MOCK-UP TEST OF REMOTE CONTROL MACHINE FOR THE JPDR BIOLOGICAL SHIELD CONCRETE DISMANTLEMENT

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ABSTRACT

A diamond sawing and coring technique is a dismantling method developed in the JPDR Decommissioning Program* conducted by JAERI. The dismantling system for this technique, consisting of a cylindrical geometric robot equipped with a sawing unit and a coring unit, concrete block/core handling devices and so on, will be applied to the dismantlement of the highly activated concrete of the JPDR.

A mock-up test was performed from 1987 to 1988 in order to confirm the performance of the system prior to the actual dismantling. A full-scale concrete structure which simulates the portion of the JPDR biological shield to be dismantled was built and the system devices were assembled to simulate the actual dismantling operation.

This paper reports the results of the steel lining concrete cutting tests and block/core handling tests, the efficacy of the damaged blade sharpening, and the applicability of this technique for dismantling the inner cylindrical structure.

1. INTRODUCTION

The dismantlement of the JPDR (Japan Power Demonstration Reactor) started in December of 1986, and this small nuclear power plant site will be completely restored in 1993. The dismantling techniques (underwater plasma arc cutting, arc saw cutting, abrasive water jet cutting, diamond sawing and coring, and etc.) were developed in the JPDR Decommissioning Program.[(1),(3)] Mock-up tests of these techniques have been carried out in order to confirm the performance and to avoid unexpected troubles occurring prior to the actual dismantling work.

Sawing with a diamond blade (a disk tipped with diamond-abrasive-embeded segments) is used for reinforced concrete cutting in general.

* This project has been performed under a contract with the Science and Technology Agency in Japan.

Coring is a concrete drilling method done with a hollow bit. The diamond sawing and coring technique is a combination of these cutting method and robotics.

Diamond sawing and coring will be applied to the highly activated biological shield dismantling. The mock-up test of this method was carried out from 1987 to 1988.

The main objectives of this test are as follows:

- Evaluation of the manpower and term of the system installation and dismantling work
- Evaluation of the dismantling performance, and the amount of expendable supplies
- Confirmation of the optimum sawing/coring condition
- Confirmation of the operability of the dismantling system
- Training for the dismantling work
- Elimination of initial failure and improvement of machines

After outlining the test structure and the dismantling system, we will report on the dismantling performance, i.e. the cutting rate, coring rate, and the time required to carry the separated concrete out. We also describe the remote-control operation of the dismantling system.

2. TEST STRUCTURE AND DEVICES

2.1 Test Structure

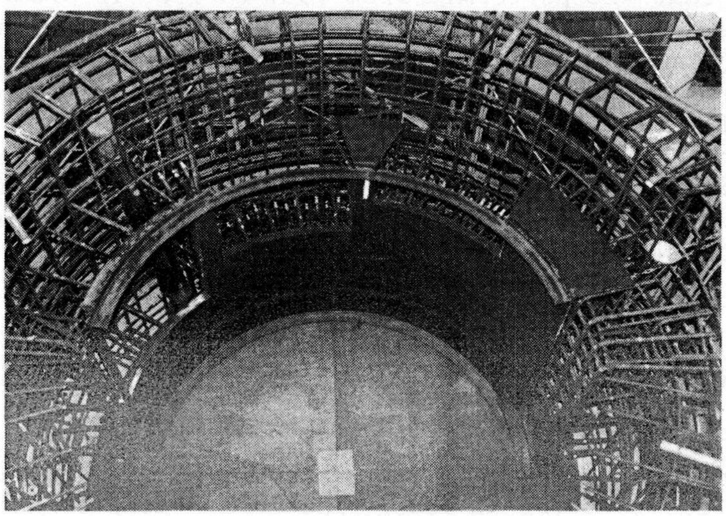

Figure 1 Reinforcing bars, piping, and steel lining of the test structure

A full-scale model of the dismantling portion of the JPDR biological shield was constructed in the mock-up test facility. The chimney-shaped concrete structure was about 7 m high, with an outer diameter of 4.5 m, and an inner diameter extending 2.7 m to 3.5 m. The portion to be dismantled was reinforced with 29 mm diameter reinforcing bars in a grid pattern of 150 mm by 150 mm, and lined with 14 mm and 10 mm thick carbon steel plates. Pipes, 34 mm and 150 mm in diameter, were also laid to simulate cooling pipes and neutron detector guide tubes. Openings in the structure simulated the holes in the biological shield through which the pressure-vessel-connecting pipes penetrate.

