# Fire Reveals Flooding Hazard at Indian Point

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## Executive Summary

On May 9, 2015, one of the transformers at the Indian Point nuclear power station in New York exploded, leading to a fire and activating the fire protection system. The fire was extinguished but water pooled on the floor of the switchgear room, where electricity is transmitted to the emergency systems. If the water level were to exceed five inches, the switchgears would be disabled, leading to a station blackout and thereby increasing the risk of a nuclear meltdown. Fortunately, the water level remained well below this threshold.

The Nuclear Regulatory Commission (NRC) sent a Special Inspection Team to determine water pooled on the floor of the switchgear room, the potential risk it posed, and how workers responded to this threat.

The NRC team determined that valves in the switchgear room that opened to spray water on the transformer fire malfunctioned because parts were corroded and clogged with debris. The valves leaked water into the room. The drain in the floor was also partially blocked by debris, allowing the room to begin flooding. The periodic tests of the drain conducted by the plant owner were inadequate to reveal clogging problems, and while tests did reveal problems with the valve, workers did not follow up by fixing the valves. Thus, the plant owner repeatedly violated NRC regulations that require it to identify and fix safety problems in a timely and effective manner.

Moreover, the vulnerability of the electrical equipment in the switchgear room to internal flooding has been flagged repeatedly and never resolved.

In 1988, the NRC required plant owners to evaluate their facilities for vulnerabilities to severe accidents that could lead to the release of radioactivity into the environment. In response, in 1994, the owner identified several scenarios in which water pouring from a broken pipe could flood the switchgear room and disable the electrical equipment. However, the NRC did not require that owners fix the vulnerabilities they identified. Thus, the owner addressed only some of these vulnerabilities.

In 2007, the owner of Indian Point submitted an application to the NRC for a 20-year operating license extension. As part of this process, the NRC requires the owner to conduct an evaluation of Severe Accident Mitigating Alternatives (SAMAs)—modifications to the plant and revisions to procedures that would lessen the chances and/or consequences of severe accidents. The owner found that installing a flood alarm in the switchgear room that would alert the control room operators when the water reached a certain level would be cost beneficial. The cost of the $200,000 alarm would be more than offset by the expected benefit of $1.4 million or more. Yet the NRC does not require that cost-beneficial modifications be made unless they address a problem that is aging related. Because a flood alarm would address a problem that had been in existence since the reactor was built, the NRC did not require the owner to install this cost-beneficial safety upgrade.

Following the Fukushima accident, the NRC required owners to re-evaluate seismic and flooding hazards, but again did not require owners to make cost-beneficial modifications to address these hazards.

Thus, to address the vulnerability to flooding of the electrical equipment in the switchgear room—as well as other vulnerabilities identified by past assessments—the NRC must require that owners make cost-beneficial safety upgrades.

## Introduction

On May 9, 2015, one of the transformers at the Indian Point nuclear power station in New York exploded, leading to a fire and activating the fire protection system. The fire was extinguished but water pooled on the floor of the switchgear room of Unit 3, where electrical equipment that passes electricity to the emergency systems is located. If the water level were to exceed five inches, the equipment would be disabled, leading to a station blackout and significantly increasing the risk of a nuclear meltdown. While workers at the plant discovered the rising water and addressed the problem before the water reached this threshold, the event raised several questions about safety at the plant.

The Nuclear Regulatory Commission (NRC) sent a Special Inspection Team to determine why the explosion and fire caused water to pool on the floor of the switchgear room, the potential risk posed by the flooding, and how workers responded to this unexpected threat.

In this report, we first describe the events on May 9—the transformer explosion, fire, and switchgear room flooding. We then discuss the findings of the Special Investigation Team, which revealed that the plant owner had repeatedly violated NRC regulations that require it to identify and fix safety problems in a timely and effective manner. We will also discuss the safety significance of the switchgear room flooding.

Then we will consider previous evidence for the vulnerability of the electrical equipment in the switchgear room to internal flooding. As required by the NRC, the owner evaluated the Indian Point power plant for vulnerabilities to severe accidents in 1994, and again in 2007. However, because the NRC did not require that owners address the vulnerabilities they identified, the owner chose not to make safety upgrades that it had determined to be cost-beneficial.

Finally, we will discuss the shortcomings in the NRC's safety oversight that are revealed by this event and that must be remedied to improve the safety of all operating reactors.

## The Events of May 9

The Indian Point Energy Center sits on the east bank of the Hudson River near the town of Buchanan, New York about 24 miles north of New York City. The plant has two operating pressurized water reactors—Unit 2 and Unit 3—and one that was permanently shut down in 1974 after 12 years of service. (See Figure 1)

### *Explosion*

At 5:50 pm (which we will take to be Time or T = 0) main transformer 31 at Indian Point exploded. Within seconds, control rods were automatically inserted into the Unit 3 reactor core to terminate the nuclear chain reaction. The transformer's catastrophic failure also automatically shut down the unit's main generator and turbine.

