Protecting Building Fuel Systems from Flood Damage

FEMA

HURRICANE SANDY RECOVERY ADVISORY

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Purpose and Intended Audience

Hurricane Sandy impacted several highly developed metropolitan areas including New York City and surrounding cities in New York and New Jersey. Some of the most significant impacts resulted from the failure of fuel tanks that supplied buildings with heat, hot water, and fuel for emergency power systems. Many buildings that experienced damage to their fuel systems during Hurricane Sandy were constructed before codes requiring flood protection were adopted.

This Recovery Advisory provides building owners, operators, facility managers, and designers with information on mitigation actions that can help protect fuel supplies from flood damage, enabling basic functionality to be restored at facilities shortly after floodwaters recede.

Mitigation actions can be taken to reduce the potential for flood damage to fuel systems. These actions are recommended for facilities damaged during Hurricane Sandy as well as facilities that were not damaged but have fuel tanks and fuel supply equipment that is vulnerable to future flood damage.

Key Issues:

1. All components of a fuel system (the main fuel tank, all pumps, power supplies, and all controls) should be protected from floodwater. Protecting system components is especially important for fuel tanks that supply emergency power systems.
2. FEMA's Hurricane Sandy Mitigation Assessment Team (MAT) observed fuel tanks on the lowest floor (in basements) in New York City and other jurisdictions in the impacted area. The New York City building code requires that main fuel tanks be placed on the lowest floor of buildings (including the basement) in order to reduce the fire risk associated with large volumes of flammable liquids. This location, while ideal for reducing the risk of fire, is usually the most vulnerable to flooding.
3. Current codes that reference American Society of Civil Engineers (ASCE) standard ASCE 24, *Flood*

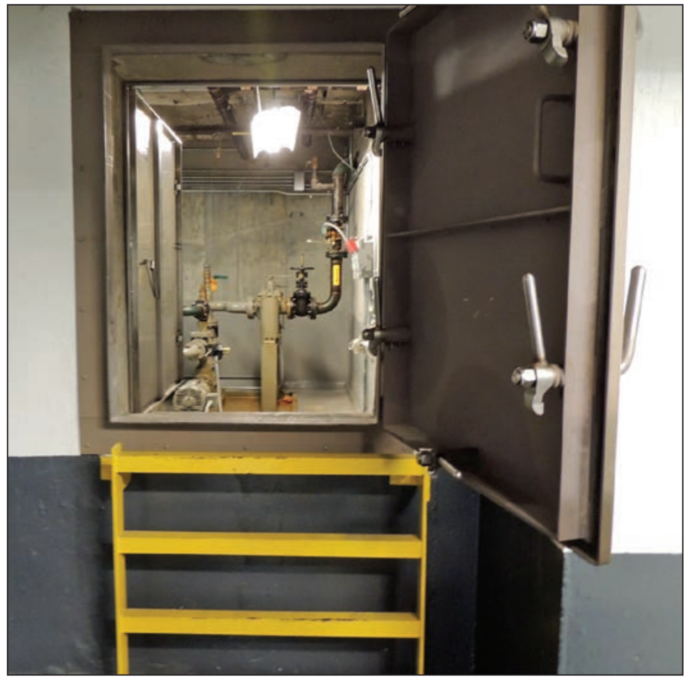

Figure 1: Fuel pump protected by watertight enclosure and "submarine doors" in Manhattan high-rise (top); 13,350-gallon fuel tank in a Manhattan high-rise protected by a similar method (bottom)

Resistant Design and Construction, require equipment and utilities to either be elevated to a specified height or protected by dry floodproofing when placed in buildings located in areas with identified flood risk. However, fuel systems in older buildings constructed before ASCE 24 provisions were adopted or buildings whose flood risk has increased since construction may be vulnerable, particularly when they have floors that extend below grade.

This Recovery Advisory Addresses:

- Codes and standards governing fuel systems
- Retrofit of fuel systems in existing buildings
- Preparing for a flood event in unmitigated buildings
- Links and useful resources

Codes and Standards Governing Fuel Systems

Several different codes and standards regulate the installation of new fuel tanks and fuel systems. The following section discusses some of the more pertinent regulations that apply to new construction and *may* apply to the repair or replacement of fuel systems in existing buildings. Local building departments should be contacted to identify all applicable requirements. In existing buildings, codes and standards that contain flood provisions should be met when fuel systems are repaired or replaced, even when not required, in order to protect these fuel systems from future flood events.

International Building Code

Section 1612.4 of the International Building Code (IBC) requires that buildings located in flood hazard areas be designed in accordance with ASCE 24. Section 7.0 of ASCE 24 contains general requirements for utilities and Section 7.4 contains specific requirements for mechanical and HVAC systems.

