SAFEGUARDS DURING CONSTRUCTION, ALTERATION, AND DEMOLITION

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1.0 SCOPE

This data sheet examines the hazards associated with construction, alteration, and demolition operations. The following recommended precautions will greatly reduce the danger of fire, explosions, water and wind damage, and collapse.

1.1 Changes

January 2006. Added information on FM Approved welding pads, blankets, and curtains for use during hot work activities. Added wall bracing guidelines, previously published in obsolete Data Sheet 1-7.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 General

This section provides general loss prevention recommendations for safeguards during construction.

2.1.1 Construction and Location

2.1.1.1 Ensure temporary trailers, sheds and offices are of noncombustible construction when located within or near the building being constructed or renovated. When the temporary structure or its contents are combustible, locate the structure at least 50 ft (15 m) away from main buildings and at least 30 ft (9 m) apart from each other, or protect with automatic sprinklers.

2.1.1.2 Install only as much roof insulation as can be covered with roof covering in a single working day, or prior to the expected start of inclement weather. Seal loose roof cover edges at the end of each day to minimize potential moisture damage. Asphalt or coal tar (as appropriate) can be used for built-up roof (BUR) covers; proprietary sealers are available for single-ply roof covers. Do not allow water to run in the deck ribs under completed roof sections. Follow manufacturer's recommendations.

Complete the installation of all respective permanent roof covers, flashing, walls, and opening protectives prior to the start of any interior work that may be damaged by moisture or mildew. Such interior work includes, but is not limited to, fire protective coatings for structural steel, gypsum board, any other interior finish materials, any materials or equipment related to the occupancy, etc. Where water or moisture has entered the building, ensure it is thoroughly cleaned and dried prior to the start of any interior work.

Distribute temporary storage of gravel or paver blocks on the roof (awaiting installation) to prevent overloading the roof in localized areas.

2.1.1.3 Use only steel (see Section 3.1.7) formwork, or limited quantities of combustible formwork, unless stored in areas protected by automatic sprinklers. Ensure formwork used to temporarily support cast-in-place concrete is designed by a qualified civil or structural engineer to prevent excessive sagging or collapse prior to setting of the concrete.

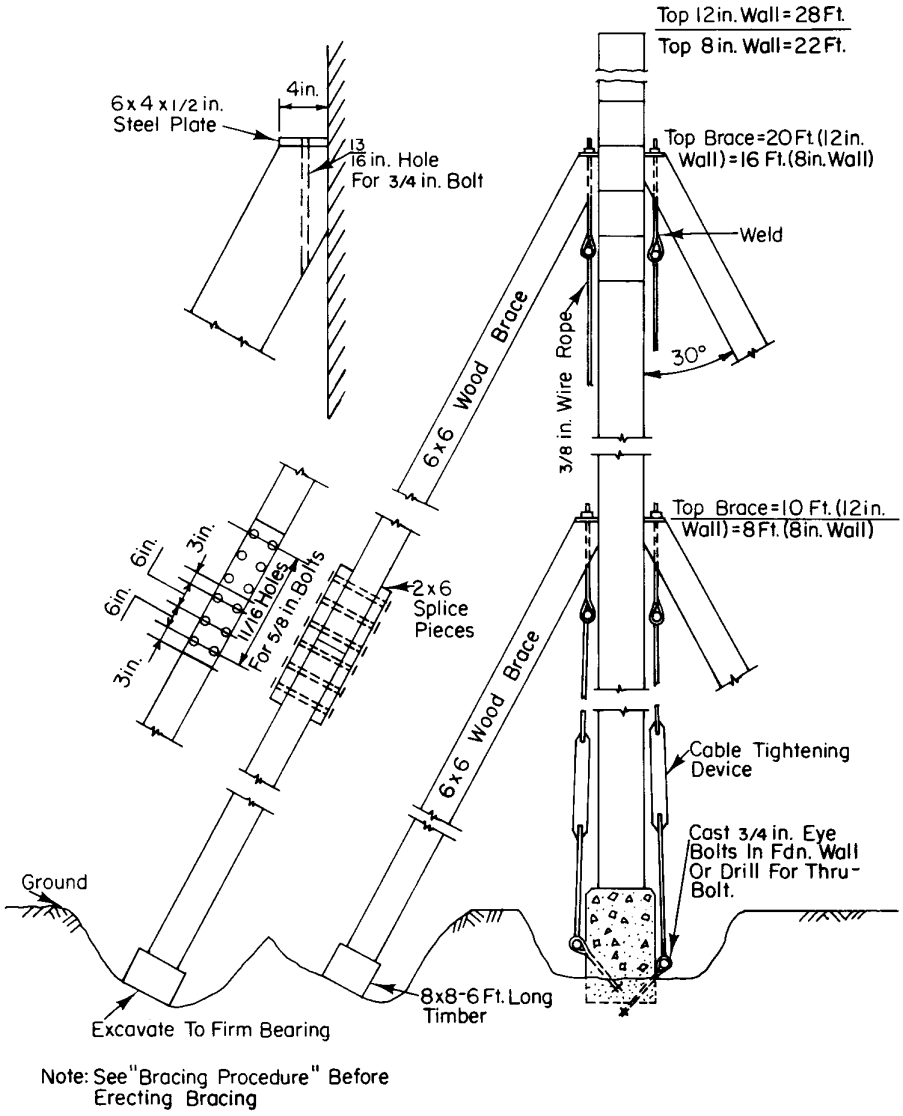
2.1.1.4 Brace building framing, as well as walls not yet tied to building framing, in accordance with Data Sheet 1-28, *Design Wind Loads*. Also, take additional precautions to prevent wind damage, as outlined in Section 3.1.14.

