Observation Technology for Remote Operation in Contaminated Turbid Water – 16113

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ABSTRACT

Remote underwater work in contaminated tanks and pools is one of major decontamination and decommissioning works under high-dose radiation environment. Generally, in this kind of work, visual information obtained by a camera (an optical camera) is limited due to turbid water caused by suspended sludge particles in the water and it makes remote underwater work difficult to be performed safely and efficiently. Therefore, some alternative observation methods to optical cameras have been required.

In order to satisfy this requirement, the alternative observation technology which can obtain visual information in contaminated turbid water has been developed since 2014. It is a technology using an acoustic imaging system in a designated airtight container. It provides the visual information in real time regardless of turbidity without significant contamination of any parts of the system. Also, it is able to provide the location information of underwater objects with contactless.

This paper will present development details of this innovative observation technology and its effectiveness to various remote works in contaminated turbid water.

INTRODUCTION

Remote work in contaminated water, such as sludge retrieval work in a waste tank, maintenance work in a fuel or waste storage pool and dismantling work for reactor internal structures, is one of major works for most of D&D facilities. To obtain enough visual information is very important for such kind of works however there are many cases that the visibility is limited due to suspended particles around working area in the water.

In remote operation, the location of objects to be cut, grasped and removed is usually recognized to touch the objects with the tip of remote equipment based on the visual information provided by optical cameras. However, there is a risk of damage to the remote equipment in case of limited visibility like an environment in turbid water. For remote operations in such an environment, it is preferable to have alternative method to know the location of objects with non-contacting.

An acoustic camera, an infrared camera and a laser scanner seem to be major technologies which can solve the problem shown above as alternatives to an optical camera. Above all, an acoustic camera is a well-proven technology for underwater use. It is also less subject to suspended particles and provides better resolution even in turbid water.

Since 2014, IHI Corporation (IHI) has started to develop the alternative observation system using an acoustic camera in order to provide more safe and efficient remote works in radioactive contaminated turbid water in D&D facilities.

DEVELOPMENT OF OBSERVATION SYSTEM

Key factors to be considered to develop the observation system in contaminated turbid water were the followings:

1. Obtain high resolution images as close as optical cameras
2. Minimize contamination of the equipment
3. Easy operation and maintenance

The unique point of this system is that the environment surrounding the system is radioactive-contaminated water. An acoustic camera is usually used for investigation activities in the sea, such as the seabed investigation and the survey for the ecology of fishes. The camera wet by sea water and attaching suspended particles in sea water is easily washed out to reuse itself. However, the camera contaminated by radioactive substances is not easily cleaned out because person has a limitation to approach to the camera, or touch it. Not to mention, it is very difficult to remove the contamination if contaminated water enters into complicated shape of parts of the camera.

For the reasons mentioned above, IHI particularly poured efforts into minimizing contamination of the equipment for the development of the observation system.

Selection of Observation Equipment

At first the acoustic camera which seemed to be the most appropriate to this observation system was selected. There are some types of acoustic cameras which are usually called imaging sonar, and those are used in different ways for underwater works in accordance to the use. In general, an acoustic camera has a capability of taking image at wide range and long distance with low resolution, and at narrow range and short distance with high resolution. For the application to remote operations in contaminated turbid water, to obtain higher resolution was a high priority function and thus, the acoustic camera which has the highest resolution in some options was selected. The selected acoustic camera can provide real-time image in around 5m distance from the camera, 30 degree horizontal viewing angle and 15 degree vertical viewing angle. Those features of the acoustic camera provide an enough good image to perform any remote operations in turbid water as well as optical cameras in clear water.

Development of Airtight Container

In order to minimize contamination of the acoustic camera, the designated airtight container was developed. The acoustic camera is housed in the airtight container which is made by stainless steel and used in contaminated environment. Because the acoustic camera has to be filled with water when it is used, the container which contains the acoustic camera is initially filled with clean water, and then it is pressurized and sealed in order to prevent to enter the contaminated water in the environment into the container. This container has a capability of over 0.3MPa of pressure-resistance. It allows that the equipment to be applicable to the environment of over 30m depth of water like the bottom area of light-water reactors. In addition, the container may give a shielding effect against radiation exposure for the acoustic camera to increase its thickness depending on radiation dose in the environment.

