DESIGN OF MACHINE FOR DISMANTLING BIOLOGICAL SHIELD CONCRETE

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ABSTRACT

The design requirements of machines to be used for dismantling biological shield concrete in a commercial nuclear power plant and two concepts of dismantling machines are discussed. The concrete structure surrounding the reactor is irradiated during operation and the radiation inside the structure is quite high. Therefore, dismantling work should be carried out by remote operation.

The durability, reliability, maintainability, operability, ease of installation, minimal disposal of part of the machine, and cost are important requirements for machines to be used in dismantling reactors. Machines that can be decontaminated easily will realize these demands.

One conceptual machine that employs a diamond saw as a dismantling device is suitable to cut into the circumference of the radioactive biological shield. The other is an on-wall-traveling platform mounting a cutting device. The platform will move on the wall and is fixed to the wall firmly by a stud welding or concrete anchor.

1. INTRODUCTION

In Japan, 10 of the 38 operating nuclear power plants have been running over 25 years by 1990, and some of them will be decommissioned in the latter part of the 20th century. Because of very limited sites for nuclear power plants in Japan, reuse of the decommissioned sites is necessary. Modification to JRR-3 (Japan Research Reactor 3) of JAERI (Japan Atomic Energy Research Institute) was carried out after the one-piece-removal of the old reactor. This removal method, however, is considered to be limited to small reactors. Therefore, methods which may be applied to commercial nuclear plant decommissioning have been developed using JAERI's JPDR (Japan Power Demonstration Reactor).

Since the structures near the reactor are made radioactive during operation, irradiated concrete removal should be performed according to the following requirements:

- Minimize any potential hazard to public health and safety
- Reduce occupational exposure of the demolition crews
- Reduce the amount of radioactive and contaminated waste

In this paper, we provide aspects of the concrete structure of nuclear power plants and design requirements for a dismantling machine. Then two concepts of the machines for radioactive biological shield disassembly are discussed.

2. ASPECTS OF BIOLOGICAL SHIELDS

2.1 Structural Aspects

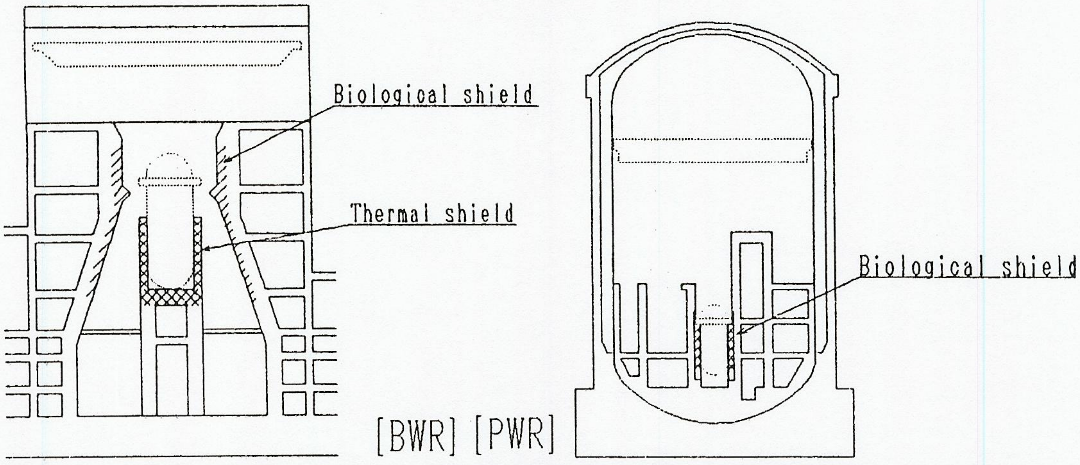

Fig.1 Cross section views of reactor buildings

The number of BWR and PWR plants amounts to over 90 % of all nuclear power plants in Japan. A cross section view of typical Japanese reactor buildings for BWR and PWR are illustrated in Fig.1.