Unless a steel framework under construction is properly braced to a heavy existing structure (such as a building or retaining wall) or permanent bracing has been installed, provide temporary cable "X" bracing in every third bay of all column lines. Brace framework in all four directions. If connections for cable "X" bracing have not been provided, install them in the field. Ensure bracing is in the plane of column center lines. Connect all beams and girders to the columns prior to bracing.

Ensure walls of hollow masonry units under construction that do not have lateral support to resist wind forces are braced in accordance with Figure 1 (see section 3.1.15.4). It is necessary that walls be braced on either side.

Ensure walls of the tilt-up precast concrete type are shored on both sides by lean-to steel pipe braces until their permanent securement is completed. Ensure slenderness ratio (L/r) of braces does not exceed 200.

To minimize wind damage to roof coverings under construction, install the perimeter flashing assembly as soon as possible. If the edge of the insulation and covering has to be exposed for short periods of time, weight all temporary edges with closely spaced concrete blocks, or equivalent, until the flashing is completed.



Courtesy of Dome Systems, Inc.

Fig. 1 Bracing details

2.1.1.5 As soon as practical after the building shell has been completed, construct proposed fire walls; install fire-resistant seals for pipe, cable and duct penetrations, and expansion and control joints in floors and fire walls.

2.1.1.6 Take precautions with regard to temporary ditches. Provide earthen diking at edges of the ditch to help prevent any runoff from adjacent yard areas from entering the ditch. This is a particular concern with buildings that have basements and frequently undergo expansions (such as hospitals). Provide temporary waterproofing at building entrances. Temporary diking within the ditch may be needed depending on its area, expected rainfall intensity, and slope. Employ extreme caution when excavating near existing underground utilities such as gas, water, or electrical lines. Ensure equipment operators are assisted by personnel on the ground in such cases.

2.1.1.7 Whenever a chute is to be utilized for debris removal, install it on the outside of the building. Ensure its construction is noncombustible. Ensure the main artery of the chute is as straight as possible to help prevent accumulations or clogging within the chute.

2.1.2 Occupancy

2.1.2.1 Store compressed flammable gases in portable cylinders as outlined in Data Sheet 7-50, *Compressed Gases in Cylinders*. When used on site, secure cylinders well to prevent them tipping or falling from upper floors or roofs. Ensure flammable liquid storage and use complies with FM Data Sheets 7-29, *Flammable Liquid Storage in Portable Containers*, and 7-32, *Flammable Liquid Operations*.

2.1.2.2 Ensure all construction-related electrical wiring and equipment for light, heat, or power is in accordance with National Fire Protection Association (NFPA) Standard No. 70, *National Electrical Code*.

2.1.3 Protection

2.1.3.1 Install and activate automatic sprinkler and standpipe protection as soon as possible after the building shell has been constructed and *before* combustibles are introduced into the area.

2.1.3.2 Install cooling tower sprinkler systems as soon as possible during new construction and leave in service whenever maintenance or alterations are in process. When this is not practical, provide charged hose lines.

2.1.4 Operation and Maintenance

2.1.4.1 Where cranes are used, refer to FM Data Sheet 1-62, *Cranes*, for guidelines.

2.1.5 Human Element

2.1.5.1 Appoint an individual to supervise all loss prevention measures and conduct at least one inspection round at the end of the working day. Appoint someone to contact the fire service immediately upon notice of fire. Contact the fire service to establish a pre-fire plan.

2.1.5.2 Supervise contractors. Ensure they thoroughly understand all policies, procedures, and precautions prior to working on site. Monitor their work and assign a company employee to oversee each group. Ensure contracts mandate compliance with company policies (and pertinent recommendations in this document) and hold the owner harmless from loss caused by contractor negligence.

2.1.5.3 Remove combustible waste, dust, and debris from structures and their immediate vicinity as often as necessary and practical—at a minimum, at the end of each work shift This also includes materials subject to spontaneous ignition, such as oily waste and rags soaked with paint, linseed oil, or other flammable/combustible liquids. Strip and remove combustible formwork from the structure as soon as concrete has reached sufficient strength.

2.1.5.4 Use extreme caution when installing a torch-applied roof system. Refer to Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installations*.

2.1.5.5 Keep to a minimum any temporary combustible storage (such as combustible roof insulation) in the yard or on the roof and limit to 6 ft (1.8 m) in height and one or two pallets in width. Where space permits, make the separation distance between adjacent storage piles and structures at least 20 ft (6 m), 25 ft (8 m) or 30 ft (9 m), for exposing storage widths of 4 ft (1.2 m), 6 ft (1.8 m) and 8 ft (2.4 m) respectively. For valuable and important equipment, also refer to Section 3.1.6.

2.1.5.6 Provide watch service and alarms, and address related items (such as the means of fire service notification and location accessibility) as outlined in Sections 3.1.1 and 3.1.11. Provide fencing and lighting for yard storage areas.

2.1.6 Ignition Source Control

2.1.6.1 Provide safe temporary heaters (See 3.1.8).

2.1.6.2 Use FM Approved welding paads, blankets, and curtains (as applicable) whenever hot work activities are performed. For a list of FM Approved products, see Chapter 15 of the *Approval Guide*, a publication of FM Approvals.

