FR0200116

Study on Reactor Vessel Replacement (RVR) for 1100 MWe class BWR Plants in JAPAN

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Keyword: Vessel, Replacement, Life

Introduction

Plant Life Management (PLM) is being studied in Japan, and reactor vessel replacement (RVR) is being considered as one option. Since reactor internals, except for reusable parts, and the reactor pressure vessel i RPV j are replaced, the RVR provides an effective technology for extending the service life of nuclear power plants substantially. At ICONE 7, we reported on the technical viability of the RVR for BWR4-type 800 MWe class plants. This time, we rationalized the RVR method through a study for BWR5-type 1100 MWe class plants to reduce the RVR duration and evaluated the technical viability and the economic efficiency of the method. In addition, we discuss how to dispose of the RPV to complete a scenario of the process from the RVR to its final disposal.

Outline of the method for 800 MWe class plants

Before discussing the RVR method for 1100 MWe class plants, the method for 800 MWe class plants was reviewed as follows. (See Fig. 1):

Step 1. Remove reusable reactor internals from inside of the RPV. Then, perform chemical decontamination to reduce radiation.
Step 2. Move all the fuel to other plant(s) to secure safety in lifting the RPV.
Step 3. Make an opening in the top of the reactor building to lift the RPV.

Step 4. Cut off the piping attached to the RPV and make preparations for lifting the RPV with the reactor shield wall (RSW) that prevents excess radiation during the RVR. Then inject mortar into the lower plenum of the RPV and attach temporary shielding on top of the RSW to cover the upper part of the RPV.
Step 5. Lift the RPV with the RSW using a large crawler crane that is set outside the building. Put the RPV and the RSW lifted out of the reactor building into an underground storage pit.
Step 6. Install a new RPV into the building using the crawler crane.
Step 7. Reconnect the piping to the new RPV.
Step 8. Close the opening in the top of the reactor building.
Step 9. Install the reusable reactor internals in the new RPV, reload its core with fuel, and perform start-up tests.

This method enables an RVR with a plant out-service period of about 230 days and a 100,000 man-day labor force.

Peculiar factors taken into consideration for 1100 MWe class plants
The following are the differences between 1100 MWe class plants and 800 MWe class plants that have an impact on the RVR:

Because the shape and the size of the RPV, the RSW and the primary containment vessel (PCV) of the 1100MWe class plant differ from those of the 800 MWe class plant, the RSW interferes with the PCV flange ribs in the 1100 MWe class plant during the lifting. Therefore we decided not to lift the RPV attached with the RSW, i.e., to leave the RSW in place and have additional temporary shielding instead.

Because the number of fuel assemblies is larger by about 40% in 1100 MWe class plants, the time necessary for moving the fuel increases. The total duration of the RVR may increase as a result.

Out of the two effects mentioned above, the increase in RVR duration can significantly affect the total cost of the RVR. Therefore, a reexamination of the critical process of the RVR is necessary, in order to make the RVR for 1100MWe class plants economically viable.

The following topics are studied for the 1100MWe class plant to reduce the RVR duration and to improve its economy.

Shielding method
We have decided to leave the RSW and to install temporary shielding around the RPV, as explained above. (See Fig. 2) In the previous study, we took advantage of the RSW as temporary shielding; however, a detailed review led us to the conclusion that this is not always cost effective, because many components are attached to the RSW, and the volume of disassembly and reassembly work is not negligible. For a 1100 MWe class plant, where the RPV does not interfere with the RSW, lifting the RPV without the RSW is more economic because no change to the shape of the RPV nozzles is necessary.

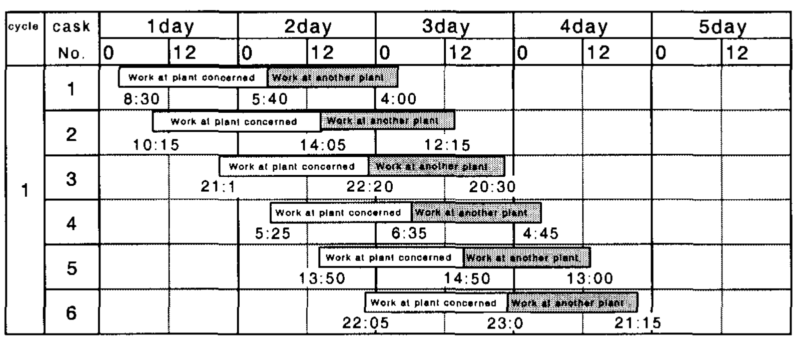
Method of making an opening in the top of the reactor building

