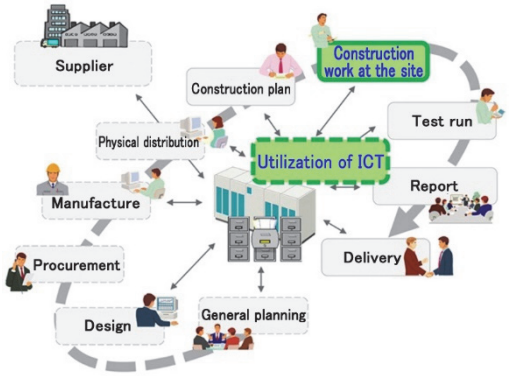
Approach to Advancement of Construction Technology for Nuclear Reactor Facilities Using ICT



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In the construction and aftersales service (A/S) of nuclear facilities, construction technology that fulfills various design requirements is required to bring the nuclear facility into operation safely within a short construction period. Furthermore, rationalization through an increase in operating efficiency and labor saving, in addition to an increase in safety and quality, is also required. To respond to these needs, our division investigated problems in various types of construction work, collected information about state-of-the-art ICT technologies and worked on their introduction into actual construction work. This report describes our approach to the advancement of construction technology and application examples.

1. Introduction

The construction of nuclear facilities is subject to strict legal and governmental regulations and requires severe design conditions and security, not to mention a high level of safety and quality. There are also many constraints on the construction and A/S work. Therefore, how labor can be reduced while increasing working efficiency when executing construction work at sites under various constraints is a major issue. On the other hand, with the recent remarkable advances in information technology, various information terminals, software, etc., have appeared on the market. To solve the issues we face by introducing these tools appropriately, we are making various activities from different perspectives. Our approach to the advancement of construction technology is introduced hereafter.

2. Issues in construction and A/S

2.1 Communication environment

To further reduce labor in construction work at the site while responding to the demand for higher quality and shorter construction periods, we absolutely need to utilize ICT (Information and Communication Technology) and IoT(Internet of Things), which have been increasingly introduced in other fields. However, the major buildings (reactor containment vessel, reactor building, reactor auxiliary building, etc.) of nuclear facilities are made of reinforced concrete with a thickness ranging from tens to hundreds of centimeters in light of earthquake resistance and radiation protection, and have an enclosed structure to prevent radioactive substances from leaking to the outside. Therefore, wireless communication (using cellular phones, wireless LAN, etc.) with the outside of the buildings is not possible. At present, the communication means normally available in nuclear facilities is mainly by PHS(Personal Handy-Phone System) line installed by the customer, but it is not capable of transmitting large-capacity data and has been a major factor in hindering the introduction of ICT and IoT.

2.2 Management of items delivered to the site

In the construction work of nuclear facilities, several tens of thousands of internally produced items and purchased items (subcontract items) in total need to be managed for acceptance, storage and delivery to the site. We handle the acceptance of items together with the shipping

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specifications indicating the shipped items. But the descriptions on the shipping specifications differ by supplier and if “One set” is described, it takes much time to identify where (on which drawing) the item should be used. The management of storage and delivery to the site is conducted using paper forms or simple electronic data, and it also takes time to search for necessary items.

2.3 On-site measurement work (measurement of installation dimensions for embedded metal fittings, etc.)

In the construction work of nuclear facilities, to connect the concrete skeletons of buildings with the support steel materials for supporting the equipment such as pipes and ducts, metal fittings with anchors are generally embedded. The installation work of the embedded metal fittings is broadly divided into three groups: installation, measurement and inspection. In the inspection work, measuring instruments such as auto levels and transits are used. Several tens of thousands of metal fittings are embedded and the setting of measuring instruments requires skill and multiple workers. Thus, the inspection work requires a great deal of labor.

2.4 On-site fitting work in installation of pipes

A seawater pipe for supplying and discharging the seawater that is used as a coolant in nuclear facilities is provided with a lining (surface treatment for forming film with resin or the like) for the prevention of internal corrosion, etc., and it has a flange connection structure on its ends. The existing pipes are warped as a result of processing or by welding heat input during manufacturing or installation. Therefore, in the execution of the repair work of a seawater pipe, the members are delivered to the site and temporarily fitted. After that they are carried into the shop for finishing and are re-delivered to the site and installed (on-site pipe fitting method). However, the temporary pipe fitting, processing at the shop and application of lining require much time. In addition, the members must be carried in and out twice, resulting in the increase of risk at the site and material handling costs.

