# Deep-Sea Water Suction Technology

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**ABSTRACT** In the area of deep-sea water suction technology, Furukawa Electric has built an excellent track record of laying eleven deep-sea water suction pipes in seven locations since its first domestic laying in Muroto City, Kochi Prefecture in 1988. During this time, we have introduced various improvements in the laying method as well as in the design of material structures including suction pipes, thereby making it possible to manufacture and install the suction pipes up to 280 mm in diameter, 680 m in laying depth, and 7200 m in pipe length.

## 1. INTRODUCTION

While it seems that deep-sea water has got through the boom becoming widespread in our daily lives, Furukawa Electric is maintaining a top share in the business of deep-sea water suction pipes.

It has been fifteen years since we laid the Japan's first deep-sea water suction pipe. During this time, we have introduced various improvements in the installation method and the design of suction pipes to carry out further developments. Explanation of deep-sea water and technological achievements will be presented in this paper.

## 2. ABOUT DEEP-SEA WATER

Although not a very precise definition scientifically, deep-sea water generally refers to sea water that lie in the sea about 200 meters or more in depth where sunlight no more reaches. The characteristics of deep-sea water comprise three elements of "stabilized low temperatures", "rich nourishment", and "cleanliness". Moreover, studies have recently advanced to draw attention to "maturity" and "richness in minerals".

Thus efforts are being made in various fields to utilize deep-sea water as a new natural resource, taking advantage of such characteristics.

### 2.1 Application Fields of Deep-Sea Water

Deep-sea water is mainly utilized in such diversified fields as fisheries, food and beverages, environmental conservation, health-beauty-and-medical, energy and resource, and agriculture. Each field is making efforts to study, develop, and practically apply deep-sea water leveraging its characteristics.

With respect to its rich nourishment, for instance, the water is expected to have much effect on aquafarming of fish and shellfish in the fisheries field as well as on improving meat quality in the livestock field.

In terms of its stabilized low temperatures, efforts are being directed to cultivate -- in a warm-temperature region-- fish, shellfish, seaweeds, vegetables, and highland vegetables that belong to cold regions by nature. Also, possibilities of applying the water to cooling water for power stations and to ocean thermal energy conversion generation are being investigated entering into the stage of practical studies.

What is more, beer, shampoo, and isotonic drink are already in the marketplace, taking advantage of the maturity and richness in minerals of the water.

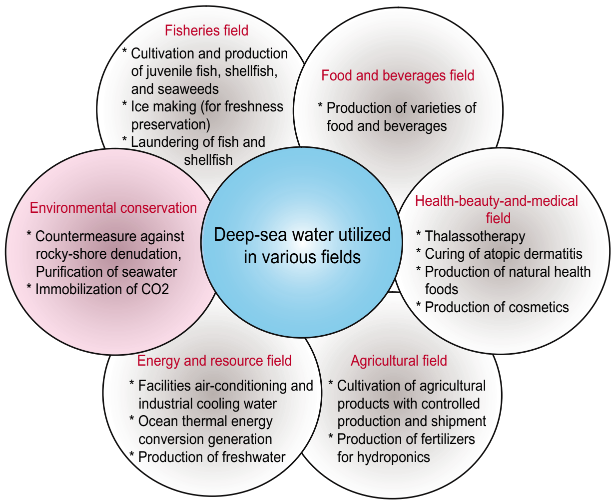


**Figure 1 Application fields of deep-sea water.**

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Figure 1 shows the applications of deep-sea water in various fields that are either planned or implemented.

## 3. DEEP-SEA WATER SUCTION SYSTEM

### 3.1 Outline of Deep-Sea Water Suction Facility

A deep-sea water suction system may be broadly divided into suction pipe, water intake, and a shore-based facility that pumps up deep-sea water to distribute it to individual facility of customers. Figure 2 shows a schematic image of the system.

The suction pipe conveys deep-sea water from the objective sea depth to the shore-based facility. The pipe is required to be in one continuous length preferably, and to have such performance as to fit well to the ups and downs of the seabed as well as to withstand the tension expected to occur when the pipe is suspended from the sea surface down to the seabed during laying work.

The water intake has a structure such that it keeps the end of suction pipe at a constant height above the seabed so as not to suck in sand or sludge lying on the seabed.