In order to make an opening in the top of the reactor building, some ceiling trusses need to be cut off. In the previous study, temporary trusses were installed on the top of the reactor building to reinforce the opening. Because this method requires a large amount of structural steel, it has been rationalized by adopting temporary supports. In this method temporary supports are installed on the ceiling to support the main truss in the manner shown in Fig. 3. This method reduces the duration of the work and associated cost.

Method of moving fuel assemblies

When we estimated the time necessary for transferring the fuel from the R/B to other plant(s) in the previous study, the maximum permissible number of the fuel assemblies in a cask was calculated based on the condition of high burn-up fuel. However, for a reactor usually has an equilibrium core that has a combination of low burn-up and high burn-up fuel, we have estimated the number of days required to move fuel, on the assumption of an equilibrium core in this study. Using 6 casks, the fuel can be moved on an around-the-clock working system, as shown in Table 1. Also, it was decided to carry low burn-up fuel prior to high burn-up fuel, which allows additional time for cooling high burn-up fuel. The time necessary for moving is reduced by 30% from the result of the previous study.

Table 1 Fuel Moving Process (for One-Cycle)



RPV storage pit

Fig. 4 shows a RPV storage pit for a 1100 MWe class plant. The temporary shielding used for the RVR work stays in place even after the completion of the RVR.

RVR duration

All steps of the RVR procedure for the 1100MWe class plant are identical to those for the 800MWe class plant, except for step 4 (lifting the RPV), which has been replaced with a new process that leaves the RSW in place, installs temporary shielding around the RPV and then lifts the RPV with the temporary shielding out of the reactor building. We estimated the RVR duration for the 1100MWe class plant, taking into account the influences of increased size, the associated work force and the improvements discussed above. It is concluded that the out-service period of the plant with this method is about 210 days (See Table 2).

Transportation and disposal of the RPV

After the RPV and the reactor internals are kept in a storage pit for about 40 years to attenuate their radioactivity, reactor internals will be removed from the RPV, making the RPV disposable as low-level radioactive waste. This will be conducted at the time of plant decommissioning. In the decommissioning process, the stored RPV will be carried back inside the reactor building and the disassembly will be conducted in the building. Because the reduction in radiation will also make it possible to satisfy the standards specified for off-site transportation, the RPV can be transported out of the power station site without any radiation shielding. Fig. 5 shows the flowchart of the transportation. The RPV will be transported by a vehicle specially prepared for this purpose, and it will be put on board a ship by a large crane and then will be carried by marine transportation to a port near the specified waste disposal facility. Then the RPV will be carried by a vehicle from the port to the disposal facility, and it will be disposed of in a shallow underground repository after mortar injection. As for the reactor internals that are categorized as high-level beta and gamma wastes, they will be carried in large transport casks from the power station to the disposal facility. Then these components will be put into a shallow underground repository located at a relatively greater depth.

Evaluation of the method

The following are the results of estimating the number of days and man-days required for RVR at a 1100MWe class BWR plant:

RVR duration:	about 210 days
Labor:	about 88,000 man-days

Conclusions

The applicability of the RVR to 1100MWe class BWR plants has been studied and found to be technically viable. As a result of rationalization, RVR duration and total labor are decreased compared with the previous study. Further study is necessary for the details of the work process and the final disposal as well as public acceptance.

