment
3. Unrated electrical equipment temporarily used in hazardous/classified electrical area.
4. Cold-work drilling, cutting in hazardous/classified electrical area.

B. Production (Routine)

1. Soldering an electrical/electronic component
2. Fusing plastic pipe or other part
3. Hot gluing
4. Shrink-wrapping using electrically-heated hot air gun

3.1.2 Hot Work Management Programs

At most facilities, human element programs require basic administrative controls for effective implementation and long-term viability and reliability. The hot work management program is no exception. Most programs require ownership, a policy statement and procedures, training, document retention, and auditing.

A policy statement should set the ground rules for conducting hot work both inside and outside buildings. Alternative cold work methods and relocating the work to a hot work designated area should always be considered first. If hot work is unavoidable, the policy should define the location of hot work designated areas

in practice, controlling fuel and ignition sources can be difficult, and methods of doing so can, at times, be unreliable. As a result, a second layer of protection should be provided during permit-required hot work to mitigate the consequences of a hot work fire. Examples include ensuring fire protection systems are in service, and supervising the hot work area during and after the work to check for fire-safe conditions.

3.1.3 Alternative Cold Work Methods

Alternative cold work methods should be explored whenever hot work is considered. Cold work is an inherently safer method from a fire or explosion risk standpoint because the operation does not create an ignition source. Examples of cold work methods are provided in Table 2.

Table 2. Alternative Cold Work Methods

Hot Work Operation	*Alternative Cold Work Method*
Thawing ice plugs in piping (in place) using an open-flame	Mechanical removal and relocation of frozen piping to a heated area
Torch cutting	Hydraulic shear cutting (metal-working)
Radial saw cutting (metal-working)	Reciprocating saw cutting (metal-working)
Welding (metal-working)	Mechanical bolting
Soldering metal pipe joints	Threaded, flanged, coupling, or mechanical pipe joints
Torch-applying roof cover systems	Mechanically fastened or fully-adhered roof cover system
Puddle welding steel roof decking to structural members	Mechanically fastened steel roof deck to structural members

3.1.4 Hot Work Designated or Production Areas

Combustible and flammable material should be restricted from entering areas in which hot work ignition sources are prevalent. This includes construction used to enclose hot work designated areas or hot work production areas. At a minimum, a continuous barrier should be provided to confine hot work ignition sources and prevent them from coming in contact with combustible constructions or occupancies.

3.1.5 Hot Work That Requires a Permit

Hot work that requires a permit should be used as a last resort when alternative cold work methods or relocating the work to a hot work designated area are not feasible. When considering hot work that requires a permit, a safety review should be conducted and a plan developed to conduct the work safely. A hot work permit should be used to document the hot work management plan and precautions to be taken in the hot work area.

Prior to the work, the permit authorizer is responsible for verifying the precautions are implemented and authorizing the hot work permit, while the fire watch assumes the responsibility of ensuring the precautions remain in place during and after the work. The permit should be posted in the hot work area as a warning, as a reference of the required precautions, and for documenting during-work and post-work precautions such as periodic atmosphere monitoring and post-work sign-offs.

Conceptually, hot work permit precautions are intended to accomplish the following prior to work, during work, and/or post-work:

A. Identify and remove combustible, ignitable, or flammable materials from the hot work area prior to work.

B. Verify fire protection systems are in-service prior to work.

C. Restrict combustible or flammable materials from entering the hot work area during-work or post-work

3.1.6 Hot Work High-Risk Areas

Hot work high-risk areas pose an increased level of risk in comparison with other areas of the facility. Additional required precautions may be necessary when conducting hot work in these high-risk areas due to the increased likelihood or severity of a fire or explosion. The intent is not to prohibit hot work in these areas, but to bring more awareness and additional precautions to safely conduct hot work that requires a permit.

The pre-work safety review in these high-risk areas should strongly consider alternative cold work methods or relocating the work to a hot work designated area. If hot work is unavoidable, additional required precautions may be warranted, including charged firefighting hose lines with trained firefighting personnel; fire service notification; isolating, draining, and purging equipment with continuous atmosphere monitoring; permit authorization by local senior management; and/or watch and monitoring using an infrared camera.

