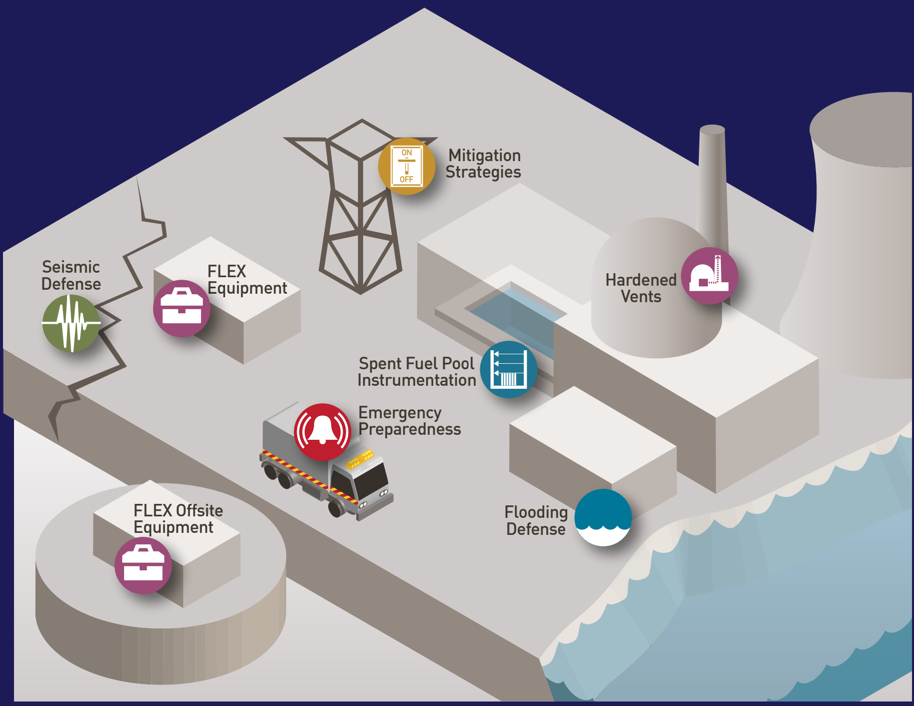
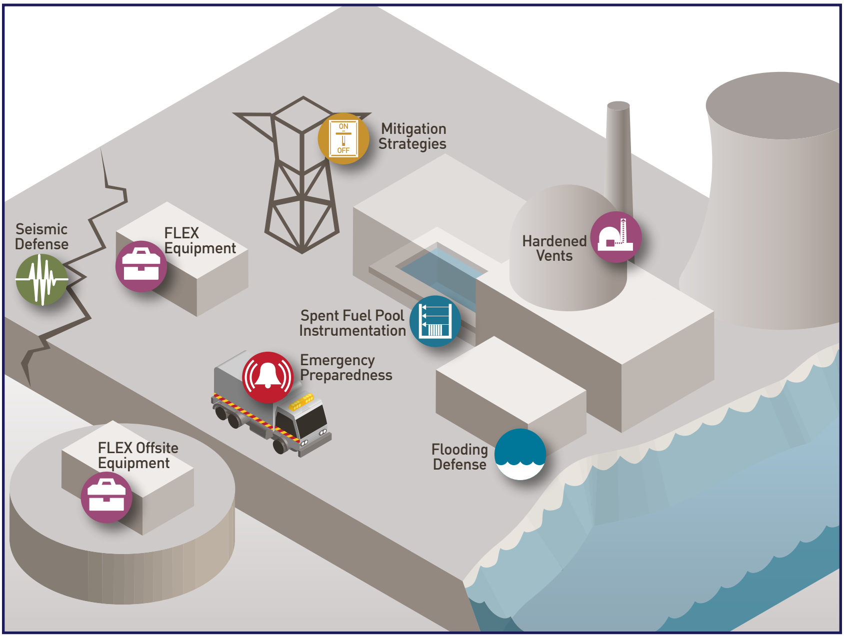
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment



SAFETY ENHANCEMENTS AFTER FUKUSHIMA

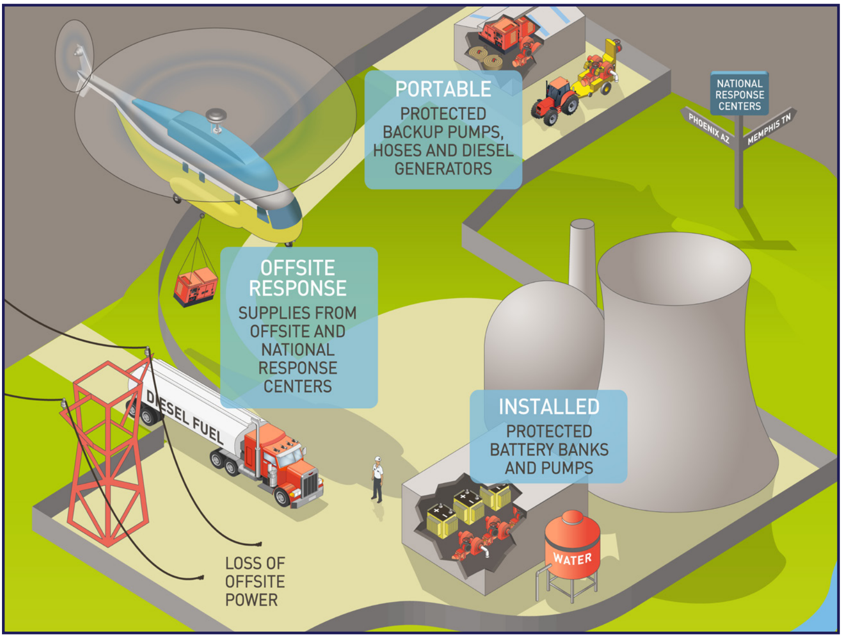


POST-FUKUSHIMA SAFETY ENHANCEMENTS

Safe Facilities Made Safer

On March 11, 2011, a 9.0-magnitude earthquake, followed by a 45-foot tsunami, heavily damaged the nuclear power reactors at Japan's Fukushima Dai-ichi facility. Following this accident, the NRC required significant enhancements to U.S. commercial nuclear power plants.[1] The enhancements included: adding capabilities to maintain key plant safety functions following a large-scale natural disaster; updating evaluations on the potential impact from seismic and flooding events; new equipment to better handle potential reactor core damage events; and strengthening emergency preparedness capabilities. Combined, these actions ensure that the nuclear industry and the NRC are prepared for the unexpected.

1 Although this brochure focuses on commercial nuclear power plants, the NRC considered the lessons of the accident for other types of nuclear facilities and required enhancements as appropriate.



MITIGATION STRATEGIES

Ability to Handle Unanticipated Events

In order to maintain key safety functions, the NRC ordered every U.S. commercial reactor operator to have strategies for dealing with the long-term loss of standard safety systems. Instead of speculating on which events might happen, the order focused on improving plant flexibility and diversity in responding to extreme natural phenomena, such as severe flooding and earthquakes. The goal is to keep the reactor core cool, preserve the containment barrier that prevents or controls radiation releases, and cool the spent fuel pool, all for an indefinite period of time. Plants with multiple reactors should be able to implement these measures at all reactors simultaneously. Each plant installed new emergency response equipment, stored onsite and protected from natural hazards. NRC inspectors have verified that the strategies are in place at all U.S. nuclear power plants. Additional equipment and resources are stored at two National Response Centers, ready to be deployed to a plant during an emergency.

FLEX EQUIPMENT

Maintain Key Functions with Backup and Redundant Equipment

The NRC accepted the U.S. nuclear power industry's proposed safety strategy, called Diverse and Flexible Mitigation Capability, or FLEX. FLEX maintains long-term core and spent fuel cooling and containment integrity with installed plant equipment that is protected from natural hazards, as well as backup portable onsite equipment. If necessary, similar equipment can be brought from offsite.

Portable equipment is stored in areas protected from potential natural hazards, such as the robust FLEX building in the background. (Photo of FLEX building outside the Hatch nuclear power plant, Southern Company.)

Portable pumps and generators provide water and power to maintain key safety functions. (Photos of pumps and generators at the Diablo Canyon nuclear power plant.)

Standard mechanical and electrical connections for the portable equipment were installed at all U.S. plants. (Photo of FLEX Jumper connection panel at St. Lucie nuclear power plant and mechanical connection at Millstone nuclear power plant.)

Backup equipment can be brought from offsite to any U.S. nuclear power plant within 24 hours. (Photos of equipment at National Response Center.)