The thermal shield wall of the BWR plant has a cylindrical-shape and is about 14 m high by 9 m in outer diameter. The thermal shield wall is about 0.6 m thick and consists of about 30 mm thick steel casing reinforced with ribs with concrete/mortar grouted into it.

The inner diameter of the BWR's bell-shape biological shield wall varies from 12 m to 30 m. The thickness of the wall is about 2 m and the height is 50 m. The structure is reinforced with 2 or 3 layers of 38 mm reinforcing bars and the inside surface is lined with steel plates.

The PWR reactor vessel is directly surrounded by an inner cylindrical shape biological shield wall. The wall is about 25 m high and 6 m in inner diameter. The thickness of the wall is about 3 m. It is reinforced with 51 mm reinforcing bars of which grid pattern is 20 cm by 20 cm and is lined with stainless plates.

There are many openings for piping in these walls.

2.2 Radiation Inventories

The surrounding portion of the reactor vessel is activated by neutron flux leakage as shown in Fig.1. Estimation of the activated area of the structure is carried out to determine the section to be dismantled by the analysis of a concrete boring of the structure before actual dismantling. The dismantling depth from the surface of the wall may be 50 cm to 100 cm.

2.3 Working Conditions

Although radiation doses within the biological shield decrease gradually after shutdown of the plant they are still too high to allow workers to access such areas. Radiation doses within the biological shield after removing the reactor enclosure may be over 10 mSv/hr (1 rem/hr) 10 years after shutdown. Since the occupational exposure is limited to 0.3 mSv/week (30 mrem/week) in general in Japan, the doses are relatively high.

3. DISMANTLING SYSTEM

3.1 Design Criteria

(1) Durability and reliability

A machine consists of many component and its reliability is determined by the durability of a weakest component. Components subject to high radiation doses should be selected considering the resistance to radiation. Under high radiation doses, the mechanical strength of high-polymers decreases, IC input currents increase gradually to cause destruction, the penetration of glass decreases, etc.. Shielding IC boards with a lead box is effective to improve their durability.

In case selection of these parts is unavoidable, their replacement should be considered in the design. Such a design will save on machine costs in some cases.

(2) Maintainability

Since dismantling machines are contaminated with radio active particles, decontamination procedures are necessary to maintain the machine. There are some hazards for radiation exposure to workers during this process. Therefore the machine should also be designed so that it can be decontaminated easily.

Decontamination methods to be applied to the machine include wrapping the machine with polyethylene sheets, painting the machine with decontamination paint, scrubbing the machine with special towels, washing the machine with a water jet, etc..

The machine shape should be designed as simple as possible for decontamination. Also, the number of cables and hoses connected to the machine should be reduced for the same reasons. Waterproof and dustproof construction by covering moving parts with bellows and covers is necessary to avoid internal contamination of the machine. The position and structure of air inlets of machine should also be designed carefully.

To replace a difficult-to-decontaminate part such as the cutting tool, a special device for replacement is necessary.

(3) Machine size for final disposal

The machine to be used for dismantling work will be decommissioned after dismantling is finished. To reduce the amount of waste disposal, it is necessary to reduce the amount of difficult-to-decontaminate components of the machine. A small machine is also preferable to reduce decontamination procedures and the amount of disposed components.

(4) Operability

The productivity of dismantling work relates to the operability of the machine. Since dismantling work is performed mainly by remote operation, the optical system is very important. An appropriate number of TV cameras moving with pan, tilt, and zoom motions is necessary. The TV cameras should also be selected by considering their resistance to radiation.

(5) Easy installation of the machine

The installation of the dismantling system will generally be performed by workers. Although the working area is assumed to be a low radiation area, it is necessary to reduce the workers' exposure to radiation by reducing the time required for installation. Therefore the machine should be designed for easy installation.

3.2 Dismantling Plan

The dismantling plan starts with a detailed structural investigation, estimation of radiation inventories, investigation of existing dismantling methods, and dismantling sequence planning.

