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APPLICATION OF IN-PIPE VISUAL INSPECTION ROBOT TO PIPING INTERNAL SURFACE LINING

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ABSTRACT

In most cases, it is difficult for inspectors to directly inspect the extent of contamination and damage to the internal surfaces of small diameter pipes, as access to the inside of these pipes is limited due to size of devices and associated in-pipe environmental conditions. Accordingly, the utilization of remote-controlled inspection technologies promises great advantages for such inspections.

We thus implemented research on in-pipe remote-controlled inspection technologies, and developed a crawler-type, self-propelled traveling device. Subsequently, we used such a device for the visual inspections of the internal surfaces of the seawater piping at a nuclear power plant before and after periodical lining maintenance was conducted on this pipe, thereby allowing the schedule to be shortened by about 40%, and also permitting the cost involved to be reduced by about 30 - 40%. Accordingly, we feels that the adoption of this remote-controlled inspection technology per this report, will bring great benefits to the user.

1. Preface

At the above nuclear power plant, embedded piping whose internal surface was lined was periodically replaced with new piping, in order to maintain its in-service safety assurance.

We visually inspected the damage to the lining of such piping using an in-pipe traveling inspection robot (Fig. 1) and found that the piping could be re-used if the internal surface was relined. Accordingly, the surface of the piping was re-lined in place using a turning seal lining method. As a result, the schedule was shortened by about 40% and also the cost involved was cut by about 30 - 40%. Thus, JGC introduces an outline of this turning seal lining method and the lining work as follows:

2. Turning seal lining method

The following are procedures for lining the internal surface of piping using the method adopted by us.

(1) Turn the end of the seal hose so that the internal surface on which adhesive is preapplied may faces outside, and apply a pressure of 0.6 - 1.0 kg/cm^2 to the nonadhesive surface.

(2) Apply the seal hose so that it expands simultaneously with the thrust produced at the end of the seal hose by the difference in the inside and outside pressure of the turning action, and the adhesive surface of the seal hose closely adheres to the inner pipe wall. The principle of the above in-pipe turning lining technique is shown in Fig. 2. Only enough earth is excavated, at two end points of the lining section of the embedded pipe, for the above lining work to be carried out.

Figure 3 shows the conditions of the turning seal lining work.