2.1.6.3 Ensure all hot work is performed in accordance with the recommendation in Data Sheet 10-3, *Hot Work Management*. Remove combustible materials within a 35 ft (10 m) radius of hot work operations (or within room boundaries, if smaller) or cover with an FM Approved welding blanket. Use a Hot Work Permit and

employ a fire watch with suitable extinguishers or charged small fire hose. Take similar precautions when hot work is conducted above open metal grating as sparks or molten metal may shower down through the grating. For additional comments, see Section 3.1.4.

2.1.6.4 Prohibit smoking in areas where combustibles are stored, where flammable liquids are stored or dispensed, near piles of debris, and on the roof. Post *"No Smoking"* signs. Permit smoking only in designated areas equipped with proper receptacles.

2.1.6.5 Avoid flame cutting in combustible buildings. Do not employ this technique when cutting through combustible walls, floors or roofs.

2.1.6.6 Locate tar and asphalt kettles in a safe place. Located them outside buildings on the ground with bitumen pumped to the roof. A less desirable location would be on a noncombustible roof without combustible roof covering or insulation below or nearby. Keep kettles under constant supervision to prevent them from boiling over and igniting. Check thermometers on kettles for accuracy, and closely control temperatures. Provide steel covers of at least 14 ga. (0.075 in. [2 mm]) thickness to close by gravity and smother flames in case of fire. Check kettles in use at the end of each day.

2.2 Demolition

The following recommendations, as well as those in Section 2.1, apply to structures undergoing demolition.

2.2.1 Occupancy

2.2.1.1 Drain flammable liquids from tanks, piping, and machinery in a safe manner and remove the residue from the building. Remove the tanks also.

2.2.2 Protection

2.2.2.1 Keep automatic sprinklers in service as long as possible or as long as conditions necessitating sprinklers (combustible construction or contents) exist. In cold weather, where wet pipe sprinkler systems are provided, maintain heat in sprinklered areas or install dry pipe valves where practical. Take sprinkler piping out of service section by section, to the extent practical, and cap as demolition progresses.

Limit sprinkler control valve operation to authorized personnel who will notify concerned parties. Check the sprinkler control valve at the end of each work day to ensure it is open.

2.2.2.2 Where standpipes for fire hose are provided, maintain them in service as described above in item 1. Use charged hose lines in areas where sprinklers are out of service and, whenever possible, near temporary combustible debris accumulations, roofing operations, cooling towers, or cutting operations.

2.2.2.3 If explosives are used, such as in demolition by implosion, provide 1½ in. to 2½ in. (38 mm to 64 mm) charged hose lines capable of reaching all areas in the vicinity of the demolition site.

Ensure demolition by implosion is performed only by engineers and contractors who are experienced in this area. Consider the effects of building debris impacting on the ground. This may, in some cases, necessitate the use of sand in the street around the building. Analyze the exposure to adjacent buildings and provide protection as necessary. Isolate underground services in the area during the implosion. Ensure the demolition engineer determines if seismic activity in the area should be monitored throughout the implosion to help determine if the impact had the potential to cause damage to underground services or adjacent structures.

2.2.2.4 Keep horizontal and vertical fire subdivision, as well as fire doors, remain intact until demolition progresses to that point to help limit potential firespread and retain heat.

2.2.2.5 To the extent practical, protect remaining structures from flying debris during demolition, such as by temporarily covering with plywood those windows that are in close proximity.

2.2.3 Human Element

2.2.3.1 Notify the fire service of all demolitions prior to the start of work.

2.2.4 Utilities

2.2.4.1 Shut off and cap gas supplies at a point outside the building prior to the start of demolition.

2.2.4.2 Reduce electrical service to a minimum and mark to identify which circuits are energized. Physically disconnect and positively lock out discontinued lines.

2.3 Concrete Shell Structures

The following recommendations apply to the construction of concrete shell structures (see Fig. 2 and Section 3.1.17).

2.3.1 Construction and Location

2.3.1.1 Cover the entire fabric membrane evenly with polyurethane foam. Ensure mixing and application of the polyurethane foam is done only by experienced mechanics. Adjust the spray equipment regularly according to temperature changes to provide proper composition and density.

2.3.1.2 Provide adequate reinforcement as determined by an experienced structural engineer.

2.3.1.3 Use an airlock with doors at each end of the entrance to the fabric membrane. Use double blowers for reliability in pressurization of the fabric membrane. Provide a diesel or gasoline engine backup to electric motors to prevent collapse during power failure.

2.3.1.4 Apply the concrete at proper pressures. Even application in the proper thickness is essential.

2.3.1.5 Do not start construction when high wind, heavy rain, or snow is expected. This can deform the fabric membrane and may cause vibrations resulting in the separation of freshly placed concrete.

2.3.1.6 Careful design is necessary with large structures to avoid failure during construction. Cables may be needed to brace some fabric membranes, particularly those of 280 ft (85 m) or more in diameter.

The following also applies to structures more than 150 ft (45 m) in diameter:

- Ensure the design considers the necessary air pressure needed and the maximum allowable working stress the coated fabric membrane can withstand.
- Ensure the density of the polyurethane foam is 2 to 3 lb/ft^3 (32 to 48 kg/m^3) and complies with the referenced ASTM E-108 listing.

2.3.1.7 Do not restrain the shells, such as by attachment to interior walls/partitions. This could result in cracking when thermal expansion of the shell occurs.

