Exploration and Thinking on Collective Protection System of Floating Nuclear Power Plant

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Abstract. Demand and development for nuclear emergency interventions and protective actions for floating nuclear power plants, Combining the collective protection systems and their functions of the monitoring system, the protection system, the washout system and the control system of the nuclear, chemical and biological weapons of large warships, To provide reasonable nuclear emergency facility support for the construction of floating nuclear power plant nuclear accident emergency plan. It provides a theoretical basis for the nuclear emergency plan of floating nuclear power plant at sea, as well as the collective protection system of floating nuclear power plant, to give full play to the functions of collective protection equipment.

Keywords: Floating nuclear power plant, Nuclear emergency, Collective protection.

1. Introduction
Nuclear energy has been widely used in land-based nuclear power plants for its advantages of high efficiency, cleanliness and economy. With the increasing demand for energy in the fields of marine development, drilling platform and island construction, nuclear power ships and floating nuclear power stations have become a new round of development upsurge of nuclear energy application in recent years. In 2016, the national development and Reform Commission agreed to set up a demonstration project of marine nuclear power platform, a major national energy science and technology innovation project; in 2017, during the 19th China International Maritime Exhibition, China's shipbuilding industry exhibited four kinds of marine nuclear power platforms and ships, including 20000 ton marine nuclear power platform, submersible marine nuclear power platform, nuclear power comprehensive support ship and nuclear power breaker ice boats, etc.

However, the development and utilization of nuclear energy on the sea also has great risks. The most typical one is that after the maritime nuclear accident, whether the marine nuclear emergency can be carried out effectively still needs more in-depth research. Nuclear accident emergency is the last barrier of nuclear safety in-depth defense, and it is a highly technical, social and political social system engineering, involving the cooperation of all parties. At present, nuclear and radiation emergency preparedness and corresponding relevant legal systems "nuclear accident emergency management regulations of nuclear power plant" and "National Nuclear Emergency Plan" all regulate nuclear emergency of land-based nuclear power plant. How to effectively carry out nuclear emergency work at sea is still under study and discussion. Therefore, in the development process of nuclear power ship and offshore nuclear power platform, combined with the collective protection of surface ships, the
paper puts forward some suggestions on how to effectively carry out the marine nuclear emergency work. With the development of the system, the concept of collective protection system under the nuclear emergency state of floating nuclear power station is put forward, which can provide effective nuclear emergency facilities for marine nuclear emergency, enhance the emergency preparedness and response of marine nuclear accident, and enhance the prevention and emergency capability of nuclear power ships and offshore nuclear power platforms to cope with nuclear accidents. Its necessity and importance are self-evident.

2. Ship collective protection system

Collective protection system is an important index to reflect the nuclear, chemical and biological protection capability of surface ships. When a ship is attacked by nuclear, chemical or biological weapons, the leakage of radioactive substances occurs in the nuclear weapons or nuclear power plant of the ship, or passes through the sea area polluted by radioactive dust, biological warfare agent and poison, the collective protection system can send filtered clean air into the protection area, and form a certain cabin positive pressure, so as to avoid the external air pollution from penetrating into the protection area and ensure the ships in the protection area without wearing personal chemical protective clothing, the crew can maintain the most basic combat command ability and normal life and work of the ship, so that the ship can smoothly pass through the polluted sea area and ensure the personal safety of the crew.

The research and design of collective protection system began in the mid-1960s, and the successful development and design of the system should be based on the DSK of the former Federal Republic of Germany. Then came citadel in the United Kingdom and CPS system in the United States. Russia's surface ships also changed from individual protection to collective protection in the 1960s and 1970s.

At present, the collective protection system of foreign warship equipment is divided into two categories, one is the German all ship collective protection system, namely DSK system. The other is the United States' zonal collective protection system, namely CPS system.

There are two types of CPS protection in the US Navy:

1) Full protection: in the full protection area, the high-pressure fan will clean any air containing nuclear, biochemical and biological pollutants in physical state through the primary filter, HEPA (high efficiency air particle filter) and activated carbon filter, and filter the contaminated particles from large to small step by step to remove aerosol, smoke, radioactive contamination, biological warfare agents and chemical agents. The filtered clean air enters the protection zone, keeping the overpressure of about 2.0 ± 0.5 inch water mark (~ 500 PA) in the cabin. There is no need to wear chemical protective clothing or mask.