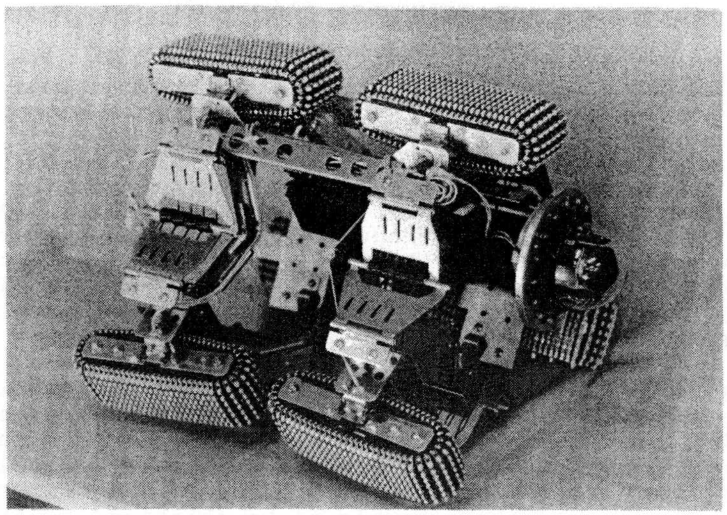

FIG. 1 IN-PIPE TRAVELING INSPECTION ROBOT

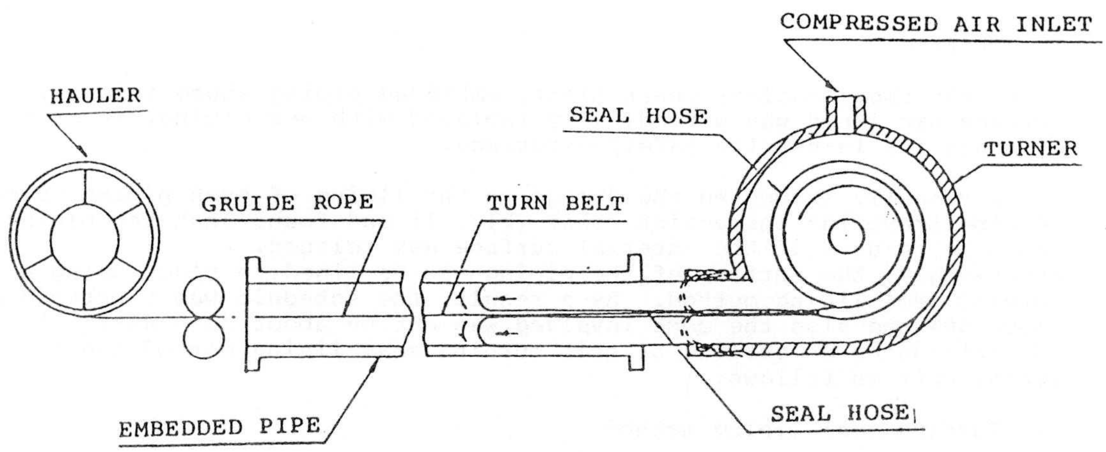

FIG. 2 TURNING PRINCIPLE

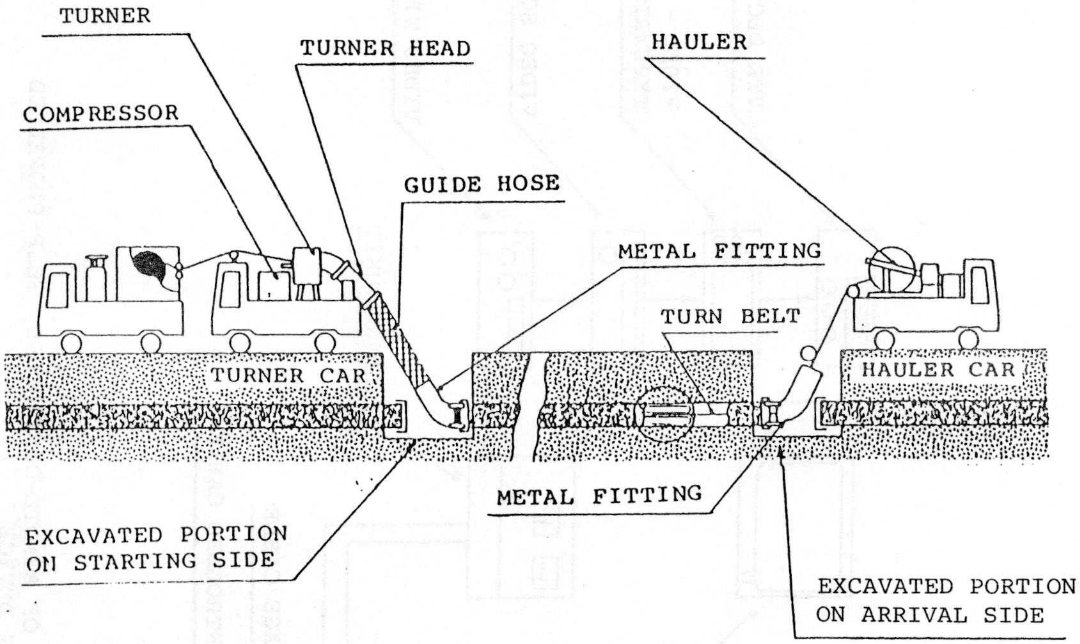

FIG. 3 CONDITIONS OF TURNING SEAL LINING WORK

3. Inspection robot

The in-pipe visual inspection robot (Fig. 1) used for the inspection of the inner pipe lining consists of a traveling section and a monitoring section.

3.1 Traveling section

The traveling section is called a self-propelled crawler device, and an outline of this device is shown in Fig. 5. The driving Section is equipped with crawlers on chains which are fitted to the driving wheels. The driving mechanism consists of three sets of crawlers pushing against the wall of the pipe at 120° intervals by a spring-loaded hinged chassis which is remotely controlled. The robot is capable of traveling in 8B - 24B horizontal and vertical pipes, and reducers, and 90° short elbows. The traveling speed of the robot is 3.5 m/min.

3.2 Monitoring section

An outline of the monitoring section is shown in Fig. 6. The monitoring section consists of a small CCD (charge coupled device) remote-controlled, mounted on the traveling device, a pan/tilt mechanism and also a focus adjusting mechanism. This section performs in-pipe monitoring.