Table.2 The RVR schedule for 1100MW class plant

Item \ Month		1	2	3	4	5	6	7	8
Principal schedule									
Step1	Remove reusable reactor internals Chemical decontamination								
Step2	Move all fuel to other plant(s)								
Step3	Make an opening in the top of the reactor building								
Step4	Cut off the piping attached to the RPV								
Step5	Lift the RPV with radiation shielding/Put it into an underground storage pit								
Step6	Install a new RPV into the building								
Step7	Reconnect the piping to the new RPV								
Step8	Close the opening in the top of the reactor building								
Step9	Install reusable reactor internals in the new RPV /Reload its core with fuel/Perform start-up tests								

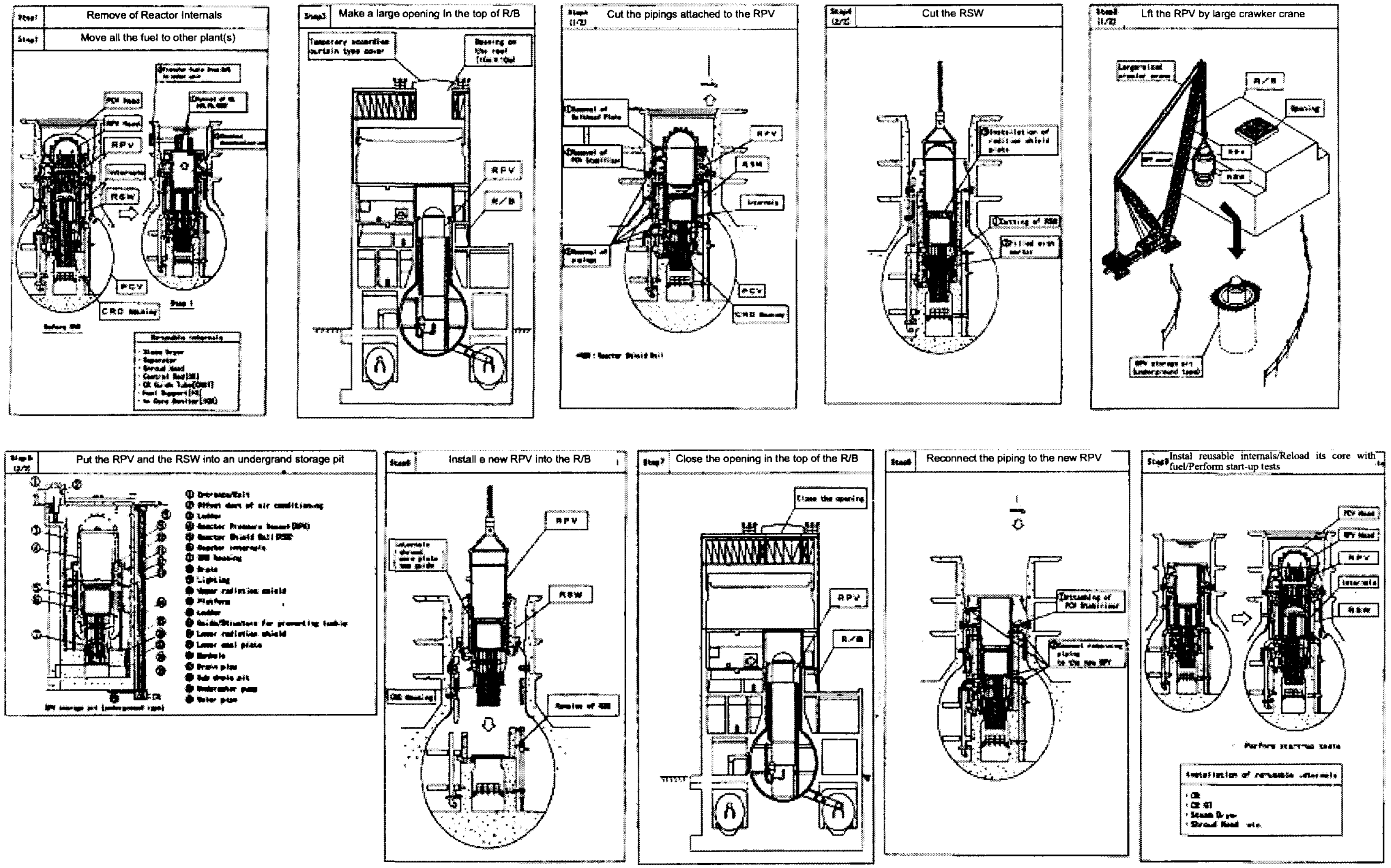
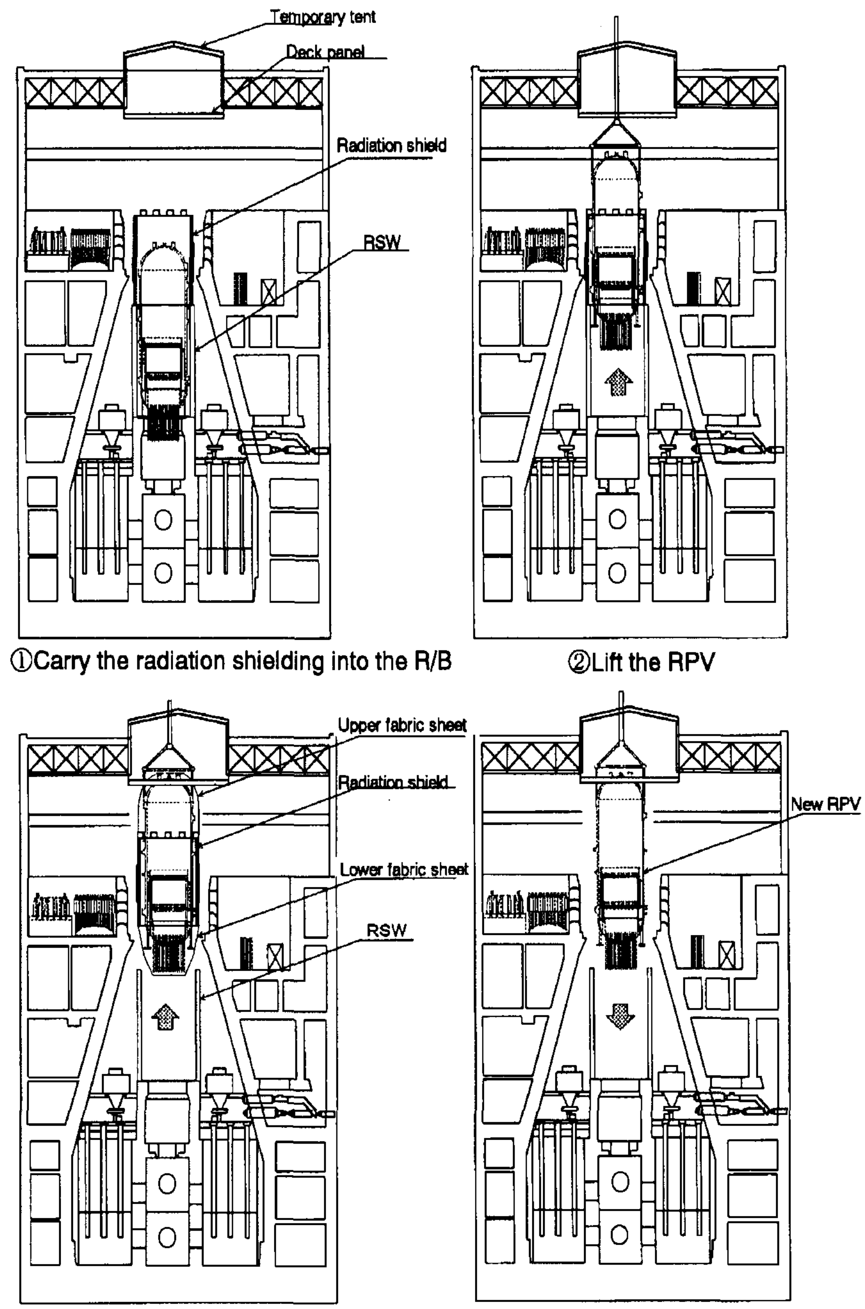