2.3.1.8 Ensure the exposed outer surface of the shell structure has adequate resistance to exterior fire exposure. Ensure the assembly has an ASTM E-108 rating for an unlimited slope or 5 in./ft (23 degrees) slope as recommended in Data Sheet 1-29, *Above-Deck Roof Components*. Ensure the polyurethane foam has a flame spread of 75 or less based on the ASTM E-84 test (see Data Sheet 1-4, *Fire Tests*); however, ensure the flame spread does not exceed that listed for the respective ASTM E-108 rating needed.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General Safeguards

The danger of a potential fire is usually much greater while a building is being constructed, altered, or demolished than after work is completed and the fire protection equipment is in service. As work progresses, accumulations of combustible building materials, wooden forms and scaffolding, scrap lumber, paper and plastic packing and wrappings, and other refuse appear at new locations daily. The fire danger is increased further by the presence of many ignition sources, such as hot work equipment, carelessly discarded matches or cigarettes; temporary heaters and lights; and roofers' tar kettles, heating guns, and torches.

Many serious fires have occurred during the construction period, destroying valuable property and delaying completion of a project. Close follow-up throughout the construction period is required to ensure that safeguards are put into practice and are strictly enforced by the contractor.

3.1.1 Human Element and Fire Alarms

Ensure one person is made responsible for the protection of property from all perils including fire, wind, explosion, vandalism and theft. This person will ensure the proper procedures for controlling fire hazards are set up and must have full authority to enforce them. Ensure this individual makes at least one round each working day.

Most projects consist of new buildings or additions to an existing facility. In such cases, the fire safety supervisor should be appointed by the owner. Where an entirely new facility is being constructed, the owner should ensure that specifications for new buildings contain a clause stating that the ‘‘contractor will take all reasonable precautions against fire, explosion, wind, vandalism and theft in accordance with good loss prevention practice.’’

Responsibility for loss prevention rests with the owner. However, loss prevention recommendations are normally implemented by the contractor. To ensure recommendations are carried out promptly, the owner’s assistance may be needed. The building management and contractor should conduct joint briefings and walking tours and documentation should be provided to verify that individual workers have been trained regarding pertinent safety practices. During alterations at existing facilities, management should supervise the work of on-site contractors.

Arrange for at least one fire alarm box or telephone on or near the premises, and inform personnel as to their location and use. Post the number of the public fire service near all telephones. Make sure the public fire service is familiar with the premises and special fire hazards, and that firefighters have ready access to all parts of the construction project. Clear access roads promptly after snowstorms.

3.1.2 Automatic Sprinklers

Expedite installation of automatic sprinklers. Provide underground mains, hydrants, and a source of water in the earliest stages of construction.

An antifreeze (nonfreeze) solution may be used in small wet pipe sprinkler systems during cold weather. Where the system has more than 20 sprinklers, or where nonfreezing systems are not permitted, install a dry valve (Data Sheet 2-8N, *Installation of Sprinkler Systems — NFPA*). Afterward, the dry valve can be removed and the system made wet.

Place sprinklers in service ahead of a combustible occupancy and immediately following combustible construction. Many serious fires have occurred only a few days before the anticipated completion of a sprinkler system. Submit sprinkler plans promptly for review, comment, and acceptance prior to ordering materials. Order all materials in advance of construction to ensure delivery when needed. Closely coordinate construction sequences of various trades.

In tall buildings, extend capped standpipes with hose connections upward as the various floors are constructed. Ensure there is a conspicuously marked fire service pumper connection on the outside of the building at street level. Notify the public fire service of the existence of the connection as soon as it is in service.

After installation, inspect control valves and check valves to ensure they are open and installed in the proper direction.

3.1.3 Disposal of Rubbish

Insist on prompt and safe disposal of combustible rubbish. Strict rules and an adequate number of cleanup personnel are essential to facilitate the removal of accumulations of paper/plastic packing and wrappings, scrap lumber, debris, and other construction rubbish. Prompt disposal is particularly necessary for materials subject to spontaneous ignition, such as oily waste and rags used with paint, linseed oil, or other flammable/combustible liquids.

3.1.4 Hot Work

Sparks from hot work cause more construction fires than any other ignition source. It is essential to have the person in charge of fire safety supervise these operations and make sure adequate precautions are taken. If the work cannot be moved to a safe area, relocate combustible materials or cover them with FM Approved welding blankets. In some cases, combustible dust and debris can be swept up. When absolutely necessary to cut and weld in an area with wood floors, they can be wet down within a 35 ft (10 m) radius before and after the operation.

At some locations, it may be unsafe to use a torch regardless of the precautions taken. Conditions may change abruptly; a cutting operation may be safe in the morning and hazardous that same afternoon because combustible materials have been moved into the area. Store acetylene and oxygen cylinders in safe locations, protected from high temperatures, as noted in Data Sheet 7-50, *Compressed Gases in Cylinders*.

In some situations, such as where conveyor belts or combustible coated electrical cables are present below or adjacent to a welding operation, it is impractical to remove combustibles. Directly covering the equipment or materials might necessitate shutting down an important manufacturing operation. In such cases, an acceptable alternative may be to suspend an FM Approved welding pad below the welding area and above the exposed object or equipment, or to place FM Approved welding curtains between these areas.

In *some* areas of *certain* locations where it is obvious the construction and occupancy is entirely noncombustible (such as in *some* areas of cement plants), the need for a hot work and fire watch may be waived. However, this can only be done after the location is inspected, and cannot become a blanket policy throughout the facility, as other areas may contain significant quantities of combustibles. It is essential that outside contractors be closely watched in this regard and not allowed to make such judgments, as they may not be sufficiently familiar with the facility.