3.2 Loss History

3.2.1 Illustrative Losses

The following loss summaries highlight the importance of good hot work management practices.

3.2.1.1 Inadequate Preparation of the Hot Work Area

3.2.1.1.1 Fire at a Corrugator Due to Inadequate Removal of Combustible Dust Accumulations

The facility manufactured corrugated boxes. The building housing the corrugator consisted of noncombustible construction with steel joists supporting the roof deck. Ceiling-level automatic sprinkler protection was provided.

During a maintenance shutdown, repairs were being made to a corrugator roll stand. In preparation for the work, a hot work permit was completed, with precautions checked off and the permit authorized by a supervisor. After torch cutting the work piece, grinding was completed. Initially the grinding operation directed the sparks toward the ground, but upon rotating the grinder around the work piece, the sparks were spraying against the underside of the lower-height ceiling. Within minutes, a fire flashed across the ceiling, opening more than 50 sprinklers. The fire was eventually controlled by automatic sprinklers and the fire service.

The hot work management program failed to recognize combustible dust deposits in the hot work area. Paper dust was present on joists and along the underside of the ceiling above the corrugator. Fortunately, sprinklers were installed and in service to limit fire spread.

3.2.1.1.2 Fire at a Sawmill Debarker due to Inadequate Safeguarding of Combustible Construction and Buildup of Combustible Dust

The facility was a softwood dimensional lumber mill. The debarker was situated next to the building housing a head-rig saw. The building was constructed of mostly combustible construction. Automatic sprinkler protection was provided through the facility, including the log deck and sawmill building.

During a weekend mill shutdown (Friday evening through Monday morning), repairs were made in the debarker area. In preparation for the work, employees and contractors completed multiple hot work permits for the cutting, grinding, and welding. Following the final hot work operation on Sunday, the hot work area was reportedly fire-safe for 5.5 hours.

Approximately 6.5 hours after the final hot work operation, a fire erupted within the sawmill building, activating sprinklers and triggering an emergency response. Sprinklers and manual firefighting efforts proved ineffective. Before sprinklers activated, the fire had spread into combustible concealed spaces within the exterior wall adjacent to the debarker, and into the ceiling. The fire spread through the sawmill building until it was eventually controlled 15 hours later. The fire service prevented fire spread into adjacent buildings.

Hot work permits were completed. Rather than removing or covering combustibles (bark, chips, saw dust,

During a night shift, contractors were installing a new gas supply line to a furnace. The gas piping was assembled using welded joints and run at ceiling-level. While working, the welder noticed a small fire involving dust accumulations below the hot work site on a steel beam flange. The welder attempted to extinguish the fire using his foot, then a fire extinguisher. The fire extinguisher dispersed the dust and fire spread to a cable tray below that also contained dust deposits. The fire spread on the horizontal cable tray, then vertically to a main cable rack containing cables feeding the entire cast house. The fire was extinguished by facility personnel after isolating power and using fire extinguishers.

The cast house was not a hot work permit-required area. Instead of a hot work permit, a work permit was used that identified a fire risk requiring a fire watch. Regardless of the permit used, the facility failed to properly remove or protect combustibles in the hot work area.

3.2.1.1.4 Fire at a Metal-Working Facility Involving a Belt Conveyor and Combustible Residue

A facility manufactured rotors and stators for electric motors. The production building was steel-frame construction with steel purlins supporting insulated metal panels. Walls were cinderblock. The cast house consisted of noncombustible construction. Automatic sprinkler protection was provided in the fire area.

During a night shift, employees were torch-cutting in the vicinity of a press at floor level. Sparks fell into a conveyor pit beneath the row of 10 mechanical presses, igniting oil residue and the wide rubber conveyor used to collect scrap metal from the presses. Sprinkler protection in the conveyor pit was impaired and the fire spread throughout the tunnel, damaging all presses. The fire was eventually extinguished after consuming most of the available fuel.