3. Application of advanced construction technology

3.1 Establishment of communication infrastructure using high-speed PLC and advancement of construction process using it

To establish a communication infrastructure in a building, we decided to use “high-speed PLC (Power Line Communication).” PLC is a technology that enables power lines to be used as communication lines. High-speed PLC systems that have been released in recent years enable higher-speed communication (maximum communication speed: 210 Mbps) compared to existing PLC systems (maximum communication speed: several kbps). The greatest feature of PLC is that it enables us to establish a communication network without laying a new LAN cable. Therefore, with PLC, we can lay a communication line in a building via a cubicle only by establishing a base station outside a building. (It can be introduced even in an existing building without requiring large-scale construction work.) With the system configuration shown in **Figure 1**, we installed a high-speed PLC system into the temporary power source for a plant under construction in a severe noise environment and started verification in the fall of 2019. As a result of optimizing high-speed PLC by installing a noise suppression device and conducting communication speed tests, we confirmed that although the communication speed tended to be reduced in the time periods when on-site work converged, we have achieved a communication speed of approximately 1.1 Mbps and are studying further improvements to the communication environment. At this moment in time, the thin client PCs and tablet terminals used in operations could be connected to the internal network and system and operated without problem.

Based on the verification results, we are currently developing a construction management system on the assumption that this communication infrastructure is used. Using character recognition, electronic tags, etc., we will streamline the construction management so that the construction progress management and the preparation of execution recording data, which were conventionally conducted in offices after field work, can be conducted at the site. We are also planning to link this system with the design information database, thereby associating the construction records with the design information data, and we also plan to adapt the system to the new inspection system required for nuclear facilities.

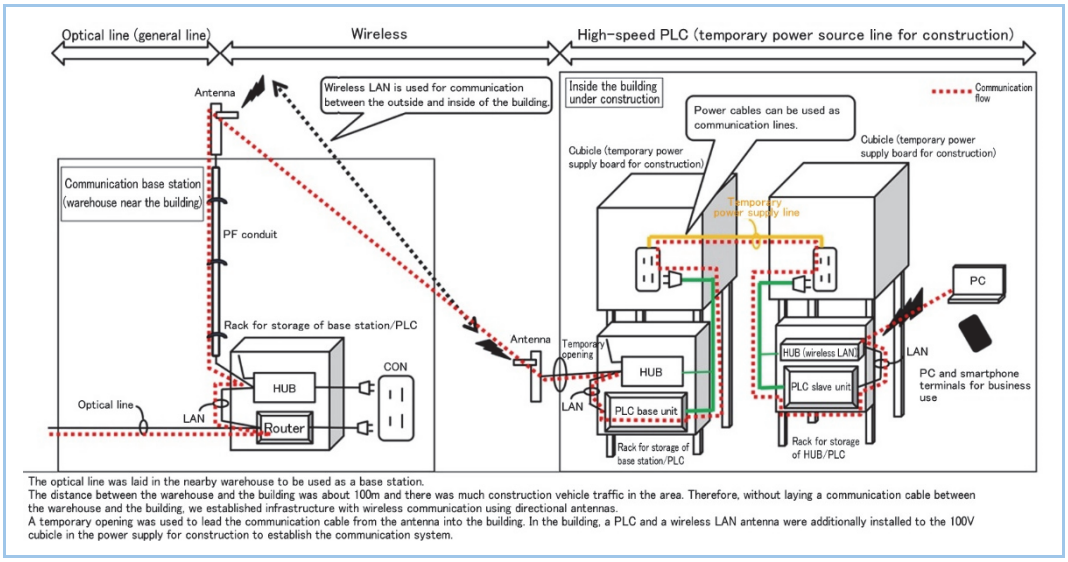


Figure 1 System configuration in verification test for high-speed PLC
The system configuration in the verification test for high-speed PLC is shown. The base station connected to the optical line and the high-speed PLC installed in the building are wirelessly connected via the antennas, and in the building, a communication line is established with the PLC connected to the cubicle.

