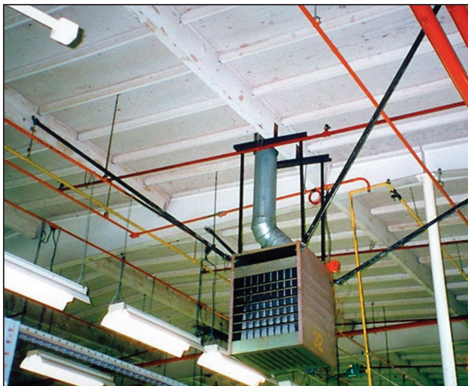

Understanding the Hazard

Fire Following Earthquake

Fire Protection

Earthquake ground shaking can result in broken piping and toppled equipment when restraint or flexibility is inadequate. In addition, flammable gas or ignitable liquid releases and fire protection impairments create significant post-earthquake fire hazards.

UTH topic categories:

- Construction
- Equipment
- **Fire Protection**
- Human Element
- Natural Hazards
- Process Hazards

This series of publications is designed to help you understand the everyday hazards present at your company's facilities. For more information on how you can better understand the risks your business and operations face every day, contact FM Global.

The Hazard

In the aftermath of a major earthquake, the ability to combat a fire is likely to be severely restricted. Unfortunately, this also is a time when the risk of fire could be significantly higher than normal. Earthquake shaking causes movement or damage of equipment and contents. This movement can result in released flammable gases or liquids and other combustible material coming into contact with ignition sources, such as open flames or electrical arcing. Further, after an earthquake, there is an increased possibility of area-wide fires or conflagrations, and uncertainty about the availability of fire suppression.

While earthquakes cannot be prevented or accurately predicted, their potential damage can be prevented or minimized by understanding the hazard, and through careful planning. News reports following earthquakes usually concentrate on visually striking structural failures in the zone of severe ground shaking. But, they largely ignore the majority of buildings that can be quickly returned to productive operation. These buildings usually remain standing, but may have experienced some nonstructural damage that might increase the likelihood of a fire, or impair sprinkler systems.

If your building sustains only moderate damage from an earthquake, protecting it against further nonstructural damage from either fire or water leakage is a critical first step toward quick recovery. This brochure focuses on practical ways to reduce risk associated with fires after earthquakes.

Science of the Hazard

Most earthquake damage results from the sudden release of energy in the form of seismic waves (wave motion) and surface rupture (physical slippage) of the earth's crust. Both phenomena can cause considerable damage to any structures exposed to them. Of the two, seismic waves cause more widespread geographic damage because they radiate outward from the initial point of disturbance in all directions, like the waves from a pebble dropped into a pond.

As a seismic wave passes beneath a building, it oscillates in three dimensions, imparting horizontal motion in both a push-pull and a side-to-side cycle, and vertical or up-and-down motion (see illustration on page 3). As the wave passes, it first moves the ground and base of the building, while all other parts of the building above ground level remain stationary. Within seconds, the upper levels also begin

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What you can do at your facility

Now:

- Install earthquake-actuated shutoff valves where flammable gas or ignitable liquid is piped into buildings.
- Incorporate earthquake-incident-response into emergency-response team activities.

Soon:

- Survey flammable gas or ignitable liquid equipment and piping inside buildings for adequate restraint and piping flexibility.
- If deficiencies are observed, contact FM Global for an earthquake review addressing fire following earthquake.
- Review *Understanding the Hazard: Lack of Earthquake Bracing on Sprinkler Systems* (P0042).
- Implement corrective measures as soon as possible to resolve any seismic upgrade recommendations for fire following earthquake and fire protection systems.
- Conduct earthquake-specific training with your emergency-response team.
- If you have specific earthquake concerns, contact your FM Global client service team to learn of additional engineering service opportunities.
- Prevent future problems by requiring FM Global review of new construction projects, fire protection installations, and modifications to protection.
- Develop minimum seismic design standards and specifications to be followed for all construction and new equipment installations.
- Develop an earthquake-recovery plan.

moving in the direction of the initial motion. The base will have reversed direction, however, because of the wave's motion (push-pull); as a result, the base and upper levels oscillate, often moving in opposite directions.