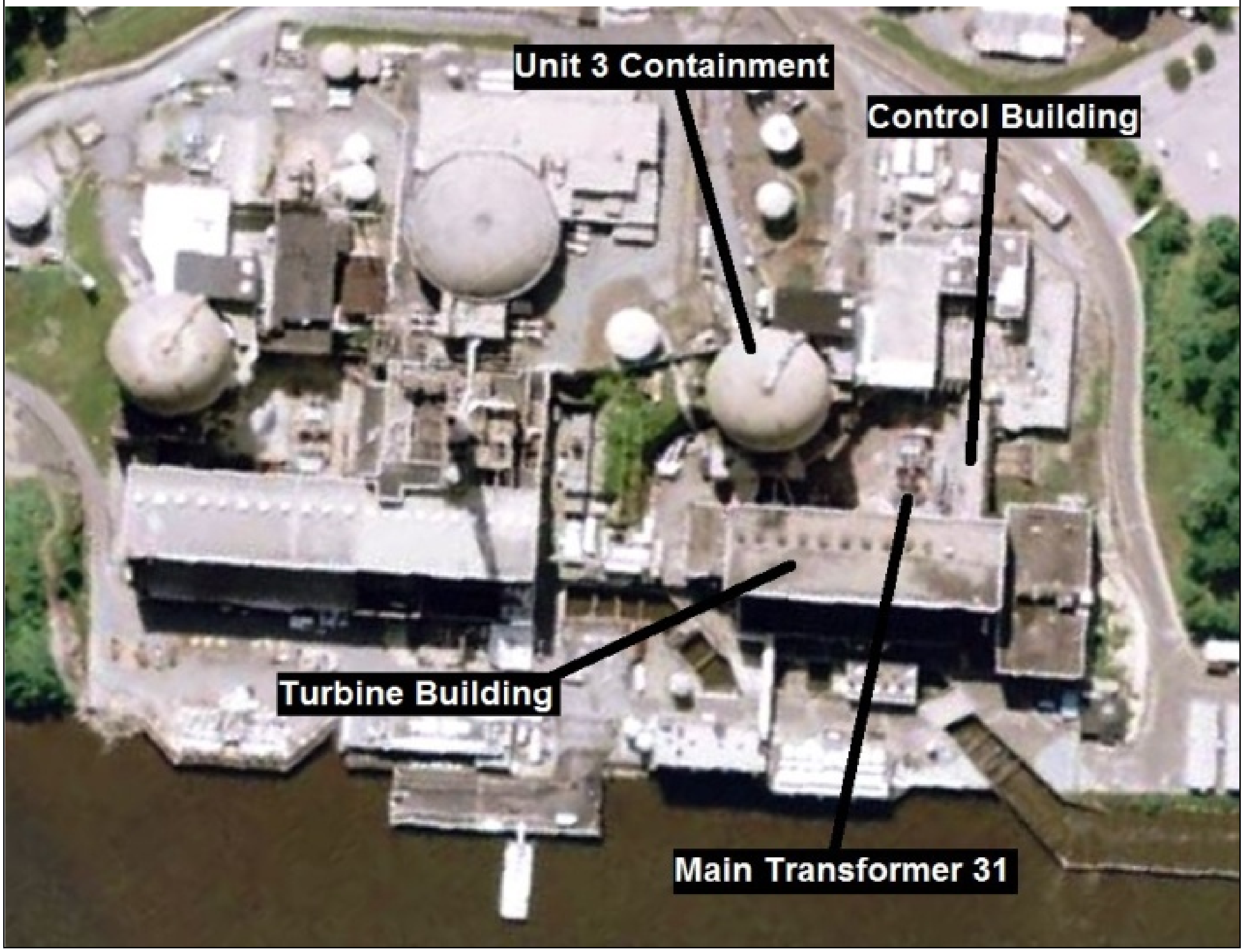
Main transformer 31 receives electricity produced at 22,000 volts by the Unit 3 main generator and boosts its voltage level to 345,000 volts for transmission from the switchyard to the electrical power grid. The failure of main transformer 31 stopped the flow of electricity from Unit 3 to the power grid, but it did not stop the flow of electricity from the power grid to Unit 3 through other circuits.

### *Fire*

Main transformer 31 uses oil to help remove the heat produced by stepping up the electrical current from 22,000 volts to 345,000 volts. The explosion ruptured pipes containing the oil, which is flammable, and ignited it. Thick black smoke billowing from the burning oil created a plume visible for miles.

The heat from the explosion and burning oil automatically activated the water deluge systems for main transformer 31 and two nearby transformers—main transformer 32 and the unit auxiliary transformer. (Water deluge systems are a type of fire sprinkler system.) When sensors detected high temperatures around the transformers, control circuits caused the valves at the deluge station to open, allowing water to flow out the sprinkler nozzles onto the transformers.

