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Study on Maintenance, Recycle, and Radioactive Waste Management of Fusion Reactor
Part I: Brief introduction of symposium
核融合炉の保守・リサイクル・バックエンド対策に関する検討
１．趣旨説明

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A fusion reactor will generate 14 MeV neutrons and the kinetic energy of these neutrons will be transferred to the thermal energy which will be taken out of the reactor to generate the electricity. In this study, a certain maintenance process was assumed and several issues were discussed which must be considered in the design phase. In the symposium, an image of maintenance will be presented and practical works will be listed. One of the key issues is "activation." Therefore, radioactive waste management must be considered. The other key issue is "tritium." All the materials used in the plasma vacuum vessel contain tritium.

1. Maintenance of Fusion Reactor

A fusion reactor will realize deuterium-tritium (D-T) reaction in high temperature and high density plasma which will generate 14 MeV neutrons and 3.5 MeV alpha particles. There are two items which must be taken into account when the maintenance, recycle and radioactive waste management of the fusion reactor are discussed.

The first one is "activation" of the material. Most of the generated fusion neutrons will be caught by blanket modules. Since the neutron has the energy of 14 MeV, it can pass through a thin first wall and a structural material and reach the blanket. In the blanket module, there is a coolant to take out the nuclear heat to outside of the fusion reactor. Lead lithium or lithium oxide will be adopted as the coolant which will breed the tritium by getting the neutrons. At the same time, beryllium particles will absorb the neutron and multiply the neutrons. These reactions will occur in the blanket and the blanket is a shielding component against neutrons. Unfortunately, some neutrons will penetrate the blanket and others will stream out of the ports. These neutrons will come out of the plasma vacuum vessel and reach the superconducting magnets and other components located in the cryostat. Therefore, most of the materials in the cryostat will be activated and emit radiation.

The second is "tritium." The tritium and the deuterium are fuel of the fusion reactor. These are isotopes of hydrogen and both can diffuse and be trapped in the materials. The deuterium exists in nature and it is harmless, but the tritium does not exist in nature and the half decay period is 12.3 years. It is harmful for a human body. So, the tritium in the fusion reactor must be controlled perfectly. During the maintenance, the component of the fusion reactor will be replaced. Since all components in the vacuum vessel contain the tritium, the components must be insulated with the cold space. At the same time, the tritium detection system must work in the cold area and the tritium removal system must stand by for 24 hours.

2. Image of Maintenance Flow

The discussion on the maintenance, the recycle and the radioactive waste will be carried out based on these two words, activation and tritium. The maintenance flow image of the component in the vacuum vessel is as follows:

2.1 Unit for Maintenance

The blanket and diverter modules must be replaced after the operation in a certain period. In case of ITER, the modules are taken out one by one. However, the modules in the fusion reactor will be activated much heavier than ITER, a large unit such as "Sector" will be replaced at one time and transferred to the hot cell. It is called as "Sector system." It will be safer and save a lot of time. The total weight which must be transferred will become large and the special transfer line will be prepared.

2.2 Carry to Hot cell

The maintenance of the sector will be carried out at the hot cell. To transfer the sector, the huge cast or the container will be connected to the fusion reactor and connections will be made perfectly to avoid gas leakage from the plasma vacuum vessel to the reactor hall because the gas contains the tritium. Then the sector will be turned to the torus direction and to the proper position to transfer to the cask. All the cooling channels and connections will be separated and connected again in the cask when the sector is pulled into the cask. The cask might have an independent cooling system to cool down the components continuously.

On the process, the remote handling system will be operated. The sector must be insulated with the air in the cold area and tritium detection system will be available. Since the tritium unites with oxygen in the air resulting in forming water, HTO, the fusion reactor hall might be filled with dried and oxygen free nitrogen gas.

2.3 Storage and Disassemble in Hot Cell

The sector will be stored in the hot cell for a certain period to wait for the reduction of the radiation emission. One sector will be settled in an individual cell where the independent air conditioning system and cooling channels will be operated to keep the sector temperature lower. After the radiation emission becomes weaker, the sector will be moved to the disassemble hall and taken apart. The disassemble hall will be filled with dried and oxygen free nitrogen and every task will be performed by the remote handling.

The neutron multiplier of the beryllium oxide will be reused for the other sets of the sector. So, the reusable materials will be separated and stored for the second use. Since the reuse material will be set in the new sector in the hot cell, the final assembly of the new sets of the sector will be performed in the hot cell.

The plasma vacuum vessel structure will be recycled and the other highly activated materials will be treated as the underground disposal. The waste materials will be cut into small pieces and storage into the special cask. The cask will be stored in the cold area until the delivery.

The recovery of the tritium is an important work in the hot cell. The component will be warmed up and the tritium will be collected from the out gas.

3. Some Special Facilities

3.1 Tritium Facility

The tritium facility is one of the key facilities in the fusion reactor. The facility will accept the tritium from the outside, store the tritium in the site, recover the tritium from the fusion system, and detect the tritium in the halls and in the site. For the maintenance of the fusion reactor and the facility, the quantitative tritium control and the tritium detection is very important. Since the operation will continue for long term, the work for maintenance must be carried out without the system interruption. The redundant system will be installed.

3.2 Remote Handling System

The remote handling system will be installed in inside the reactor, the reactor hall, and the hot cell where the tritium will be treated. The system for in-vessel maintenance will be stored in the proper area when the fusion reactor is in operation. The each tool and system must be repairable with other remote handling system. Once the machine touches a polluted material or a part, the special attention must be paid when it is maintenance.

3.3 Hot Cell

Hot cell will have a role for the storage of activated sector for waiting for the decay, the disassemble task of the sector, the blanket and the diverter, the recovery of the tritium, cutting and packaging of the disposals, and the storage of the cask for the final disposal. The space for the work with the activated components will be separated definitely. The utilities of the air conditioning system and the cooling water system will be also separated and redundant. The electric power will have own generation system for emergency.

The draft of the related regulation or rule must be prepared and it will be helpful to discuss the safety guard system in the hot cell and in the site.

3. Program of Symposium

The symposium program will be as follows:

1. Outline of the symposium by Arata Nishimura, NIFS. (10 minutes)
2. Research trend of maintenance, recycle, radioactive waste management case study by Kenji Tobita, JAEA. (15 minutes)
3. Outline of the maintenance engineering of the reactor by Hiroyasu Utoh. (15 minutes)
4. Remote control system in reactor hall and hot cell by Kenichi Fukumoto, Fukui University. (15 minutes)
5. Some issues related to maintenance in hot cell by Satoshi Yanagihara, Fukui University. (15 minutes)
6. Some issues on tritium treatment during maintenance and storage of activated devices in hot cell by Takumi Hayashi, JAEA. (15 minutes)
7. General discussion by Shinzaburo Matsuda, Tokyo Institute of Technology. (20 minutes)