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Fact Sheet
on
U.S. Nuclear Powered Warship (NPW) Safety

1. Commitments of the U.S. Government about the Safety of U.S. NPWs

U.S. Nuclear Powered Warships (NPWs) have safely operated for more than 50 years without experiencing any reactor accident or any release of radioactivity that hurt human health or had an adverse effect on marine life. Naval reactors have an outstanding record of over 134 million miles safely steamed on nuclear power, and they have amassed over 5700 reactor-years of safe operation.

Currently, the U.S. has 83 nuclear-powered ships: 72 submarines, 10 aircraft carriers and one research vessel. These NPWs make up about forty percent of major U.S. naval combatants, and they visit over 150 ports in over 50 countries, including approximately 70 ports in the U.S. and three in Japan.

Regarding the safety of NPWs visiting Japanese ports, the U.S. Government has made firm commitments including those in the Aide-Memoire of 1964; the Statement by the U.S. Government on Operation of Nuclear Powered Warships in Foreign Ports of 1964; the Aide-Memoire of 1967; and the Memorandum of Conversation of 1968. Since 1964 U.S. NPWs have visited Japanese ports (i.e., Yokosuka, Sasebo and White Beach) more than 1200 times. The results of monitoring in these ports conducted by the Government of Japan and the U.S. Government, respectively, demonstrate that the operation of U.S. NPWs does not result in any increase in the general background radioactivity of the environment. The U.S. Government states that every single aspect of these commitments continues to be firmly in place. Particularly, the U.S. Government confirms that all safety precautions and procedures followed in connection with operations in U.S. ports will be strictly observed in foreign ports, including Japanese ports. Also, the U.S. Government notes here that its commitments are supported by concrete measures that ensure the safety of U.S. NPWs and that are continuously being updated and strengthened.

2. Naval Reactor Plant Design

All U.S. NPWs use pressurized water reactors (PWRs). PWRs have an established safety history, their operational behavior and risks are understood, and they are the basic design used for approximately 60% of the commercial nuclear power plants in the world.

The mission that naval reactors support is different from the mission of commercial reactors. All NPWs are designed to survive wartime attack and to continue to fight while protecting their crews against hazards. They have well-developed damage control capabilities, redundancy, and backup in essential systems. In addition, to support the mission of a warship, naval reactors are designed and operated in such a way as to provide rapid power level changes for propulsion needs, ensure continuity of propulsion, and have long operational lifetimes (current naval reactor cores are designed such that aircraft carriers are refueled just once in the life of the ship and submarines never have to be refueled). These are the significant differences between NPW and commercial reactor missions. Also, the fact that operators and crews have to live in close proximity to the nuclear reactor requires that the reactor have redundant systems and comprehensive shielding and be reliable and safe. For these reasons, naval reactor plant designs are different from commercial reactors, which results in enhanced capability of naval vessels to operate safely under harsh battle conditions, or even more safely during peacetime operations.

There are at least four barriers that work to keep radioactivity inside the ship, even in the highly unlikely event of a problem involving the reactor. These barriers are the fuel itself, the all-welded reactor primary system including the reactor pressure vessel containing the fuel, the reactor compartment, and the ship's hull. Although commercial reactors have similar barriers, barriers in NPWs are far more robust, resilient and conservatively designed than those in civilian reactors due to the fundamental differences in mission.

U.S. naval nuclear fuel is solid metal. The fuel is designed for battle shock and can withstand combat shock loads greater than 50 times the force of gravity without releasing fission products produced inside the fuel. This is greater than 10 times the earthquake shock loads used for designing U.S. commercial nuclear power plants. With the high integrity fuel design, fission products inside the fuel are never released into the primary coolant. This is one of the outstanding differences from commercial reactors, which normally have a small amount of fission products released from the fuel into the primary coolant.