**FIGURE 1. Satellite View of Indian Point Energy Center**




*The explosion of main transformer 31 on May 9, 2015 shut down the Unit 3 reactor and turbine, and led to flooding of the switchgear room on the ground floor of the control building.*

SOURCE: www.mapquest.com

***Nuclear Emergency!***

The operators declared an Unusual Event, the least serious among the NRC's four emergency classification levels at 6:01 pm (T + 11 minutes) due to the explosion and fire within the security fence at the plant.

At 6:12 pm (T + 22 minutes), the leader of the fire brigade, a team of plant workers trained in firefighting, ordered the deluge valves to be closed because the fire was nearly out and to facilitate the application of fire suppression foam to finish that job.

**FIGURE 2. Switchgear Room for Unit 3**

The switchgear room gets its name because it houses two switchgears, through which electricity flows to the electric motors of the pumps, fans and other equipment needed for the reactor and containment.

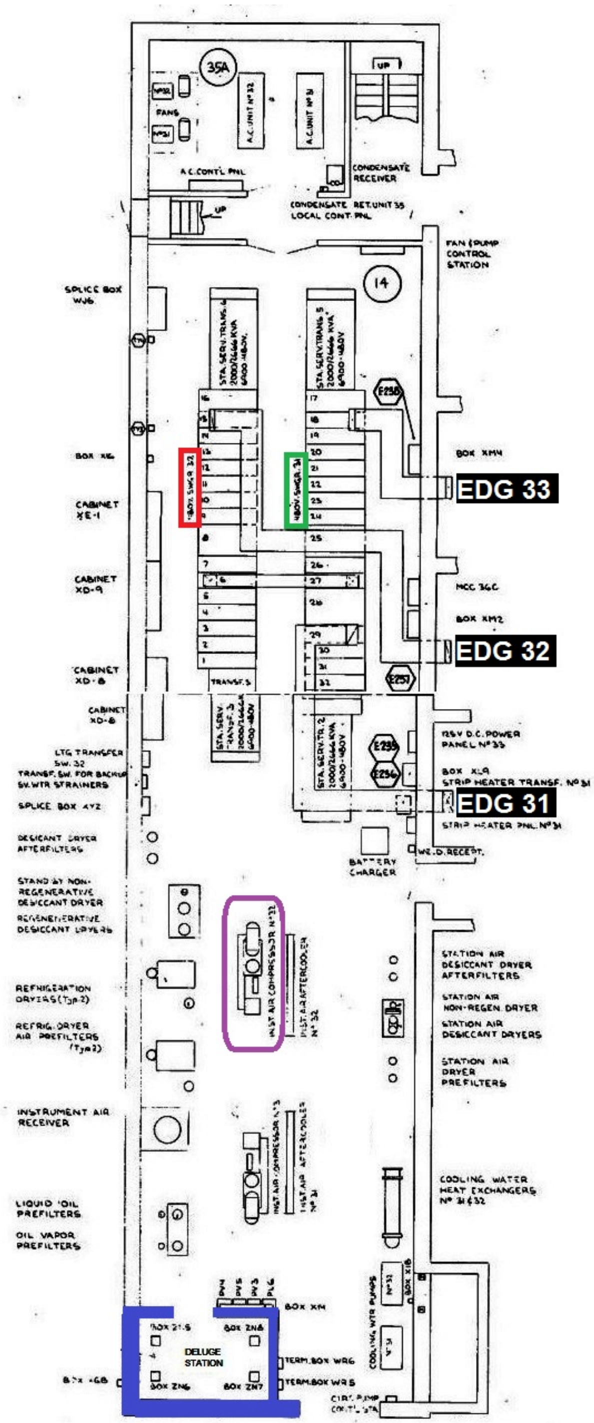
Switchgears control the flow of electricity; switchgear 31 is outlined in green, and switchgear 32 in red.

Adjacent to the switchgear room is a building containing three emergency diesel generators (labeled EDG 31, 32, and 33). These generators provide backup power when the normal power supply is unavailable or degraded.

The switchgear room also houses other equipment. The deluge valves are located within the deluge station room outlined in blue. A 10-inch diameter pipe is connected to the four valves at the deluge station that control the flow of fire suppression water to the main, auxiliary, and station transformers.

Two instrument air compressors, one circled in purple, are in the room.

Two air conditioning units are located in the area next to the stairwells at the upper end of the room. A 2-inch diameter pipe supplies cooling water to these air conditioning units. A 6-inch high curb installed at the doorway to the switchgear room protects the switchgears from flooding caused by rupture of this cooling water pipe.




SOURCE: New York Power Authority Systems Interaction Study Volume 16, November 30, 1983

***Switchgear Room Flooding at Indian Point***

At the same time (6:12 pm), the control room operators received reports of water on the floor of the switchgear room, which is located on the first floor of the control building (see Figure 2).