Fig.1 The RVR method for 800MWe class plants



①Carry the radiation shielding into the R/B

②Lift the RPV

③Lift the RPV with the radiation shielding

④Install a new RPV into the R/B

Fig.2 The method of lifting the RPV for 1100MWe class plant

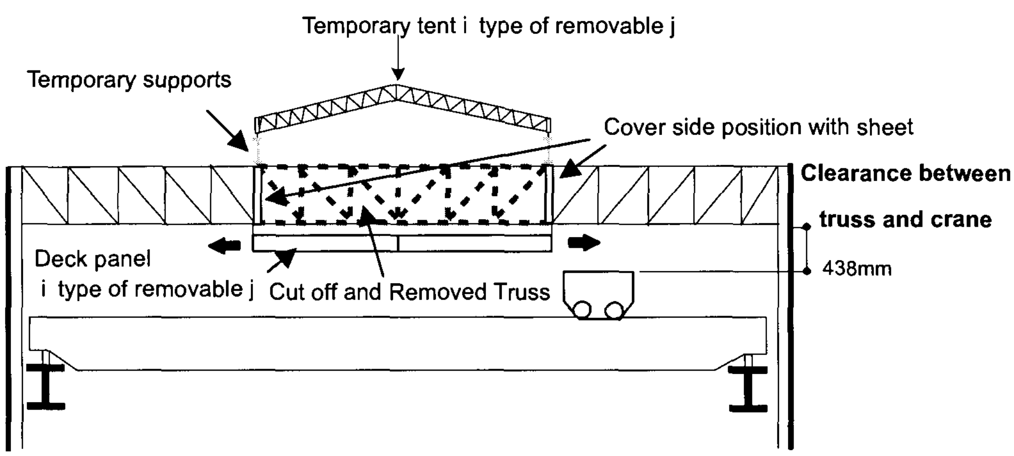


Fig.3 The method of making an opening in the top of R/B

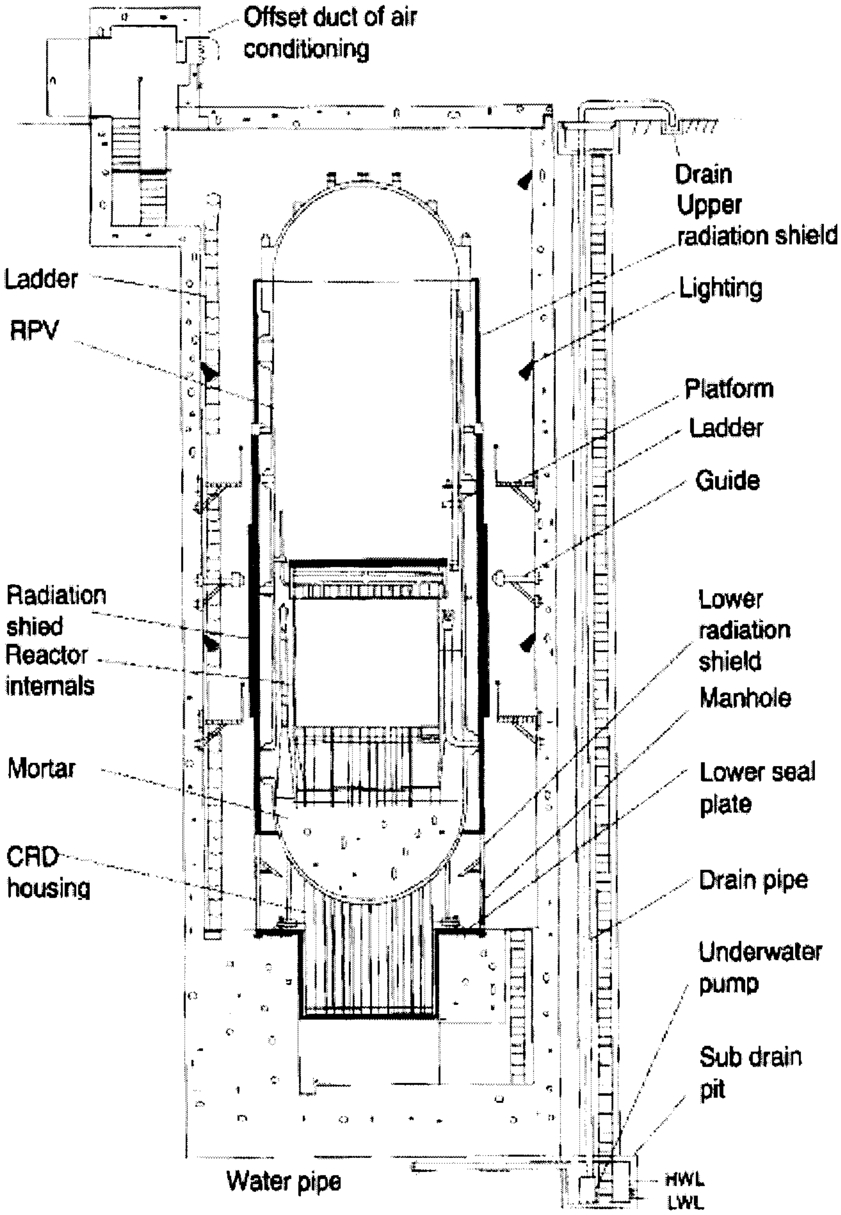


Fig.4 RPV storage pit (underground type)