For further information on this subject, refer to Data Sheet 10-3, *Hot Work Management*.

3.1.5 Construction Sheds

About as many fires have occurred in temporary construction sheds as in main buildings. Locate construction sheds in a safe area. Some fires have been unnecessarily large because sheds have been grouped closely together or because they exposed the main building under construction. Locate temporary sheds at least 50 ft (15 m) from the main building and 30 ft (9 m) from each other. Noncombustible construction is advised if tight grouping or close proximity of the shed(s) to the main building cannot be avoided. If this is not practical and space is limited, a minimum separation of 40 ft (12 m) from main buildings can be tolerated for small sheds having an exposing wall area not exceeding 100 ft^2 (9 m^2). Provide ample clearance at stoves and around flues to prevent ignition of wooden construction (see Data Sheet 1-13, *Chimneys*).

3.1.6 Equipment Storage

Arrange temporary storage of valuable and important equipment during construction in the following order of preference: (1) under sprinkler protection; (2) if no sprinklers, then subdivided in moderate amounts in noncombustible buildings; and (3) if in combustible, unsprinklered buildings, provided with watch service, fire hose and extinguishers, heated by safe methods, and separated from other ignition sources. Subdivision in #2 above can be by walls with noncombustible surfaces or by clear spaces of 50 ft (15 m). When space and storage is limited, closer separation can be tolerated as outlined in recommendation 2.1.5.5.

3.1.7 Material Storage and Use

Arrange the temporary storage of combustible construction materials in the same order of preference as described in Section 3.1.6. Do not locate combustible storage in areas where specified fire-resistive coatings for structural steel have not been completed. Do not store foamed-plastic materials in buildings under construction unless protected by sprinklers and piled no higher than 5 ft (1.5 m).

The use of fire-retardant treated lumber for concrete formwork may not be practical as it is more costly than regular wood and cannot be reused, due to either damage during disassembly or because of the adverse effect the moisture from the concrete would have on its fire retardancy and strength.

3.1.8 Temporary Heaters

Provide safe temporary heaters. Unsafe heaters cause many construction fires.

Where steam is available, steam unit heaters are a desirable method of heating. Do not fire temporary heaters with scrap. Use safely arranged portable gas-fired (natural gas or propane), electric or kerosene heaters. Safeguards for compressed gases are given in Data Sheet 7-50, *Compressed Gases in Cylinders*. Place temporary heaters on a solid base so they will not overturn. Locate them away from woodwork. Secure them if exposed to wind, and keep the floor around them free from all combustible material. Secure combustible material so wind does not blow it against heaters and cause ignition. Check temporary heaters to ensure they are turned off at the end of the work day. If intended for continuous operation, have the heaters checked at least hourly if watch service is provided.

Locate portable kerosene heaters with built-in fans to circulate heated air outside buildings under construction and far away from combustible material. Ensure a capable employee operates and maintains the heaters, following all safeguards recommended by the manufacturer. Locate a minimum 15 lb (6.8 kg) portable dry

Courtesy of Dome Systems, Inc.

Fig. 2. Concrete shell structure.

chemical extinguisher near all entrances to heated areas. Kerosene heaters are much safer than those burning gasoline, which are prohibited by some fire regulations and not recommended. Gas-fired, electric, or steam heaters are preferred.

3.1.9 Weather Enclosures

Use flame-resistant tarpaulins and plastic sheeting to enclose buildings temporarily, and fasten them securely to avoid their being blown against temporary heaters by the wind. One good arrangement is to provide vertical timbers spaced about 4 ft (1.2 m) on centers to serve as a rigid frame to which the tarpaulins or sheeting can be secured. Do not use tarpaulins that appear to have lost their fire-retardant qualities through leaching (i.e., if they look weathered). Ensure flame-resistant materials meet the requirements of ‘‘Test No. 2’’ as noted in NFPA 701.

3.1.10 Hose and Extinguishers

Provide adequate temporary fire protection. Order a supply of fire hose and nozzles in advance so they will be available as soon as hydrants are ready. Connect hose lines in areas where construction, alteration, or demolition is in progress. The use of fire hoses is preferred to fire extinguishers as the quantity, type, or arrangement of combustibles often lends itself to possible rapid firespread in which the capabilities of a typical fire extinguisher would be exceeded. Hoses can also be used for combustible dust control.

When the use of a hose is impractical, distribute ample hand-extinguisher equipment throughout the premises, including contractors’ buildings. The 15-20 lb (6.8-9.0 kg) multipurpose dry chemical extinguisher is recommended. Where low temperatures are possible, use extinguishers not subject to freezing. Ensure hydrants, hose connections and other fire-fighting equipment is readily accessible at all times and never blocked by construction materials.

If there is an unavoidable delay in the completion of yard mains and hydrants, it may be possible to provide limited protection with a garden hose supplied from the piping system that furnishes water for construction uses. Sometimes, a temporary fire pump can be installed.

For additional information on hoses/standpipes and extinguishers, refer to Data Sheets 4-4N, *Standpipe and Hose Systems (NFPA)*, and 4-5, *Portable Extinguishers*.

3.1.11 Watch Service

Besides the potential for fire damage, construction and demolition sites also are often targets for vandalism, incendiarism, and theft. The problem is magnified when the site is located in a high crime-rate urban area, when the building under construction is linked to social and/or political causes, or where there are labor disputes involving the trades employed in the construction/demolition. Yard storage is very vulnerable and needs to be enclosed by fencing and well lighted.