The switchgear room contains both switchgears that transmit electricity from the offsite power grid, the main generator, or the onsite emergency diesel generators to equipment in the Unit 3 reactor. The electrical switchgears would be disabled if the water level in the switchgear room exceeded 4.875 inches. In this case, all alternating current (ac) power to Unit 3's equipment would be lost, initiating a station blackout condition.

***Switchgear Room Flooding at Fukushima***

Disaster occurred at Fukushima Daiichi in March 2011 when tsunami water flooded the switchgear rooms in the basements of the turbine buildings for Units 1, 2, 3, and 4. The submerged electrical switchgear prevented safety equipment from getting the ac electricity it needed to pump cooling water to the reactors. Thus, the Fukushima Daiichi Unit 1, 2, and 3 reactor cores overheated and melted due to insufficient cooling water flow.

If water had submerged and disabled the switchgears in the switchgear room at Indian Point, it would not automatically have resulted in a meltdown of the Unit 3 reactor core. But it would have been several steps down the same pathway that caused the disaster at Fukushima, and only successful worker intervention would have avoided repeating that outcome.

***Ending the Flood and Fire***

Workers closed the deluge valves at the deluge station at 6:16 pm (T + 26 minutes). The closures stopped the spray onto the transformers from the sprinklers, but did not stop the leakage of water onto the floor. Four minutes later (T + 30 minutes), workers closed the main fire protection valve in the turbine building upstream of the deluge station. The leakage of water onto the floor stopped. Workers notified the control room operators at 6:50 pm (T + 60 minutes) that the water had completely drained from the switchgear room floor.

The fire brigade leader reported the fire extinguished at 8:05 pm (T + 2 hours and 15 minutes). After waiting to ensure that the fire did not re-flash and the plant conditions were stable and trending in the right direction, the operators terminated the Unusual Event at 9:03 pm (T + 3 hours and 13 minutes).

**NRC's Special Inspection Team**

The NRC announced on May 19 (T + 10 days) that it was dispatching a Special Inspection Team (SIT) to Indian Point to investigate. The SIT was not tasked with examining the causes for the main transformer's explosion and fire. Transformer failures, while undesired, are certainly not uncommon. Instead, the SIT was directed to determine why this transformer failure caused water to pool on the switchgear room floor, the potential risk it posed, and how workers responded to this threat.

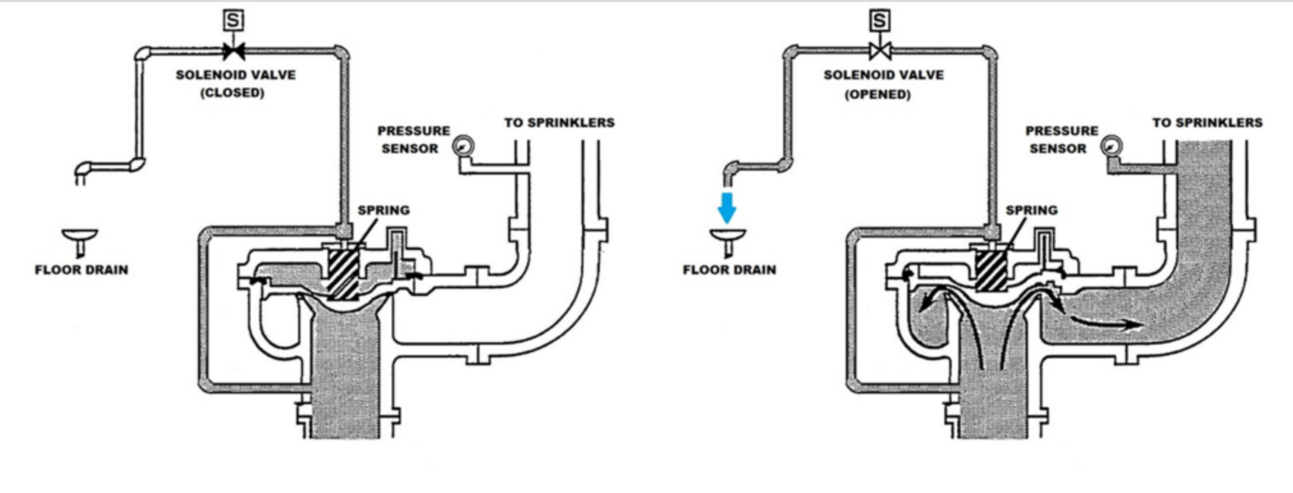
Some had speculated that a drain pipe shared by the floor drains in the switchgear room and the storm drains in the transformer yard provided a flow path for water sprayed onto the transformers to flow into the switchgear room. This problem has occurred, or has nearly occurred, at other nuclear plants. And not just once. Or just twice. There's been a veritable flood of reported flood protection problems.