The shore-based facility comprises a siphon tank, i.e., a primary tank for deep-sea water which is installed lower than the sea-level to maintain siphon effects; a strainer for filtering out foreign objects; a pump for conveying the pumped up deep-sea water to destinations; and a sand filtration tank to filter out minute sand and the like in accordance with the intended use.

### 3.2 Deep-Sea Water Suction Pipe

#### 3.2.1 General Structure of Deep-Sea Water Suction Pipe

The steel-wire armored polyethylene pipe (submarine water pipe by the brand name of “AQUALEX”), which Furukawa Electric has been supplying since 1969, is basically suitable for meeting the performance requirements mentioned above.

The design pressure for deep-sea water suction pipes can be set lower than ordinary water pipes because the one end immersed in the sea is always kept open and because the principle of siphon is used for water suction. Consequently, whereas conventional water pipes have a structure in which armoring steel wires are wound after reinforcing the polyethylene bare pipe by winding steel tapes, the deep-sea water suction pipes have armoring steel wires directly wound via bedding layers without using reinforcing steel tapes. Figure 3 shows the general structure of a water suction pipe and a photo of pipe sample.

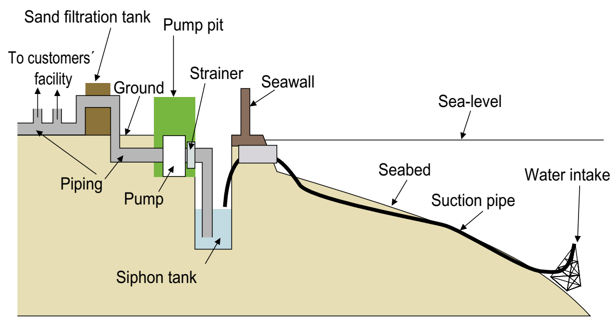


**Figure 2 Schematic image of deep-sea water suction system.**

#### 3.2.2 Large-Diameter Deep-Sea Water Suction Pipe

As the use of deep-sea water spreads, the demand increased rendering the conventional pipes with ordinary diameter insufficient for enough volume of suction water.

Laying multiple pipes to increase the suction water volume is subject to restrictions such as site requirements and the like along with poor economical effectiveness. Thus it was concluded that increasing the diameter of the pipe was most effective. However, increasing the pipe diameter posed two problems as follows:

1) Problem of laying work: The pipe itself increases in weight making it difficult to hold the pipe by laying tension.
2) Problem of manufacturing: The admissible pipe diameter at the steel wire armoring machine may form a major bottleneck.

In an effort to solve these two problems, reduction of the wall thickness of polyethylene pipe was studied together with weight control of armoring steel wires. Because, as mentioned before, the water suction pipe permits lower design pressures than ordinary water pipes, the wall thickness of the polyethylene bare pipe was reduced leaving the outer diameter unchanged to increase


**Figure 3 General structure and photo of water suction pipe.**


**Figure 4 General structure and photo of large-diameter water suction pipe.**


**Figure 5 General structure and photo of lightweight water suction pipe.**

the inner diameter, thereby achieving an increase in the water suction volume. Whereas reducing the wall thickness might possibly degrade the sidewall pressure resistance of the pipe, every equipment for pipe laying was accordingly reviewed, as described later, in terms of sidewall pressures during laying work.

The weight of the water suction pipe is mostly due to the mass of the armoring steel wires, so that some of the steel wires were replaced by polyethylene-coated steel wires to reduce the weight.

Figure 4 shows the general structure of a large-diameter water suction pipe and a photo of pipe sample.

3.2.3 Lightweight Deep-Sea Water Suction Pipe

While the depth for deep-sea water is generally defined as 200 m or deeper, it sometimes reaches almost 700 m depending on the site. Increased sea depth eventually leads to an increase in the tension during pipe laying. We have therefore proceeded, regardless of the weight reduction described in Section 3.2.2, to reduce the pipe weight further using polyethylene terephthalate (PET) rods with smaller specific weight in place of polyethylene-coated steel wires.

Figure 5 shows the general structure of a lightweight water suction pipe and a photo of pipe sample.