ASCE 24 requires that utilities and attendant equipment be elevated or protected from flooding. The amount of elevation or protection required depends on the type of facility (e.g., critical facilities, such as fire or police stations, and hospitals) and its flood risk identified on FIRMs (i.e., Coastal A Zone, Zone V, etc.). Utilities and attendant equipment (fuel pumps, control systems, motors, etc.) are required to be elevated from 1 to 3 feet above the base flood elevation (BFE) or elevated above the design flood elevation (DFE), whichever is greater. The elevation requirements are listed in Table 7-1 of ASCE 24. In the upcoming edition of ASCE 24 (ASCE 24-13), it is anticipated that buildings in Category IV will be required to be elevated to the BFE + specified freeboard, or DFE, or 500-year elevation, whichever is greater. In terms of required elevation, both Advisory Base Flood Elevations (ABFEs) and any applicable local requirements (such as freeboard) should be considered. Refer to text box for ABFE information, and refer to Hurricane Sandy Recovery Advisory No. 5 for a description of freeboard.

Terminology

Base Flood Elevation (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year (also known as “base flood” and “100-year flood”). The BFE is the basis of insurance and floodplain management requirements and is shown on FIRMs.

Design Flood Elevation (DFE): Regulatory flood elevation adopted by a local community. If a community regulates to minimum NFIP requirements, the DFE is identical to the BFE. Typically, the DFE is the BFE plus any freeboard adopted by the community.

Design Flood: ASCE 24 defines the design flood as the “greater of the following two flood events: (1) the *base flood*, affecting those areas identified as *special flood hazard areas* on the community’s FIRM; or (2) the flood corresponding to the area designated as a *flood hazard area* on a community’s *flood hazard map* or otherwise legally designated.”

Advisory Base Flood Elevation (ABFE): After severe coastal storms, FEMA may issue ABFE maps for areas where the existing FIRMs no longer adequately represent the actual base flood risk. ABFE maps are based on *in-progress* or *approximate* studies. They are intended to offer guidance on elevating new and reconstructed buildings. ABFE maps provide interim information for reconstruction efforts. Use of ABFE maps is mandatory only when a State or community adopts them. ABFE maps for portions of New Jersey and New York are available at http://www.region2coastal.com/sandy/abfe.

For more information, refer to Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy* (FEMA 2013).

Appendix G of the IBC, *Flood Resistant Construction*, covers tank requirements in section G701.

Section G701.1: Specifies that underground tanks must be designed and constructed to prevent flotation, collapse, or lateral movement from hydrostatic loads (including the effects of buoyancy) during design flood conditions.

Section G701.2: Specifies that aboveground tanks must be located above the DFE specified in ASCE 24, or designed, constructed, and anchored to prevent flotation, collapse, or lateral movement from hydrostatic and hydrodynamic loads.

Section G701.3: Specifies that all tank inlets and vents extend above the DFE specified in ASCE 24 or be fitted with covers designed to prevent the inflow of floodwater and the outflow of tank contents. The inlets and vents must also be properly anchored to prevent lateral movement from hydrostatic and hydrodynamic loads, including the effects of buoyancy.

International Mechanical Code

The International Mechanical Code, Section 1305.2.1, specifies that all fuel oil pipe, equipment, and appliances located in flood hazard areas must be either located above the flood elevation required by ASCE 24 or be capable of resisting all flood forces associated with the design flood.

International Fire Code

The International Fire Code (IFC) specifies that the design, fabrication, and construction of fuel tanks must comply with National Fire Protection Association (NFPA) 30, *Flammable and Combustible Liquids Code*. The IFC also includes requirements limiting the size and location of tanks to protect against the risk of fire. If the local building codes have requirements that conflict with the IFC, the building official is responsible for making the determination on which code governs.

Section 603.3.2.5. Requires that tanks in basements be located not more than two stories below grade.

Section 5704.2.7.8. Specifies that uplift protection be provided in accordance with NFPA 30 Sections 22.14 or 23.14 in locations subject to flooding. Section 22.14 applies to above ground tanks; Section 23.14 applies to underground tanks.

New York City Building Codes

The New York City codes have more specific requirements for fuel oil systems than the IBC, likely because of the large number of high-rise buildings in the city. These buildings often require large fuel oil tanks to provide heat and hot water to tenants, and often the fuel tanks must be stored within the building itself. The New York City Mechanical Code specifies that fuel-oil storage and piping systems must comply with the requirements of Chapter 13 and, to the extent not otherwise provided for in the code, with the requirements of NFPA 31, *Standard for the Installation of Oil-Burning Equipment*. The pertinent requirements from the New York City Mechanical and Building Codes are:

Section 1305.11.1 (Mechanical Code). The New York City Mechanical Code specifies that no more than 100,000 gallons of fuel may be stored inside any building.