3.2 On-site delivered items management system

In conventional construction work, as shown in **Figure 2**, there was unconformity in descriptions such as drawing number or name of part on the installation drawings, on the list of delivered items and on the packages of the actual items. We integrated information on items, which had been managed individually by the internal design division, the site construction division and the manufacturer, and established the on-site delivered items management system that allowed us to conduct integrated management of information on items. In the established system, as shown in the flow of **Figure 3**, after the design division issues the purchase request, the internal design division, the site construction division and the manufacturer enter necessary information in the same system so that the consistency of the information is ensured. The necessary information is recorded on an IC tag with a QR code and the IC tag is affixed to the item with each shipment. As shown in **Figure 4**, by reading the QR code with a tablet, we can check the association of the actual items and the item information in a timely manner. From the tablet, information such as storage location and delivery destination can be registered in the system. This system enables integrated management of the status of each item in design, manufacture, receiving and delivery to the site, thereby reducing the time required to search for items in inventory control and for delivery to the site.

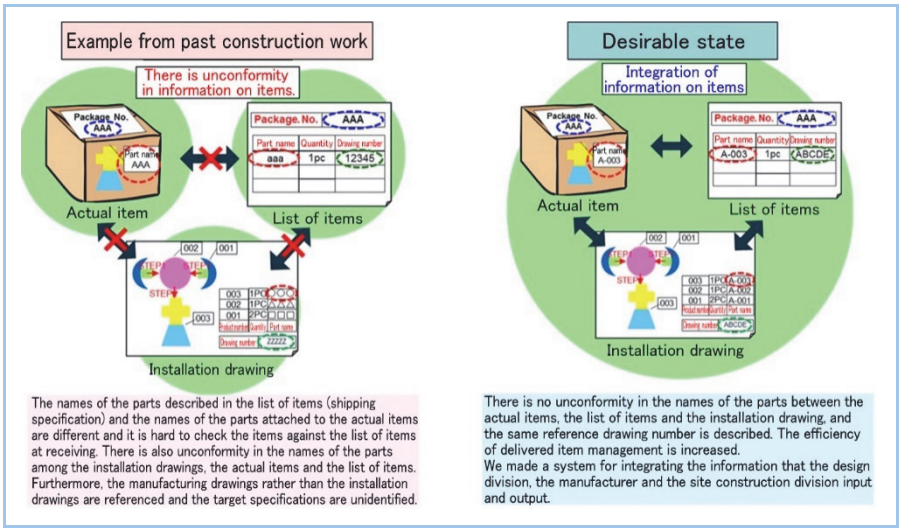
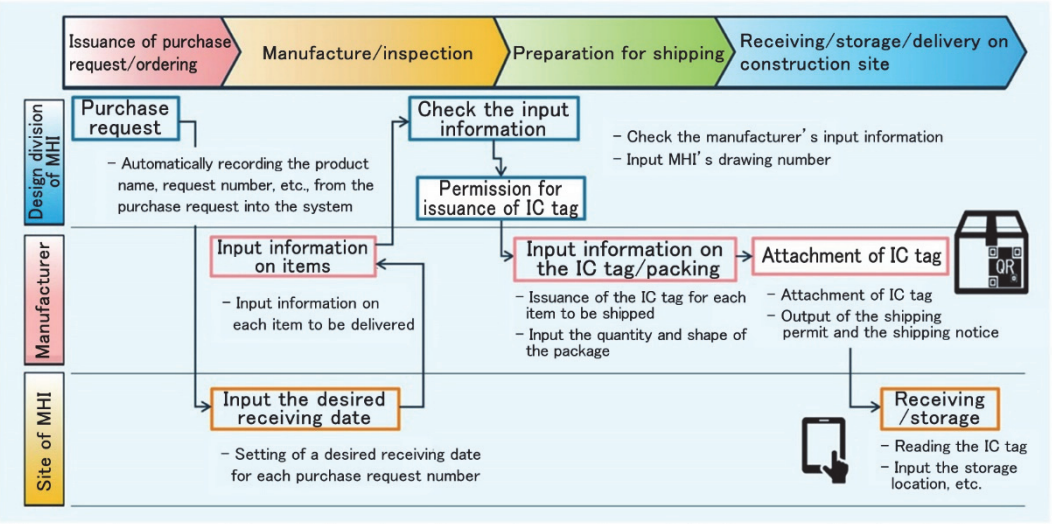


