

**CHARACTERISTICS AND COMMON VULNERABILITIES
INFRASTRUCTURE CATEGORY: NUCLEAR POWER PLANTS –
COMMERCIALY OWNED AND OPERATED**

Protective Security Division
Department of Homeland Security

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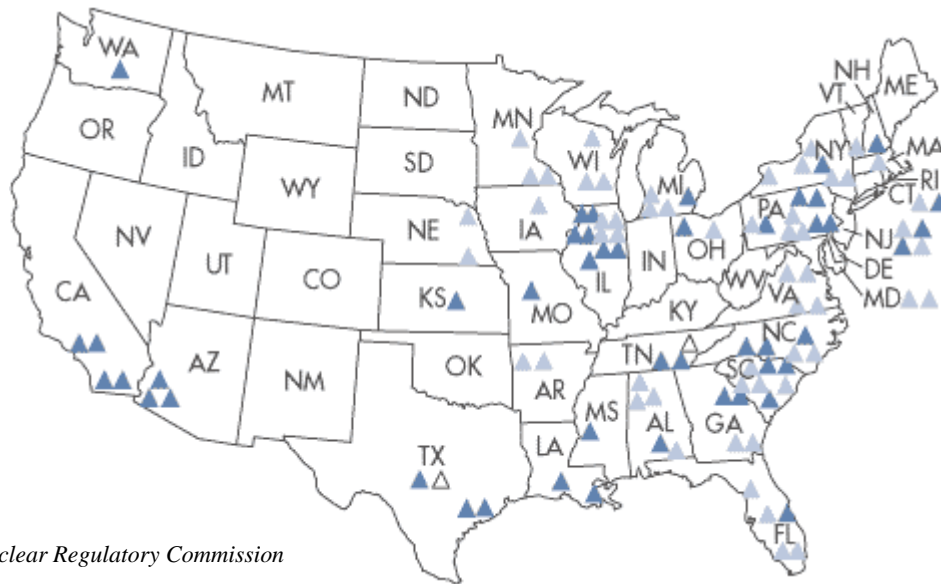
Preventing terrorism and reducing the nation's vulnerability to terrorist acts requires understanding the common vulnerabilities of critical infrastructures, identifying site-specific vulnerabilities, understanding the types of terrorist activities that likely would be successful in exploiting those vulnerabilities, and taking preemptive and protective actions to mitigate vulnerabilities so that terrorists are no longer able to exploit them. This report characterizes and discusses the common vulnerabilities of nuclear power plants, which are located in 31 states and produce about 20% of the electricity in the United States.

FACILITY CHARACTERISTICS

Characterization of the Industry

There are 104 reactors located at 65 sites that are licensed to operate in the United States (U.S): 69 are pressurized water reactors (PWRs) and 35 are boiling water reactors (BWRs). Figure 1 shows the distribution of nuclear power plants around the country. With the exception of six units in Alabama and Tennessee, which are owned by the Tennessee Valley Authority, all of the plants are commercially owned and operated.

Nuclear generating capacity amounts to about 97,400 MW. Nuclear power provides approximately 20% of the electricity generated in the U.S. This percentage has remained at about that level since 1990. There are no new nuclear power plants under construction. The last new unit began commercial operation in 1993.



Source: Nuclear Regulatory Commission

Figure 1 Nuclear Power Plants in the U.S.

Common Facility Characteristics

A nuclear power plant is an arrangement of components used to generate electric power. Boiling water reactors (Figure 2) use a direct cycle in which water boils in the reactor core to produce steam. This steam drives a steam turbine, which spins a generator to produce electric power. Pressurized water reactors (Figure 3) use an indirect cycle in which water is heated under high pressure in the reactor core and passes through a secondary heat exchanger to convert water in another loop to steam, which in turn drives the turbine. The advantage of the PWR design is that the radioactive water/steam never contacts the turbine. With the exception of the reactor itself, there is very little difference between a nuclear power plant and a coal-fired or oil-fired power plant.