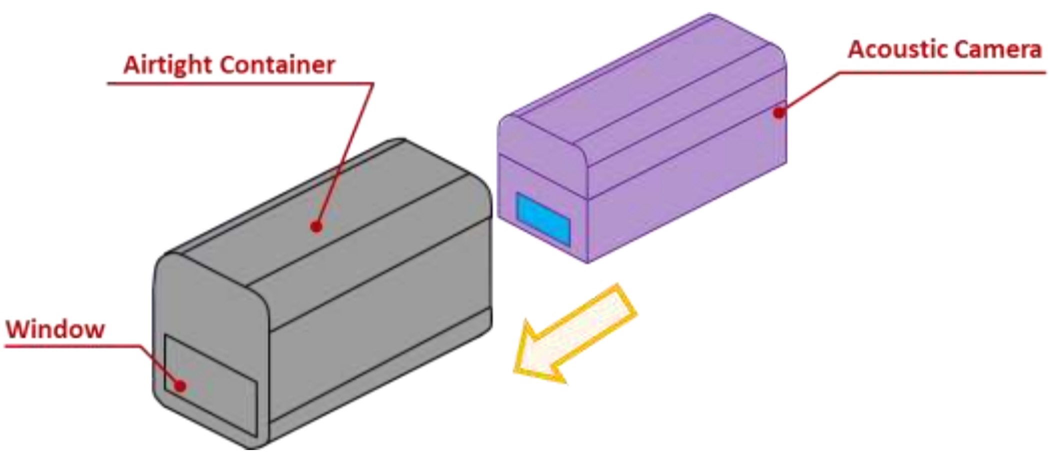
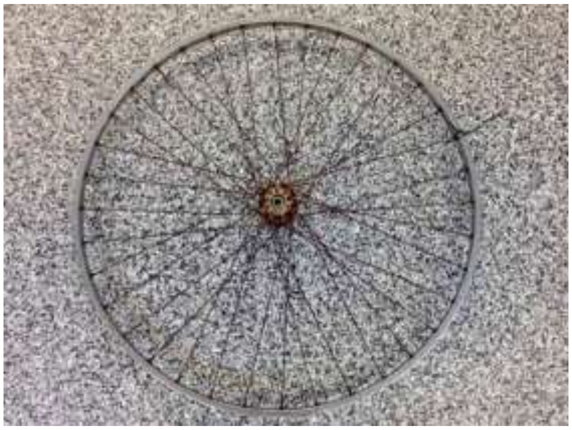


Figure1: Airtight container for the acoustic camera

Thin plate made by resin material which relatively has high radiation tolerance was adopted as the interface (window) of the container to transmit and receive ultrasonic waves of the acoustic camera. It gives a high resolution image even the camera is housed in the container.   Figure 2 shows that there are no differences of image taken from the camera directly (no window) and the camera in the container (through the window).



Target: Bicycle Wheel

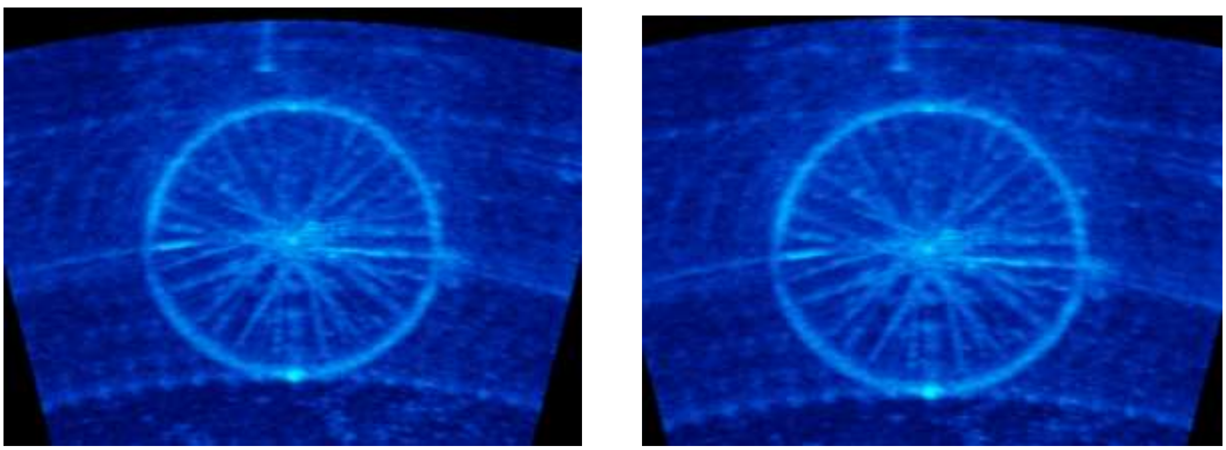


Image: A Image: B

Figure 2: Images taken from the acoustic camera directly (Image: A) and through the window (Image: B)