The SIT examined the potential for water to enter one or more storm drains in the transformer yard and pass through the floor drains into the switchgear room. The SIT concluded, based on compelling evidence, that elevation differences made it highly unlikely that water entered the control building via this pathway. One piece of evidence is that the water in the transformer yard became mixed with oil but the water inside the switchgear room lacked the sheen that this mixture creates.

### *Source of the Deluge—The Deluge Valves*

Workers traced the flood's source to the deluge valves at the deluge station in the corner of the switchgear room. When the fire protection system is in use, the valves are designed to release a small amount of water onto the floor of the deluge station, where it flows through a drain in the floor. When the system is shut down, the water flow should stop. However, workers found that a sensor was corroded and clogged with debris (the water in the system is unfiltered and contains silt and other small particles). The clogged sensor then prevented a valve from closing when it should have, allowing water to continue to flow onto the floor.

**How Indian Point's Deluge Valves Work—and Stopped Working**




The schematic on the left shows a closed deluge valve. Water from the fire protection system pipe flows through a small tube around the deluge valve until it is stopped by the closed solenoid valve. The closed solenoid valve causes the water pressure on both sides of the deluge valves' diaphragm (also called a flapper) to equalize. The spring force acting on the upper side of the diaphragm holds it closed, preventing the flow of water through the pipe to the sprinklers.

Manual or automatic actuation of the deluge system energizes the solenoid valve and opens it to allow water on the upper side of the diaphragm to flow through the vent and enter the floor drain, as shown in the figure on the right. The water pressure on the upper side of the diaphragm drops low enough that the fire protection system's water pressure overcomes the spring force, pushing the diaphragm to the opened position.

Fire protection system water flows through the pipe to the sprinklers to spray onto the transformer. The water flow (and pressure) is monitored by a sensor in the discharge pipe. At a certain pressure, the sensor sends a signal that de-energizes the solenoid valve, closing it.

With the solenoid valve closed, the pressure on both sides of the diaphragm equalizes. But the spring force does not drive the diaphragm closed again until a retainer pin (shown to the right of the spring) is manually reset. This retainer pin engages when the diaphragm opens to permit flow to the sprinklers until it is reset.

Debris and corrosion in the tubes to the pressure sensors prevented them from detecting the pressure in the discharge pipes and signal the solenoid valves to close. Consequently, water continued to flow through the open solenoid valves onto the switchgear room floor.

Water pooled to a depth of about four to six inches in the deluge station and flowed under the door into the switchgear room. Water then began pooling in the switchgear room.

The SIT concluded that the combined flow rate through the faulty deluge valves was approximately 50 gallons per minute. The floor drains in the switchgear room were designed to handle 100 gallons per minute and thus should have easily carried away this flow and prevented flooding. Workers inspected the drain lines with a boroscope and found them partially blocked by debris. Tests revealed the partially clogged drain line could only carry away 25 gallons per minute—one fourth of the design flow rate.

### *How Deep Did the Water Get?*

Workers initially reported one to two inches of water on the switchgear room floor. But instrument air compressor 32 within the switchgear room (circled in purple in Figure 2) had its own flood protection barrier that was one inch tall. The dry floor inside this barrier proved that the water level in the switchgear room never rose above one inch to spill over into this area.

The SIT concluded that the switchgear room flooded to a depth of about 0.4 inches. The SIT based its estimate on a net flooding rate of 25 gallons per minute (50 gallons per minute flowing through the three open solenoid-operated valves minus 25 gallons per minute draining through the partially clogged drain in the switchgear room), a flooding duration of about 30 minutes, and the surface area of the room of 3,000 square feet.

Note that the valves were open and leaking water for approximately 30 minutes. Workers reported the switchgear room drained of water about 30 minutes after the fire protection valve was closed to stop the leaks. Thus, the flood time roughly matches the drain time, which confirms that the net flooding rate was 25gallons per minute.

### *How Long Would It Have Taken to Disable the Switchgears?*

The SIT reported that the switchgears would be disabled if the water depth in the switchgear room exceeded 4.875 inches. Above that level, water would submerge and short out electrical cables. Based on the net flood rate of 25 gallons per minute, the NRC estimated that it would have taken six hours to flood the switchgear room to the level needed to disable the switchgears.

## Did Closing the Fire Protection Valve Avert Disaster?

When workers manually closed the fire protection valve, they stopped the flow of water into the switchgear room. But had workers been unable to close the valve, they would have had other options to prevent the flooding of the switchgears.

Workers could have opened a door between the switchgear room and the three emergency diesel generator rooms (labeled EDG 31, EDG 32, and EDG 33 in Figure 5). The flood water would have spread out, requiring more time to reach a depth of 4.875 inches. Instead of, or in addition to, opening this door, workers could have installed portable pumps to bail out the switchgear room and supplement the drain rate.

