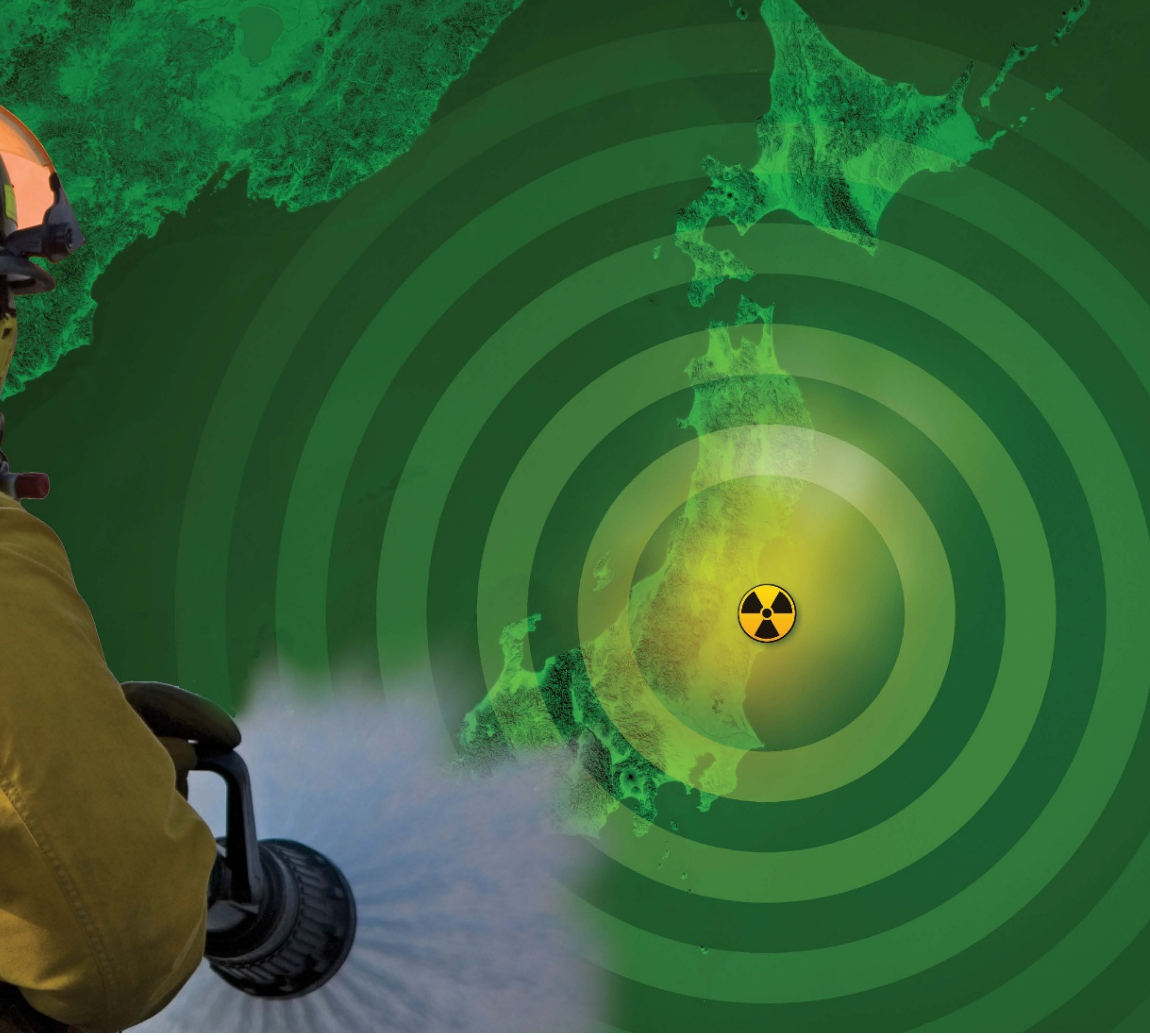
Japan's earthquake and tsunami forced a re-evaluation of nuclear power plant protection. Now, a veteran firefighter examines the state of American preparedness and looks at what needs to be done next.

IN THE SHADOW OF FUKUSHIMA

Facing the Fires of a Meltdown

BY ROBERT LEWIN



During a long career in the fire service with a nuclear power plant in my jurisdiction, I attended many required training drills, participated in evaluated exercises, and even responded to several fires at the plant. Even though I toured the facility and conducted fire safety inspections on the non-nuclear parts of the plant, never in my 30-plus year career did I consider that my firefighters might be called upon to stop a reactor meltdown by applying water.