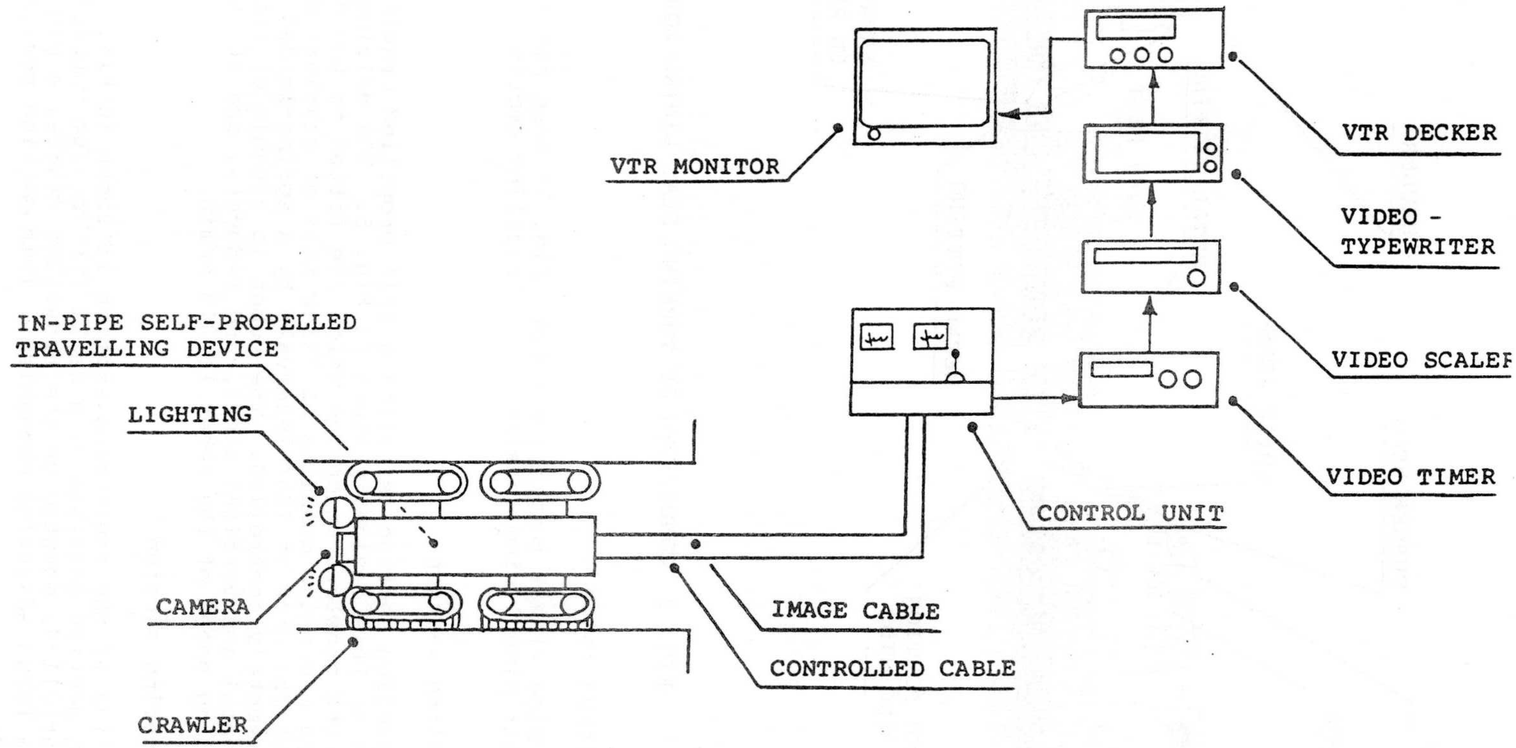

FIG. 4 SYSTEM CONFIGURATION OF REMOTE-CONTROLLED, SELF-PROPELLED TRAVELLING INSPECTION DEVICE

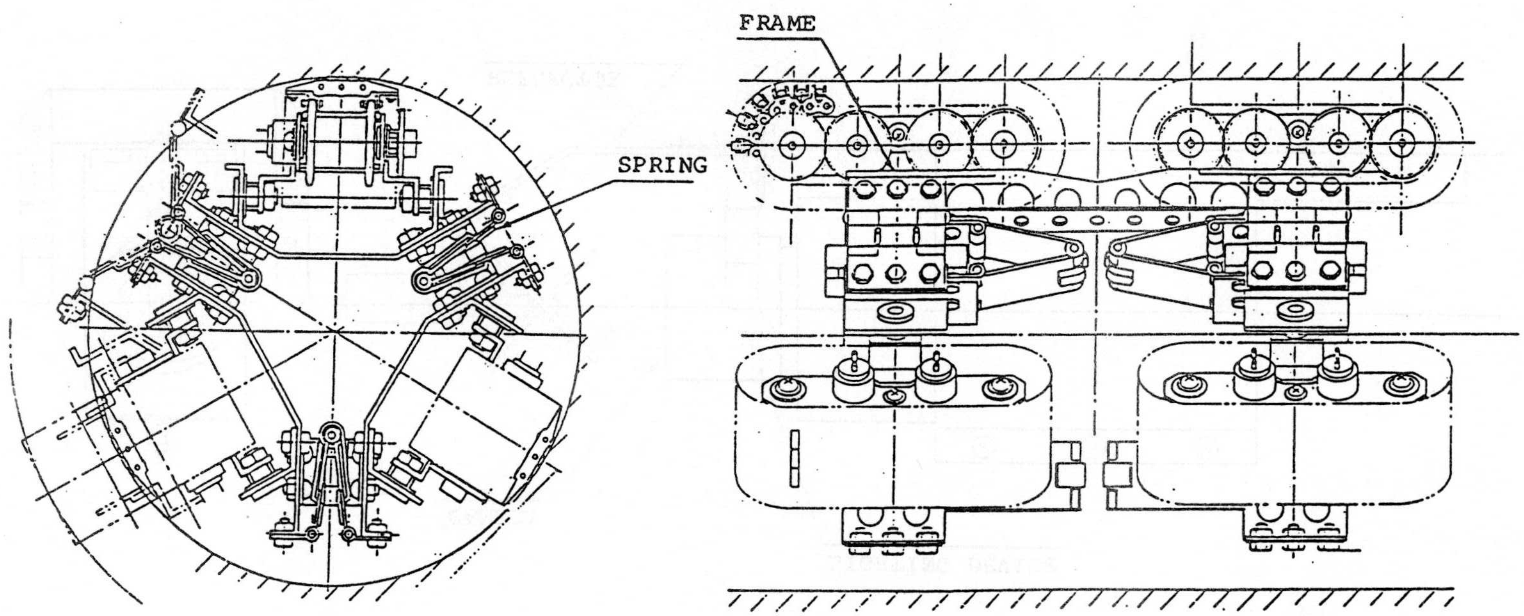

FIG. 5 OUTLINE OF INSPECTION ROBOT TRAVELING SECTION

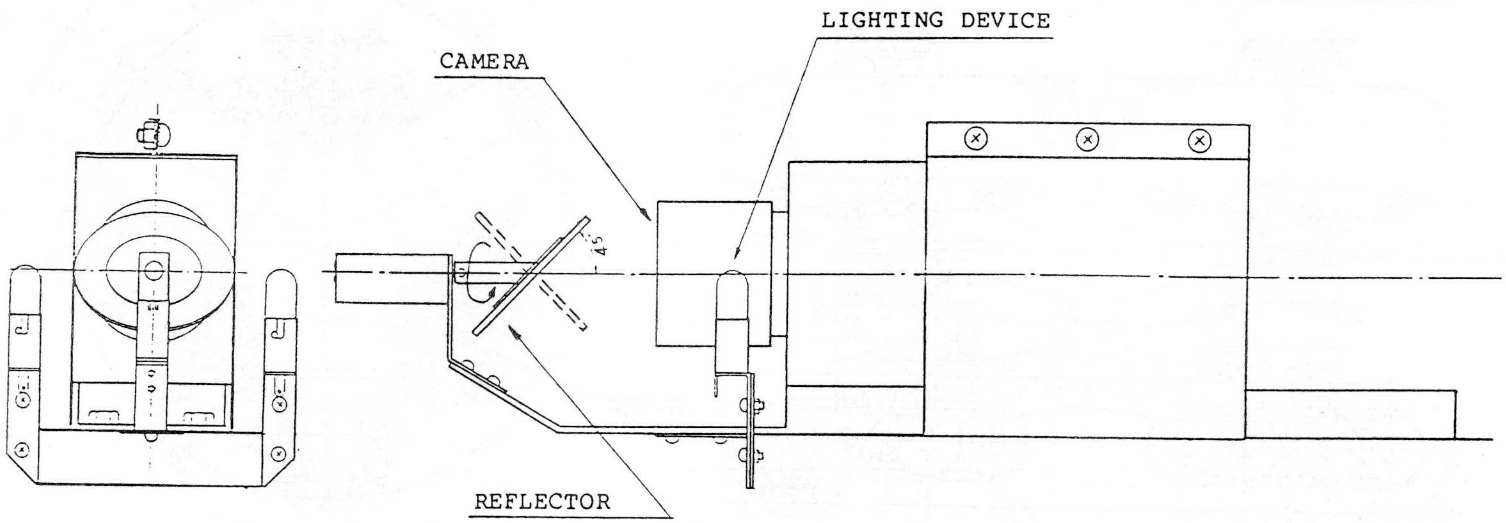

FIG. 6 OUTLINE OF INSPECTION ROBOT MONITORING SECTION

4. Work procedure

A summary of each process is as follows:

Preparatory work

In-pipe cleaning by pig

In-pipe inspectionby inspection robot

Turning seal lining technique

Lining inspection by inspection robot

4.1 Preparatory work