An all-welded primary system provides a second substantial metal barrier to the release of radioactivity. This system is formed by the reactor pressure vessel, which is a very robust and thick metal component containing the reactor core, and primary coolant loops. They are tightly and firmly welded to stringent standards to constitute a single structure that keeps pressurized high temperature water within the system. The primary system coolant pumps are canned motor pumps, which means they are completely contained within the all-welded primary system metal barrier. No breach in the primary boundary is needed to power the pump; the pump is operated from outside by the force of an electromagnetic field. No rotating parts with associated packing seals penetrate the metal barrier. While the design ensures that no measurable leakage takes place from this primary system, it should be noted that there is only a very small amount of radioactivity within the primary coolant. As explained above, there are no fission products released from the fuel into coolant. The main sources of radioactivity in the primary coolant are trace amounts of corrosion and wear products that are carried by reactor cooling water and activated by neutrons when the corrosion products pass by the reactor fuel. The concentration of radioactivity (Becquerels per gram, Bq/g) from such activated corrosion products is about the same as the concentration of naturally occurring radioactivity found in common garden fertilizer. The U.S. Navy monitors radioactivity levels in the reactor cooling water on a daily basis to ensure that any unexpected condition would be detected and dealt with promptly.

The third barrier is the reactor compartment. This is the specially designed and constructed high-strength compartment within which the all-welded primary system and nuclear reactor are located. The reactor compartment would hold back the release of any primary coolant system liquid or pressure leakage in the event a leak were to develop in the primary system The fourth barrier is the ship's hull. The hull is a high-integrity structure designed to withstand significant battle damage. Reactor compartments are located within the central, most protected section of the ship.

The U.S. Naval Nuclear Propulsion Program has a dual agency structure with direct access to the Secretaries of Energy and Navy. The Program is responsible for all aspects of U.S. naval nuclear propulsion, including research, design, construction, testing, operation, maintenance, and ultimate disposition of naval nuclear propulsion plants. None of these activities can be undertaken without the approval of the Program.

Furthermore, the U.S. Nuclear Regulatory Commission and the Advisory Committee on Reactor Safeguards independently review each of the Navy's reactor plant designs. These organizations have concluded that, in many areas, military requirements have led to features and practices that meet objectives that are more demanding than those necessary for commercial nuclear reactors. After rigorous reviews, the U.S. Nuclear Regulatory Commission and the Advisory Committee on Reactor Safeguards have concluded that U.S. NPWs can be operated without undue risk to the health and safety of the public.

3. Naval Reactor Operation

Operation of naval reactors is also different from that of commercial reactors because of the different purpose they serve. First, naval reactors are smaller and lower in power rating than typical civilian reactors. The largest naval reactors are rated at less than one-fifth of a large U.S. commercial reactor plant. Also, naval reactors do not normally operate at full power. The average power level of reactors on nuclear-powered aircraft carriers over the life of the ship is less than 15% of their full rated power. In contrast, commercial reactors normally operate near full power.

Second, the naval reactor power level is primarily set by propulsion needs, and not by the ship's other service needs, which are also powered by the reactor but require a small fraction of the power required for propulsion. Consequently, reactors are normally shut down shortly after mooring and they are normally started up only shortly before departure, since only very low power is required for propulsion in port. While in port, electric power for service needs is provided from shore power supplies. This has been and will continue to be the case for NPWs in Japanese ports where sufficient shore power is available.

From these two facts alone, it follows that the amount of radioactivity potentially available for release from a reactor core of a U.S. NPW moored in a port is less than about one percent of that for a typical commercial reactor. A large fraction of the fission products that are produced during the operation of the reactor, and are of concern for human health, decay away shortly after the reactor is shut down.

4. Radiation Exposure to U.S. Personnel Associated with NPWs

With the four barriers to the release of radioactivity and comprehensive shielding, U.S. Navy reactors are so effectively shielded and radioactivity is so controlled that a typical NPW fleet crew member receives significantly less radiation exposure than a person would receive from background radiation at home in the U.S. in the same period. This is due to the comprehensive shielding built into the ships and the absence of radiation from the earth itself, most notably from radon, while the NPW is deployed.

The average exposure per person monitored in the Naval Nuclear Propulsion program has been on a downward trend for the last 24 years. For fleet personnel, the average exposure per person in 2004 is 0.038 rem (0.38 mSv), while the annual average over the 25 years since 1980 is about 0.044 rem (0.44 mSv),

For comparison, this average annual exposure of 0.044 rem (0.44mSv) since 1980 is:

- less than 1 percent of the U.S. Federal annual worker limit: 5 rem (50 mSv)
- approximately one-third the average annual exposure of commercial nuclear power plant personnel: 0.109 rem (1.09mSv).
- approximately one-fourth of the average annual exposure received by U.S. commercial airline flight crew personnel due to cosmic radiation: 0.170 rem (1.7 mSv)
- less than 15 percent of the average annual exposure to a member of the population in the U.S. from natural background radiation: approximately 0.3 rem (3.0 mSv).