Provide watch service at night and during nonworking days as soon as new construction is started. For large and important construction projects, ensure recorded watch service rounds include all parts of the buildings and outside areas where there are hazardous equipment or materials. Conduct rounds every half-hour for two hours after suspension of work for the day, and every hour thereafter during nights and off days.

For additional information on watch service, refer to Data Sheet 9-1, *Supervision of Property*.

For additional information on protection against incendiary fires, refer to Data Sheet 9-17, *Protection Against Arson and Other Incendiary Fires*.

3.1.12 Flammable Liquids Handling

Large quantities of paint, flammable thinner, asphalt, gasoline, and tar may be used in the construction of a new building, and particularly with regard to roofing operations. Follow the same precautions for safe storage and handling that apply in the completed plant as nearly as practical (see Data Sheets 7-29, *Flammable Liquid Storage in Portable Containers*, and 7-32, *Flammable Liquid Operations*). Store hazardous liquids in a small detached structure or in the open, not inside main buildings. Handle low-flashpoint liquids, such as gasoline and alcohol, in maximum 5 gal (20 L), FM Approved safety cans only. Keep delivery trucks carrying flammable or combustible liquids outside buildings.

3.1.13 Smoking

The control of smoking is critical in reducing ignition sources. Prohibit smoking near combustible storage or where conditions are particularly hazardous. Strictly enforce the “No Smoking” rule:

- during flammable liquid dispensing and fueling operations;
- where flammable paints, thinners, and roofing or insulating materials are being used; and
- where temporary debris accumulations exist.

3.1.14 Wind

The number of wind losses to buildings under construction is approximately equal to the number of fire losses. Most wind damage at construction projects has involved masonry walls, roof coverings, framework, or forms.

Plan construction so framing is adequately braced and walls can be anchored to the building framework as soon as they are erected; otherwise, temporary shoring may be necessary (see Data Sheet 1-28, *Design Wind Loads*). Proper methods of roof application are extremely important, particularly on insulated steel-deck roofs. Do not store construction materials on a roof overnight since they can be blown away by moderate winds. Ensure roofing in construction is properly secured or weighted down at the close of the day’s work to prevent damage to these materials and blockage of drains that may lead to collapse or roof leakage. Construction forms should be suitably secured. Bolt the steelwork securely enough to withstand a severe windstorm. Anchor roof-mounted equipment to the structure immediately after it is set on the roof. Take extra precautions whenever severe winds are predicted, and be prepared for sudden, unpredictable storms.

3.1.15 Buildings under Construction

During construction, building elements such as the structural frame, walls, flashings, and roof coverings are vulnerable to wind action until permanently constructed or attached.

3.1.15.1 Structural Steel Frame

Structural beam-to-column connections during erection are frequently secured by only one or two bolts. This facilitates movement of the frame so it can later be plumbed. Until the remainder of the bolts are installed and tightened, the connections are not rigid enough to resist strong winds and the frame may be severely damaged unless it has been braced (Fig. 3).

Courtesy of Dome Systems, Inc.

Fig. 3. Wind damage to steel frame. This framework is only one of many that did not have adequate cable bracing.

One form of simple structure consists of two columns supporting the ends of a beam or truss. A series of these structures tied together by longitudinal beams, such as girts on walls and purlins on the roof, make up the frame (skeleton) of the building. Erection of the first structure or frame is critical, as there is no other structure of similar kind to brace against. After the columns are bolted to the foundation, bracing the erected frame by temporary struts or cables will stabilize it and prevent it from being blown over by wind forces. Other braced frames placed at right angles to the first erected frame will stabilize the framework in the other direction.

The erecting contractor is responsible for installation of some type of bracing to prevent collapse during construction. Installation of bracing is facilitated when end-connecting plates (to which the bracing will be attached) have been shop welded to the steelwork. Cable bracing can be effectively tightened by jacks or turnbuckles and is needed only in a few of the total bays.

When any column line of the structural frame has permanent diagonal bracing, installation of the bracing members as the structure is erected will be sufficient to act as temporary bracing, providing the column base plates are securely bolted down, and the beams are connected to the tops of the columns. Some column lines, however, may not have permanent bracing so temporary bracing is needed (see recommendation 2.1.1.1).

3.1.15.2 Precast Concrete Walls

Precast and tilt-up type concrete wall panels are supported at the bottom on the foundation wall and at the top by the structural roof. Each erected panel needs temporary shoring until the roof is completed and the panel top secured to it. Lean-to steel pipe braces are often used, and in some cases have buckled when they are too slender, resulting in damage to the panels.

Buckling of a brace or other compression member may be prevented by designing the member according to specifications by the American Institute of Steel Construction (AISC) or comparable standard.

The AISC specifications limit the L/r ratio of steel braces to a maximum of 200, where L is the length of the brace in inches and r is the radius of gyration, equal to Ö I/A (I is the moment of inertia, A is the area of the section). The radius of gyration may be found in structural engineering handbooks. Table 1 gives acceptable minimum pipe diameters based upon the above specification.