System Configuration

The observation system consists of the following major equipment:

- Observation Camera (Acoustic Camera in Airtight Container)
- Remote-Controlled Equipment
- Cable Management System
- Washing Equipment

Figure 3 gives an example of the observation system. In this example, a single manipulator arm is applied as the remote-controlled equipment for the observation camera. However, it can be changed to the other remote equipment such as ROVs and simple hoists according to the environment and purpose to use. The cable management system which mainly consists of a remote-controlled cable reel allows proper control of the cable length for power supply and transmitting image signals following the motion of the remote-controlled equipment.

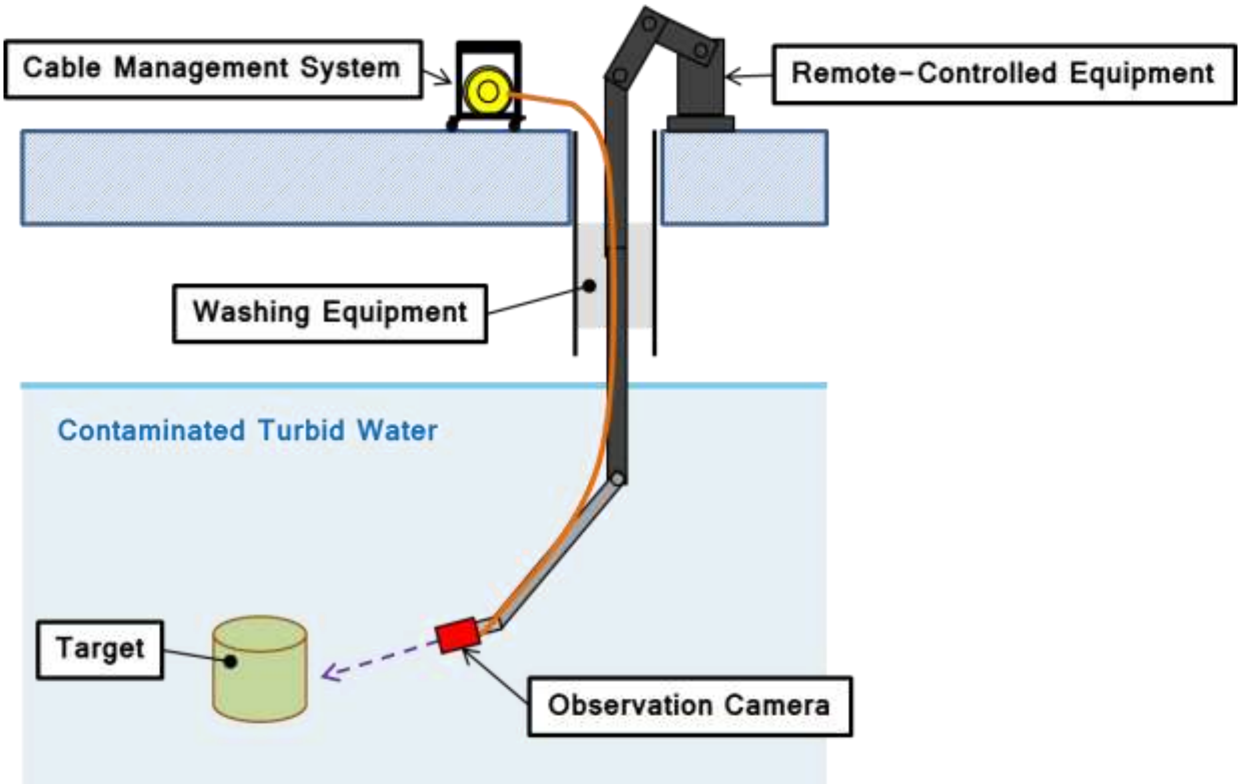


Figure 3: Example of observation system configuration

The washing equipment is installed on the entrance of the observation camera (e.g. nozzle of tank). By using high pressure water and brushes, it decontaminates the whole surface of the observation camera before the camera is fully retracted in order to reduce operator's radiation exposure as much as possible.