- less than the difference in the annual exposure due to natural background radiation between Denver, Colorado and Washington, DC: 0.070 rem (0.7mSv)

5. Waste Disposal and Maintenance

As is the case for commercial reactors, the operation of naval nuclear reactors involves creation of liquids containing low levels of radioactivity. In the case of commercial reactors, low-level radioactive liquids are routinely discharged as part of plant operation within limits established to ensure that there is no significant effect on the environment or on public health. For U.S. NPW reactors, extensive efforts have been taken to control routine discharges strictly so as to minimize the amount of radioactivity released.

U.S. Navy stringently controls NPW effluent discharges in such a way that is wholly consistent with Japanese as well as established international standards, including those issued by the International Commission on Radiological Protection. Specifically, U.S. policy prohibits discharge of radioactive liquids, including primary coolant, from U.S. NPWs within 12 miles of shore, including in Japanese ports. Forty years of U.S. and Japanese environmental monitoring confirm that U.S. NPW operations have had no adverse effect on human health, marine life, or the quality of the environment. Solid wastes are properly packaged and transferred to U.S. shore or tender facilities for subsequent disposal in the U.S. in accordance with approved procedures. U.S. NPWs have not discharged demineralizer waste (i.e., ion exchange resins used for purification) into the sea for over 30 years.

The U.S. commitment expressed in the 1964 aide-memoire regarding fuel change and repair remains absolutely in place. Fuel change and reactor repairs are not performed in foreign countries. Fuel change can only be accomplished with proper specialized equipment and in facilities authorized by the U.S. Naval Nuclear Propulsion Program, which are only located in the United States.

6. Impact on the Environment

The robust and redundant design, relatively low power operation history particularly in port (typically shut down), and very strict control of radioactive waste all contribute to the fact that there has never been a reactor accident nor any release of radioactivity that has had an adverse effect on human health, marine life, or the quality of the environment throughout the entire history of the U.S. Naval Nuclear Propulsion Program.

Since 1971, the total amount of long-lived gamma radioactivity released each year within 12 miles from shore from all U.S. naval nuclear-powered ships and their support facilities, combined, has been less than 0.002 curie (0.074 GBq); this includes all harbors, both U.S. and foreign, entered by these ships. As a measure of the significance of these data, this amount of radioactivity is less than the quantity of naturally occurring radioactivity in the volume of saline harbor water occupied by a single nuclear-powered submarine, and less than one tenth of the quantity of radioactivity naturally occurring in the volume of saline harbor water displaced by a single aircraft carrier. This means that a U.S. NPW releases far less radioactivity than exists naturally in the comparable volume of seawater. In addition, even exposure to the entire amount of radioactivity released into any harbor in any of the last 34 years would not exceed the annual radiation exposure permitted for an individual worker by the U.S. Nuclear Regulatory Commission. One typical U.S. commercial nuclear power plant will, safely within its operational license limits, annually discharge over one hundred times the amount of long-lived gamma radioactivity released within 12 miles from shore by all of the U.S. NPWs and their support facilities.

Further, as a measure of how stringently the Navy's policy is applied even on the high seas outside of 12 miles from shore, the entire fleet of U.S. NPWs collectively released less than 0.4 curie (14.8 GBq) of long-lived gamma radioactivity in each year since 1973. This total is still less than the amount of radioactivity a single typical U.S. commercial nuclear power plant is permitted to release in a year by the U.S. Nuclear Regulatory Commission. Such low levels of radioactivity released on the high seas have not had any adverse effect on human health, marine life, or the quality of the environment.

No national or international standard requires that the level of radioactivity released by nuclear facilities be as low as this level. The stringent efforts of the U.S. Navy to implement this policy have ensured that the operation and servicing of U.S. NPWs do not result in any increase in the general background radioactivity of the environment.