A hot work permit was not used. Workers failed to recognize the combustible materials in the pit underneath the hot work site or verify that fire protection was in ser-33v tfreIoaugrmmd-Proche Fire at a Metal- a Belt-333(a)-sionMetal-thatthe

Employees were cutting steel equipment supports in the boiler room when exposed foam insulation was ignited. The workers left the room to alert building personnel. The fire quickly spread along combustible wall and ceiling surfaces. Several hours after ignition, having consumed most of the available combustible loading in the area, the fire was extinguished by the fire service.

A hot work permit was used, but information was not available on most of the precautions implemented. A during-work fire watch was not in place. The workers failed to recognize the exposed foam insulation.

3.2.1.1.8 Fire at a Sawmill Involving Combustible Debris with Impaired Fire Protection

The facility was a sawmill that produced dimensional kiln-dried lumber. The subject mill building consisted of either steel or wood frame supporting a combustible roof, while walls were mostly wood on wood frame. Automatic sprinkler protection was provided throughout.

Employees were torch-cutting sprinkler piping on the sawmill operating floor. The workers broke for lunch. Later on, other personnel returning from work noticed a glow on the floor below the operating floor. Personnel attacked the fire with a fire hose and later the sprinkler control valve was opened (system was under repair). Five hours later the fire was extinguished by the fire service after controlling spread and limiting the fire to the building of origin.

A hot work permit was used, but information was not available on most of the precautions implemented. The workers failed to recognize floor openings and remove combustible accumulations from the floor below. A continuous during-work fire watch was not in place during the lunch break. Sprinkler protection was impaired during the work.

3.2.1.2 Inadequate Preparation for Hot Work on or in Equipment

3.2.1.2.1 Fire at a Power-Generating Facility Involving Combustibles Within Equipment

The facility was a gas-fired combined cycle power generating station. The power generating and ancillary equipment was contained within an open steel process structure while support buildings were of noncombustible construction.

During a maintenance shutdown, repairs were being made to close holes that had opened in the air inlet filter housing serving a gas turbine. In preparation for the work, a hot work permit was completed because the holes were to be welded closed. The hot work ignited the filters and the evaporative cooler within the unit. The fire was controlled several hours later using hose streams.

Details on the completed hot work permit were not available. Regardless, the permit authorizer and/or workers failed to recognize the combustible filters and other components within the unit that could be in contact with thermally-conductive work surfaces, or exposed to molten slag or sparks via the functional openings in the inlet filter housing.

3.2.1.2.2 Fire at a Power-Generating Facility Involving Combustibles Within Equipment

The facility was a coal-fired power generating station. The coal bunkers were located in a room constructed of noncombustible or fire-resistive construction with fiberglass insulated metal panels. The dust collector served a dozen coal bunkers used to stage coal in the building.

During a shutdown of the dust collection system, a contractor was altering the inlet ductwork to the collector. In preparation for the work, a contractor hot work checklist analysis was used, rather than a hot work permit, for the cutting and grinding to be completed. Several hours after restarting the dust collection system, smoke was detected emanating from the collector and the collector was hot. The fire service extinguished the fire within an hour. The preaction sprinkler system installed within the collector did not automatically trip, nor was the deluge valve manually operable.

Details on the completed hot work checklist analysis were not available. Regardless, the workers failed to recognize the combustible filters or combustible dust deposits in the system, and sprinkler protection was impaired.

3.2.1.2.3 Fire at a Mining Complex Involving Combustible-Lined Equipment

The facility was a gold-silver mining and ore processing complex. The dust collection system (cyclones) serving two ball mills was located in a mostly noncombustible building consisting of Class 1 insulated steel deck roof on purlins and steel trusses, and Class 1 insulated metal panel walls. No automatic sprinkler protection was installed.

During a process slow-down, an employee was weld-repairing a crack in a roughly 3 ft (1 m) diameter rubber-lined pipe discharging from the ball mill cyclones. In preparation for the work, the facility completed a hot work permit for the weld repair. While welding on the pipe, the worker noticed the pipe was hotter than usual, as compared to previous weld repairs, and concluded the 2.5 in. (6.4 cm) thick rubber-lining was on fire. The helper rushed to insert a firefighting hose line upstream of the hot work site, but could not spray water into the piping due to insufficient access. After discharging fire extinguishers into the upstream end of the burning piping, the welder and helper were forced to evacuate. A smoke detection alarm notified the emergency response team and the fire service. The milling operator attempted to inject slurry and water into the burning piping; however, the fire had already compromised control valves and wiring. The fire service spent five hours battling the fire within the rubber-lined equipment and a small roof fire involving a combustible parapet.