A pig launcher for in-pipe cleaning and turning seal lining equipment, was installed. The earth at the starting and terminal points of the lining pipe was excavated, and this pipe was exposed and disconnected from the other pipes, in order to insert the inspection robot.

4.2 In-pipe cleaning by pig

A pig was launched into the pipe to flush and clean the pipe, in order to allow the inspection robot to accurately carry out the visual inspection of the internal surface, and also to ensure the close adherence of the seal hose to the in-pipe wall.

4.3 In-pipe visual inspection using inspection robot

Prior to lining work, an inspection robot was inserted into the lining pipe (Fig. 7), and traveled to the in-pipe terminal point while monitoring the inner pipe wall by means of the robot camera.

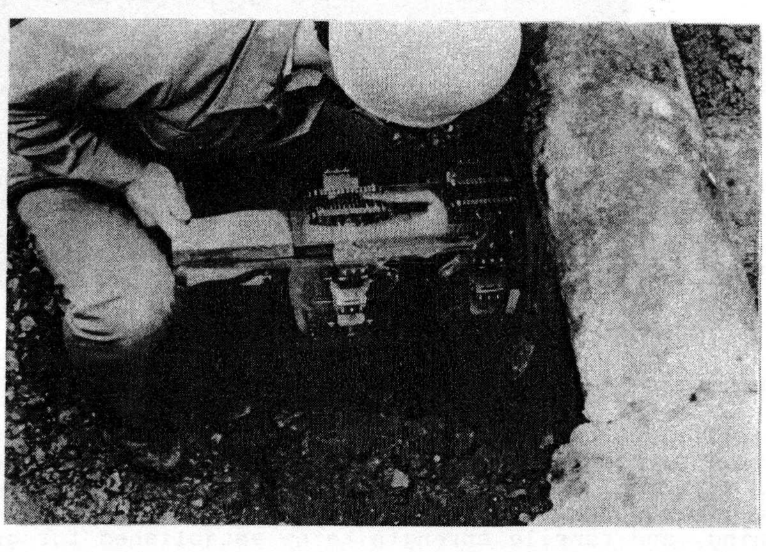

FIG. 7 INSERTION OF INSPECTION ROBOT INTO EMBEDDED PIPE

The inspection robot traveled in the horizontal, vertical and elbow portions of the pipe, and monitored the following items (1) and (2). As a result, the re-lining conditions could be confirmed before actual re-lining was started. Time, traveling distance and scale were indicated on the inspection image.

(1) The damaged conditions and regions of the lining materials.
As shown in Fig. 8, the exfoliation of the lining materials was detected on the flanged joint corner.