7. Environmental Monitoring

To provide additional assurance that procedures used by the U.S. Navy to control radioactivity are adequate to protect the environment, the Navy conducts environmental monitoring in harbors frequented by its nuclear-powered warships. In the U.S., quarterly sediment, water, and marine life samples are obtained from harbors where ships have operating bases or are serviced. The results of this monitoring are reported annually, and are also shared with the Government of Japan. Similarly in Japan, the U.S. Navy takes quarterly sediment, water, and marine life samples from Sasebo and Yokosuka harbors, and Nakagusuku Bay on Okinawa.

This monitoring shows that radioactivity in the harbor environment has not increased above natural background levels as a result of the operations by U.S. NPWs, and that nuclear-powered warship operations have had no discernable adverse effect on human health, marine life or the quality of the environment. The results of the environmental samples in Japanese ports are provided annually in a report to the Government of Japan.

The U.S. Government understands that, since 1964, the Government of Japan has independently taken similar environmental samples in Japanese ports with comparable results, showing no discernable impact on the environment, human health, or marine life.

8. Emergency Preparedness - Defense in Depth

Due to the four barriers in place in U.S. NPWs, it is extremely unlikely that radioactivity would ever be released from the reactor core into the environment. For additional assurance, however, U.S. NPWs have multiple safety systems to prevent problems from happening and expanding.

The all-welded primary system is designed with a zero-leakage design criterion that allows NPWs reactor operators to determine quickly if there were even a very very small primary coolant leak and take prompt corrective action before it could lead to additional problems.

Further, U.S. NPWs have a failsafe reactor shutdown system, which brings about reactor shutdown very quickly, as well as other multiple reactor safety systems and design features, each of which has back-ups. Among these is a decay heat-removing capability, which depends only on the physical arrangement of the reactor plant and on the nature of water itself (natural convection driven by density differences), not on electrical power, to cool down the core. Also, naval reactors have ready access to an unlimited source of seawater that can, if ultimately necessary, be brought on board for emergency cooling and shielding and would remain on the ship. All reactors on U.S. NPWs are located in robust compartments and have multiple ways of adding water to cool the reactor. These multiple safety systems ensure that, even in the highly unlikely event of multiple failures, naval reactors would not overheat and the fuel structure would not be damaged by heat produced in the reactor core. Thus, it would require virtually incredible accident conditions, where these safety systems and their back-ups all fail, to cause a release of fission products from the reactor core to the primary coolant.

The NPW crew is fully trained and fully capable to respond immediately to any emergency in the ship. Naval operating practices and emergency procedures are well defined and rigorously enforced; and the individuals are both trained for dealing with extraordinary situations and subject to high standards of accountability. Also, the fact that the crew lives in such close proximity to the reactor provides the best and earliest monitoring of even the smallest change in plant status. The operators become very attuned to the way the plant sounds, smells, and feels.

In the extremely unlikely event of a problem on board involving the reactor plant of a U.S. NPW visiting Japan, the U.S. Navy would initiate actions required to respond and could call on other U.S. national response assets if necessary. While the U.S. Government will keep the Government of Japan informed while the U.S. is responding, the U.S. Government will not require assistance from the Government of Japan to respond to an affected NPW.

Because of the rugged design of the reactor plant, multiple safety systems, and fully trained and capable crew, the safety of U.S. NPWs is extremely high. In order for an accident that affects the operation of the ship or the crew to happen, the ship must simultaneously experience numerous unrealistic equipment and operator failures. Even though such an accident scenario is very unrealistic, the U.S. NPWs and their support facilities are required to simulate such situations as they conduct meaningful training on highly unlikely reactor accident scenarios.

With such a defense-in-depth approach, even in the highly unlikely event of a problem involving the nuclear reactor of a U.S. NPW, all radioactivity from the fuel would be expected to remain inside the ship.

9. Potential for Release of Radioactivity during a Highly Unlikely Accident Scenario

All of the above discussion leads to the conclusion that the likelihood of an accident resulting in radioactivity from the nuclear reactor core itself being released from the ship to the environment is extremely small. However, the U.S. Navy never dismisses such an accident scenario as something that does not deserve serious consideration. The U.S. Navy has made thorough studies on: what could bring about a release of radioactivity from the ship during highly unlikely accident scenarios, what effect such a release could have on the environment, and what emergency plans would be required for such a situation.