Figure 2 Issues in delivered items management
The issues in the present state and the effects of system introduction are shown. In the present state, there is unconformity in the descriptions on the actual items, the list of delivered items and the drawings.



When a purchase request is issued, information such as product name is recorded in the system. After that, the site construction division and the manufacturer each enter necessary information and the design division checks the contents and permits the issuance of an IC tag. Since the IC tag on which the article information is recorded is affixed to the actual items, workers at the site can check information on items at any time by referring to the QR code.

Figure 3 Flow of delivered items management system

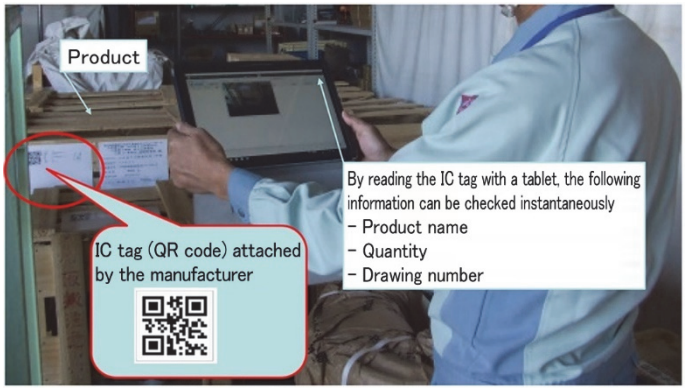


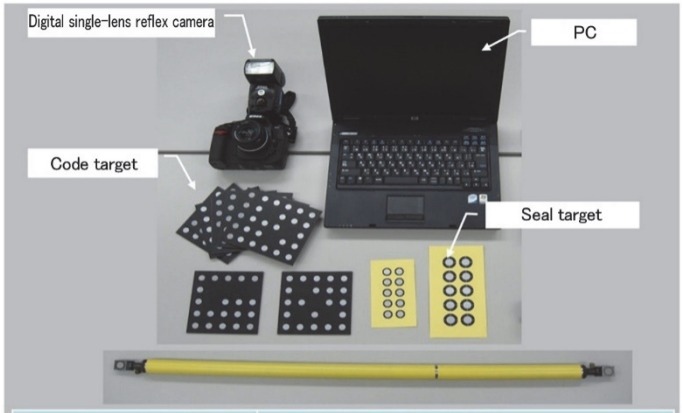
Figure 4 On-site receiving work

When the QR code in the IC tag is read with a tablet, the necessary information on the product is displayed. At the time of receiving a product, the information from the IC tag is compared with the product, and the delivery date, the storage location and other information are entered in the system.

We also established a server in the firewall protected area and introduced multi-factor authentication to restrict the access of external users to enhance security. In the future, we will implement modifications to the system, such as the expansion of the scope of application so that it can be applied to internally produced items and the provision of a receiving inspection function, toward further efficiency improvement.

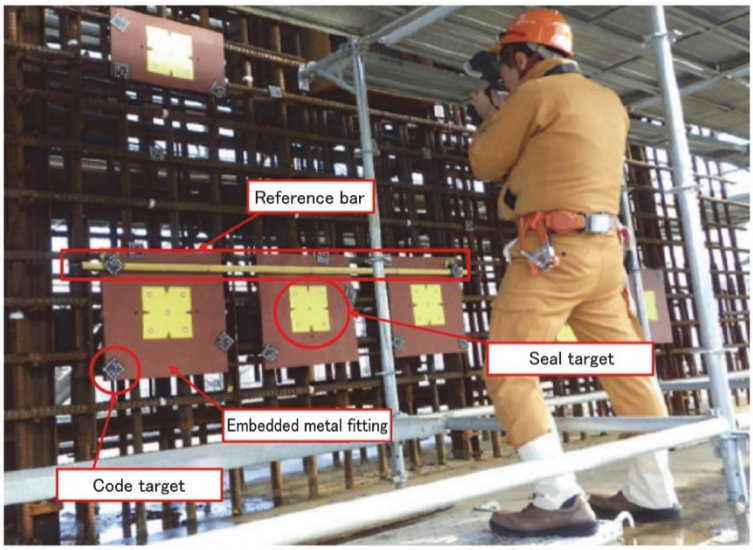
3.3 Application of photo measurement to the inspection of embedded metal fittings