As the cycle continues, the entire structure moves and sways. Earthquake ground motions typically are amplified by the building — horizontal design forces at the roof can be two- to four-times larger than those at ground level. Earthquake forces on objects in a building also are affected by the items' physical properties (e.g., mass and stiffness). For example, heavier items will experience larger forces. Moreover, an earthquake can cause inadequately anchored equipment to slide, overturn or swing, regardless of size or weight. Piping or electrical connections to this equipment can be severed unless adequate flexibility has been provided. Fittings and couplings on unbraced piping can separate or leak due to excessive bending, rotation or movement. Excessive swaying of the pipe can damage hangers, resulting in loss of vertical support for the pipe, and often leading to catastrophic failure.

Fires after earthquakes commonly initiate from electrical or fuel gas-related sources because their use is widespread. In the United States, natural gas (methane) is a factor from 15 to 50 percent of the time, and electrical ignitions typically account for 40 percent or more of post-earthquake fires. Ignitable liquid spills, chemical reactions and the contact of combustibles with heat sources also have initiated or contributed to many fires after earthquakes.

Loss Experience

Although the chance of a fire is greatly increased after an earthquake, losses from large post-earthquake fires are less common than losses from shake damage to structural and nonstructural items (including fire sprinkler systems). When fires do occur, however, they have the potential to be extremely large events. A notable example took place in northern California in 1992, when an uncontrolled fire burned to the ground a retail building insured by FM Global. Multiple breaks in underground piping caused a fire pump to overheat and shut down when cooling water was lost, depriving the sprinkler system of water to control the fire. The breaks also allowed two 500,000-gallon (1890 m^3) elevated fire protection water tanks to completely drain.

It is important to recognize that minor changes in conditions can make a big difference in the number of fires and their outcome. For example, industry data from the 1994 Northridge, Calif., earthquake (magnitude 6.8) indicates there were more than 14,000 leaks in natural gas lines and at least 110 fires in the shaken area. Electric service was interrupted for at least one hour throughout the area, reducing the potential for fire. After four hours, power had been restored to only 22 percent of customers. If electricity had not been lost and only 1 percent of the 14,000 gas leaks had found an electrical ignition source, the number of fires would have more than doubled.

Controlling post-earthquake fires can be much more difficult than fire control in ordinary conditions. Multiple post-earthquake fires and physical damage can delay fire service response and reduce or exhaust water supplies. At FM Global customer facilities surveyed in areas of highest ground shaking during the North-

Reducing Losses

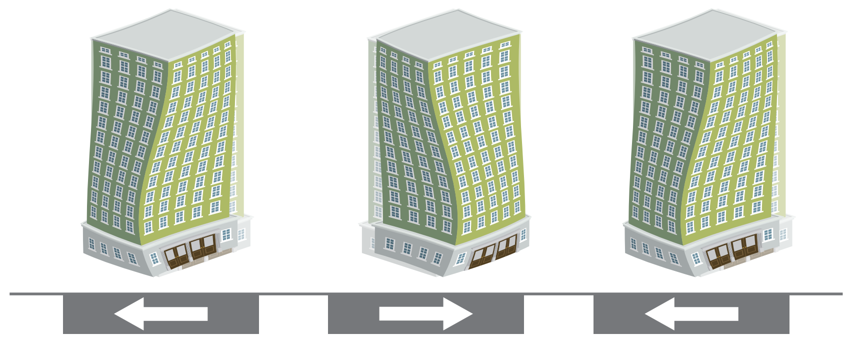
Fire prevention is critical because post-earthquake conditions can cause the following results:

- Multiple simultaneous ignitions: typically, 50-75 percent of earthquake-initiated fires start immediately after the event.
- Fires grow undetected: damaged alarm equipment and overtaxed communication systems often allow fires to grow.
- Delayed fire service response: delays are common due to the large number of fires, other emergencies, damage to fire stations and blockage of access routes.
- Impaired fire protection systems: on-site protection often performs poorly when seismic protection is inadequate. Public water supplies often are reduced or exhausted due to pipe breaks and demands of fighting multiple fires.

Fire management and emergency response remain key because fires can still occur for these reasons:

- Uncontrolled ignition sources: it is impossible to identify all ignition sources (most electrical ignitions, for example, occur in distribution elements, like wiring). Ignitions created by installation mistakes, material defect, or manufacturing processes often are difficult to find or impractical to eliminate.
- Delayed ignitions: fires often occur as a result of restoration of electrical and gas service in damaged buildings. Equipment or cooling system damage has resulted in overheating and fire in equipment that remains operating.

