ABSTRACT
As one of the requirements for safety issues of equipment installed in a spent-nuclear-fuel reprocessing plant, maintenance activities related to corrosion management for a dissolver of spent-fuel play an increasingly important role, and corrosion management is therefore essential to maintain the integrity of the facility. Dissolvers for spent nuclear fuel are usually installed in a hot cell, where plant operators cannot conduct direct inspections. Furthermore, the intense radioactivity requires facilities that use heavy and thick shielding and remote operational equipment to perform the maintenance activities. Therefore, we have developed a remote inspection system for the dissolvers at the Tokai reprocessing plant. In this paper, the development activities and experiences are described.

INTRODUCTION
Tokai reprocessing plant (TRP) is the facility to recover uranium and plutonium by reprocessing of the spent nuclear fuel generated in light-water-reactors in Japan. Uranium and plutonium are basically recovered and purified in a liquid-liquid extraction process. The most popular method, the plutonium and uranium recovery by extraction (PUREX), has been experienced at TRP as a pilot plant. The Outline of the process flow of TRP is shown in Fig. 1. The spent fuels cooled over a certain period are chopped into pieces about 5 cm long. They are sent into a dissolver and are dissolved in nitric acid. Subsequently, uranium, plutonium and fission products dissolved in the dissolver are separated through PUREX process, respectively. The separated uranium is recovered as a form of uranium trioxide powder and the separated plutonium is recovered as plutonium oxide powder. The Fission products are processed to the vitrified waste. Thus, the dissolver is one of the most important equipment in the reprocessing plant. Three dissolvers (R10, R11, R12) are installed in a hot cell at TRP. The schematic structure of the dissolver is shown in Fig. 2. The dissolver is composed of a slab tank and two barrel parts. The material of the dissolver is made of URANUS65 (25Cr-20Ni-Nb addition austenitic stainless steel). The barrel parts work to dissolve chopped pieces of fuels by heating with steam. There are welding parts on the barrel surfaces, where periodic inspection should be made because of severe conditions such as high-radiation and high-temperature [1].

In general, Maintenance activities related to corrosion management for the dissolver play an increasingly important role, and corrosion management is therefore essential to maintain the integrity of the facility. Therefore, we have developed a remote controlled system for inspection of the dissolvers.
As shown in Fig. 3, a pin-hole was found in the welding part of the dissolver (R11) in 1982, and another pin-hole was also found in similar part of the dissolver (R10) in 1983.

To repair these dissolvers installed in a hot-cell, where is under high radiation and is impossible to make human access, some remote-operation devices were developed as shown in Fig. 4. Using these devices, the repair of the both dissolvers was carried out by means of overlay welding for the pin-holes in 1983. Since then, a series of inspections to confirm the integrity of the dissolvers has been conducted once a year by remote inspection such as ultrasonic testing technique [1] [2] [3]. However, there were some problems to carry out a periodical inspection using different devices for each purpose; the inspection operations were complicated, time-consuming and difficult in the limited space of the hot cell (see Fig. 5). Moreover, it costs too much and it is extremely difficult to maintain the inspection device itself. Therefore, we have developed a remote inspection system [4] to overcome above mentioned problems. In this paper, the development work performed so far is described.
REMOTE INSPECTION EQUIPMENT

Outline of multifunction type remote inspection equipment

The dissolver has high radiation levels because it dissolves spent-nuclear-fuels and contains the solution. Therefore, the operators can not handle it easily. Furthermore, operation work is extremely difficult because it is installed in the cell shielded with thick partition of concrete. By the way, the top of the barrel has a plug. The inspection equipment can be inserted from this plug position of the barrel. It was then thought that inserting small inspection equipment from the plug in the barrel, and inspecting it by remote control were the most realistic methods in the inspection of the dissolver. Therefore, the remote inspection device for this was developed.

The contents of the inspection of the dissolver are the external observation, the thickness measurement, and the leakage check. When a pin-hole or crack is found in inspection activity, the welding repair should be done immediately. It is therefore decided to develop the remote inspection device that was enforceable of this inspection task. In the course of the equipment development, the device and the inspection equipment accessed in the barrel were divided from the viewpoint of operativeness and the economical reason. Namely, to make a device having multifunction that exchanged the inspection tool according to the purpose of work was strongly desired. In addition, Remote exchanges of the main parts of the per-device were aimed from the viewpoint of maintainability. The developed multifunction type remote inspection equipment is shown in Fig.6 and Table.1 [2] [4].