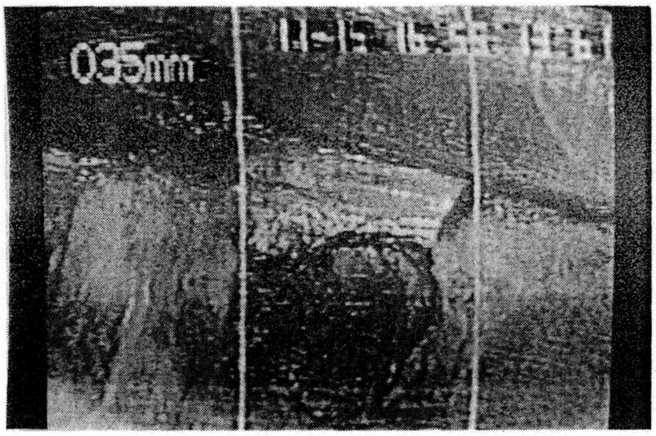

FIG. 8 IMAGE BY INSPECTION ROBOT

(2) Conditions of in-pipe scale

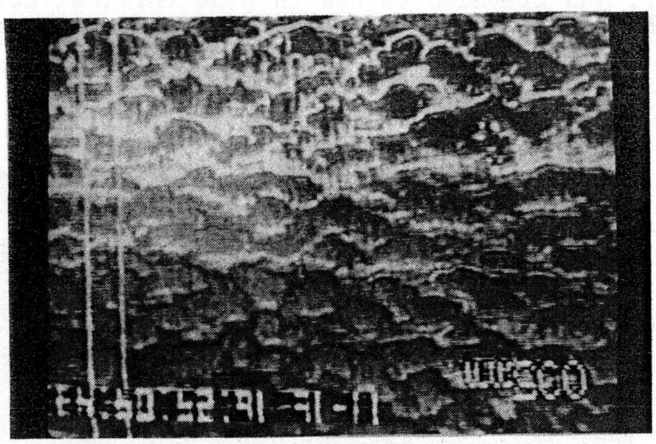

FIG. 9 IN-PIPE LINING CONDITIONS

4.4 Turning seal lining

We studied information obtained as a result of the in-pipe visual inspection by the inspection robot, lining records of the old pipe, as well as empirical data on the turning seal lining, and could know in advance lining precautions to be taken, such as pneumatic pressure during the lining, and tensile strength to be established for guide ropes. As a result, we were able to smoothly carry out the re-lining work.

Time required for the hardening of adhesive, after the seal hose was turned outside, was 42 hours. As the atmospheric temperature at this time was 8 - 18°C, and pressure in the seal hose was maintained at 1.0 kg/cm^2, only 44 hours in total was required to conduct the re-lining work.

4.5 Inspection of lined conditions by inspection robot

After completing the re-lining work, an inspection robot was again sent through the pipe and visual inspection was conducted. The inspection robot was able to travel on the re-lined internal surface of the pipe without damaging it, and monitor the following.

(1) The seal hose evenly and closely adhered to the inside surface of the pipe.

(2) The amount of wrinkling of the seal hose produced on the internal side of the elbow portions was minimal and hardly discernable, and the flow of seawater was not adversely affected.

(3) The lined conditions of flanged portions were the same as those of straight pipe portions.

5. Work effects

The combined adoption of the in-pipe traveling inspection robot and the turning seal lining method enabled the following benefits to be detailed.

5.1 Work schedule

In the case of piping exchange	:	40 days
In the case of piping re-use by lining:		24 days

TABLE 2. COMPARISON IN NUMBERS OF WORKING DAYS (12B, 60 m)

The turning seal lining technique and the re-lining using the inspection robot allowed the schedule to be reduced to 60% thanks to the unnecessity of the excavation and backfilling of earth and also of piping installation, compared with the conventional technique by which the embedded pipe is dug out and replaced with the new lining pipe.

5.2 Work cost

The work cost could be cut by about 30% because of the shortening of the schedule, the reduction in the excavation and backfilling of excavated earth, and also the re-use of the pipe (12B, 60 m).

5.3 Confirming soundness of pipe lining

Previously, it was necessary to replace the seawater with new pipe on the basis of periodic maintenance. However, with the adoption of the inspection robot, the necessity for replacing the seawater pipe could be confirmed simply by visual inspection.

6. Future of robot utilization

When evaluating the results of robot utilization, attention is apt to focused on only the functions of the robot. However, in the above in-pipe seal lining work, which was carried out in 5 stages, the robot was systematically incorporated to visually inspect the internal surface of the 12B pipe to which, in the past, workers had not direct access and therefore could not properly evaluate the in-pipe lining. As a result, the quality control of the entire in-pipe linig work was successfully completed. Therefore, it is highly recommended that personnel concerned have a thorough understanding of the function of the existing robots and incorporate these functions into the associated systems, in order to heighten the effects of the robot utilization. If such recommendation is implemented, the existing robots as well as the robots to be developed in the future will be more widely used.