Figure 1 shows the steel plate, the reinforcing bars, and pipes to be laid in the concrete.

2.2 Concrete Removal Sequence

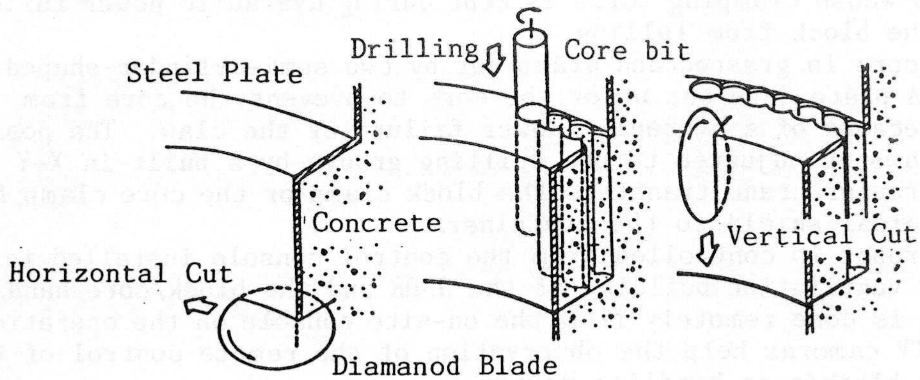

Figure 2 Concrete removal sequence

The basic dismantling sequence of the inner cylindrical-shaped structure using the diamond sawing and coring technique is as follows (See Figure 2): 1) make a horizontal cut into the biological shield at a depth of 400 mm, 2) repeat core drillings side by side to the depth of the horizontal cut, and remove the cores, 3) make a vertical cut into the depth of core drilling and remove the separated concrete block.

2.3 Devices

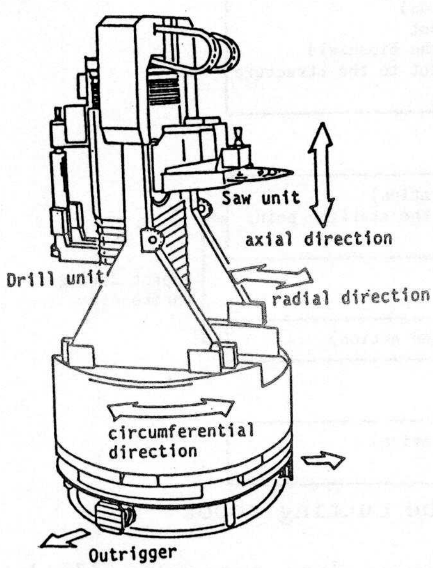

Figure 3 Cutting robot

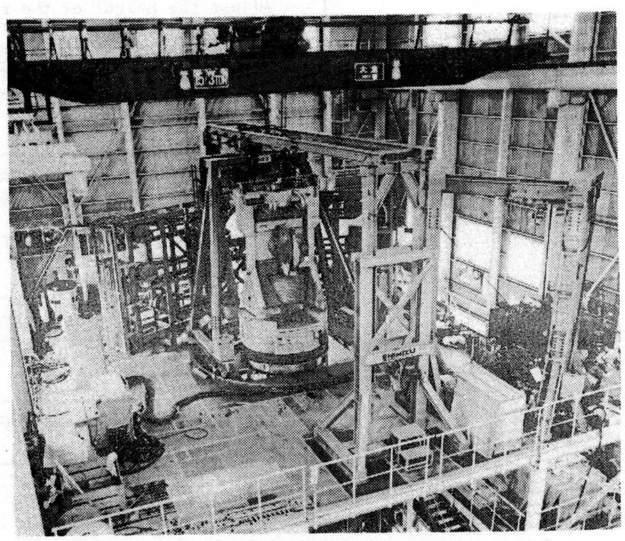

Figure 4 Dismantling system

Figure 3 shows an overview of the cutting robot.[(2),(4)] A sawing unit and a coring unit are attached to the arms of a cylindrical geometric manipulator of the cutting robot. The blade direction is changed by a built-in direction changer according to horizontal or vertical cuts. The manipulator is mounted on a platform equipped with three outriggers and a X-Y horizontal level adjuster. The motion of the manipulator is controlled by computers during the cutting process. A blade sharpener and a core bit sharpener are attached to the manipulator.