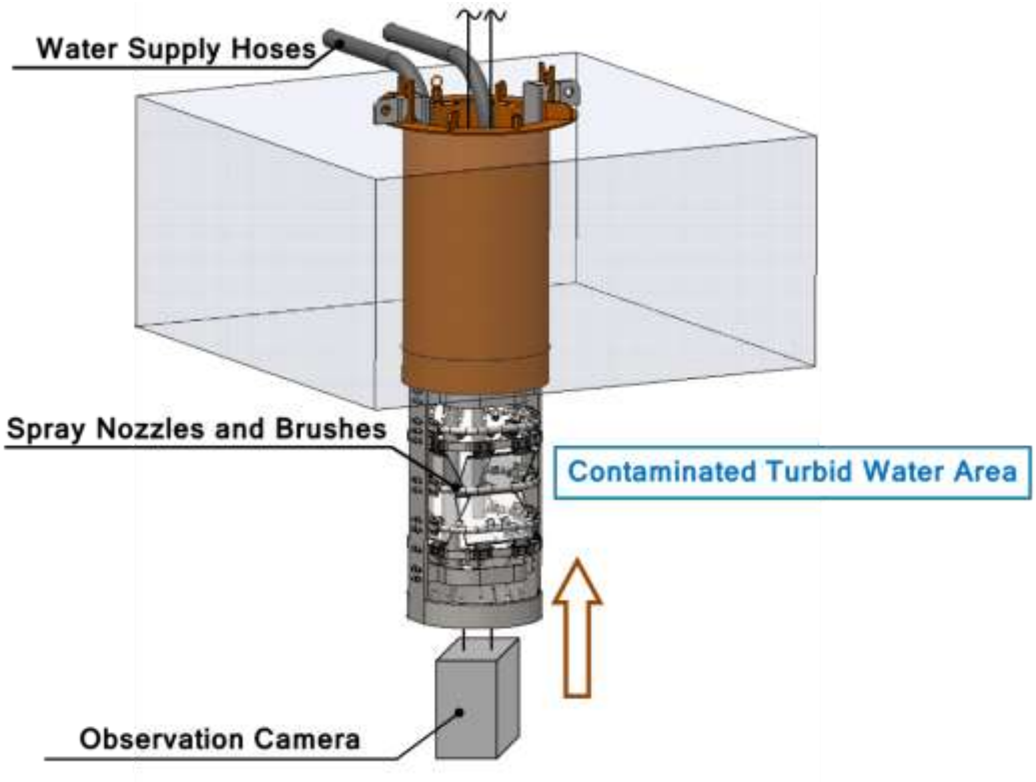


Figure 4: Washing equipment for the observation camera

Demonstration Test

Through 2014 to 2015, several cold demonstration tests for the observation system were performed in order to confirm the functions and performances of the system in the simulated actual contaminated water. Figure 5 shows the example of the simulated contaminated water used for the demonstration test. It was clouded by magnesium hydroxide at first, and additionally a large amount of iron powder and sand grain were put into the tank. The demonstration test was performed in enough conservative condition using the simulated contaminated water which was much worse turbidity than the actual condition.

Figure5: Simulated contaminated water used for the demonstration test

Figure 6 is the image taken by the optical camera in the simulated contaminated water. It shows how it is difficult to obtain a clear image by using the optical camera in this condition.

Figure 6: Image taken by the optical camera in simulated contaminated water

Several different kinds of targets were used for the demonstration tests in order to know differences of performance for the observation camera according to the targets. Figure 7 shows the major targets and their images taken by the observation camera. Those targets were placed on the bottom of the tank, 2-3m away from the camera. It is very easy to understand that the observation camera could take much clearer image than the optical camera (Figure 6), even in such a worse condition.

Distance measuring function which is another important function for the system were also confirmed in the demonstration tests. Dimension measuring accuracy of the target was 10 to 20mm, and distance measuring accuracy between the target and the camera was 20 to 30mm. From those results, it was shown that the observation system has an enough performance of distance measurement for remote operations in turbid water.