Dismantling work should be arranged such as the existing building would function as a boundary to reduce any potential hazards to the public health and safety. Application of remote operations to the work should especially be simple and easy.

A dismantling technique should be selected from various ways considered to be applicable to dismantling according to the following requirements:

- Use of remote control
- Dismantle the activated portion without damaging the remaining structure
- Reduce secondary waste

3.3 System Configuration

The dismantling system generally consists of dismantling machines, separated material handling machines, equipment such as a ventilation and drainage, and a radiation monitoring. Existing buildings and equipment should be utilized as much as possible.

4. CONCEPTS OF DISMANTLING MACHINES

This section shows the concepts of the machines for disassembly of biological shield walls. The dismantling methods described here use cutting because conventional methods such as a hydraulic breaker are all hard to be applied to heavily reinforced and lined concrete.

The disassembly starts from the inside surface of the biological shield. After dismantling the activated portion of the biological shield, the remaining non-activated concrete in the structure can be demolished by conventional means.

4.1 Diamond Wire Sawing Machine

To cut behind the inner surface of the biological shield, various cutting techniques are available. For line drilling, drilling an intersecting series of holes with a diamond-tipped hollow drill is just one method. The drilling rate for ordinary concrete using a 150 mm diameter drill is about 1 m/hr which is equivalent to about 0.15 m^2/hr cutting rate.

Diamond wire consists of a string of beads molded to contain diamond abrasive and a mixture of metal powders. Cutting is generally made by putting the wire around the concrete and drawing it in the same way as cutting rock using a traditional helicoidal wire. In an application of diamond wire sawing, hooking the wire with pulley blocks and inserting the pulley blocks into pre-drilled holes enables a plunge cut to be made as illustrated in Fig.2. This figure also shows the conceptual dismantling sequence using a diamond wire sawing and coring.

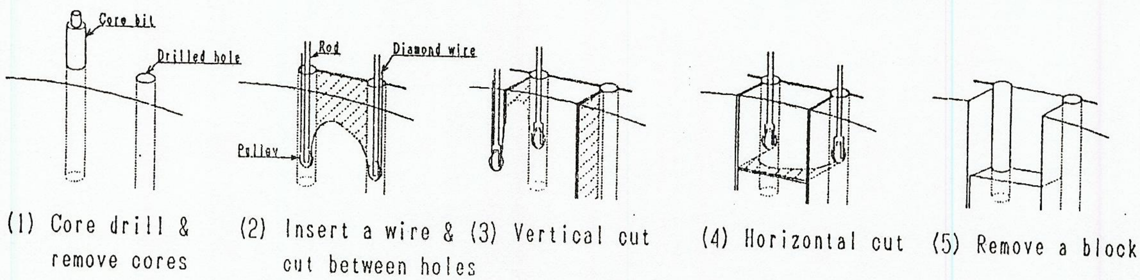

Fig.2 Dismantling sequence using a diamond wire sawing

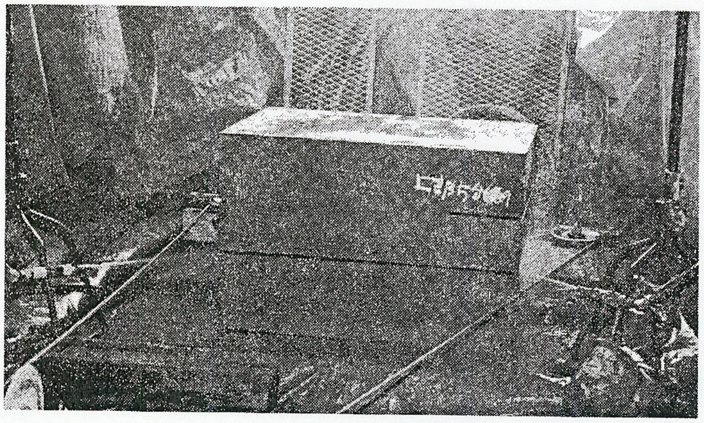

Fig.3
Wire sawing a concrete block reinforced with 29 mm rebar @150 mm.