Six major components are common to all nuclear power plants:

1. Nuclear Reactor Core, Reactor Vessel, and Containment Structure
2. Heat Transfer/Working Fluid Loop
3. Cooling Water System
4. Plant Control Room and Reactor Control System
5. Generation Step-up Transformer
6. Transmission Lines and Downstream Substations

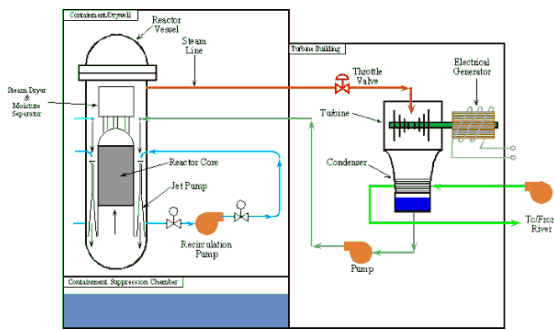


Figure 2 Boiling Water Reactor

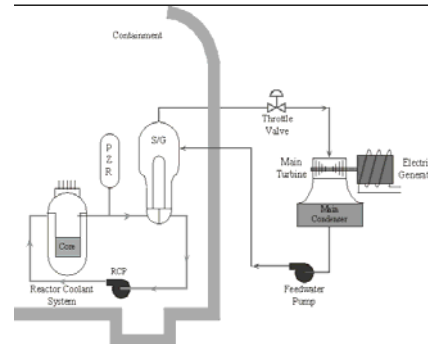


Figure 3 Pressurized Water Reactor

Nuclear Reactor Core and Containment

The most commonly used fuel is enriched uranium U^{235} isotope. Typically, uranium is formed into pellets approximately 0.75 in. in diameter and 1.0 in. long. The pellets are stacked into long rods, the rods are assembled into fuel bundles, and the bundles are arranged to form the reactor core inside the reactor vessel.

The reactor vessel and the containment structure provide substantial barriers and defense-in-depth protection against the release of radioactive fission products to the environment. The reactor vessel is typically housed inside a concrete liner that acts as a radiation shield. That liner is housed within a much larger steel containment vessel. This vessel contains the reactor core as well as the hardware (cranes, etc.) that allows workers at the plant to refuel and maintain the reactor. The steel containment vessel is intended to prevent leakage of any radioactive gases or fluids from the plant. Finally, the containment vessel is protected by an outer, domed-shaped concrete containment building (Figure 4), which is constructed to maintain leak tight functional integrity, even in the event of an earthquake. The containment building is also designed to provide tornado missile protection for enclosed safety-related components.



Figure 4 Nuclear Reactor Containment Building

Heat Transfer/Working Fluid Loop

The heat transfer/working fluid loop removes heat that is generated by the fission process in the reactor core, creates steam, and transfers it to steam turbine generators. Heat-removal system arrangements include single- and double-loop heat transfer cycles. The BWR design described previously is an example of a single-loop system in which steam created in the reactor flows directly to the steam turbines. The PWR design is an example of a two-loop system in which water in a primary loop transfers heat from the reactor core to a secondary steam loop that flows to the turbine.

Cooling Water System

Excess heat is removed from the heat transfer/working fluid loop to the environment by the cooling water system. Cooling water systems are comprised of three general types: once-through, natural draft cooling towers, and mechanical draft cooling towers. Once-through systems take a large amount of water directly (or via a very large man-made pond) from a natural water body and pump it through an in-plant heat exchanger to remove excess heat from the working fluid loop(s) before the working fluid is returned to the reactor.

In a natural draft cooling tower, the natural buoyancy of the hot air moves the air upward through the tower, drawing in fresh, cool air through the air inlet at ground level where it cools the working fluid. No fan is required. The tower shell is usually constructed in reinforced concrete, can be as high as 650 ft, and is easily recognizable from the air and large distances on the ground.



Mechanical draft cooling towers use a fan to generate the airflow through the tower. Because fans are used, mechanical cooling towers are much smaller than natural draft cooling towers; however, fan diameters of up to 30 ft are commonly used.



Plant Control Room and Reactor Control System



Modern reactors have numerous control systems. All of these systems are monitored and controlled from a central control room. The function, layout, and configuration of a nuclear power plant control room are typical and similar to those of other types of power plants and large industrial operations. In most nuclear power plants, the control room is located in or adjacent to the large steam turbine generator building. It is secured by locked doors, but because it is located inside the guarded parameter, it is not separately guarded.

In addition to all other plant systems, the control room houses the nuclear reactor controls. This control system regulates the rate at which nuclear fission occurs and how much heat is produced within the reactor. The basic method of accomplishing reactor control is by use of control rods

made of a material that absorbs neutrons. The rods are installed between the fuel assemblies in the reactor core. When an operator wants to produce more heat, the rods are raised. To create less heat, the rods are lowered. The rods can also be lowered completely to shut down the reactor in the event of an accident or fuel change.