<table>
<thead>
<tr>
<th>Device</th>
<th>Function</th>
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<tr>
<td>Ultrasonic Testing</td>
<td>Thickness measurement</td>
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<tr>
<td>Periscope</td>
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<td>Bubble Testing</td>
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<td>Dye Penetrant Test</td>
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Figure 6 - Multifunction type remote inspection equipment  Table 1 - Outline of Device

The multifunction type remote inspection equipment consists of the lifting device and the periscope, the ultrasonic testing device, the bubble testing device. The lifting device equips the electric cable and the hoses, and makes the inspection device go up and down. The periscope observes and records the state of inside of the barrel. The ultrasonic testing device measures the thickness of the barrel material. The bubble testing device checks the leakage of bubble from the barrel.

In addition, when a mechanical trouble is discovered in inspection, in order to repair it by welding, the equipment has the remote repair devices that can perform grinding, welding, dye penetrant test and washing, respectively. The grinding device conducts surface treatment before
welding. The welding device has a function of automatic operation using TIG welding technique to repair a defect part. The dye penetrant testing device has a function to confirm the welding result. The washing device gets rid of the adhesion things with high-pressure water. The outline of each device function is shown in Fig. 6. The lifting device and the inspection device have special structures that the remote replacement of each device was able to be done. In addition, the main parts such as motors of the lifting device facilitate for the remote replacement (see Fig. 7 and 8).

Meanwhile, γ-ray irradiation examination of parts of the device to use in the cell was executed in consideration of the resistance to radiation. As a result, the parts that function and performance do not decrease were selected.

Figure 7 - Remote Connector

Figure 8 - Remote replacement of Main Parts

The schematic of the remote inspection system for the dissolver is shown in Fig. 9. Above mentioned inspection equipment is connected with the lifting device and is set on the top of the barrel in the dissolver loading cell. Afterwards, the device is inserted and inspects in the barrel. Furthermore, various inspection devices are exchanged in the dissolver loading cell according to the work purpose. These works are all done by remote controls. The monitor, the lifting device controller, and the
inspection device controller are arranged in the operation district outside the cell. The device in the cell and the controller are connected with cables that penetrate through the concrete shielding wall.

![Figure 9 - Remote Inspection System](image)

**Improvement of ultrasonic testing device**

The purpose of ultrasonic testing device is to measure the thickness of the barrel material. The device is composed of the probe and controller setup. They are connected with cables that pierce through the concrete shielding wall. The measuring method is based on the immersion testing (pulse reflection method). This device has functions of rotating and up-and-down movement. The ultrasonic probe has also a function to replace the probe itself in the case of breakdown. The dissolver has been continuously corroded in actual operations for 30 years or more, and monitoring for the corrosion has been carried out. Figure 10 shows the wall thickness measurement result of the dissolver tank. Although there still exists enough thickness of the wall against the marginal one (7 mm), it was found from the results that the material reduces its thickness in direct proportion to the heating time of dissolver.

In the examination of the dissolver using the ultrasonic testing device, an immersion testing method (pulse echo method) has been applied to measure the thickness of the material. However, uneven surface of the measuring point has affected to this method because of diffused reflection of pulse echo since 1996. Figure 11 shows the detected waves in the case that diffused reflection of ultrasonic signal generated.

![Figure 10 - Thickness reduction measurement results](image)

![Figure 11 - Reception of Ultrasonic Waves](image)
In order to detect the diffused reflection signal, we have improved the detector of the ultrasonic testing device so that irregular signals can be precisely detected. Especially, the probe can move to detect signals at appropriate positions for acquisition of exact data [5]. The improved ultrasonic probe is shown in Fig. 12. The probe has two micro-motors and can move in every direction with an angle of ±5 degrees.

Through the experience with above mentioned improvements, smooth operation for remote inspection of the dissolver has been continuously performed so far.

![Figure 12 - Improvement of Ultrasonic Probe](image)

**CONCLUSIONS**

1) The multifunctional type system for remote inspection and repair of the dissolvers installed at TRP has been newly developed. This remote equipment has feature that processes from inspection to repair can be all operated remotely. As a result, operativeness and maintainability in the maintenance activities in the narrow cell have improved, and an economical load has greatly decreased.

2) The developed system has been effectively functioning for observation of the dissolvers.

3) By the ultrasonic test of the dissolver, ultrasonic wave was scattered by the ruggedness on the measurement surface. To overcome this problem, the ultrasonic probe with a detector has been improved to detect such irregular signal. Good performance has been obtained in the experiences done in the actual maintenance activities.

4) The technology produced in our development activities can be expanded not only to nuclear facilities but also to any other industrial plants where operators can not easily approach to the inside.

**REFERENCES**