Details on the completed hot work permit were not available. Regardless, the workers failed to take the appropriate required precautions when working on combustible-lined piping. The piping was mechanically coupled, so the damaged pipe segment could have been removed and relocated to a hot work designated area during a production outage. If the work needed to be conducted in the field, additional required precautions should have been considered, such as flooding or continually spraying water into equipment, staging a firefighting hose line upstream and/or downstream of the hot work site, or disconnecting piping upstream and/or downstream of the hot work site.

3.2.1.2.4 Explosion of a Pulp Mill Digester Blow-Tank Involving Flammable Gas Within Equipment

The facility was a pulp mill consisting of two parallel pulp production streams. The blow tank was a vertical, four-story tank receiving cooked chips from batch digesters. A roof-mounted cyclone supported blow-tank operations by separating fiber from the volatile organic compounds (VOC) produced as a by-product of chemical pulping. The blow-tank had several inlet and discharge connections in the lower tank hopper.

During a planned shutdown, repairs were done on and around the blow-tank at several locations. In preparation for the work, the tank was emptied, purged of VOCs, and locked out. Atmosphere monitoring was done around the open manway and inside the upper portion of the tank. At some point during the work, a water hose was inserted to the blow-tank through an upper manway, which was immediately followed by an explosion that ruptured the blow-tank dome, tore apart the duct leading to the cyclone, and relieved from the building through the roof.

Details on the completed hot work permit were not available. Regardless, the facility failed to properly isolate the tank from sources of VOCs and detect the heavier-than-air VOCs collecting in the tank hopper several stories below the manway used for atmosphere monitoring. The lock-out procedure called for opening the bottom tank connections, which may have been the source of VOCs as determined after the incident. The water spray likely stirred the VOCs mixing with air and were either exposed to a hot work ignition source while in the tank (entered the tank through an open manway), or VOCs were ejected through an open manway where the flammable atmosphere was exposed to active hot work sites in the immediate vicinity around the tank and the flame front propagated/flashed back into the tank (grinding and welding).

3.2.1.2.5 Explosion at a Pharmaceutical Plant in a Waste-Water Recovery Tank Involving Flammable Gas Within Equipment

The facility was pharmaceutical plant producing active pharmaceutical ingredients. A roughly 10,000 gal (270 m^3) tank was used to collect waste water for treatment prior to being released.

Alterations were done on the inlet line to the tank. In preparation for the work, a hot work permit was completed. At some point during the work, an explosion occurred, relieving through the tank dome and wall seam.

Details on the completed hot work permit were not available. Regardless, the mill failed to either properly purge and detect, or isolate sources of VOCs from the tank and connected piping.

3.2.1.2.6 Fire at a Grain Elevator Leg Involving Combustible-Lined Equipment

The facility was a grain elevator with six bucket elevators. Building construction was reinforced concrete, while most grain-handling equipment was lined with either steel wear plates, ceramic tile, or plastic. No automatic sprinkler protection was provided.

National Fire Protection Association (NFPA), *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*. NFPA 51B.

VdS Schadenverhuetung GmbH. Fire Protection Guidelines, ″Safety Guidelines for Hot Work″ Number VdS 2008:2009-07

APPENDIX A GLOSSARY OF TERMS

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.

Hot work: Any temporary or routine work (operation) involving open-flame, producing hot surfaces, and/or

Welding curtain, FM Approved: A heat-resistant fabric designed to be placed in the vicinity of a hot work operation. The curtain is intended for vertical orientation while subjected to light to moderate thermal exposures from hot work activities such as grinding, mechanical cutting, and welding that does not result in molten metal contact (i.e., no slag exposure). The curtain is intended to prevent sparks from escaping a confined hot work area. A curtain provides the least thermal protection compared to a blanket or pad.