If workers had been unsuccessful in preventing flooding from disabling the switchgears, their loss would have put Unit 3 into a station blackout. During a station blackout, the loss of all alternating current electricity renders much of the emergency equipment unusable. But direct current electricity from onsite batteries can allow a turbine-driven auxiliary feedwater pump to supply sufficient cooling water to prevent reactor core damage. (This pump gets its steam by boiling water using the reactor core's decay heat; the water that is boiled away is replaced by the water supplied from this pump.)

The NRC's risk analysts estimated that the workers had an 80 percent chance of successfully using one or more of these options to prevent reactor core damage. The owner estimated that the workers had a 96 percent chance of success.

## What If?

The risk that a flood will disable both switchgears in the switchgear room depends on timing. How long would it take for the flood water to submerge and disable them? That answer determines how much time workers have to intervene. The more time they have, the more likely they will be successful.

In this event, the net flooding rate was estimated to be 25 gallons per minute, and the switchgear room was flooded to a depth of 0.4 inches in 30 minutes—a flooding rate of 0.8 inches per hour. But, as we discuss in more detail below, the plant owner has identified other credible flooding scenarios that would involve higher flooding rates. The rupture of the 10-inch fire protection pipe to the deluge station could cause flooding of 7,500 gallons per minute. In that case, the switchgears could be disabled in less than ten minutes. If the fire protection pipe in the stairwell broke, the switchgears could be lost in less than four minutes. And the flood rate of 170 gallons per minute from the rupture of the cooling water pipe to the instrument air cooling unit could disable the switchgears in less than 54 minutes.

But workers do not have two, four or fifty four minutes to respond and avert disaster. Their response time is shortened by the time needed to discover that the switchgear room is flooding. In this event, it took about 22 minutes for workers to notice that the switchgear room was flooding. This delay reduced the time available for their response and, in turn, reduced their chance of success.

Had the flooding rate been greater or had discovery of the flooding been further delayed, workers may have been unable to successfully take steps to protect the switchgears from being submerged and disabled.

**Soggy Sister**

Indian Point Unit 2 operates right next door to Unit 3. It is a sister reactor of similar design and age. The switchgear room for Unit 2 also has unresolved flooding problems.

The NRC issued a green finding on April 30, 2012, to the owner for failing, since the reactor initially began operating in the early 1970s, "*to classify equipment failures of the drains in the 480-volt switchgear room as repetitive such that an apparent cause would have been performed*." The NRC noted that the failure "resulted in instances of the drains in the 480-volt switchgear room being clogged."

As Hurricane Irene passed through the region on August 28, 2011, workers observed rainwater leaking into the Unit 2 switchgear room around two cooling water pipes that penetrated the room's wall. The floor drain in the switchgear room was clogged, allowing the incoming water to flood the room. Workers stacked sandbags around the switchgears to protect them and installed a temporary collection trough to route the leaking water into another drain.

The NRC's inspectors reviewed records over the prior decade and found that the drains in the switchgear room for Unit 2 had a history of clogging. The drains clogged in July 2001, August 2003, September 2003, January 2007, October 2008, October 2009, September 2010, October 2010, and again in August 2011.
The NRC's inspectors found debris in the switchgear room drains in January 2007. Workers responded to this NRC finding by promising to develop a preventative maintenance task to check the drains every two years. But the NRC's inspectors noted in December 2011 that the preventative maintenance procedure had not yet been written.

On August 26, 2011, workers inspected the drains in the switchgear room and identified no problems. Two days later, water leaking into the room during Hurricane Irene could not leave through the clogged drains. The inspection method was obviously ineffective.

## Futile Safety Tests at Indian Point

Workers at Indian Point periodically tested the drain lines in the Unit 2 and 3 switchgear rooms for potential blockage. Every two years, they poured ten gallons of water into a floor drain and checked whether it was gone within one minute. But this test did not verify that the drain line was free from obstruction—ten gallons might merely fill the space between the drain and the obstruction. At best, this test method verified the floor drains could handle ten gallons per minute. This test method could not ensure the floor drains would handle the design flow rate of 100 gallons per minute.

Workers also tested the deluge valves at Indian Point Unit 3 every two years. On April 7, 2011, a deluge valve for main transformer 31 failed to close properly during the test. Workers replaced one part, but did not confirm that this replacement solved the problem. In fact, they fixed something that was not broken and did not fix what was really broken. On April 2, 2013, this valve again failed to close properly. This time, workers took no actions at all to fix the problem (or even fix a non-problem). And the valve again failed to close properly during a test on March 24, 2015. Workers initiated paperwork reporting the failed test, but had taken no steps to fix it. There could not have been any surprise, then, when the valve failed to close properly during the transformer explosion and fire on May 9, 2015. After all, workers demonstrated that it did not work properly several times over many years. Concurrently, they also demonstrated that the testing program was not working properly, either.