The concrete block is held by a block clamp. The clamping mechanism of the device is actuated by a hydraulic cylinder and a link mechanism whose clamping force is kept during hydraulic power failure to prevent the block from falling.

The core is grasped and drawn out by two semi-cylinder-shaped claws. A plate juts out under the core to prevent the core from falling because of a hydraulic power failure of the claw. The position of the claws is adjusted to the drilling groove by a built-in X-Y table.

A circular crane transfers the block clamp or the core clamp from the biological shield to the container.

The robot is controlled from the control console installed in the emergency ventilation building of the JPDR and the block/core handling operation is done remotely from the on-site console on the operating floor. ITV cameras help the observation of the remote control of the robot and block/core handling devices.

Figure 4 shows the disposition of the dismantling system in the mock-up test facility. The dismantling system assembled simulates the actual dismantling operation of the JPDR.

3. TESTS OF THE DIAMOND SAWING AND CORING TECHNIQUE

3.1 Operation of the Cutting Robot

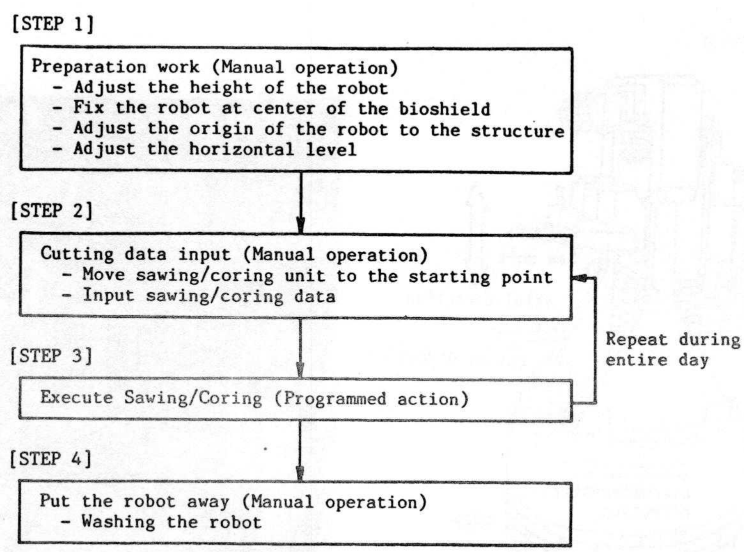

Figure 5 Operation of the cutting robot

The cutting motion of the manipulator is done automatically by the combination of point-to-point control and cutting process control. Manual operation, i.e. adjusting the machine position to the starting point of programmed action, however, is required in the same way as for industrial robots. Since the robot moves within the concrete structure and fixes its position firmly by actuating outriggers toward the wall, the operation of adjusting the height and the centering of the machine to the origin of the structure is also required. Therefore, the robot operation is performed by the sequence shown in Figure 5.

The average time to execute STEP 1 measured about 30 min, and the time for STEP 2 measured about 15min in the mock-up test.

3.2 Dismantling of Structure

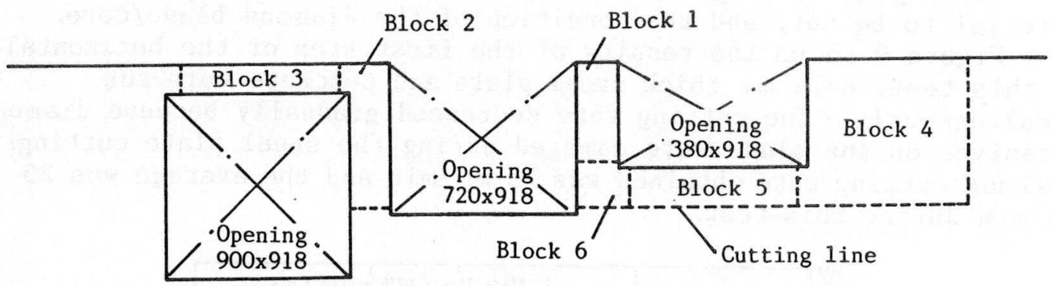

Figure 6 Unfolding plan of cutting line

Figure 6 shows the cutting line of the test structure. The structure was dismantled by using the above-mentioned concrete removal sequence.

