S-P3-4

Study on Maintenance, Recycle, and Radioactive Waste Management of Fusion Reactor
Part IV: Outline of recycle scenario

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
4. リサイクル対策

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A safety and environmental advantage of fusion energy is a limited production of long-lived radioactive waste. On the other hand, fusion energy has a disadvantage of producing a large amount of activated waste, albeit low level. Recycling is one of key tactics to minimize the amount of the waste. This paper summarizes a waste management strategy for fusion with a focus on recycling.

1. Introduction

The necessity of recycling is based on the fact of 1) inevitable lack of fusion-specific resources, 2) the political difficulty of constructing new repositories for radioactive waste and 3) public eyes on waste generation. Accordingly, a waste management strategy including recycling could have great implications in terms of public acceptance. For this reason, numerous studies have been widely carried out based on lessons from fission technologies [1,2], which indicate a common prospect of waste management on fusion. The paper introduces recent views on fusion waste management as well as recycling.

2. Waste management strategy

It should be noted that the amount of radioactive waste produced during operation and after the decommissioning of a fusion reactor will be well above 10,000 tons, being much more than that from a light water reactor. In this sense, a waste management strategy needs to be considered to minimize the amount of the waste to be disposed of land burial and eventually acquire public acceptance of fusion. Figure 1 shows a possible management strategy of fusion waste. Basically, the dismantled components will be temporarily (typically, for 50 years) stored for the radioactivity to decay, and then categorized into clearance waste, radioactive materials for recycling or reuse, and radioactive waste to be disposed, in accordance with radioisotope concentrations in each component [3]. The amount of waste or materials classified into each category is strongly dependent on reactor design, choice of materials, radiologically detrimental impurities contained in materials. In fact, the estimated values for them vary greatly among studies. Even in a such situation, it is certain that the recycling of waste is an important disposal option to reduce the amount of land burial waste.

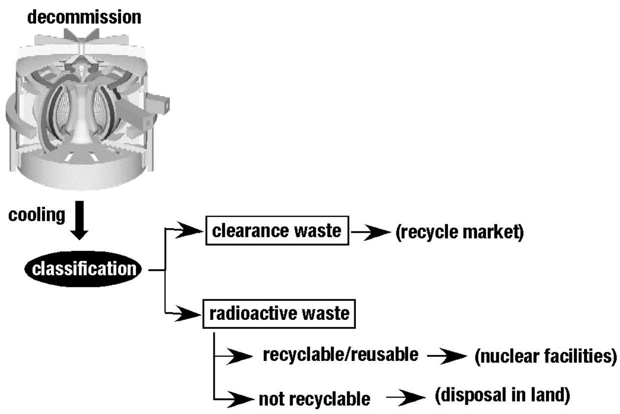

Fig.1 Management strategy of fusion waste

3. Recycling scenario

Along the “clearance” concept suggested by the NSC and IAEA, slightly activated materials could be released to the commercial market for recycle as shielding blocks in nuclear facilities, containers for radioactive waste, reinforcing steel for concrete buildings, concrete rubble base for roads, etc., or simply be disposed in non-nuclear landfills.

In the case of activated materials, all recycling processes need to be performed using remote handling (RH) equipment in radiation-controlled areas. An example of the contact dose rate of reactor components is shown in Fig.2. Since a fusion reactor is mainly composed of steel-based materials whose main contributors to the dose rate are ^{54}Mn ($T_{1/2}$ = 312 days) and ^{60}Co ($T_{1/2}$ = 5.27 years), the dose rate rapidly decays in several tens of years. As shown in the figure, the dose rate of the structural material (F82H) of blanket is still too high for recycle even after 50-year storage. In contrast, outer components such as shield and cryostat could be recycled because of low dose rate.

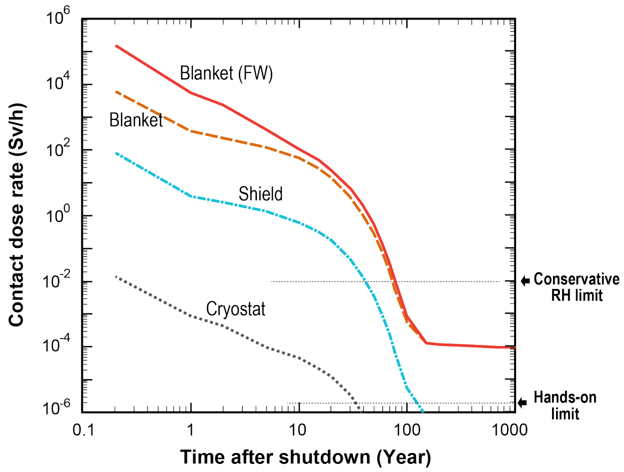

Fig.2 Contact dose rate of the steels used in main components.

Functional materials such as tritium breeder (e.g., lithium ceramics) and neutron multiplier (beryllium or beryllium alloy) should be reused or recycled from the viewpoint of efficient use of resources. The DEMO reactor SlimCS uses the solid breeder and multiplier as a mixture of Li_2TiO_3 pebbles and $Be_{12}Ti$ ones. For recycling of these pebbles, detritiation treatment is necessary prior to recycling process. Then the mixed pebbles need to be separated by material and be chemically processed. An advanced reactor using liquid breeder such as PbLi has an advantage in reuse of breeder because the used liquid breeder can be supplied to its succeeding reactor after reprocessing the chemical composition of the liquid breeder.

4. Critical issues for recycling

(1) Remote handling equipment

Dismantling, re-melting, reprocessing and fabrication of radioactive waste are required using RH equipment such as robots and manipulators in the recycling process. Presently, the conservative dose criteria for RH is considered to be 0.01-0.02 Sv/h from the experience of fission power plants. Practically, the dose limit could be increased by a few orders of magnitude in that re-melting of waste from fission plants has already been carried out on material with 0.1 Sv/h and, in addition, much higher dose rates up to of ~1,000 Sv/h are present in routine operations in the reprocessing of spent fuel [4]. However, as seen in Fig.2, radiation-hardened RH equipment durable at ~10,000 Sv/h will be required for fusion use.

(2) Storage

When a fusion power plant is shut down, there will be a production of 30,000 tons or more of radioactive waste. The waste needs to be stored safely for 50-100 years prior to waste classification and recycling. In the early period of storage, tritium recovery and active heat removal from the waste are necessary. A question is whether waste should remain not dismantled or be segmented into pieces to keep them in containers. This should be determined from a point of view of safety and cost.

(3) Recycle market

In principle, slightly activated materials satisfying the clearance limit is qualified to enter the commercial market for recycle. For example, in Germany and Belgium, metal waste cleared from nuclear facilities has been in circulation as scrap in the market and concrete is recycled as rubble base for roads. The waste produced in fusion power plants will potentially have the same uses. On the other hand, as to more activated waste, the recycle market is restricted to nuclear facilities, which means the market will be small compared with clearance waste. Although tritium breeder and neutron multiplier will be reused or recycled in the same or another reactor for the same purposes, possible uses of activated steel-based materials are not many. We need to figure out possible uses which do not require strict quality management on chemical composition, strength and machining accuracy. Finally, we have to be careful about economics; recycled materials will be costly compared with new materials.

References

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