Table 1. Permissible Minimum Diameters for Steel Pipe Braces

Length of Brace	*Nominal Diameter*
Up to 16 ft (4.88 m)	2-½ in. (64 mm)
16 to ‹20 ft (4.88 to 6.10 m)	3 in. (76 mm)
20 to ‹22 ft (6.10 to 6.71 m)	3-½ in. (89 mm)
22 to ‹25 ft (6.71 to 7.62 m)	4 in. (102 mm)

3.1.15.3 Concrete Block Walls

Building contractors sometimes take extreme risks by laying up hollow masonry units (such as concrete blocks) 15 to 20 ft (4.57 to 6.10 m) without lateral support. The wall then acts as a cantilever, and having low-strength uncured mortar, can be blown over by moderate winds. When the building has a steel skeleton frame, erect the frame, and then attach the concrete blocks to the frame by steel straps. Forces on the masonry will then be transferred directly to the permanent steel frame.

Steel reinforcing placed vertically in concrete-filled cores will strengthen a hollow masonry wall under construction, provided the steel is anchored into the foundation wall, but usually not enough so that bracing may be eliminated. The bracing may be unnecessary if the wall has reinforced concrete pilasters specially designed with steel reinforcing to transfer the wind load to the foundation wall.

When the hollow masonry units are of sand or stone aggregate, an 8 in. (203 mm) unsupported wall may be built safely upward without bracing to a height of 8 ft (2.44 m); a 12-in. (305 mm) wall to 10 ft (3.05 m). Hollow masonry units of lightweight aggregate such as cinders or slag have less stability. Safe heights without bracing are about two-thirds that for sand and stone aggregate masonry units.

Unless a wall is attached or has built-in resistance, bracing will be needed after it is built to its safe unsupported height. Once braced, the wall may be built up above the braces an equivalent distance, then braced at that level. The process can be continued until the wall is finished. The compression force in the brace needs to be transferred to both the ground and masonry wall. Bracing normally is placed at about 30° with the vertical.

3.1.15.4 Bracing Procedure

The bracing system shown in Figure 1 is capable of resisting winds of approximately 55 mph (24 m/s) from either direction.

Anchor two ¾ in. (19 mm) steel eye bolts, one on each side, in the concrete foundation wall every 16 ft (4.9 m). It is extremely important that the bolts and braces are installed directly opposite each other. If the anchors were not installed when the wall was poured, holes can be drilled through the wall for 1 in. (25 mm) diameter through bolts.

After the pair of braces is erected, install the cables on both sides and tighten simultaneously. This will create a compression force in the braces that will seat the ground timbers and also stabilize the braces. If the timbers settle an inch (25 mm) or more, shims or blocking installed at the base of the brace may be necessary to prevent the top of the brace from moving significantly downward on the wall.

Ensure spacing of both upper and lower braces is 32 ft (9.8 m). Place the upper braces halfway between the lower braces.

3.1.15.5 Roof Perimeter Flashing

This acts as a weather closure between the building wall and roof covering. The edge of the covering is protected from wind and rain by the flashing. Loss investigations have revealed many cases in which the covering had been installed long before the flashing, and intervening winds rolled back the unprotected edge.

3.1.16 Demolition

Serious fire losses have occurred during demolition operations as well as during construction. Such losses can be reduced by practicing the above procedures, plus the following:

- Shut and cap gas supplies at a point outside the building to help reduce the probability of fire and explosion.

- Reduce electrical service to a minimum and identify energized circuits to help limit and control ignition sources.
- Leave fire walls, fire doors, and other cutoffs in service as long as possible to help limit firespread.
- In cold weather, maintain heat as long as possible for the protection of automatic sprinklers, hose, and fire extinguishers.
- Retain automatic sprinklers and waterflow alarms in service as long as possible throughout the operation; then, remove section by section, and cap.
- In buildings or areas without sprinkler protection, retain standpipes in service as long as possible through the operation. Also, employ charged hose lines where the construction is combustible, as potential firespread may be beyond the capabilities of fire extinguishers.

3.1.17 Concrete Shell Structures

In the past, concrete shell structures were generally built with conventional formwork and rebar. These types of structures have not been a major concern during construction (other than as noted in Section 2.3). In recent years, however, the construction of concrete shell structures has often used a membrane, which is air-supported during the construction stage only, and polyurethane foam and concrete, which are spray-applied to the underside of the membrane. Loss experience is favorable for completed structures; however, there have been some losses (not insured by FM Global) during construction.

These structures are popular in the agricultural industry in lieu of tanks and silos and are also being used for housing, recreational buildings, water tanks, shopping malls, and other occupancies where large column-free areas are desired.

Usually, a coated fabric membrane is inflated with air and polyurethane foam is sprayed on the inside surface in layers or stages.

After the polyurethane foam has set, concrete (gunite) is sprayed in stages onto the inside of the polyurethane foam. The fabric can either be removed and an FM Approved weather-resistant coating sprayed on top of the polyurethane foam, or the fabric can remain and, if necessary, be supplemented with a weather-resistant coating.

Arches can be formed for door openings or shell-to-shell connections by spraying polyurethane foam and gunite up to the arch and later cutting away the coated fabric membrane.

A thorough and even covering of polyurethane foam over the inside surface of the membrane is necessary to prevent delamination and collapse. The proper density of polyurethane foam is also critical. A density of 2 to 3 lb/ft^3 (32 to 48 kg/m^3) is generally recommended. Lesser densities may cause structural problems and greater densities may adversely affect firespread across the top surface. Maintenance of proper air pressure during construction is necessary to prevent collapse until the concrete is strong enough to support itself. Air pressure depends upon the size of the structure and various material properties. The designer must specify the air pressure needed.