3.2.4 Deep-Sea Water Suction Pipe Using PE-100

A polyethylene material called PE-100 with better creep performance has begun to be used as a water pipe. In response to the fact that PE-100 has been acknowledged in JIS and the standards of Japan Water Works Association, we have applied PE-100 to the suction water pipe for the sake of material unification.

**Figure 6 Photo of water suction pipe using PE-100.**

Figure 6 shows a photo of the pipe sample.

### 3.3 Deep-Sea Water Intake

Deep-sea water intake where the water is taken from should basically be maintenance-free because, due to its considerable depth, repair work after installation to replace the filters and the like provided against entry of sand and sludge would cost enormous cost and time.

The water intake plays the role of a platform that is provided to maintain the end of suction pipe at a certain height above the seabed so as to prevent sucking in of sand or sludge lying on the seabed. Two

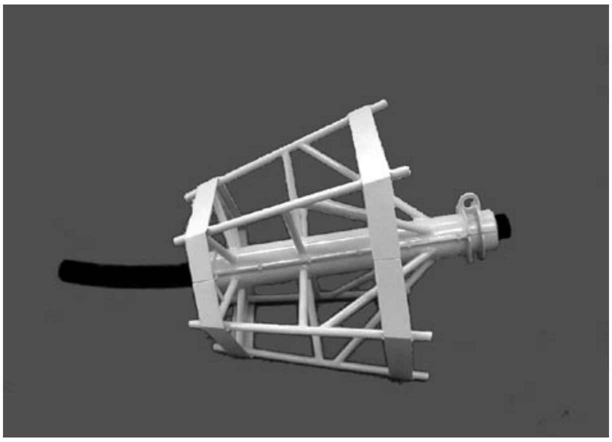

**Figure 7-1 Hexangular pyramidal water intake.**

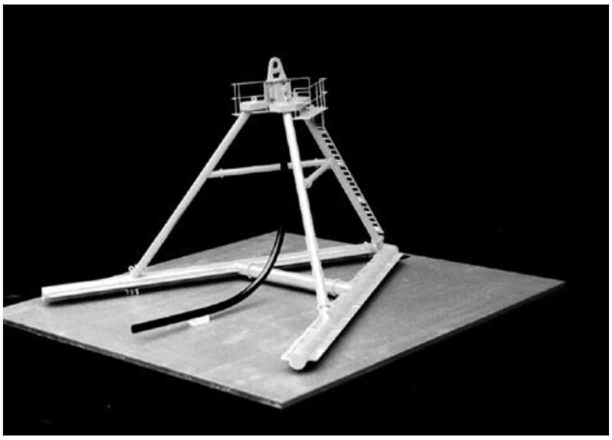

**Figure 7-2 Triangular pyramidal water intake.**

types of structures, i.e., hexangular pyramidal type and triangular pyramidal type, are applied depending on the geographical situations of the seabed.

The hexangular pyramidal water intake shown in Figure 7-1 is suitable for installation on a seabed area whose slope is rather steep. Because the end of the suction pipe is located at the center of the bottom face, it has a structural characteristic that the height of the pipe end above the seabed remains unchanged on whichever face the water intake may be landed.

The triangular pyramidal water intake shown in Figure 7-2 is suitable for installation on a muddy seabed area where the pipe end is required to rise high above the seabed. Because the pipe end is located at the top of the triangular pyramid, its height above the seabed is permitted to be higher than the hexangular pyramidal water intake. However, its position during installation should be controlled with the greatest care.

## 4. CHANGES IN TECHNIQUES FOR INSTALLATION OF WATER SUCTION PIPE

### 4.1 Outline of Laying Work of Deep-Sea Water Suction Pipe

In case of land transportation, the pipe has to be delivered in short lengths capable of being carried on a truck since it cannot be accommodated on reels due to its large allowable bending radius. Because, moreover, short lengths would result in too many intermediate splices at the site dissipating too much working time, they are not suited for ocean installation work whereby short working period is essential not to be affected by adverse ocean conditions. Therefore, the suction pipe is coiled up in one continuous length in a barge with adequate load capacity to be transported to the site. The pipe-carrying barge travels directly to the site, where the barge is converted to a pipe-laying barge to be used during the laying work.

The procedures of laying a deep-sea water suction pipe are shown in the flow chart here.