Target: Cart

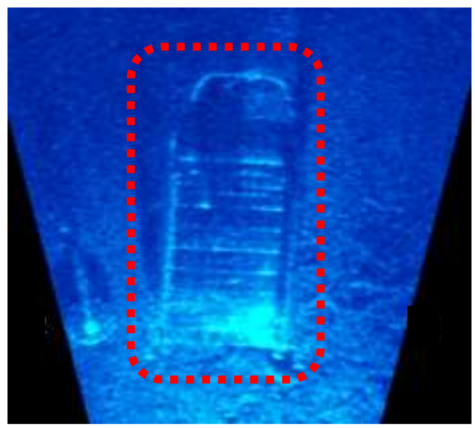


Image by the observation camera

Target: Concrete block

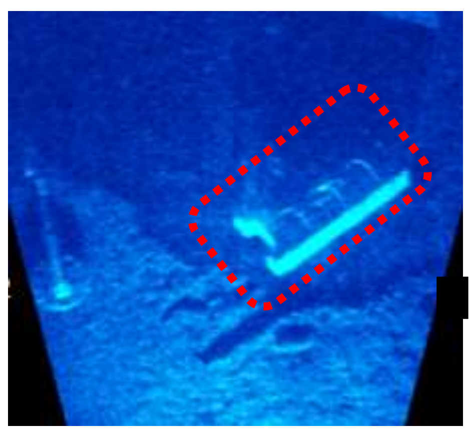


Image by the observation camera

Figure7: Images taken by the observation camera

Target: Steel Plate

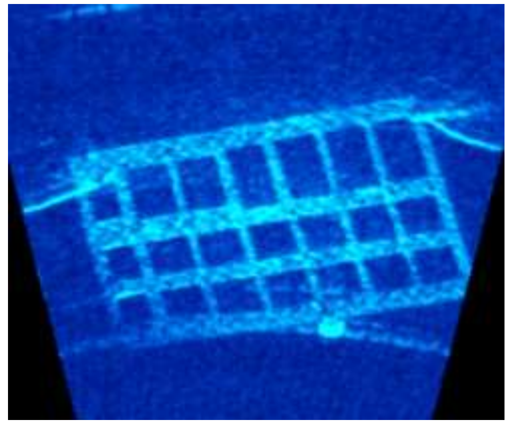


Image by the observation camera

Figure7: Images taken by the observation camera (Continued)

APPLICABILITY TO VARIOUS D&D WORKS

The observation system which has been developed as mentioned above is applicable to various remote works in contaminated turbid water. The followings show examples of expectable applications of the observation system:

Dismantling Works in Reactors and Tanks

A lot of dismantling works in reactors or tanks are planned in the world nuclear decommissioning sites. Underwater cutting operations usually make surrounded water turbid and difficult to obtain a good visibility using optical cameras. The observation system provides the visual and location information in even such an environment. Operator can recognize the proper location of the cutting tool to the cut objects and observe the tool and the objects during cutting operation.

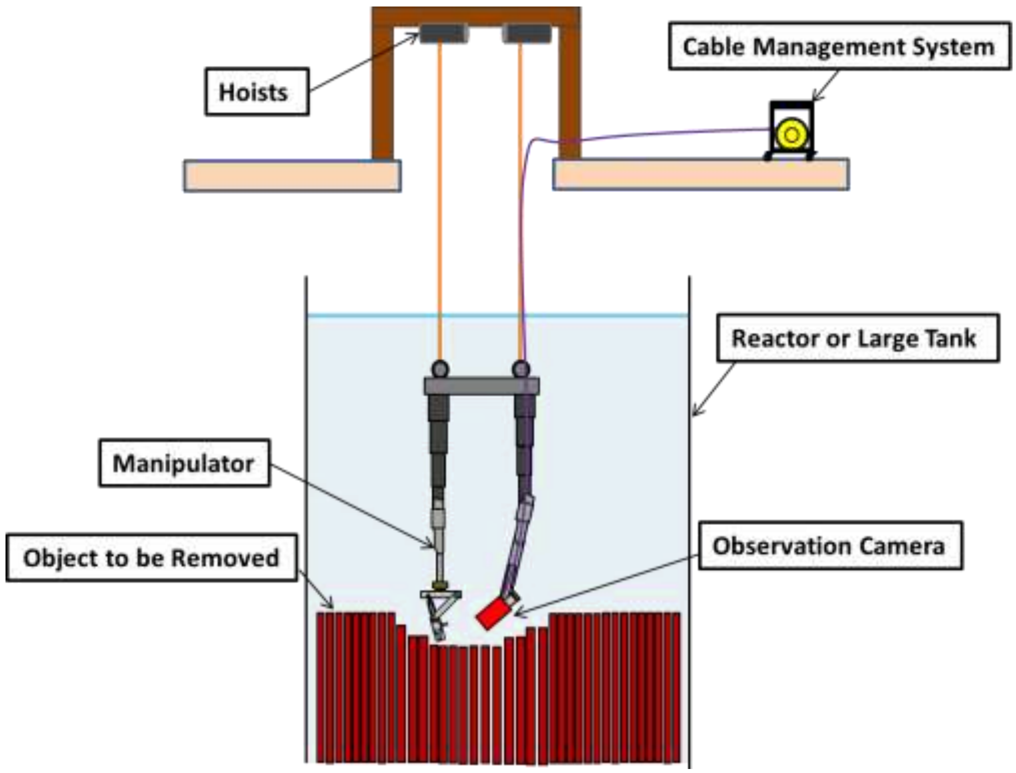


Figure 8: Application example of the observation system to dismantling works in reactor and tank