Welding pad, FM Approved: A heat-resistant fabric designed to be placed directly beneath a hot work operation. The pad is intended for horizontal orientation while subjected to moderate to severe thermal exposures from hot work activities such as torch cutting and welding that may result in molten metal contact (i.e., slag exposure). The pad is capable of resisting burn-through and thermal conduction through the pad that may ignite combustibles on the opposite side of the pad. A pad provides the most thermal protection compared to a blanket or curtain.

APPENDIX B DOCUMENT REVISION HISTORY

July 2018. Interim revision. A sample Hot Work Permit was updated (Appendix D).

April 2018. Interim revision. Made editorial changes to the post-work fire watch and fire monitoring section.

October 2017. Interim revision. Simplified and combined tables related to post-work fire watch and monitoring periods. Added further torch applied roofing guidance. Added Appendix D, Sample Hot Work Permit. Minor editorial changes were made.

April 2017. Interim revision. Appendix D, *Sample Hot Work Permit*, was deleted, other minor editorial chages were made.

October 2016. The entire data sheet has been revised. The following changes were made:

A. Redirected the emphasis of the data sheet to avoiding hot work whenever possible and, if unavoidable, employing required precautions to control combustible materials.

B. Organized the section on hot work that requires a permit to align with the FM Global Hot Work Permit.

C. Clarified existing and added new recommendations on implementing a hot work management program.

D. Clarified existing and added new recommendations on protecting hot work designated areas at both new and existing locations.

E. Clarified existing and added new recommendations on hot work permit authorization.

F. Clarified existing recommendations on defining a hot work area.

G. Added illustrations to aid in defining a hot work area.

H. Added new recommendations to address the following:

1. Hot work on thermally-conductive surfaces extending through building assemblies

2. Hot work high-risk areas and operations such as on or in combustible-lined equipment, in unprotected areas, and torch-applied roofing

I. Clarified existing recommendations on post-work fire watch responsibilities and durations.

J. Clarified existing recommendations on post-work fire monitoring methods and durations.

K. Added recommendations to address low-energy hot work operations in both production areas routinely conducting low-energy hot work and hot work permit-required areas.

L. Expanded illustrative losses.

M. Added an appendix with a sample hot work management policy statement.

N. Added an appendix with a sample hot work permit (FM Global Hot Work Permit).

October 2013. Editorial changes were made in several sections of the document. The scope was revised. Several definitions were added and/or revised in the glossary.

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

May 2003. Minor revisions were made to the illustrative losses section.

September 2001. This data sheet has been completely rewritten and supersedes the preceding Data Sheet 9-5/15-1, *Hot Work.*

Hot Work Management

APPENDIX C SAMPLE HOT WORK MANAGEMENT POLICY

[COMPANY NAME] HOT WORK MANAGEMENT POLICY

This facility has implemented a hot work management program to prevent hot work fires and explosions, and mitigate hot work fires. The program is applicable to both facility employees and contractors conducting hot work anywhere within the facility whether building or equipment installation or alterations. When considering the use of hot work operations, the following steps should be taken: (a) seek alternative cold work methods; (b) consider relocating the work to a hot work designated area; and (c) use a hot work permit when conducting work outside hot work designated areas.

The following hot work operations shall be controlled by the hot work management program.

High-Energy Hot Work	*Low-Energy Hot Work*
[List operations]	[List operations]

The following areas of the facility are defined as hot work designated, hot work production, hot work permit-required, and hot work high-risk.

[List or Insert floor or site plan showing the areas.]

Hot Work Permitting (Minimum Requirements)

1. All hot work permits will be reviewed and authorized by the designated permit authorizer.

2. All contractors will be required to use the facility's hot work permits, including facility authorization (by the designated permit authorizer) and supervision.

3. All facility and contractor personnel conducting hot work, performing fire watch, or fire monitoring will be trained on the hot work permit system at least annually. Permit authorizers will also be trained at least annually.

4. A management audit of the program, including a review of program records and facility changes, will be conducted at least annually.

5. An incident log of all hot work fires will be maintained, in which deficiencies and corrective actions will be identified.

6. Permit-required hot work will be provided with post-work fire watches and fire monitoring periods as shown below.

[Insert list or floor/site plan showing the post-work categorized areas.]