## Switchgear Room Flooding Long Identified as a Safety Problem

Like the periodic testing of the deluge valves that repeatedly identified a problem that repeatedly eluded its solution, the vulnerability of the switchgears to flooding has been repeatedly flagged and repeatedly unresolved.

**FIGURE 3. Conclusions from the Indian Point Unit 3 Individual Plant Examination Submitted in 1994**

**Section C5**

**CONCLUSIONS AND RECOMMENDATIONS**

Internal flooding can initiate or exacerbate a core damage accident. A large number of flooding scenarios were evaluated and subjected to deterministic and probabilistic analyses. From these analyses, it was concluded that three flooding scenarios have estimated frequencies exceeding $10^{-6}$/yr:

- The rupture of the instrument air closed cooling water system in the control building switchgear room (case C4.2.2.2)
- The rupture of the fire protection system in the control building switchgear room (case C4.2.2.4)
- The rupture of the fire protection system in the control building east stairwell (case C4.2.2.8).

SOURCE: New York Power Authority

***Individual Plant Examination – Flood Warning!***

In November 1988, the NRC required that plant owners evaluate their facilities for vulnerabilities to severe accidents that result in reactor core damage and failure of the containment to restrict the release of radioactivity to the environment. But the NRC did not require that owners fix any of the vulnerabilities identified during the mandated evaluations:

> *After each licensee conducts a systematic search for several accident vulnerabilities in its plant(s) and determines whether potential improvements, both design and procedural, warrant implementation, it is expected that the licensee will move expeditiously to correct any identified vulnerabilities that it determines warrant correction.*

In response to the NRC's November 1988 mandate, the owner of Indian Point Unit 3 submitted its Summary of the Indian Point 3 Individual Plant Examination for Internal Events (Level I and II) to the NRC in June 1994. This Individual Plant Examination (IPE) evaluated several scenarios that could result in reactor core damage and containment failure, and lead to the large release of radiation.

Topping the list (Figure 3) of postulated scenarios leading to severe accidents were a trio in which water pouring from a broken pipe inside the plant flooded the switchgear room and disabled the switchgears.

In the scenario labeled case C4.2.2.4 in Figure 3, the 10-inch diameter pipe to the valves at the deluge station breaks. In those days, this pipe was not designed with supports that would protect it from being ruptured by the shaking it could experience during a design basis earthquake. Consequently, it had a relatively high chance of breaking. If it broke, it could dump as much as 7,500 gallons of water onto the floor every minute. Workers would have only ten minutes to successfully intervene. The owner estimated that workers had less than a 25% chance of success of preventing a meltdown if this fire protection pipe broke.

While the NRC did not require that owners implement steps to reduce vulnerabilities identified in the IPEs, they did not prevent them from undertaking these safety upgrades. The owner installed supports on the fire protection pipe to protect it from breaking during earthquakes up to the design basis magnitude.

Case C4.2.2.8 examined the consequences of a break in the smaller diameter fire protection system pipe at the other end of the switchgear room. The slower flooding rate from the broken end of the smaller pipe would give workers a better chance of successful intervention—the owner estimated the workers would have a 74% chance of preventing a reactor core meltdown. The owner took no steps to improve their odds.

Case C4.2.2.2 looked at the rupture of the pipe providing cooling water to the instrument air compressor in the switchgear room. The owner estimated that this pipe had a greater likelihood of breaking than either of the other two pipes. The owner further estimated that if this pipe broke, there was only an 11% chance that the workers could prevent the meltdown of the reactor core. The owner took no steps to reduce either the chance of pipe failure or the risk of core damage resulting from it.

***License Renewal Application – Cost/Beneficial Flooding Fix!***

A decade later, in 2007, the owner submitted a license amendment request to the NRC seeking approval to extend the Unit 3 operating license by 20 years. Per the NRC's regulations, the request included the owner's evaluation of Severe Accident Mitigating Alternatives (SAMAs)—modifications to the plant and revisions to procedures that lessen the chances of or consequences from a severe accident.

The owner's license amendment request ranked the type of accidents most likely to result in reactor core damage. Internal flooding events topped the list, accounting for nearly 20 percent of the risk of reactor core damage. (See Figure 4)

**FIGURE 4. Unit 3 Core Damage Frequency (CDF) as calculated by the owner using Probabilistic Safety Analysis (PSA). Internal flooding contributes almost 20% to the overall risk of core damage (i.e., a meltdown).**

Indian Point Energy Center
Applicant's Environmental Report
Operating License Renewal Stage