- Belowground tanks: The maximum tank capacity for tanks installed below ground is 35,000 gallons.
- Aboveground tanks on lowest floor: For tanks installed above ground on the lowest floor, the maximum tank size is 660 gallons, and no more than 1,375 gallons stored in the same 2-hour fire area (the 2-hour fire area is defined in the New York City Fire Code). Tanks larger than 660 gallons are allowed for some construction types when the tanks are located in dedicated rooms or enclosures that are separated from the rest of the building by fire-rated construction. For example, in a building of Type I, II, IIIA, IV, and VA construction with a maximum total allowed quantity of 15,000 gallons, a 15,000-gallon tank is allowed if it is separated from the rest of the building by 3-hour fire-rated construction.

Section 1305.12 (Mechanical Code). Both aboveground and belowground tanks must be in compliance with appropriate design standards.

Section 1305.2.1 (Mechanical Code). To protect against flood hazards, tanks must be in compliance with Appendix G of the New York City Building Code. If a tank or tank vault located in a Zone A area is to be dry floodproofed, it must be designed and installed in accordance with ASCE 24-05.

Section 1704.16 (Building Code). Fuel-oil storage equipment shall be inspected in accordance with the approved construction documents, and testing shall be in accordance with Section 1308.1 of the New York City Mechanical Code.

Appendix G of the New York City Building Code. Most pertinent flood provisions in Appendix G of this code are consistent with those described for Appendix G of the IBC, but are numbered differently. The appropriate sections in the New York City Building Code are Sections G307.1 (corresponds with IBC G701.1), G307.2 (corresponds with IBC G701.2), and G307.3 (corresponds with IBC G701.3). Section G102.1 of the New York City Building Code differs from the IBC.

– *Section G102.1:* Item 9 applies to pre-FIRM buildings and actions that increase the degree of non-compliance. Any changes that would increase the degree of non-compliance, such as relocating equipment, are prohibited.

Requirements for Buildings with Substantial Damage or Undergoing Substantial Improvement

If a building is determined by the local building official or floodplain administrator to have been substantially damaged or will be substantially improved, it must be brought into compliance with the flood resistant construction requirements for new construction, including requirements for fuel tanks.

Substantial Damage: Defined by the NFIP as "damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred."

Substantial Improvement: Defined by the NFIP as "any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure (or smaller percentage if established by the community) before the 'start of construction' of the improvement. This term includes structures that have incurred 'Substantial Damage,' regardless of the actual repair work performed."

Refer to FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010) for more information. Homeowners should consult a local building official to determine whether their local codes and regulations have more restrictive definitions.

Retrofit of Fuel Systems in Existing Buildings

Existing buildings may lack the hazard-resistant design features required by current codes. In addition, the flood hazard at the building location may have changed since construction—the building location may be more vulnerable to flooding or may be subject to a higher base flood elevation. As a result, existing buildings may be more vulnerable to floods. Common flood-related failures of fuel systems in existing buildings include:

- Inadequately anchored fuel tanks can become displaced from their foundations when inundated by floodwater. Once displaced, the tanks or the fill, vent, and fuel lines that connect to them, are often damaged, allowing the discharge of fuel that can contaminate the building and surrounding area.
- Partially filled fuel tanks can implode when submerged by floodwaters and cause fuel to be released.
- Fuel tanks with vents that do not extend above the design flood depth or fuel tanks with non-watertight fill lines can either become contaminated with floodwater when submerged, or allow fuel to be released when displaced by floodwaters.
- Fuel pumps—used to move fuel oil from main storage tanks to tanks or equipment on elevated floors—that are not designed for submersible operation can fail when inundated by floodwaters. When fuel pumps fail, the equipment they serve can only operate for a limited time before the equipment exhausts the fuel stored on the upper floors.

To ensure fuel systems remain operational during and after a flood event, all components and equipment should either be elevated above the BFE or DFE as defined by ASCE 24, whichever is higher, or protected from inundation to that height. Because codes may require placing portions of the fuel system at risk of flooding, elevating all components of a fuel system may not be possible, so protecting system components from inundation may be necessary. The following mitigation measures describe floodproofing techniques for the major elements of a fuel oil system.

Fuel Tanks

For situations where fuel oil tanks cannot be elevated, it may be feasible to provide flood protection by replacing the tank with one that can resist floods and flood forces or by placing the tank in a dry floodproofed area.