To streamline the on-site measuring inspection for embedded metal fittings, we have conducted verification of utilization of "photo measurement" since 2018. Photo measurement is a three-dimensional measurement method and we have confirmed that it is effective at streamlining measurement work. The equipment that is used in photo measurement is shown in **Figure 5**. In the photo measurement method, different kinds of targets for connecting measurement points and a reference bar serving as the nominal dimensions in a photo are used. As shown in **Figure 6**, the targets that have been established at the site and the metal fittings to be measured are photographed from various distances/angles. When the photos taken are analyzed using the dedicated photo measurement software, the same targets are automatically identified and 3D coordinates of the metal fittings to be measured can be obtained. In addition, the arrangement of the measured target on the obtained 3D coordinates is compared with that on the drawing data input to the software in advance and the measurement result form can be output.



Name	Remarks
Code target	Used to connect multiple photos
Seal target	Used to indicate measurement points such as the centers of embedded metal fittings
Reference bar	Used to check the reference dimensions

Figure 5 Equipment for photo measurement
The camera for taking photos and PC for data capture, analysis and output of forms are general-purpose products. Different kinds of targets for connecting measurement points and a reference bar for providing distance information on a photo taken are used.



This shows the state of photo taking in photo measurement. With different kinds of targets being affixed, the embedded metal fittings are photographed from multiple points. When the photos are joined together, coordinate transformation for each target is performed and the dimension measurement results can be obtained.

Figure 6 State of photo measurement work for embedded metal fittings

A general-purpose camera is used, and the analysis work does not require any special knowledge or skill. Measurement can be performed by the person who takes the photos. Therefore, it is expected that the photo measurement method can contribute to a reduction in the workload at the site. The streamlining effect of the application of photo measurement in terms of working hours is shown in **Figure 7**. We have already started applying the method to actual construction and we have been accumulating results. Application of the method to equipment other than embedded metal fittings is also under consideration.

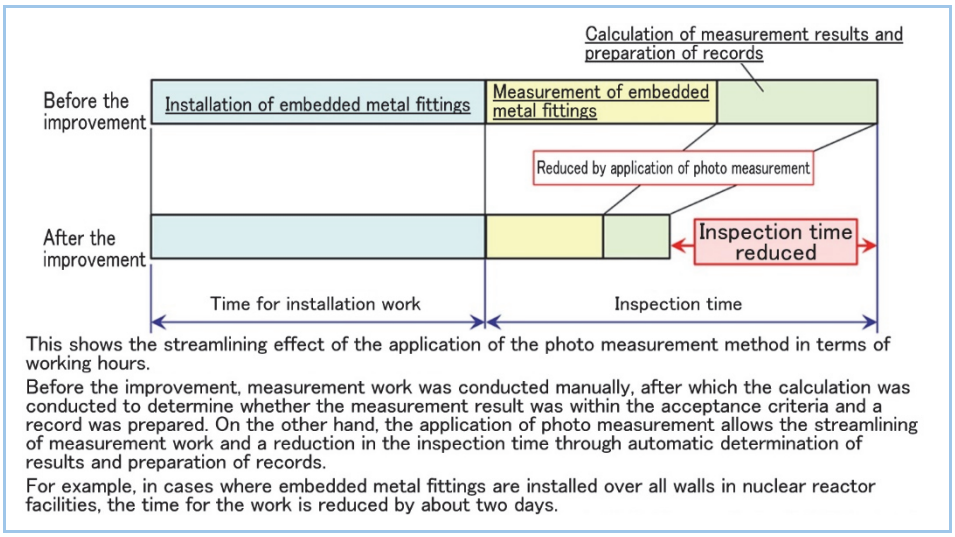


Figure 7 Working hours before and after photo measurement is applied to embedded metal fittings.