Never until March 11, 2011, a date now known in Japan as 3/11, had I considered the need to go inside a reactor's containment dome or the need to look down at the spent fuel pools. It was deemed unnecessary. As I watched the situation in Fukushima, Japan, unfold, first seeing helicopters dropping water on a nuclear power plant, using the same techniques our wildland firefighters use, then firefighters on the ground applying water, did I realize that I had to face the possibility, albeit remote, of overseeing a response to a similar disaster.

As I watched videos of brave firefighters responding to the ailing plant, connecting hoses to systems applying water to the melting uranium and plutonium mixed-oxide fuel, I wondered, "Could this happen in the US? Could our firefighters be charged with responding as our brothers in Japan did?" I needed to see the reactor; I needed to see the spent fuel pools. I needed to ready my people.

I began to prepare.

On March 11, 2011 at 2:46 pm, Japan time, for six protracted minutes, a colossal earthquake measuring 9.0 on the Richter scale rocked the earth. Of a magnitude beyond anything in Japan's history, it began approximately 20 miles deep in the ocean 42 miles east of Japan. It unleashed a tsunami, with waves topping 100 feet high in places, that produced even more havoc on the island nation. Over a year later the official death toll stands at near 20,000 people.

Three Japanese nuclear reactors damaged in the catastrophe, while in "cold shutdown," are still emitting radiation.

The lesson those power plants teach is clear: Protection of nuclear facilities by skilled full-time onsite fire departments and well trained and equipped offsite fire departments needs to be significantly increased. The US Nuclear Regulatory Commission (NRC) must require that industry, local, state and federal firefighting services review and participate in comprehensive improvements to the way nuclear power plants are protected. If US firefighters are expected to follow the example of what Japanese firefighters did to stabilize damaged reactors, then comprehensive changes must occur at and around nuclear power plants.

Beyond Design Basis

While the shaking was underway, the six-reactors at the Fukushima Daiichi nuclear power plant on the east coast of Japan began a SCRAM, the abrupt shutdown of a reactor by inserting control rods into its fuel to halt the reaction. Even though the reaction was stopped, the extreme heat of the uranium fuel assemblies still required vast amounts of circulating water in order to cool the temperatures and prevent a meltdown. A meltdown, the greatest fear of all nuclear facility operators, can result in a loss of containment, hydrogen explosions and fires that can spew radioactive smoke into the atmosphere, contaminating the land, sea and people.

Because of the earthquake's devastating effects on the electrical grid, the enormous pumps that circulated essential cooling water were without offsite power, so diesel generators automatically started to supply the back-up power. All seemed to be working as designed until the tsunami struck the plant at a height that was beyond its design basis. The wave crossed over the sea walls and flooded the plant, including the diesel back-up generators; this was never envisioned.

While operators at the badly damaged power plant began their efforts to bring the affected reactors under control, they continued to run into setback after setback: Battery back-up failed, and power lines were laid only to be damaged by falling debris from an ensuing hydrogen explosion. Within the first 24 hours, fire engines were deployed to use their pumps to put seawater into the melting reactors.

Fukushima had an onsite fire department with three fire engines. One of the fire engines was damaged beyond use by the tsunami. The second was unable to be used because of debris that prevented its response. Only the third began cooling the reactors on the first day after the earthquake. At that point, offsite firefighters and engines were brought in. Parked next to the reactors, they began injecting large quantities of water into the reactors to prevent further radioactive release from super-heated uranium exposed to air in the absence of coolant. The firefighters also applied water to the spent fuel pools to ensure they were not overheating. Later it was determined that, very likely, the firefighters' efforts would have been better used elsewhere.

As three of the reactors melted down and spent fuel pools also threatened to overheat, the firefighters applied sea water to overheated fuel using time, distance and shielding tactics. While engaged in this effort, firefighters, along with the many brave operators, received doses of radiation.

During operations from March 19 to 25, a total of 526 firefighters were dispatched from fire departments in Tokyo, Yokohama, Kawasaki and Osaka as part of the mission. About 200 of these firefighters set foot on the premises of the Fukushima plant. Firefighters who took part in the cooling mission were exposed to radiation levels of up to 27 millisieverts (2.7 Rems), lower than the Japanese government-set yearly limit of 100 millisieverts for times of emergency, later raised to 250 millisieverts per year during the crisis. In order to reduce radiation exposure, lead shields were installed at the command post.