Tank replacement. Replacing the tank with one that can resist flood forces provides flood protection by ensuring that the fuel tank can resist the hydrostatic pressures and buoyancy (uplift) forces for the design flood event. This may include ensuring that the tank's application is within the boundary conditions stated in testing performed on it, standards it complies with, or manufacturer's guidance provided.

- *Hydrostatic pressures* can cause tanks to implode. For example, a tank that extends 10 feet below the flood level needs to resist pressures as high as 640 pounds per square foot. Even tanks listed for underground applications may not be designed to resist hydrostatic pressures if they are placed at greater depths than those specified by the manufacturer.
- *Buoyant force* on a tank may cause it to separate from its foundation or, in the case of a buried tank, may force it out of the ground. For example, an empty 25,000-gallon fuel oil tank will be subject to over 200,000 pounds of buoyant force when submerged. Using this example, if concrete ballast were used to anchor the tank and the ballast was inundated with floodwaters, nearly 2,400 cubic feet of concrete (approximately 14 feet square by 14 feet high) would be needed to counteract the buoyant force. The weight of material stored in a tank offsets the buoyant force and reduces uplift. Because the level of fuel in a tank can vary, however, the weight of the material within the tank should not be relied upon to resist buoyant forces. When possible, tanks should be anchored sufficiently to prevent flotation when the tank is completely empty. If the required amount of anchorage is not possible, anchorage should be sufficient to prevent flotation of the tank when it contains the least amount of fuel oil that it would normally store. Anchorage points should be distributed across the tank to prevent unequal uplift forces on the tank.

NFPA 30 Tank Requirements

For **aboveground tanks**, NFPA 30 requires that at least 30 percent of a vertical tank's volume extend above the "maximum flood stage" (the phrase "maximum flood stage" is not defined in that code). It requires that anchorage be provided to resist buoyancy when more than 70 percent of a horizontal tank's capacity will be submerged at the "established flood stage" (the phrase "established flood stage" is also not defined). The amount of anchorage only needs to resist uplift for a full tank.

For **underground tanks**, NFPA 30 requires that tanks be anchored to resist buoyancy when empty and fully submerged.

Dry floodproof. Providing protection by dry floodproofing involves placing the tank in a water-tight space. Tanks that cannot resist hydrostatic pressures or cannot be anchored to resist buoyancy may be placed in reinforced rooms designed to resist hydrostatic pressures and anchored to prevent flotation. The rooms, often called vaults, are typically constructed of reinforced concrete because its mass helps counteract buoyancy, and with proper reinforcement, concrete can resist hydrostatic pressures. Steel vaults, which are typically lighter than concrete, can also be used but generally require additional mass or anchorage to resist buoyant forces. Because rooms containing tanks require access and ventilation to prevent explosive concentration of fumes from collecting, they should be equipped with specially designed, watertight submarine doors and ventilation equipment that vents above the design flood level. Also, although dry floodproofing entails making a building or an area within a building "substantially impermeable," meaning that no more than 4 inches of water depth will accumulate during a 24-hour period, some water may accumulate so an internal drainage collection system is required. Sump pumps supported by emergency power sources are recommended. Due to space limitations in many buildings, dry floodproofing may require constructing vaults around existing tanks. Refer also to Hurricane Sandy Recovery Advisory No. 2, *Reducing Flood Effects in Critical Facilities* (2013), and NFIP Technical Bulletin 3, *Non-Residential Floodproofing – Requirements and Certification* (1993).

Fuel Pumps

Fuel pumps and their controls should also be protected from floodwaters. There are two general types of pumps: submersible pumps and external pumps. Submersible pumps, which are installed within the fuel tank, are typically used in underground tanks and sometimes in aboveground tanks within buildings. External fuel pumps are generally not resistant to floodwaters and should only be used when located in dry floodproofed areas. The pump controls and power for both types of pumps should be elevated, dry floodproofed, or designed for submerged operation.

Fill Lines and Tank Vents

All fill lines, pipes, and connections should include appropriate components (i.e., valves) to prevent floodwaters from contaminating fuel tanks and to prevent fuels from escaping during a flood. Also, tank vents should either extend above flood levels or be provided with check valves that prevent floodwaters from entering the vents when submerged. Because failure of a check valve can result in contaminated fuel, extending vent lines above the DFE is preferred. These recommendations are consistent with NFPA 30 requirements.