3.3 Sawing and Coring

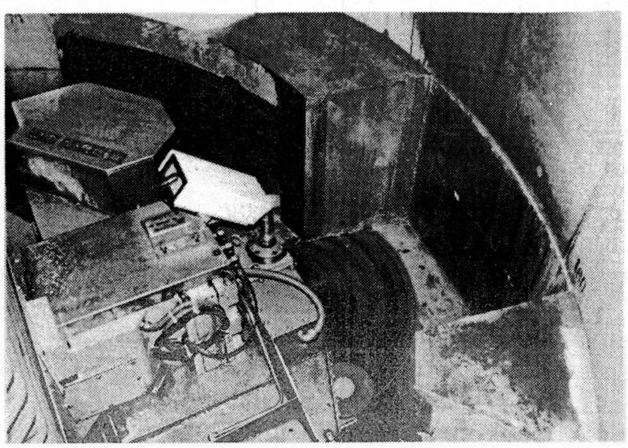

Figure 7 Horizontal cutting

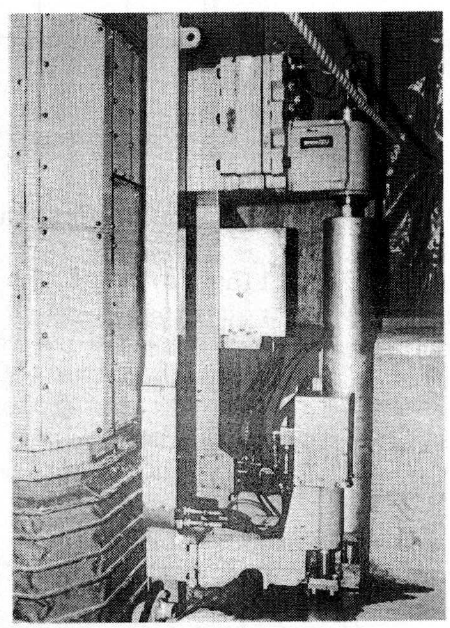

Figure 8 Coring

Figure 7 and 8 show the cutting and drilling operation.

The sawing of the structure is done in a step cut produced by repeating plunge cut and feed cut until the full depth is reached. Examples of the depth of the step cut are shown in Table 1.

Table 1 Depth of Step Cut

Direction	1st step	2nd step	3rd step	4th step
Horizontal cut	50 mm	100 mm	125 mm	125 mm
Vertical cut	50 mm	100 mm	·85 mm	85 mm

Cutting rate changes according to the process control value, material to be cut, and the condition of the diamond blade/core.

Figure 9 shows the results of the first step of the horizontal cut. In this test, a 14 mm thick steel plate and concrete were cut simultaneously. The cutting rate decreased gradually because diamond abrasives on the blade were damaged during the steel plate cutting. The maximum cutting rate obtained was 75 mm/min and the average was 25 mm/min during this test.