2) Limited protection: the limited protection area can only provide a low degree of protection safety, and the radioactive, chemical and biological aerosols in the gas supply entering the limited protection area can be removed only by using the HEPA filter. The inlet fan in the limited protection area is not a high-pressure fan, so overpressure cannot be established. Moreover, HEPA filter cannot filter chemical warfare agent steam. Therefore, it is necessary to wear a full set of chemical warfare protective clothing and protective mask. Limited protection is generally set in cabins with extremely high air flow requirements such as engine room.
3. Basic principles of collective protection system for floating nuclear power plant

The collective protection system of floating nuclear power station is a necessary means to deal with the consequences of nuclear accident and support nuclear emergency and survivability. A stable positive pressure must be maintained in the collective protection area. At the same time, the air flow in the decontamination station and air lock chamber of the protection area must maintain a certain pressure gradient, so as to ensure continuous air purging and decontamination in the inlet and outlet channels of the protection area, so as to remove gaseous pollutants. Therefore, the overpressure control of collective protection zone is mainly aimed at the pressure gradient of decontamination station and air lock chamber and the stable establishment of positive pressure in protection zone. The basic principle is shown in Figure 1.

The collective protection system of floating nuclear power station can be divided into two types: full station protection and regional protection. Due to the particularity and complexity of the floating nuclear power station structure, it is generally difficult to implement the whole plant protection for the floating nuclear power station. A certain number of limited collective protection areas can be set up on
the power station. The limited collective protection areas are under the platform emergency and off-site emergency conditions. Limited protective actions are provided for the personnel in the area who cannot be evacuated in time, so as to ensure the life safety of the staff in the floating nuclear power station. These limited collective protection areas are filtered out of toxic and harmful substances by the nuclear leakage filtration system, and the overpressure of 500pa in the protection area is met by the pressurized air supply system, and then sent to each collective protection area by the air conditioning and ventilation system.

4. Composition of collective protection system for floating nuclear power station

According to the characteristics, nature and possible consequences of accidents in floating nuclear power plant, the collective protection system of floating nuclear power station includes radiation monitoring system, protection system, decontamination system, automatic control and monitoring system.

4.1. Radiation monitoring system

The monitoring system is used to measure the radiation dose of various parts of floating power station. The system is divided into two types of equipment: one is the fixed gamma radiation detector, which is composed of one host, one environmental monitoring probe, two or three air probes and one seawater probe. The absorbed dose rate, absorbed dose and seawater contamination concentration in the sea area where the floating nuclear power station is located are monitored comprehensively. If the absorbed dose rate exceeds the preset value, the sound and light alarm signals will be sent out. The main engine is installed in the emergency control center of the floating power station. The seawater probe is placed inside the outer plate below the water line of the power station, and the air probe is placed in the cabin related to personnel safety protection. The other is mobile gamma radiation detector and personal dose detector. The former is used to discover radioactive contamination, determine contamination boundary and contamination area grade, survey personnel, technical equipment and surface radioactive contamination level of various objects, determine whether food and water sources contain radioactive substances, and roughly determine their contamination ratio and concentration. The latter is used to directly measure the dose of gamma rays received by personnel in the contaminated area [2-5].

4.2. Protection system

4.2.1. Isolated protection

When the filter protection equipment of the power station fails, the irrelevant nuclear emergency personnel cannot be evacuated temporarily. The floating nuclear power station can use the air tightness of its cabin for isolation protection. Isolation protection requires that the airtight performance of the cabin should be high, and the traditional watertight doors, windows and hatch covers should be replaced with air tight ones to improve the air tightness of the cabin.

4.2.2. Filtering protection

The floating nuclear power station should adopt the filtering protection adopted by modern large surface ships. The filtering and ventilation system in the airtight cabin of the power station is to filter the outdoor contaminated air into clean air and send it into the cabin to ensure that the personnel can live, work and perform nuclear emergency tasks for a long time in the cabin. The technological process of modern large surface warship's poison filtering and ventilation device is shown in Fig. 3. The external air first passes through the pre filter element (first stage) to remove large particles and fibrous contaminants in the air, and then enters the high efficiency filter element (second stage). After filtering out radioactive pollutants, toxic smoke and toxic fog of 0.3 μm and above, it enters the carbon filter element (third stage) to remove gaseous chemical warfare agents. In this way, the contaminated air outside the cabin is changed into clean air after three-stage filtration and adsorption, and then sent to the air-conditioning and ventilation system by the fan, and then sent to the airtight cabin by the air supply pipe. In order to maintain the good protection effect of the cabin, it is
necessary to ensure that the net overpressure value caused by the enclosed cabin is at least equal to the dynamic overpressure value formed by the external air flow. The overpressure should be maintained at 500pa. The exhaust gas in the cabin can be directly discharged through the overpressure valve, kitchen or toilet, etc. for large ships, most of the exhaust gas can be discharged from the main engine compartment, so as to ensure that the air in the cabin is clean and free from external contamination of poisonous air.