Fig.3 shows a preliminary test made in 1986. The cutting rate obtained from this test exceeded 1.0 m^2/hr.

A concept of a dismantling machine using a diamond wire is shown in Fig.4. This machine consists of a diamond wire drive, pulley blocks and rods, and the vehicle. The machine moves along the rail laid along the circumference of the cavity by remote control. A core drilling machine is also attached to the vehicle.

The diamond wire is drawn by the main pulley of the wire drive mechanism. The wire drive mechanism consists of a diamond wire, a wire drum, and a wire tension control device. The diamond wire is wound round the motor driven wire drum and is drawn around it. The drum is separated from the drum drive motor to easily replace the diamond wire. The wire tension control device maintains the wire tension according to the pay-in and pay-out length of the wire. Use of a weight or hydraulic cylinder for the wire tension control device is possible.

The pulley blocks are attached to the end of the rod. The rods are actuated by a rack-and-pinion mechanism. By connecting an extension rod the sawing may be performed into deeper portion. The pulley block consists of a pulley for the diamond wire, a guide roller, and a holder. The guide roller reduces frictional losses caused by contact between the pulley and the concrete surface. The holder changes the pulley direction.

Water is supplied to cool the diamond wire through nozzles located near the pulley block via a hose during sawing. The hose is wound around a special drum which automatically reels in and reels out the hose. Some shields are attached to the machine to protect it from water splashes. To reduce wire contamination by radioactive concrete particles, rotating brushes are attached to the machine near the rod.