Today the government continuously monitors the radiological effects on the firefighters.

Protecting a Nuclear Power Plant

Like the events of Sept. 11, 2001, which pressed changes in the way nuclear power plants were protected from terrorism, Fukushima is changing the way we protect nuclear power plants from natural disaster and beyond-design-basis conditions.

The lessons of success

Diablo Canyon Nuclear Power Plant on the rugged coast of central California is a plant with a full-time fire department. In 2008 an explosion in a large transformer occurred in the middle of the night when there were limited plant personnel on site, including those in the large six-story administration building overlooking the plant and transformer.

The explosion peppered shrapnel on the administrative and generating buildings, penetrating glass windows and lodging in the walls where people worked during the day. The incident was followed by an oil fire, since large quantities of oil spread away from the transformers. Automatic fire suppression systems on both the transformer and its adjoining neighbor activated, protecting the second transformer, but the water spread the oil fire.

The full-time fire department was alerted by the plant operators and responded in a very new fire engine with a 1,500 gallon per minute pumping capacity and a built-in foam system and monitor.

When the five-person crew arrived, the oil fire was igniting a metal building that contained compressors for the pneumatic systems used to operate the facility's valve systems. After passing through security barriers, the crew made its way to the protected area of the plant and began applying foam on the large pool of fire. Their actions not only protected the pneumatic systems but the adjoining transformer as well.

The loss of two transformers would have put the nuclear reactor unit out of service for many months rather than the few weeks that occurred. Because of the decisions and efforts of the full-time, onsite firefighters operating on a modern fire engine, the utility saved millions of dollars.

Operators of nuclear power plants have always believed it crucial to mitigate nuclear accidents, and they invest heavily in employee training. However, they have not trained their staffs for a loss of outside power (known as LOOP) during a nuclear accident when all redundant power supplies that provide for cooling systems fail as well. Further, they have not trained personnel in procedures for handling two or more reactors failures at the same time. And while the probability of something like this occurring is as remote as a jet flying into a skyscraper, it cannot be completely ruled out.

Nuclear power plants are all designed with redundant systems to ensure a safe shutdown. The bulk of people who oversee nuclear power plants are engineers and by their nature and training they believe that any potential problem can be mitigated by engineering. In this view, procedures can be written, practiced and followed that will allow engineered systems to work.

Engineers also believe that upon a potential engineering failure, "defense-in-depth" can be provided by building multiple backup devices. For example, procedures exist in case of power loss to automatically start the diesel generators. If they fail, backup battery systems can temporarily run safety equipment until other power is restored. If all those fail, another unit at the plant can provide backup power.

To an engineer, this system will ensure the all-important cooling of the reactor. But what if there is a total blackout of all power to all cooling systems? An engineer will say it is a near-zero probability; a firefighter will say even a near-zero probability is possible.

Firefighters are different from engineers. Firefighters believe that failures often occur when humans or machines are involved. While these two cultures have a different worldview, combining the expertise of both provides the best defense for protecting a nuclear power plant.

Nuclear power plants should be designed with redundant safety mechanisms and should also be equipped and staffed with highly skilled full-time fire departments.

Operating in the real world

Clearly, safety is inculcated in the culture of the nuclear power industry. The industry says it, believes it and strives for it. But it needs to do more. Real world scenarios must be exercised.

If, for example, spraying sea water on a reactor to provide cooling is a procedure we would use, as was done in Fukushima, then it must be fully exercised following the maxim "train like you fight and fight like you train." No one expects to actually pour sea water into the reactor during training, but firefighters need to deploy hoses and pump water from the source to the reactor building in as close a simulation as possible. We need to know if it would take two fire engines or a strike team of five fire engines to lay and pump the hose line. We need to practice time, distance and shielding during training as we would during an operation.

Offsite firefighters are essential to the protection of a nuclear power plant and they must be ready to protect their communities by containing a radiological emergency at its source. While the NRC requires training of offsite responders, that training is not rigorous enough. The training must include responding to a hostile fire and responding to a nuclear power accident. Whether the local fire department is all-volunteer or from a large municipality, that fire department needs to be educated and ready.

In the event of a hostile radiological fire or a reactor losing its cooling, it would take more than a single engine company to handle the disaster. Hundreds of firefighters would need to rotate in and out of the fight to limit their exposure to radiation. Again, fire commanders must understand and practice the strategy of time, distance and shielding to protect their firefighters while still putting them into the fight.