Generation Step-up Transformer

The generation step-up transformer is usually located on the nuclear power plant site either just outside of the reactor and power plant building or adjacent to the plant site. This device transforms electric power produced by the steam turbine generators to the high voltage required by the transmission system. Generation step-up transformers are very large, expensive devices that are difficult and time-consuming to replace. Spares are not generally available.

Transmission Lines and Downstream Substations

Although not technically part of a nuclear power plant site, the transmission lines connecting the plant to the electric grid are necessary to continuously operate the plant. Any sudden loss of significant transmission capacity, either by a downed tower or line, or by destruction or disruption of a downstream substation, if large enough and at the right network location, could cause the plant to shut down and interrupt power production. Because these systems extend for miles outside the plant boundary and are not physically guarded, they are vulnerable to terrorist attack.

CONSEQUENCE OF EVENT

There are two consequences of concern. First, malevolent action could possibly cause damage to the nuclear power plant, resulting in a radioactive release that could impact public health and safety. Second, malevolent action could possibly cause the reactor to shut down or damage the electrical generation step-up transformer or the transmission lines, resulting in an interruption to power production or power distribution.

The Nuclear Regulatory Commission (NRC) has determined that nuclear power plants must be sited such that if there is a fission product release from the reactor, an individual located at any point on the site boundary would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure. The NRC also defines “radiological sabotage” as any deliberate act directed against a plant or component that could directly or indirectly endanger public health and safety by exposure to radiation.

Rather than defining worst-case scenarios, the NRC takes the conservative position of ensuring that adequate physical protection measures are in place at nuclear power plants to protect against the Design Basis Threat (DBT) for radiological sabotage so that malevolent events do not occur that would negatively impact public health and safety. The licensee is responsible for establishing and maintaining an on-site physical protection system and security organization that would ensure that the plant retains the capability to safely shut down the reactor and assure long-term heat removal in the face of a malevolent act by the DBT against the facility. The objective

of the licensee’s physical protection program is to provide high assurance that malevolent activities do not constitute an unreasonable risk to public health and safety.

COMMON VULNERABILITIES

The following is a list of common vulnerabilities found at nuclear power plants and associated transmission lines. Nuclear power plants are likely the most hardened publicly owned infrastructure in the U.S. Although all listed vulnerabilities might not be observed at a particular nuclear power plant, the list is generally representative of vulnerability concerns related to the nuclear power plant and transmission line infrastructure.

Exhibit 1 Site-Related Vulnerabilities	
<i>Site-related vulnerabilities are conditions or situations existing at a particular site or facility that could be exploited by a terrorist or terrorist group to do economic, physical, or bodily harm or to disable or disrupt facility operations or other critical infrastructures.</i>	
Access and Access Control	
1	Public roads may be in close proximity to critical step-up transformer or transmission line assets, allowing easy access by a vehicle-borne explosive device.
2	Critical assets such as transmission substations and switching yards may be set close to the perimeter fence, allowing for a successful attack from outside the fence line. This could potentially interrupt power transmission.
3	Plants with once-through cooling have access points at cooling water intake/outlet that may potentially be vulnerable to a water-borne threat.
4	Plants are potentially vulnerable to an aircraft attack.
5	Facilities may use contract guard services, and guard turnover may be difficult to control.
6	Rules of engagement and use of force are narrowly defined for situations where a threat to the guard’s life is not eminent. Guards are subject to individual state criminal prosecution for actions taken during the performance of their official duties.
Operational Security	
7	Environmental impact statement information is publicly available.
8	Critical assets not located inside buildings may be easily identifiable.
9	Websites may provide information on plant locations, critical assets, and other data.
10	Lists of nuclear power plant locations are readily available through several public sources.
Reactor and Process Control	
11	There is a potential for an intruder to hack into peripheral plant systems.
<i>(Continued on next page.)</i>	

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LAW ENFORCEMENT SENSITIVE

Emergency Planning and Preparedness	
12	Spare parts that are large and/or expensive are in short supply. Some parts, like generation step-up transformers, have long lead times to obtain or replace and can cause continued interruption of power production.
Plant Interfaces (Inputs and Outputs)	
13	Loss or destruction of major transmission lines from plant or major substations could cause plant shutdown and interrupt power production.
14	Loss or destruction of cooling water intake (once-through) or cooling towers (mechanical or natural draft) could cause plant shutdown and interruption of power production.
15	All key assets in electric substations and switching yards can be destroyed with small amounts of explosives, thus interrupting power transmission. Charges would have to be placed in direct contact. Blast effect weapons would have less impact due to the open construction of the substation.
16	Frequencies of handheld radios can be scanned by adversaries to determine operating conditions, location of employees, ongoing activities, etc.