Inspection and Investigation Works using ROVs

There exist a lot of kinds of ROVs with optical cameras used for underwater inspection and investigation works in various industries including nuclear D&D projects. However, sometimes it is hard to use it in contaminated turbid water such as in old tanks and pools which have stored spent fuels or wastes. The observation system is applicable to those works using ROVs instead of optical cameras. The observation camera is relatively small (200mm x 200mm x 300 mm) and it is capable of mounting on some of ROVs mentioned above.

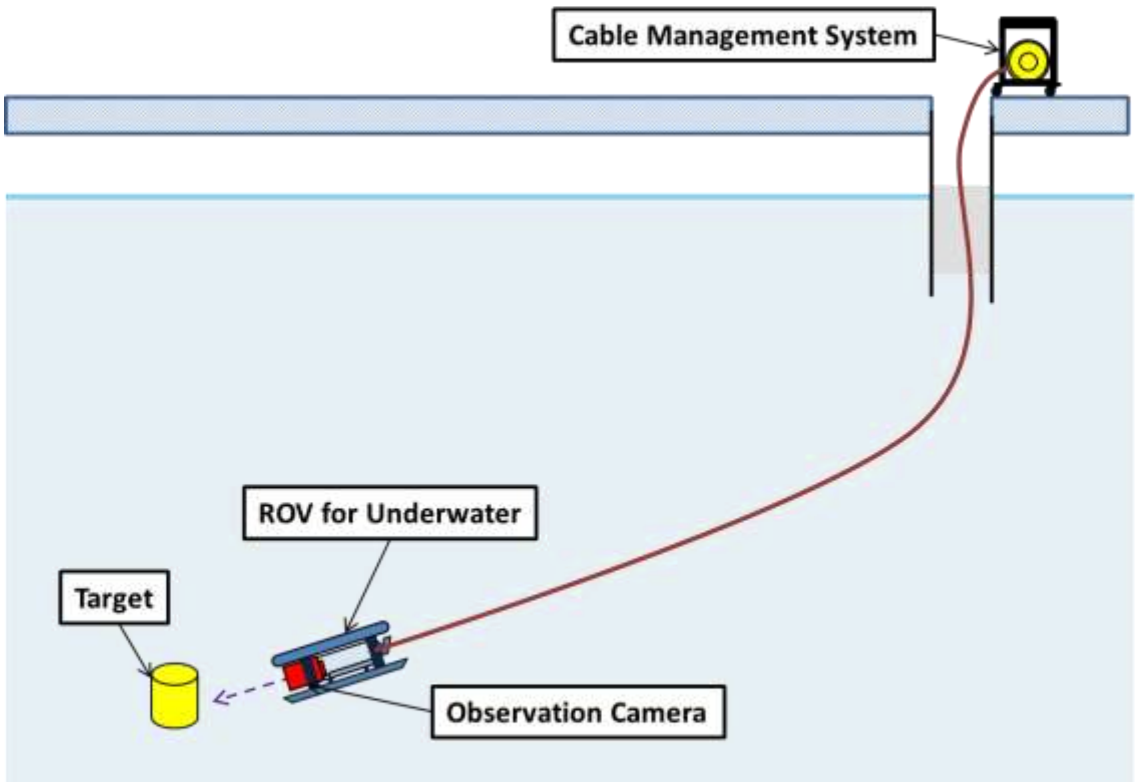


Figure9: Application example of the observation system to inspection and investigation works using ROVs

CONCLUSIONS

The observation technology is important to perform remote operations in radioactive-contaminated turbid water safely and efficiently. However, an optical camera is basically limited to provide enough visual information in the turbid water and thus, alternative observation technology to an optical camera has been required.

IHI has developed the alternative observation system applying acoustic camera which gives much clearer image than optical cameras in the turbid water. It also provides distance information which has enough accuracy for the remote operation. Additionally, contamination of the equipment is minimized to reduce radiation exposure to operators, and to give easy operation and maintenance works. This observation system has a capability of providing safe and efficient remote operations in the radioactive-contaminated turbid water in D&D facilities.