![Ventilation device flow](image)

**Fig. 3 Ventilation device flow**

4.2.3. **Personal protection.** Personal protective equipment (PPE) is used by shipmen to protect themselves from radioactive dust. Including respiratory protective equipment. Respiratory protective equipment mainly filters through smoke filter layer and anti-virus carbon filter parts. The function of smoke filter layer is to filter out the toxic and harmful aerosol produced by nuclear leakage; the function of anti-toxic carbon is to provide clean air for staff by physical adsorption, chemical absorption and catalysis.

4.3. **Collective protection and decontamination system of floating nuclear power station**

4.3.1. **Water curtain decontamination system.** The platform decontamination system of floating nuclear power station is composed of water curtain system, decontamination fluid supply system, decontamination system and portable decontamination device. Modern advanced ships have organically combined and optimized the water curtain system, firefighting system, decontamination system and decontamination fluid supply system to establish an efficient decontamination system integrating water curtain, decontamination and firefighting, which can play the maximum function of equipment, reduce unnecessary equipment duplication, save platform cabin space, and improve the use efficiency and effect of equipment. The platform can start the water curtain system when the radioactive material is released to form a water curtain on the platform surface to prevent the radioactive suspended particles from contaminating the open deck surface. The seawater supply of the water curtain system comes from the firefighting system of the ship. The water curtain system can be filled with decontamination fluid, which helps to prevent radioactive suspended solids particles from contaminating the deck and helicopter platform. The preparation of decontamination fluid is supplied by the decontamination concentrated solution preparation centre. According to the division of the platform area, 3-4 decontamination liquid preparation stations and corresponding decontamination liquid main pipelines can be set up. The preparation station is mainly composed of solid detergent, liquid detergent and mechanical agitator. The decontamination liquid prepared according to a certain
proportion is distributed into each water curtain subsystem through the decontamination main pipeline for ship deck and equipment Surface decontamination.

In the local decontamination of the power station, portable decontamination device can be used to decontaminate the key parts of the platform and the parts that the staff must contact during the nuclear emergency, so as to remove the radioactive pollutants on them.

4.3.2. Decontamination channel. It is inevitable that there will be personnel in and out of the fully enclosed nuclear power platform during the nuclear emergency period. Therefore, the nuclear power platform should at least set up two access channels at the bow and stern of the ship, and each channel should be composed of decontamination equipment, wearing protective equipment and radioactive monitoring equipment. The personnel entering the cabin must be decontaminated through the platform decontamination channel before the contamination on the surface of personal protective equipment can be eliminated. After taking off the protective equipment in the decontamination channel, the personnel can enter the cabin only after the radiation monitoring meets the requirements. Personnel leaving the cabin should also wear personal protective equipment in the decontamination channel before leaving the cabin to perform the task on the deck. The decontamination channel should also be equipped with decontamination equipment and radioactive dose monitoring equipment.

4.4. Automatic control and monitoring system of collective protection

4.4.1. Automatic control system for radioactive monitoring. The automatic control system monitors, displays, alarms and re displays the gamma radiation air probe and sea water probe. The computer processes the monitoring parameters, effectively controls the control systems and actuators, displays the on-site radioactive dose monitoring on the monitor and repeater, and sends warning information to the decision-makers, so as to provide the basis for nuclear emergency command and decision-making. Then, according to the nuclear emergency plan, the radioactive dose monitoring equipment is effectively controlled, and the intervention effect is fed back to monitor the operation status of the system and to give early warning for the failure.

4.4.2. Protective equipment monitoring system. The monitoring system of protective equipment is to monitor the ventilation device and the closed area, and to effectively control the control system and actuator. The resistance signal is obtained by differential pressure transmitter, and the air flow signal is obtained by using velocity averaging pipe flow probe and micro differential pressure transmitter to monitor the resistance and air volume of ventilation device. The start and stop of booster fan is controlled by solid relay, and the constant air volume is controlled by electric control valve to ensure that the poison filtering ventilation device provides enough fresh air to the closed area. It has the functions of monitoring the overpressure in the closed area, opening and closing of the closed tuyere on the perimeter of the closed area, the status of the remote control air tight butterfly valve, and the operation state of the water curtain system.

5. Conclusion
The construction of collective protection system for floating nuclear power station platform is a complex and comprehensive system, which requires the cooperation of design, construction and supervision departments of floating nuclear power station, so as to establish a perfect and effective collective protection system, so as to ensure the effective implementation of floating nuclear power station nuclear emergency plan.

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