To get into the environment, fission products would have to pass through each of the four barriers: the fuel, the all-welded reactor primary system, the reactor compartment, and the ship's hull. Also, it would require that all reactor safety systems and their back-ups malfunction. Further, it would require that the fully trained and very capable crew could not react to and control the situation. If all of these abnormalities took place simultaneously in a highly unlikely accident scenario, then a U.S. NPW could potentially release fission products to the environment. In other words, such an accident would be possible only in a very unrealistic situation of multifold and simultaneous errors and malfunctions. Nevertheless, the U.S. Navy does prepare for and test its response to simulated highly unlikely accident scenarios.

As was stated by the U.S. Government in the 1967 aide-memoire, based on a detailed and conservative safety analysis in which the maximum credible accidents resulting in the release of radioactivity are assumed, nuclear-powered warships do not represent unreasonable radiation or other nuclear hazards to the civilian population in the neighborhood of their mooring locations. Even in these highly unlikely events, the maximum possible effect of the predicted amount of radioactivity released would be localized and not severe: the effect would be so small that the area where protective actions, such as sheltering, would be considered at all would be very limited, and only in the immediate vicinity of the ship and well within the U.S. Navy bases in Japan. This statement is based on existing thresholds for public protective actions set by the U.S. Federal Government, and is equivalent or more conservative than the existing guidelines set by the International Atomic Energy Agency (IAEA) for similar emergencies.

A number of factors contribute to keep the effect of such a highly unlikely accident localized and not severe. First, fission products in the fuel would not be directly and immediately exposed to the atmosphere. The fission products would first have to pass through the four barriers. Even in a very unrealistic situation where radioactivity passed through all four barriers, the amount of radioactivity for potential release would be significantly reduced after passing through each successive barrier. This means that the amount of radioactivity eventually released from the ship during an accident would be only an extremely small portion of what could have been released into the primary coolant.

Second, the process through which radioactivity would be potentially released from the ship would not be a short-time event like an explosion. It would take a long time for radioactivity to pass through the four barriers. The high-strength reactor compartment and ship's hull would restrict the movement of radioactivity such that the radioactivity could not be released in a short time period through an explosive-like force.

Third, since it would take a long time for radioactivity to pass through the four barriers, there would be sufficient time for the crew to respond to the problem and mitigate potential consequences before any radioactivity reached the outside of the ship. Also, a large fraction of the fission products that are produced during the operation of the reactor, and are of concern for human health, decay away shortly after the reactor is shut down and before they could pass through the four barriers.

The process described above is totally different from an atomic bomb explosion. It is physically impossible for this type of nuclear explosion to occur in a land-based commercial reactor or naval nuclear propulsion reactors.

10. Emergency Planning

As explained above, areas outside of U.S. Navy bases in Japan should not have to implement any protective action whatsoever, even in the highly unlikely event that some radioactivity escaped from the ship. Consequently, the U.S. Government considers that existing Japanese emergency plans for responding to natural and industrial disasters such as earthquakes and chemical transportation accidents are sufficient to deal with any highly unlikely event on a U.S. NPW. It is important to note that there are no NPW-specific plans for public protective actions, such as sheltering, evacuation, or distribution of potassium iodide, in any U.S. port where NPWs are homeported or maintained since it is not required for public safety.

The fact that U.S. NPWs can be moved is a safety feature that is not available to land-based nuclear facilities. Given the fact that no public protective actions would be required for areas outside the Navy facility even in the highly unlikely event of radioactivity escaping from the ship, it is hard to imagine a situation in which the ship would have to be moved from the port. Nevertheless, the ship can be moved using its own propulsion power or assisted by tugboats as necessary, if it is deemed appropriate. Any action to move an affected NPW would be taken after consultation with the Government of Japan.

11. Indemnity

Regarding judicial actions arising out of a nuclear incident involving the nuclear reactor of a U.S. NPW, where the Status of Forces Agreement is not applicable, the Public Vessels Act (PVA) and Suits in Admiralty Act (SIAA) apply and waive U.S. sovereign immunity. The authority to pay administrative claims and judgments under 42 U.S.C. §2211 supplements the PVA and SIAA by permitting administrative claims settlements using a no-fault standard. There is no statutory limit on the amount of compensation that may be paid in the event of a U.S. NPW nuclear reactor incident.