Additional Resources

1.Refer to the following internal procedures for additional requirements and guidance on the hot work management program:

- [List SOPs]

2.Refer to the following external resources for additional hot work management guidance:

- [www.fmglobal.com and/or other websites]

Program Owner:_____ Signature:_____

Manager Endorsing Program:_____Signature:_____

Effective Date of Policy:_____

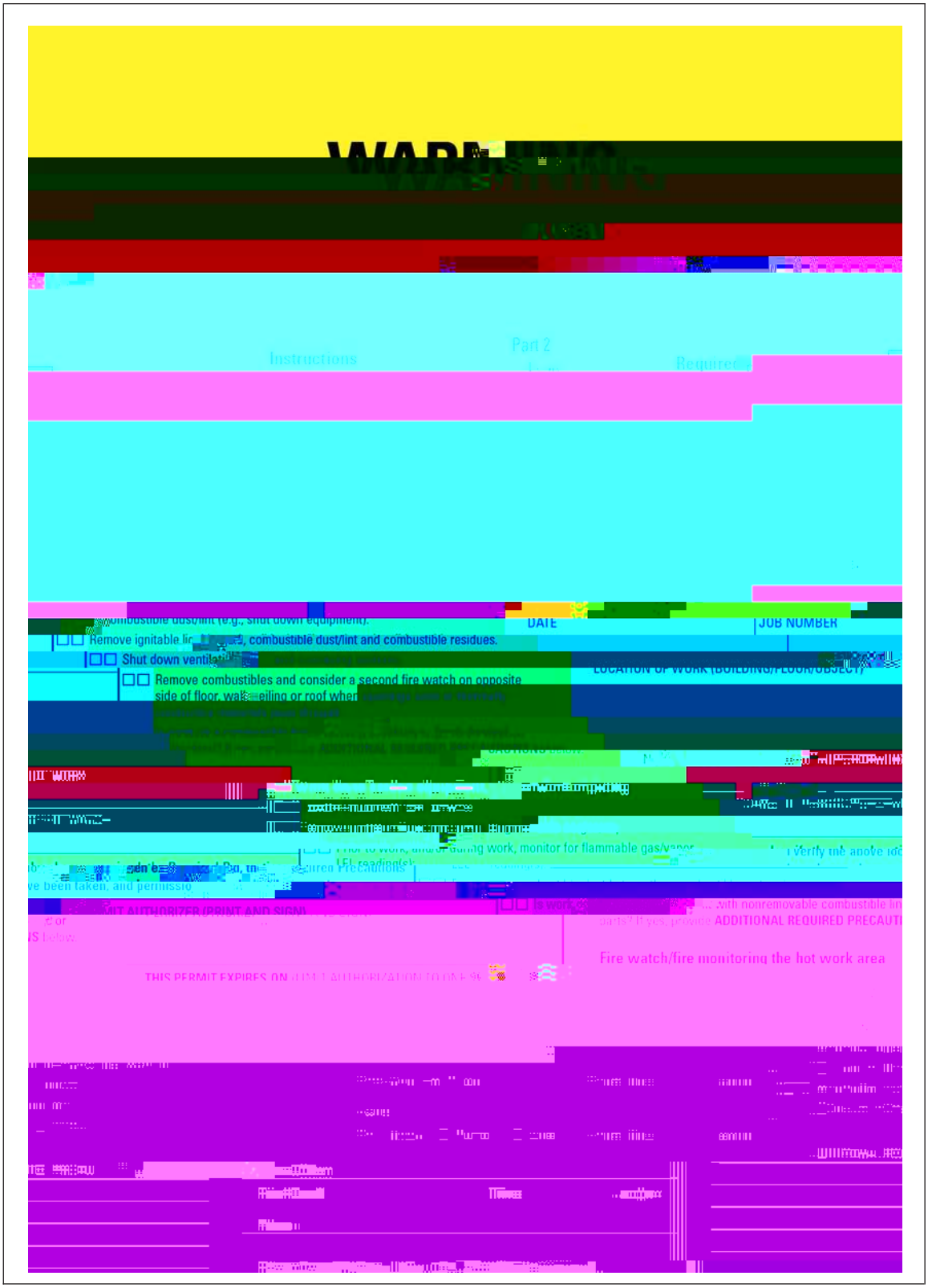


Fig. 7. Hot work permit (page 2)