**Table E.3-1**
**IP3 PSA Model CDF Results by Major Initiators**

| Accident Type | Point Estimate CDF (/ry) | % Contribution to Point Estimate CDF |
|---|---|---|
| Internal flooding | 2.24E-06 | 19.66 |
| Loss of coolant accident (LOCA) | 2.16E-06 | 18.95 |
| Steam generator tube rupture (SGTR) | 1.57E-06 | 13.78 |
| Anticipated transient without a scram (ATWS) | 1.54E-06 | 13.51 |
| Loss of 125 VDC power | 1.00E-06 | 8.78 |
| Transients[1] | 8.48E-07 | 7.44 |
| Station blackout (SBO) | 7.20E-07 | 6.32 |
| Total loss of service water system | 5.41E-07 | 4.75 |
| Loss of non-essential service water | 2.76E-07 | 2.42 |
| Interfacing system LOCA (ISLOCA) | 1.53E-07 | 1.34 |
| Loss of offsite power [1] | 1.19E-07 | 1.04 |
| Loss of component cooling water | 1.11E-07 | 0.97 |
| Vessel rupture | 1.00E-07 | 0.88 |
| Loss of essential service water [1] | 1.78E-08 | 0.16 |
| **Total** | **1.15E-05** | **100.00** |

1. Contributions to CDF from SBO and ATWS are listed separately and thus not included in the contributions shown for other accident types.

SOURCE: Entergy

The owner then assessed the costs and benefits of various SAMA candidates.

As one example, the owner considered installing an alarm that would notify the control room operators when the water level in the switchgear room got too deep, so they could intervene to prevent the switchgears from being disabled.

The owner estimated that this flood alarm would reduce the risk of reactor core damage by over 17% relative to the risk without this alarm. The owner further estimated that the alarm would reduce the risk of radiation dose exposure to the public by nearly 20% and found that the benefit of these risk reductions would be $1,400,000. The owner estimated the cost of the alarm to be $200,000. Thus, the owner estimated a net benefit of over a million dollars from installing a flood alarm in the Unit 3 switchgear room.

The Indian Point Unit 2 reactor is next to Unit 3 and has a very similar design. Its switchgear room is also vulnerable to flooding. The owner estimated that installing a $200,000 flood alarm in the Unit 2 switchgear room would reduce the risk of core damage by nearly 20 percent and lower the offsite radiation exposure risk by over 40 percent, resulting in a benefit of $1,700,000, for a net benefit of one and a half million dollars.

The owner's license renewal amendment request indicates that over 19.2 million people lived within 50 miles of the Indian Point nuclear plant. The cost of installing flood alarms at the two reactors would have amounted to two cents per person.

Yet during the switchgear room flooding event at Indian Point Unit 3 on May 9, 2015, no flood alarm notified the control room operators about the rising threat to the crucial switchgears. The alarm did not malfunction—it had never been installed. Instead, the flooding threat was identified by workers who fortuitously entered the switchgear room to access the deluge room and close the deluge valves, allowing workers to take actions to prevent both switchgears from being disabled.

Fukushima Daiichi Unit 1 was nearly 40 years old on March 11, 2011. Assume for a moment that this reactor had been under the NRC's jurisdiction and its owner had applied to the NRC in April 2007 to renew its operating license for 20 more years, as did the owner of the Indian Point plant. Suppose that the owner's license amendment request included a SAMA evaluation that explicitly found that the plant's sea wall was too low to protect against credible tsunamis, the onsite station batteries had insufficient capacity to enable reactor core cooling for more than a handful of hours, the spent fuel pool lacked reliable indicators of water level and temperature, the containment vent valves could not be reliably opened during a station blackout, and several of the other problems that factored into the worst-ever nuclear plant accident. Further assume that the owner's SAMA evaluation estimated that the measures collectively costing a single dollar could be readily implemented and would have a net benefit of about $250 billion—the estimated cost of the Fukushima compensation and clean-up.

The NRC would *not* have required that single dollar to be spent for those safety upgrades to be undertaken before approving the license renewal of Fukushima Daiichi Unit 1. *None* of these safety upgrades would have been directly related to aging management—the *only* thing that the NRC considers during its review of license renewal applications.

It is often said that doing the same thing over and over and expecting a different outcome is insanity. If so, the NRC's approach to managing the risk from severe accidents is insane. The NRC keeps requiring owners to consider severe accident risks. But the agency never requires that owners protect against the known risks.

Shortly after the Fukushima disaster, the NRC formed a six-person task force to study the accident's causes and recommend measures to reduce vulnerabilities at U.S. reactors. The Near Term Task Force's #1 recommendation was:

> *…establishing a logical, systematic, and coherent regulatory framework for adequate protection that adequately balances defense-in-depth and risk considerations.*

But a majority of the NRC Commissioners voted to derail this priority recommendation and to handle the remaining task force recommendations using the existing illogical, non-systematic, and incoherent framework. Thus, the NRC mandated that owners re-evaluate seismic and flooding hazards, but did not require that owners undertake cost-beneficial solutions. The NRC would serve the American public far better by taking steps to shorten the list of unimplemented solutions than by taking steps that lengthen the list of unresolved problems.