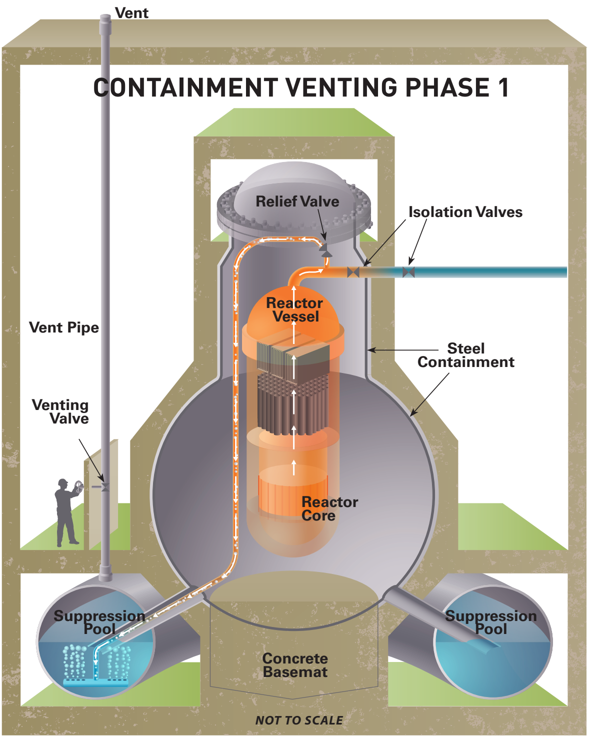
Debris removal equipment and alternative plans ensure access to the site. (Photos of support equipment used by U.S. Forest Service in California and the Diablo Canyon nuclear power plant.)

CONTAINMENT VENTING SYSTEM

Improved Fukushima-Style Designs

The Fukushima accident disabled the plant's reactor core cooling systems, causing heat and pressure to build within the concrete and steel containment buildings that surround the reactors. This buildup eventually damaged the buildings and made it easier for radioactive material to spread to the environment. The NRC required all U.S. nuclear power plants similar in design to the Fukushima plants to improve or install a reliable, hardened vent to remove heat and pressure before potential reactor core damage. This helps preserve the integrity of the containment building, while delaying reactor core damage or melting.

Subsequently, the NRC updated the order to ensure those vents would function in the conditions following reactor core damage. Upgrades have been completed at all affected plants and verified by NRC inspectors. These upgrades were not necessary for other designs of nuclear power plants, so the order did not apply to them.



SPENT FUEL POOL INSTRUMENTATION

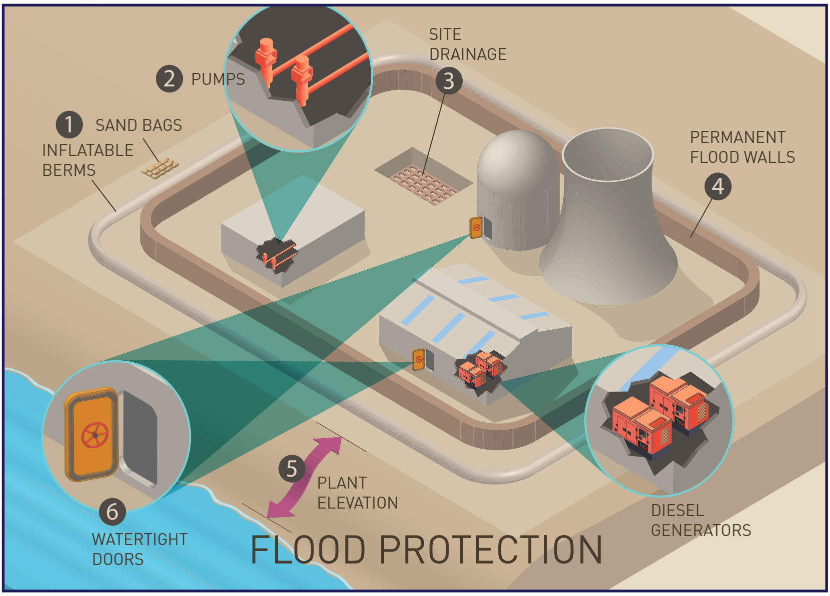
Ability to Monitor Level of Cooling Water

During the accident at Fukushima, the plant operators lost both their ability to cool the spent fuel pools and determine the amount of water in the pools. If enough water boiled away or was otherwise lost, the spent fuel rods could overheat and potentially release significant amounts of radiation. Weeks later, it was learned that the spent fuel was always covered, but the information gap diverted attention and limited resources from more important tasks during the accident. The NRC required all U.S. nuclear power plants to install water level instrumentation in their spent fuel pools. The instrumentation currently in place reports at least three distinct water levels: (1) normal level; (2) low level but still enough to shield workers above the pools from radiation; and (3) a level near the top of the spent fuel rods where more water should be added without delay. NRC inspectors verified these capabilities.