OTHER INFORMATION

Role and Activities of the Nuclear Regulatory Commission

Nuclear power plants in the U.S. are commercial facilities that are owned and operated by various entities. For decades, however, these facilities have been licensed and regulated by the NRC. The Atomic Energy Act of 1954, as revised, and the Energy Reorganization Act of 1974 give the NRC the responsibility for protecting public health and safety at commercial nuclear power plants. To accomplish this goal, the NRC established a regulatory program, described in 10CFR73.55, which contains requirements that must be implemented by licensees at nuclear power plants to protect against radiological sabotage. To define the threat that must be protected against, the NRC established a DBT for Radiological Sabotage (10 CFR73.1 (a) (1)). This DBT describes the approximate size and attributes of the threat. To ensure that the DBT remains a current characterization of the threat, the NRC, in close coordination with the national intelligence and law enforcement communities, constantly monitors the actual threat environment, continually examines the assumptions underlying the DBT, and makes changes, as appropriate. The NRC also has a continuing inspection program to review the implemented physical protection program at each nuclear power plant to ensure continued compliance with the NRC regulations.

The NRC took security seriously well before the September 11, 2001, terrorist attacks and has redoubled its efforts since then in light of the increased threat. As discussed above, nuclear power plants already had security measures in place in accordance with the NRC regulations, making them among the most robust and well-protected civilian facilities in the country. Nevertheless, the events of September 11th have resulted in many enhancements to ensure that these facilities remain secure.

Following the September 11th terrorist attacks, the NRC immediately advised nuclear facilities to go to the highest level of security in accordance with the system in place at the time. A series of advisories, orders, and guidance documents have since been issued to further strengthen security at nuclear power plants. Details of the specific actions taken are sensitive, but for facilities such as power reactors, they generally include increased security patrols, augmented security forces, additional security posts, installation of additional physical barriers, vehicle checks at greater stand-off distances, enhanced coordination with law enforcement and intelligence communities, and more restrictive site access controls for all personnel.

In addition to physical protection measures, the NRC requires expanded, expedited, and more thorough background checks for nuclear power plant employees to ensure that they are reliable and trustworthy. Every employee who has access to safety equipment is required to pass background checks, including an examination of past employment, references, credit history, education history, military service history, and an FBI criminal record check. Employees also undergo psychological testing. While on the job, each employee is also subject to random drug and alcohol testing.

The adequacy of these defensive measures is subject to detailed review and inspection by the NRC, including periodic commando-type exercises designed to probe for weaknesses so that any

corrections can be made promptly. The NRC has conducted force-on-force security exercises at nuclear power plants since 1991. These tough, simulated commando-style raids are designed to identify shortcomings in security personnel performance or strategy. An important component of these reviews includes enhanced “table-top” exercises (facilitated discussion using credible scenarios) that now involve a wide array of federal, state, and local law enforcement and emergency planning officials. In addition to the NRC-evaluated exercises, many licensees conduct frequent force-on-force exercises as part of their guard force training programs. Identification of a significant weakness during an exercise leads to immediate corrective or compensatory measures. The NRC is not aware of any other comparable performance-testing program of security measures for any other commercial facilities in the U.S.

Furthermore, the NRC is taking steps to augment training and qualifications requirements for security personnel at nuclear power plants, especially in the area of tactical response. This includes more frequent firing of weapons, more realistic training under different conditions, and firing against moving and fixed targets. To minimize security personnel fatigue, the commission is establishing detailed requirements for a 48-hour workweek, except for special circumstances, and limits on the amount of overtime guards can work.

The NRC requires licensees to have detailed emergency preparedness procedures for responding to events, making timely notifications to appropriate authorities, and providing accurate radiological information. These licensees are required to exercise their programs on a periodic basis and to coordinate their planned actions with federal, state, and local officials. Since September 11, 2001, the NRC has issued orders to its licensees requiring that emergency plans be reviewed and revised as necessary to ensure that they are compatible with the heightened security posture that currently exists at each plant.