3.4 Installation of pipes at the site using 3D measurement

Applying conventional 3D measurement methods for existing pipes, we established a process for substantially reducing the on-site installation cost as the [3D measurement method] by managing the measurement results consistently in the stages from design to product manufacturing. In this method, the positions of the peripheries of existing flanges, the tightening bolt holes, etc., in the repair area are measured, and the measured results are reflected in the drawing dimensions. Furthermore, during manufacturing at the shop, the distortions that occurred during the processing or welding of the pipe block are corrected and the pipe block is reproduced with high accuracy. The reproduced pipe block is carried into the site, replaced and installed serially. In the [on-site pipe fitting method], an on-site fitting pipe for correcting manufacturing errors at the time of on-site installation was used and steps for temporary pipe fitting and returning it to the shop were required. However, the 3D measurement method eliminates the need for these steps, resulting in the shortening of the on-site construction period and a reduction in the safety risk and cost. A comparison between the on-site pipe fitting method and the 3D measurement method is shown in **Figure 8** and **Table 1**. **Figure 9** illustrates the procedure of the 3D measurement method. At present, we have conducted verification of the feasibility and a comparison of costs for each repair area, made proposals to customers and have received their approval. Thus, we have accumulated actual execution results.

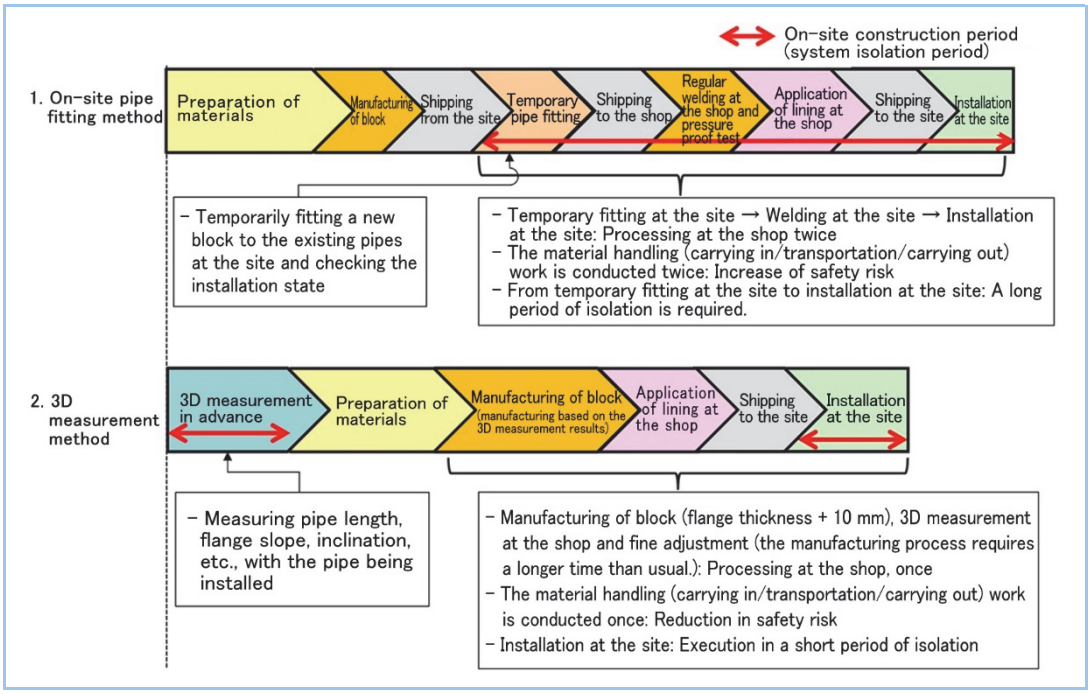


Figure 8 Comparison between on-site pipe fitting method and 3D measurement method