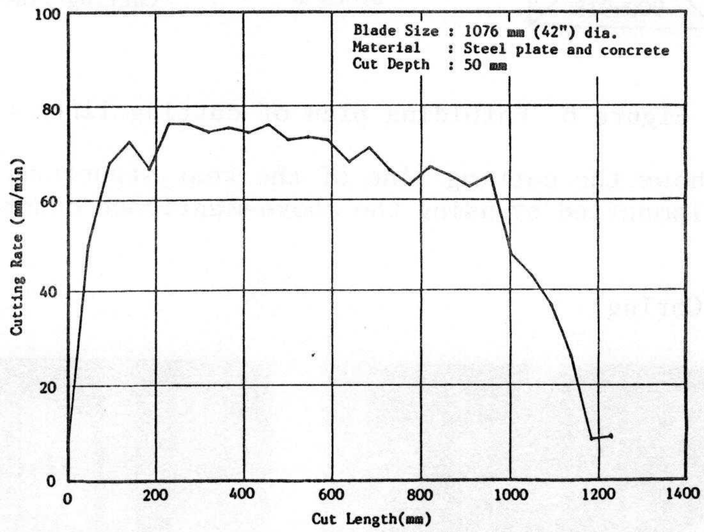

Figure 9 Cutting rate during liner cutting

The drilling rates of the steel plate and concrete were compared by changing the rotational speed of the coring unit with a gearbox. Table 2 shows the test results. A rotational speed of 150 rpm was more than four times higher than the 430 rpm rate during the steel plate drilling. The drilling time of the biological shield was estimated at each drilling speed. Consequently, the rotational speed of 150 rpm was obtained slightly shorter time.

Table 2 Rotational speed and drilling rate

Material	150 rpm	430 rpm
Concrete	31 mm/min	42 mm/min
Steel plate	0.37 mm/min	0.08 mm/min

3.4 Blade Sharpening

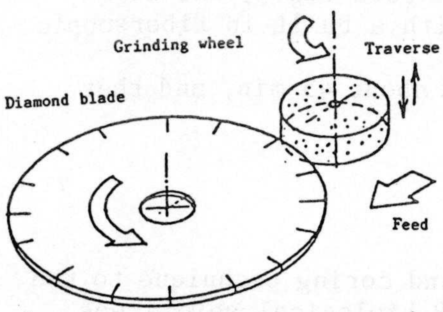

Figure 10 Blade surface grinding

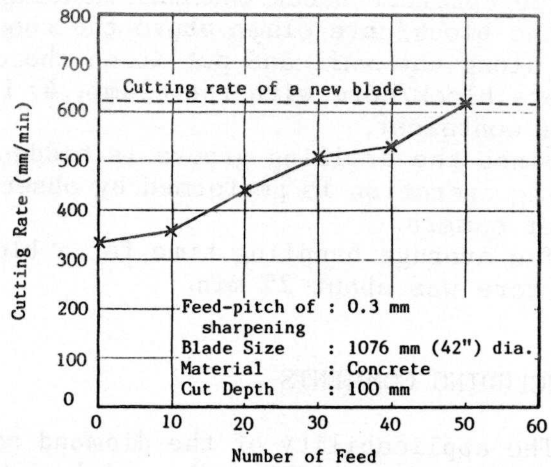

Figure 11 Blade sharpening and cutting speed

The diamond abrasives on the blade are crushed and/or burnt during the steel lined and/or heavily reinforced concrete cutting. The blade sharpeners remove the damaged diamond abrasives from the surface of the segment and expose the new diamond abrasives.

Figure 10 shows a diagram of a blade sharpener. A rotating grinding wheel is fed toward the diamond blade with a preset feed-pitch for every traverse.

Figure 11 shows the concrete cutting rate at a depth of 100 mm. The concrete cutting rate of a new diamond blade dropped to about 300 mm/min after the steel lined concrete cutting, and increased gradually after each ten traverses of blade sharpening.

3.5 Concrete Block/Core Handling

Figure 12 Block handling

Figure 13 Core handling

Figure 12 and 13 show the block/core handling operation.

The concrete block and core handling sequence is as follows: 1) move the block/core clamp above the concrete block/core, 2) descend the clamp along the wall and put it on the concrete, 3) hold onto the concrete block/core with the clamp, 4) Lift the block/core and put it into a container.

Since the drilling groove is hidden by the core clamp, the core gripping operation is performed by observing with a built-in fiberscopic monitor camera.

The average handling time for a block was about 45 min, and that for a core was about 25 min.

4. CONCLUDING COMMENTS

The applicability of the diamond sawing and coring technique to the dismantling of the full-scale model of the JPDR biological shield was confirmed. The diamond blade cutting rate, which decreased during steel plate cutting was improved by the blade sharpening. The relationship between the drilling rates and the rotational speed is complex because the drilling rates depend on following: the objective material, the horsepower of the motor, the stiffness and precision of the machine, diamond segment design, and the control condition. The high drilling rate for steel plate was obtained by a low rotational speed within the limits of this tests.

5. ACKNOWLEDGMENT

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