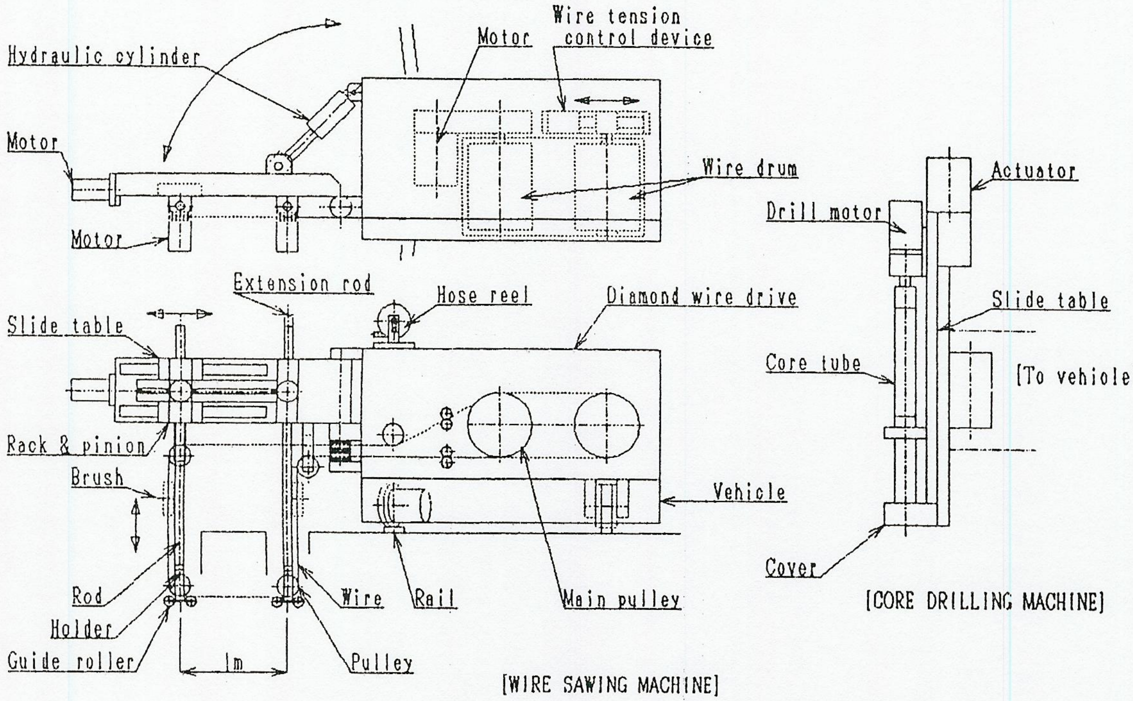

Fig. 4 Dismantling machine using a diamond wire

4.2 On-Wall Traveling Platform For Dismantling Devices

The dismantling sequence shown in Fig.2 is applicable to a concrete structure without a steel lining. An additional process of steel cutting for a steel-lined structure is required because cutting the steel liner using a diamond wire shortens the wire life and shows low productivity.

To cut the liner, several methods such as Oxyacetylene gas cutting, machining, and a grinding wheel are available. Suction disks or electromagnetic disks are suitable to locate a low reaction force cutting tool such as Oxyacetylene gas cutting equipment in place. A machining or grinding tool generates a large reaction force during cutting and requires the device to be firmly fixed in place. The device also should be stable, produce low levels of vibration, be highly precise and produce a large transmission force.

Fig.5 shows a platform which fixes the cutting tool firmly to the wall. The platform consists of an automatic stud gun and a manipulator and four legs equipped with stud-fixing devices. The platform is suspended from a crane and is initially positioned on the wall. Then studs are welded onto the liner and a leg is transferred to the studs along the guide shaft. The leg is then fixed to the studs with a fixing device. The platform travels along wall by repeating the sequence shown in Fig.6. The fumes generated during welding is collected by a ventilation system via a duct connected to the platform.