The shell sizes can be categorized as small (less than 80 ft [25 m] in diameter), medium (80 to 150 ft [25 to 45 m] in diameter), and large (over 150 ft [45 m] in diameter).

When conventional steel reinforcing bar (rebar) is used, employ caution during concrete spraying to prevent voids.

Ensure interior partitions are self-supporting and not rigidly attached to the shell. Any restraint caused by such attachment could result in cracking when thermal expansion of the shell occurs.

3.1.18 Excavation

Excavation adjacent to buildings has caused losses. In some cases, walls have collapsed due to the loss of stability provided by the adjacent soil. Where large ditches are to be excavated next to a structure, have a civil or structural engineer ensure that either the excavation will not adversely affect the structure or that adequate temporary bracing is provided. Ditches, particularly those dug for piping entering the adjacent building, can allow rainwater to enter the building, damaging it and its contents. Take precautions to prevent a loss due to rainwater that would directly enter the ditch or run off into the ditch and enter the building.

3.2 Loss History

3.2.1 General

For loss experience relating to torch-applied roof systems, refer to Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installations*.

Information for the following loss experience is based on experience of FM Global, and values in Tables 2 and 3 are based on gross estimates indexed to 1991 dollars.

During the ten-year period from 1981 through 1990, there were 1,308 construction-related losses (involving fire, wind/hail, explosion, collapse and other perils) totaling US$485 million, for an average loss of US$370,000. There were 193 losses of over US$100,000 each, totaling US$398 million. These larger losses averaged about US$2 million each.

The top ten perils based on number of occurrences and dollar loss are noted in Tables 1 and 2, respectively. Perils such as theft occur quite commonly, but the loss is generally limited to portable equipment or yard storage of construction materials and the dollar loss is proportionately low. In many cases, however, the value of equipment and storage exposed, and potential business interruption loss due to construction delays, may justify the provision of watch service, fencing, and lighting.

Table 2. Top Ten Builders' Risk Perils Based on No. of Occurrences from a Recent Ten-year Period

Peril	*No. of Occurrences*
Fire	290
Wind or Hail	286
Water-Liquid Damage	137
Theft	109
Collapse	103
Sprinkler Leakage	83
Riot and Civil Commotion	72
Escaped Liquids Damage	40
Surface Water	25
Rigging	20

Table 3. Top Ten Builders' Risk Perils Based on Dollar Loss from a Recent Ten-year Period

Peril	*Gross Aggregate Estimate in US$1000's*
Fire	US$398,711
Collapse	37,765
Wind or Hail	34,272
Water-Liquid Damage	20,649
Sprinkler Leakage	7,951
Riot and Civil Commotion	7,936
Surface Water	4,253
Explosion	4,240
Escaped Liquids Damage	3,589
Flood	2,194

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-4, *Fire Tests*
Data Sheet 1-13, *Chimneys*
Data Sheet 1-28, *Design Wind Loads*
Data Sheet 1-28R/1-29R, *Roof Systems*
Data Sheet 1-29, *Above-Deck Roof Components*
Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installations*
Data Sheet 1-62, *Cranes*

Data Sheet 2-8N, *Installation of Sprinkler Systems (NFPA)*
Data Sheet 4-4N, *Standpipe and Hose Systems*
Data Sheet 4-5, *Portable Extinguishers*
Data Sheet 7-28N, *Explosive Materials*
Data Sheet 7-29, *Flammable Liquid Storage in Portable Containers*
Data Sheet 7-32, *Flammable Liquid Operations*
Data Sheet 7-50, *Compressed Gases in Cylinders*
Data Sheet 9-1, *Supervision of Property*
Data Sheet 10-3, *Hot Work Management*
Data Sheet 9-17, *Protection Against Arson and Other Incendiary Fires*

4.2 NFPA Standards

NFPA 70, *National Electric Code*

NFPA 241, *Safeguarding Construction, Alteration, and Demolition Operations*

NFPA 701, *Flame Propagation of Textiles and Films*

Note: For locations outside the United States, reference comparable international standards.

4.3 Other Standards

American Society of Testing and Materials: ASTM E-84-98, *Standard Test Methods for Surface Burning Characteristics of Building Materials*; ASTM E-108-96, *Standard Test Methods for Fire Tests of Roof Coverings*.

APPENDIX A GLOSSARY OF TERMS

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

Hotwork: Any work involving burning, welding, or similar operation that is capable of initiating fires or explosions, including cutting, welding, brazing, soldering, grinding, thermal spraying, thermal welding, thawing pipe, torch-applied roofing, or any other similar activity.

APPENDIX B DOCUMENT REVISION HISTORY

January 2006. Added information on FM Approved welding pads, blankets, and curtains for use during hot work activities. Added wall bracing guidelines, previously published in obsolete Data Sheet 1-7.

September 2001. Changes were made to Recommendation 2.1.1.2. Hot Work Permit forms were updated.

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

January 1992. The term "cutting and welding" was changed to the more inclusive *hot work*. The new Hot Work Permit has been included, as well as a new recommendation for contractor supervision.

APPENDIX C COMPARISON WITH NFPA STANDARDS

NFPA 241, *Safeguarding Construction, Alteration, and Demolition Operations*, is similar to this data sheet.

Criteria for spacing combustible sheds from main building areas are slightly different.

NFPA 241 does not address concrete shell structures, as potential problems relating to their construction are mostly structural and not fire-related. In some other areas, NFPA 241 contains additional details, including a section on torch-applied roofing that is in general agreement with Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installations.*