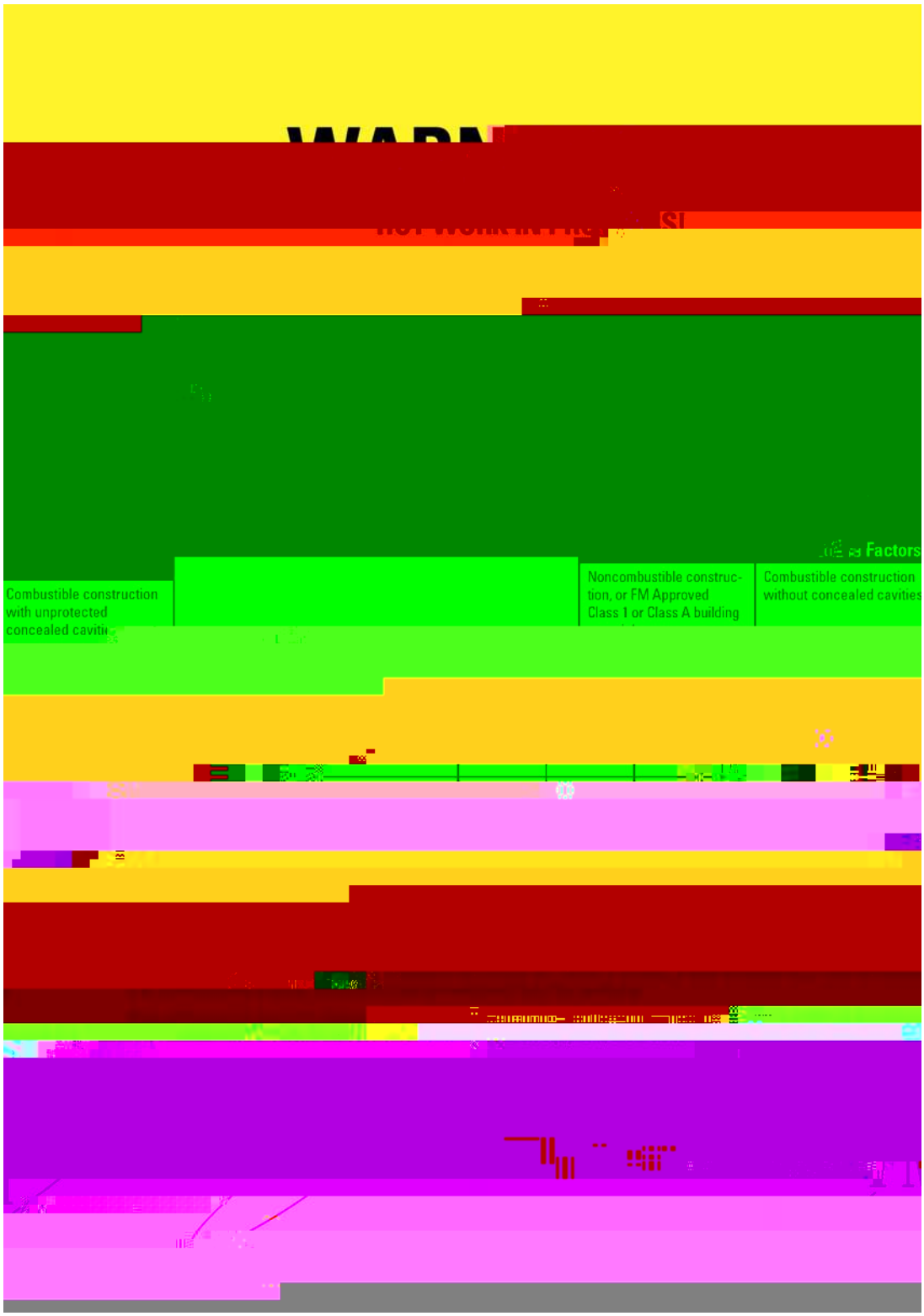


Fig. 7. Hot work permit (page 3)