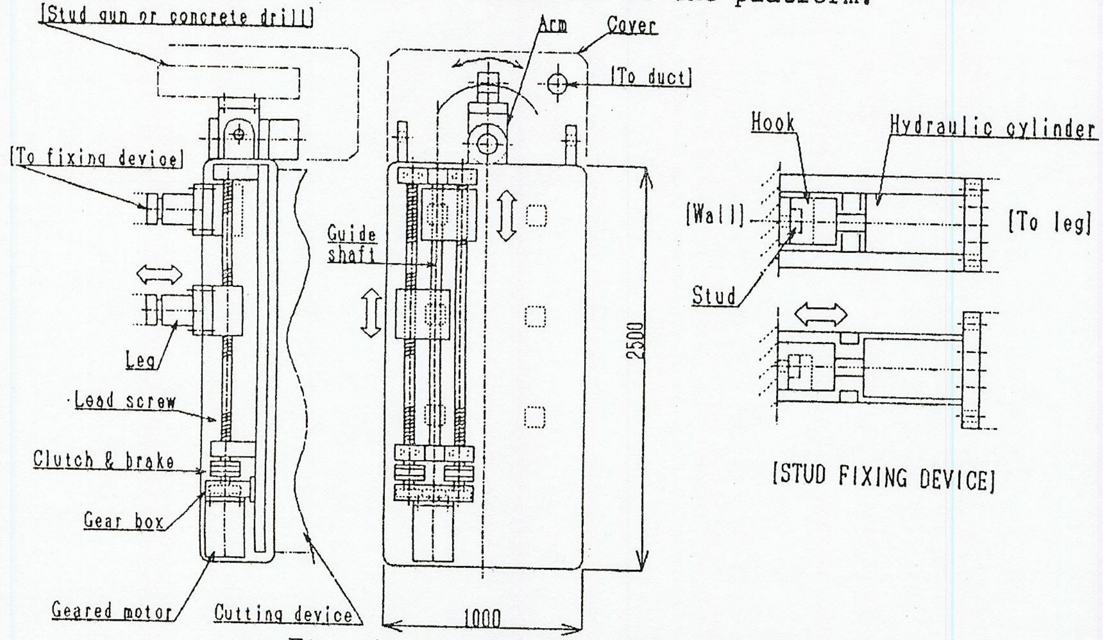

Fig. 5 On-wall traveling platform

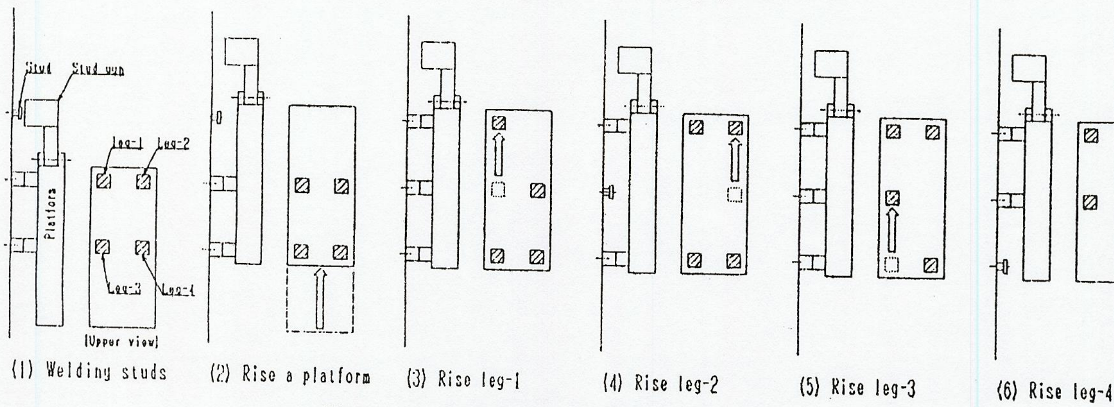

Fig. 6 Wall traveling sequence

This platform may be fixed to concrete by replacing the stud gun and stud-fixing devices with a concrete drill and the concrete-fixing devices shown in Fig.7. This enables application to wall sawing by a circular diamond blade.

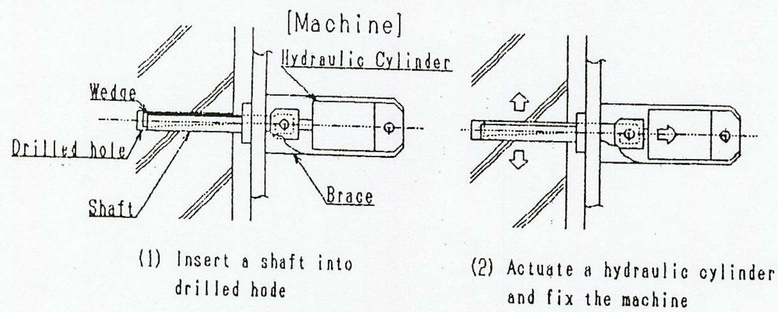

Fig. 7 Concrete wall fixing device

5. CONCLUSION

Using a machine equipped with a diamond wire described in this paper, dismantling of a biological shield may be safely performed. The advantages of this method are:

- The machine may be easily maintained because all the machines are installed on the operation floor where workers can have easy access
- The part to be sawn in the circumference of the biological shield contains less reinforcement and is easily cut by a diamond wire
- The system enables separation of large concrete blocks from the biological shield

The machine size is expected to be small by using an on-wall-traveling platform. Consequently, decontamination and maintenance will be minimized. The system will also reduces the final disposal including the dismantling machine.

REFERENCES

Onishi, N., et al., 1987, 'Investigations Related to a One-Piece Removal of the Reactor Block in the Frame of the JRR-3 Reconstruction Program', Proceedings of 1987 International Decommissioning Symposium, pp VI95-105

Nakamura, H., et al., 1988, 'Remotely Controlled machine for Biological Shield Concrete Dismantlement', The 5th International Symposium on Robotics in Construction

Daniel, P., 1986, 'More granites succumb to diamond wire', Industrial Diamond Review, pp189-193

1989,'Nuclear Power Plants in the World', Japan Atomic Industrial Forum