Preparing for a Flood Event in Unmitigated Buildings

In the days and hours before a large storm, facility owners can make temporary adjustments to limit damage to fuel tanks in their buildings. These actions are especially critical for instances where no long-term solutions have been implemented to protect tanks and associated equipment. Although these temporary adjustments may reduce the potential for damage to the fuel system and reduce clean-up costs, planning and executing more robust measures as described in this advisory are recommended as they will provide more complete flood protection.

Before the Flood

- **Shut off all fuel-burning equipment**. An example of such equipment is a boiler. If emergency generators are supplied from the main fuel tank or if the amount of fuel stored in day tanks is not sufficient to provide power long enough for code-required life safety protection, the building will need to be evacuated.
- **Fill the fuel tank to minimize buoyant forces and mitigate against structural failure**. If possible, the tank should be completely filled with fuel oil. While completely filling a tank increases the amount of fuel that could be discharged if the tank fails, the potential for tank failure is greatly reduced by filling a tank.

  As a stop-gap measure, water can be used to fill a tank. NFPA 30 describes this approach as water loading. Since freshwater is approximately 12 percent denser than fuel oil, filling a fuel tank with water will increase stresses in the tank and, in extreme cases, could lead to tank failure. The risk of tank failure from water loading is greatest if the tank is empty before it is filled with water; topping off a nearly full fuel tank with water only slightly increases stresses. Water loading should only be done after it can be confirmed that the tank can withstand water loading.
- **Provide shut-off valves at the tank for all lines the tank supplies**. Install the valves as close to the tank as possible. Close the valves if flooding is anticipated.

After the Flood

- **Inspect equipment**. Inspect all portions of the fuel system for damages. Repair or replace all flood damaged equipment.
- **Clean tank**. If water was used to fill the tank, remove water from the tank and properly dispose of the water or fuel oil/water mix. Flush lines and restart the equipment.

Resources and Useful Links

Referenced Codes and Standards

ASCE and ICC

- ASCE (American Society of Civil Engineers). 2005. ASCE 24-05: *Flood Resistant Design and Construction.* FEMA prepared "Highlights of ASCE 24" online at http://www.fema.gov/library/viewRecord.do?id=3515.
- ICC (International Code Council). 2012. *International Building Code/International Residential Code*. Country Club Hills, IL. The ICC offers a free viewer that shows the codes at http://www.iccsafe.org/content/pages/freeresources.aspx.

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities, including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

  - ICC. 2012. *International Fuel Gas Code*. Country Club Hills, IL.
  - ICC. 2012. *International Mechanical Code.* Country Club Hills, IL.

NFPA

- NFPA (National Fire Protection Association). Web page located at http://www.nfpa.org/aboutthecodes/list_of_codes_and_standards.asp.
  - NFPA 30. *Flammable and Combustible Liquids Code*.
  - NFPA 31. *Standard for the Installation of Oil-Burning Equipment*.

New York and New Jersey Codes

- New York City Codes. 2008, with 2011 Amendment. Available at http://publicecodes.cyberregs.com/st/ny/ci-nyc/YC-P-2008-000006.htm.
  - Building Code. Available at http://publicecodes.cyberregs.com/st/ny/ci-nyc/b200v08/index.htm?bu=YC-P-2008-000006.
  - Mechanical Code. Available at http://publicecodes.cyberregs.com/st/ny/ci-nyc/b1100v08/index.htm?bu=YC-P-2008-000006.
- New Jersey Codes. 2009. Available at http://www.ecodes.biz/ecodes_support/Free_Resources/NewJersey/06_09NewJersey_main.html.

Other Resources for Protecting Fuel Supplies

- FEMA (Federal Emergency Management Agency). 1993. FIA-TB-3, *Non-Residential Floodproofing – Requirements and Certification.* Available at https://www.fema.gov/media-library/assets/documents/3473?id=1716.
- FEMA P-348. 1999. *Protecting Building Utilities from Flood Damage*. Available at http://www.fema.gov/library/viewRecord.do?id=1750.
- FEMA 577. 2007. *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds*. Available at http://www.fema.gov/library/viewRecord.do?id=2739.
- FEMA 543. 2007. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*. Available at http://www.fema.gov/library/viewRecord.do?id=2441.
- FEMA P-936. 2013. *Floodproofing Non-Residential Structures*. Available at http://www.fema.gov/media-library/assets/documents/34270.
- FEMA. 2013. Hurricane Sandy Recovery Advisory No. 2. *Reducing Flood Effects in Critical Facilities*. Available at http://www.fema.gov/media-library/assets/documents/30966?id=6994.
- FEMA. 2013. Hurricane Sandy Recovery Advisory No. 5. *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy.* Available at http://www.fema.gov/media-library/assets/documents/30966?id=6994.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at http://www.fema.gov/frequently-asked-questions.

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