Fires occur at all power plants, including non-nuclear ones. There are transformer fires, threatening wildfires, insulation fires and oil fires, among others. The threat of terrorism has also received attention. For the last 10 years, the NRC has been securing nuclear power plants behind concrete and concertina security barriers. In addition, it has required and tested security forces that would rival any metropolitan police tactical team in order to protect the plants from hostile actions of all sorts.

But while all this security has been ramped up, fire engine response and training have been sacrificed. Today, even fire engines must be processed through the security web, causing unacceptable response delays and limited training exercises. Because of these security shifts, even fire personnel who need to get in to fight hostile fires are slowed when time is of the essence. It's worth remembering: No terrorist act has ever occurred at a nuclear power plant and if one did, it would be the firefighters who would be called in to put out any ensuing fires.

Of the 104 commercial reactors operating at 65 power plants in the United States, only 10 have full-time fire departments on site. The rest have volunteer fire brigades of on-duty plant operators who, when the alarm rings, stop what they are doing, don fire protective uniforms, and muster for whatever the alarm might be. During an emergency, pulling off valuable operations personnel to fight fire is a dangerous plan since they would likely be needed to help stabilize the plant. Firefighting is complex and requires tough and rigorous training—operators should be trained to stabilize the plant, not to engage in a firefight. Because nearly all American nuclear plants were licensed in the 1970s and 1980s, the practice of using volunteer brigades instead of full-time firefighters has not been questioned at most plants.

Actually, it is imperative for full-time firefighters to be housed at every plant.

Some fire departments next to nuclear power plants may believe they will not be called upon to respond to a fire, a hazardous material incident, or even a rescue at a plant. Some will even declare that they will see the nuclear power plant in their rear view mirrors as they drive away from a radiological release.

However, it's wrong to think incidents at a nuclear power plant are always dangerous. In almost all cases, a fire there is no more dangerous than a fire at any power plant because of safety systems designed to contain radiation. However, the onsite firefighters will need help—and a lot of it.

Analysis: What Needs to Change

We need to learn from the events at Fukushima. Fire departments, both onsite and offsite, provided cooling to stabilize the Japanese reactors. If the expectation of the US nuclear industry is that fire departments will respond in a nuclear emergency, then both must engineer for "beyond design basis" events, as well as ensure that both onsite and offsite firefighting forces are properly prepared. The following should be implemented:

- All nuclear power plants need to have onsite fire departments staffed daily with a minimum of four firefighters and a chief officer.
- Onsite fire stations need to be built far enough away from the reactor so that they will not be involved in an incident but close enough for a quick response.
- Both nuclear plant firefighters and offsite firefighters need to be trained to industry standards and then have additional specialized training on protecting a nuclear power plant.
- Offsite responders must be required to participate in rigorous training with the onsite fire departments in all areas of the plant, including within the radiological control area.
- Onsite notification systems and communications systems need to be modern and interoperable with offsite responders.
- Fire engines at nuclear power plants should be tested regularly and put on a replacement schedule, and these engines need to be equipped with large pumps and built-in foam systems.
- Local emergency plans need to focus offsite fire departments' emergency response onsite and limit their expectations for offsite.
- Security systems need to be evaluated for their speed in getting emergency response personnel into the incident to begin operations. Industry standards should be used as a measure.
- Firefighters must understand and practice laying and pumping large-diameter hose with fire engines to the reactors and spent fuel pools from sources such as the sea.
- Firefighters need to train on time, distance and shielding on the ground, not in a classroom.
- Firefighters must be brought into the discussion with the NRC and the nuclear industry to collaborate on the surest methods to protect nuclear power plants and the communities that surround them.
- Large numbers of firefighters must have high-end dosimeters in order to know their radiation exposure.
- Specialized equipment needs to be stored off site where it will not be contaminated and should include personal protective equipment, water and food.
- An ordering process needs to be developed similar to the nationally used Resource Ordering Status System that would be able to quickly order firefighters and radiological workers from other nuclear power plants to assist the affected plant.

It is not for firefighters to debate the pros and cons of nuclear power; rather they must plan and train on the appropriate ways to protect nuclear power plants and the lives, property and natural resources near them. Much is to be learned from the Fukushima firefighters. If we fail to analyze their challenges, future consequences may be disastrous. **HST**

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