Table 1 Comparison between on-site pipe fitting method and 3D measurement method

Comparison item \ Method	On-site pipe fitting method	3D measurement method
1. Manufacturing at the shop	△ Processing at the shop: twice	◎ Processing at the shop: once
2. Safety risk (material handling work)	○ Carrying in/out: twice	◎ Carrying in/out: once
3. System isolation period	△ The isolation period during execution is long.	◎ The isolation period during execution is kept to a minimum.
Applicable environmental condition	None	- Space for measurement can be secured. - Vibration of the measurement target is limited (system isolation). - Not applicable to wall-penetrating pipe
Assessment	○	◎

Relative assessment:
◎ Best
○ Good
△ Acceptable

In past seawater pipe replacement work, the method was selected according to the execution location, environment, period, etc., in light of the isolation process, workability, etc.
⇒The 3D measurement method has more advantages in terms of securing a process margin in construction and a safety margin at work.

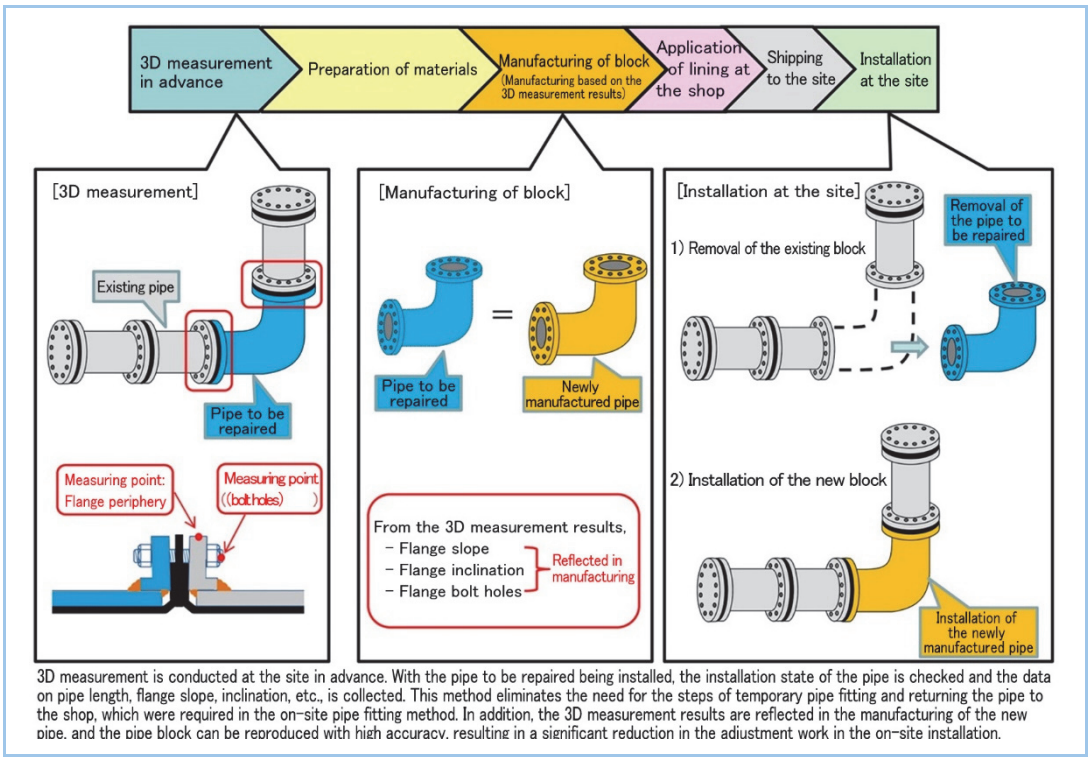


Figure 9 Pipe replacement procedure using 3D measurement method

4. Conclusion

To promote construction work and A/S for nuclear facilities with increased safety and shorter construction periods, we have made efforts to introduce new findings and promote the advancement of construction technology. We firmly believe that the approach that was introduced in this report will contribute to a reduction in the working hours in processes, the improvement of work efficiency and labor saving in the future construction of new reactors. Going forward, we will make efforts to promote the advancement of technologies while confirming effectiveness through the A/S work currently being carried out, and work on technological innovation in construction while obtaining the latest information toward expected future construction work.