Landing (See Figure 8)

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Laying (See Figure 9)

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Installation of water intake (See Figure 10)

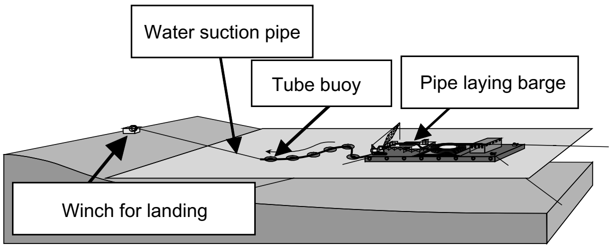



**Figure 8 Schematic image of landing work of deep-sea water suction pipe.**

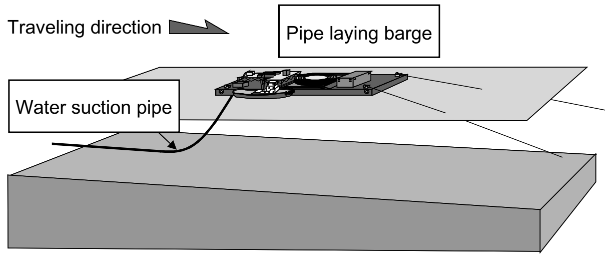



**Figure 9 Schematic image of laying work of deep-sea water suction pipe.**

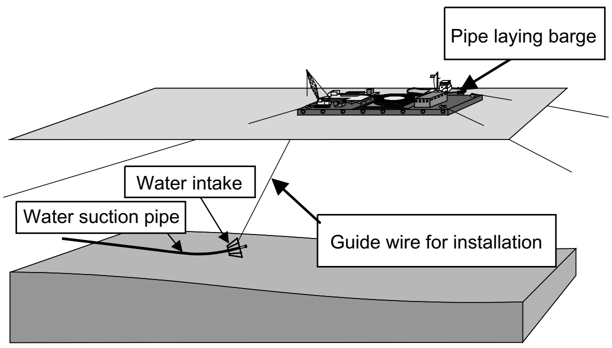



**Figure 10 Schematic image of installation work of water intake.**

First, landing work is carried out whereby the barge loaded with a water suction pipe approaches the seashore as near as possible, and, while attaching tube buoys, gradually pays out the pipe afloat on the sea to land it ashore. When the landing work is completed, the barge moves forward steadily to lay the pipe on the seabed. The landing work and the laying work are very similar to those of conventional water pipes and submarine cables.

But one big difference of installation work between water suction pipe and conventional water pipe is that one end of the former is installed in the sea. The water intake is mounted on the end of water suction pipe, which is connected with a guide wire for installation and is installed on the seabed using a winch. Whereas the end of ordinary water pipe or submarine cable stays during installation in a position that is visible to eyes, the end of deep-sea water suction pipe is in the sea precluding visual confirmation. Meanwhile, underwater camera cannot be used in fear of entangling of the power-supply and control cable with the guide wire for installation. Moreover, simultaneous installation of two linear lines of different bending stiffness, i.e., water suction pipe and guide wire makes it difficult to project the catenary configuration. In addition, physical orientation of the water intake comes in constituting a major problem.

Given the conditions mentioned above, we adopted an installation method whereby information from underwater transponder, the tension, pay-out length, and incident angle of the guide wire are synthesized together to make a judgment about the seabed landing of the water intake; and a underwater camera is used after the completion of pipe laying to visually confirm the landing situation of the water intake. Then sonic signals are sent to actuate the decoupling device mounted on the water intake to retrieve the guide wire together with the decoupling device.

### 4.2 Development of Installation Equipment for Water Suction Pipe

4.2.1 Hauling machine

During pipe laying, the pipe has to be paid off gradually while being held on board not to let it run into the sea in one go. A hauling machine is used as this holding machine.

Performance requirements for a hauling machine are determined by the sea depth and the own weight of the pipe, so that a hauling machine that is suitable to site conditions in terms of tension holding capacity, holder's shape, and holder's length has to be selected to carry out installation.

4.2.2 Large-Size Turntable

A turntable is indispensable for transporting a water suction pipe in one continuous length.