Example of differential movement (in one dimension)



Earthquake force + inertia = the effect of seismic wave

ridge earthquake, 74 percent of those with inadequately braced sprinkler systems experienced sprinkler leakage or failure. Moreover, 27 locations lost access to their water supply. Had fire occurred at any of these facilities, it would have almost certainly been larger than under normal circumstances, with buildings burning to the ground in some cases.

Achieving Adequate Seismic Protection

Preventing releases of flammable gas and ignitable liquid from equipment and piping is the most practical way to significantly reduce the risk of fire following earthquake. This risk can be mitigated by installing affordable, effective earthquake-actuated shutoff valves that stop the flow of flammable or ignitable material; by restraining equipment and piping and by providing appropriate flexibility in piping. At some sites, it may be practical to mitigate other deficiencies to reduce fire risk.

Earthquake-Actuated Shutoffs

Earthquake-actuated shutoff valves, unlike excess flow valves, stop the flow until it is safe to restart. They often are provided directly on small flammable gas lines. In other designs, flow in a pipe can be stopped, or other processes shut down, by a signal sent from a separate seismic sensor to a control panel or valve.

Restraint

The probability of a fire is not uniform from site to site; facilities with significant deficiencies are more likely to have a fire. For example, it has been estimated that restraining gas-fired equipment reduces the risk that a fire will be initiated at this equipment by more than 80 percent.

Restraint of equipment and piping is needed to limit damage and consequent flammable or ignitable material release or fire initiation. Equipment restraint prevents sliding, overturning and swinging. Braced piping will withstand earthquake motions because the pipes move with the building as one unit, not as individual parts.

Need more information?

Ask your FM Global engineer or client service team about the following:

- *Earthquake Checklist* (P9807)
- *Protecting Your Facility from the Dangers of Earthquake* (P9595)
- *Understanding the Hazard: Lack of Seismic Gas Shutoff Valves* (P0290)
- *Understanding the Hazard: Lack of Earthquake Bracing on Sprinkler Systems* (P0042)

Flexibility

Allowing movement where piping connects to equipment (even when the equipment is restrained) and where piping spans two locations that can move in different directions, is necessary to avoid piping damage. Often, adequate flexibility can be provided using FM Approved flexible couplings, or by configuring rigid pipe to allow some movement.

But What About . . .

…the cost of retrofitting?

The cost is typically very small if included during installation. Pipe bracing may add 3 to 4 percent to the system cost. Rarely does the cost of anchoring new equipment exceed US$500 per item.

By comparison, the cost of retrofitting varies widely. While some retrofit restraint may be simple (e.g., restraining water heater with straps), other retrofit restraint can be more complex and expensive, requiring expert analysis by qualified consulting engineers.

The cost of earthquake-actuated shutoff valves can be from as little as US$500 to US$2,500 when installed directly on a gas line, but US$10,000 or more for large-diameter pipe or complex systems such as a separate seismic sensor that sends a signal to close key valves or shut down processes.

…false tripping of an earthquake-actuated shutoff valve?

Earthquake-actuated shutoff valves have become much more reliable in recent years. When manufactured to meet appropriate third-party (e.g., FM Approvals) performance requirements, these valves will close in response to strong ground shaking, but not in response to normal vibrations — such as those caused when a truck drives by. Because the shutoff valve is a mechanical device, a false trip is possible, but the likelihood is low.

…the need to do both. Must we anchor equipment and provide an earthquake-actuated shutoff valve?

Even when a shutoff valve closes, damage to unrestrained equipment or piping may allow release of flammable or ignitable material, or could be unnoticed when the valve is reset. If equipment is anchored but a shutoff valve is not provided, a weakness in equipment or piping can cause a leak. Therefore, it is best to provide both equipment and piping restraint and an earthquake-actuated valve.

Don't Let This Happen to You

This post-earthquake fire grew uncontrolled when damage to underground piping impaired the sprinkler system and delayed water delivery. Photo courtesy of ABS Consulting — EQE Structural Engineers Division.

Ordering Information

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