The NRC is also coordinating with the Immigration and Naturalization Service (INS) in an effort to validate the employment eligibility of personnel at nuclear power plants. They seek to ensure that only persons authorized to work in the U.S. are employed in nuclear power plants. However, there are limitations on the NRC’s and its licensees’ ability to obtain and use information available in INS and other federal databases for this purpose. For example, current law (8 U.S.C. §1342b) prohibits discrimination on the basis of alienage in the context of employment. This section has been interpreted to preclude asking non-citizens for more proof of identity than citizens. In addition, in the process of dealing with access authorization, the Constitutional rights of both citizens and non-citizens must be protected.

To require licensees to implement additional protective measures, the NRC is responding to the terrorist threat in a comprehensive fashion. The NRC has undertaken a comprehensive reevaluation of the agency’s safeguards and security program, regulations, and procedures that has resulted in numerous security improvements. As part of this program review, the NRC has revised its DBT for radiological sabotage. Meetings to discuss the proposed revisions were held with representatives of the nuclear industry cleared to receive such information, as well as with authorized federal and state agencies. It should be noted, however, that it will take time to implement all associated changes in physical protection measures.

The NRC has studies under way to further investigate potential vulnerabilities of nuclear power plants. Although nuclear power plants were not designed to withstand an intentional attack from a large commercial airliner, reactor containments are massive structures, typically constructed with 2 to 5 feet of steel-reinforced concrete. The containments have an interior steel lining and redundant safety equipment to add further protection. Notwithstanding, the NRC has completed a preliminary vulnerability assessment for deliberate aircraft crashes on power reactors. While these studies are being conducted, certain interim compensatory measures have been put in place. For example, capabilities have been improved to respond to an event that results in damage to large areas of a nuclear power plant from explosions or fires. Additional measures have been put in place to protect against land attacks (including the use of a larger vehicle bomb) and water-borne attacks.

The NRC is also working with appropriate federal agencies to deal with a potential airborne threat. For example, the NRC has worked with the Federal Aviation Administration and the U.S. Department of Defense to put in place a Notice to Airmen advising pilots to refrain from circling or loitering above nuclear power plants and other nuclear facilities, or they can expect to be interviewed by law enforcement personnel.

The NRC developed a new Threat Advisory and Protective Measures System, corresponding to the color-coded Homeland Security Advisory System, that allows government officials to communicate the nature and degree of terrorist threats consistently nationwide. The NRC's system identifies specific actions to be considered by NRC licensees for each threat level to counter projected terrorist threats. If a credible threat emerges against a specific nuclear facility, additional protective measures may be mandated even without a change in the overall threat level.

Finally, the NRC has provided legislative proposals to Congress detailing specific initiatives that would further enhance security of NRC-licensed activities. These proposals address a spectrum of activities. One provision would authorize guards at NRC-regulated facilities to use deadly force to protect property significant to the common defense and security. This would give guards protection from state criminal prosecution for actions taken during the performance of their official duties. Another provision would allow the NRC, in consultation with the Attorney General, to confer upon guards at NRC-designated facilities the authority to possess or use weapons that are comparable to those used by the U.S. Department of Energy's guard forces. Some state laws currently preclude private guard forces at NRC-regulated facilities from utilizing a wide range of weapons. Another provision would make it a federal crime to bring unauthorized weapons and explosives into NRC-licensed facilities. The NRC would also make federal prohibitions on sabotage applicable to the operation and construction of certain nuclear facilities. The NRC is hopeful that these legislative initiatives will be enacted but also realizes that there are concerns involved with these activities.

USEFUL REFERENCE MATERIAL

1. *Code of Federal Regulations*, 10CFR73.55.
2. Nuclear Regulatory Commission Website [<http://www.nrc.gov/>].
3. *Nuclear Regulatory Commission Fundamentals Course Manual — Boiling Water Reactors*.
4. *Nuclear Regulatory Commission Fundamentals Course Manual — Pressurized Water Reactors*.
5. How Stuff Works Website [<http://www.howstuffworks.com/>].
6. Nuclear Tourist Website [<http://www.nucleartourist.com/>].
7. Nuclear Energy Institute Website [<http://www.nei.org/>].
8. Nuclear Control Institute Website [<http://www.nci.org/>].