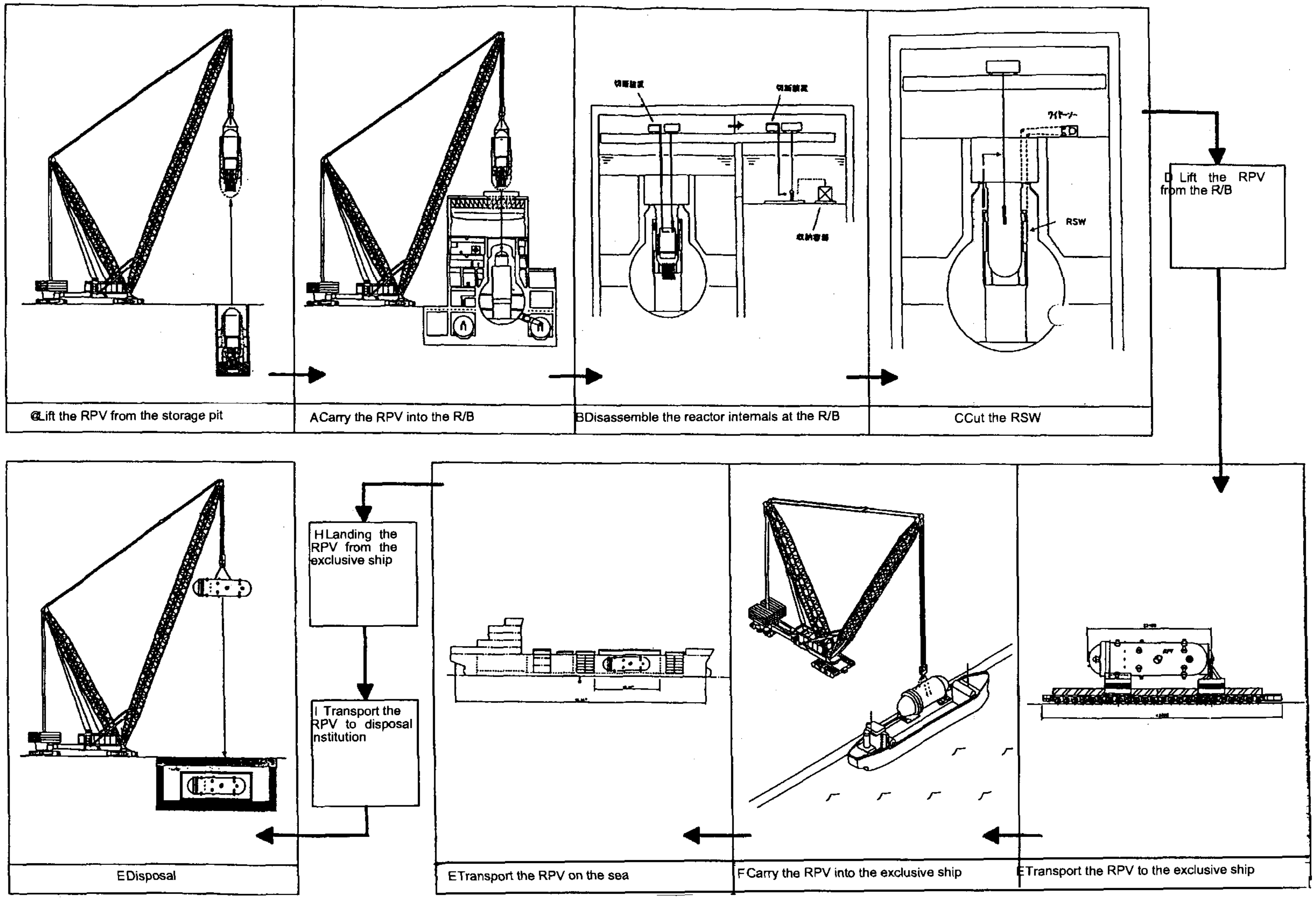


Fig.5 The process of dissambly, transportation and disposal of the RPV