If the pipe is small in diameter and short in length, it may be directly coiled on a barge, but in such a case, a large allowable bending radius is required since twisting is introduced into the pipe by coiling.

Recently, as water suction pipes grow in diameter and length, use of turntables has become the mainstream technology of pipe loading since it enables small bending radius introducing no twist. Furukawa Electric has long been developing the turntable, and the product has been used in the installation works of not only the company but also other companies.

4.2.3 Barge with Onboard DPS

In conventional laying work of deep-sea water suction pipes, anchoring method has been used to move the barge forward whereby an anchor is set up ahead of the barge, and the driving wire tied to the anchor is wound up by a winch on the barge. This laying method raises two problems to be solved such that the anchor has to be set up in the seabed as deep as 1000 m, and that the route keeping and proposed position keeping are easily affected by the oceanographic conditions.

To solve these problems, we have developed a barge with DPS (Dynamic Positioning System) onboard which is provided with capabilities of route keeping and proposed position keeping. The DPS is a navigation system to automatically control the position of a ship, which comprises a position measuring system based on satellites and an associated thruster which is used to move the ship keeping the position.

Conventionally, this navigation system has been employed in cargo ships, but this time the system has

**Figure 11 Hauling machine.**

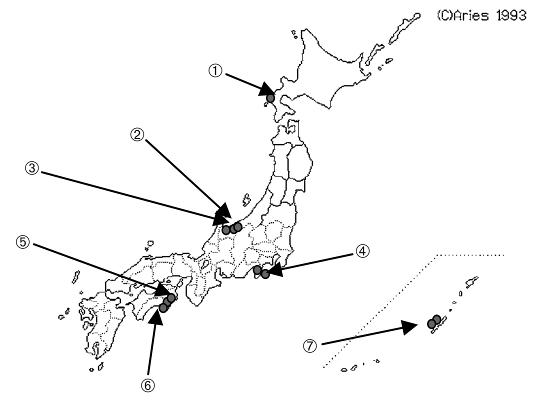
**Figure 12 Turntable.**


**Figure 13 Barge with onboard DPS.**

**Figure 14 Control stand of barge with onboard DPS.**

been applied to a broad-beamed barge to enable loading and laying of deep-sea water suction pipes. The barge with onboard DPS is applicable to not only deep-sea water suction pipes but also submarine water pipes and submarine cables. Although operation of this type of barge has just begun, the DPS technology is developing day by day, as the track record builds up, introducing various improvements.

**Figure 15 Thruster.**




① Offshore Kumaishi, Hokkaido: Production of juvenile abalone
② Offshore Nyuzen-Machi, Toyama Pref.: Shipment adjustment of marine products, Washing water for disposal of goods
③ Offshore Namerikawa-City, Toyama Pref.: Onshore breeding of masu salmon, Thalassotherapy
④ Offshore Yaizu-city, Shizuoka Pref.: Water suction from two sea layers of different depths
⑤ Offshore Takaoka, Kochi Pref.: Deep-sea water supply terminal installed for exclusive use by businesses
⑥ Offshore Muroto Cape, Kochi Pref.: Japan's first facility for deep-sea water suction
⑦ Offshore Kumejima Island, Okinawa Pref.: Supply of mother prawn for prawn breeding

**Figure 16 Track record of installation of deep-sea water suction pipe.**

## 5. TRACK RECORD OF INSTALLATION

Deep-sea water suction pipes have been installed at seven locations domestically, ranging from Hokkaido to Okinawa, while each location has its own features as shown in Figure 16.

## 6. IN CONCLUTION

Given the fact that we are receiving a lot of inquiries from not only Japan but also overseas, deep-sea water application is a business area that is expected to be increasingly active.

In terms of its technological aspect, deep-sea water suction is tending toward large quantity water suction in such applications as fertilization of sea areas, ocean thermal energy conversion generation, cooling water for power stations, etc. From the standpoint of understanding deep-sea water suction as an element of deep-sea laying technology, the technology developed here is very valuable since it can be extended horizontally to deep-sea laying of submarine power cables and the like.

We will be most gratified if we could play a role, through our engagement in deep-sea water suction, in such aspects as the development of deep-sea water applications, regional development, and the development of ocean engineering.

Lastly, we would like to express our gratitude to those people who kindly cooperated with us in the development.