EMERGENCY PREPAREDNESS

Enhanced Disaster Response Capabilities

The accident at Fukushima highlighted the complexity of emergency response when multiple reactors on the same site are affected at the same time and electrical power is unavailable. In response, the NRC asked U.S. nuclear power plant operators to assess how many emergency staff they will need to respond to a large accident that may affect multiple reactors at their site and make changes to their emergency plans as necessary. The NRC also asked the plant operators to ensure that they can power the communications equipment staff will need to effectively respond to such an accident. This included power for response team radios, cellular telephones, and satellite telephones. Licensees purchased additional equipment and modified their emergency response procedures, based on the insights from these evaluations. NRC inspectors reviewed these enhancements.



FLOODING AND SEISMIC DEFENSE

Addressed Potential Impacts from Natural Disasters

In light of the Fukushima plant damage from the extreme earthquake and tsunami, the NRC requested U.S. nuclear power plants operators to perform detailed "walkdown" inspections of their installed seismic and flooding protection features. The operators ensured the features met current requirements, and identified, corrected, and reported any degraded conditions. NRC inspectors performed follow-up reviews.

Based on advances in the knowledge and understanding of seismic and flooding hazards and given the severity of the event at Fukushima Dai-ichi, the NRC requested the licensees of operating reactors to reanalyze potential flooding and seismic effects. These reevaluations used updated information and methodologies to inform plant operators of potential impacts to their sites. As a result, several nuclear power plant owners modified the protection of certain plant structures, systems, and components, or they identified alternative strategies to maintain the safety of the reactors in the event of a flooding or seismic event.

Examples of Flooding Protection Features

1. **Sandbags and/or Inflatable Berms:** Temporary watertight barriers that would be installed in advance of a flood, designed to keep the site dry.
2. **Pumps:** Temporary and permanent pumps can alleviate the effects of flooding by removing water from the site.
3. **Site Drainage:** A site's design can reduce or even prevent flooding by directing floodwaters away from vital power plant areas. Drainage systems can be either man-made (drains) or natural (grading).
4. **Permanent Flood Walls:** Man-made structures primarily designed to prevent floodwaters from entering a power plant site. These walls, built from engineered and/or natural materials, also reduce flood effects associated with erosion, wave action, and debris flow.
5. **Plant Elevation:** Permanently increasing the elevation of a nuclear power plant's site during construction helps to ensure potential flooding sources are less likely to affect the site.
6. **Watertight Doors:** Specially-designed doors, similar to those found on ships, keep floodwaters away from vital reactor systems and equipment, such as emergency diesel generators.

Examples of Seismic Protection Features

1. **Anchorages and Restraints:** Mechanically attaching equipment to a surface to prevent movement during an earthquake. This minimizes potential damage to the restrained equipment as well as nearby equipment.
2. **Spatial Separation:** Physical separation of equipment or structures to minimize their interactions during an earthquake.
3. **Isolation Systems and Dampers:** Structural elements that substantially decouple equipment or structures from the base substructure impacted by an earthquake. This protects the structural integrity of the isolated equipment or building.

POST-FUKUSHIMA SAFETY ENHANCEMENTS RESOURCES

NRC Order on Mitigation Strategies (EA-12-049)
(*https://www.nrc.gov/docs/L1205/ML12054A735.pdf*)

NRC Order on Spent Fuel Pool Instrumentation (EA-12-051)
(https://www.nrc.gov/docs/ML1205/ML12056A044.pdf)

NRC Order for Containment Venting Systems (EA-13-109)
(https://www.nrc.gov/docs/ML1314/ML13143A321.pdf)

NRC Request for Information letter related to seismic, flooding and emergency preparedness
(https://www.nrc.gov/docs/ML1205/ML12053A340.pdf)

Post-Fukushima Safety Enhancements Resources
(https://www.nrc.gov/reactors/operating/ops-experience/japan-dashboard.html)

Recommendations for Enhancing U.S. Reactor Safety in the 21st Century: The Near-Term Task-Force Review of Insights from the Fukushima Dai-ichi Accident
(https://www.nrc.gov/docs/ML1118/ML111861807.pdf)

Resolution of Post Fukushima Tier 2, Tier 3, and Non Tiered Activities
(https://www.nrc.gov/docs/ML1810/ML18101B396.pdf)

UNITED STATES NUCLEAR REGULATORY COMMISSION

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