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# Shortening Method of Construction Period by Using 3D Measurement

TANEMURA Kazuteru[*1] KYOZUKA Toshikatsu[*2] KANDA Junichi[*3]

***Abstract:***

*About 50 years have elapsed since the majority of steel works in Japan were constructed, and deterioration of aging facilities is proceeding. Although it is necessary to carry out renewal work to avoid the impact on operations, shortening of the construction period is required due to production stops. Also, since many facilities that are already in operation were constructed in the surrounding area, construction methods used at initial construction time cannot be adopted, and it is often necessary to devise new method. In this report, the effectiveness of 3D optical measurement for the improvement of the efficiency of the confirmation of the surrounding interferers when carrying in the large equipment, and the minimization of the field adjustment by the preset determination of the installation position in the case of updating the water cooling duct of the converter exhaust gas treatment facility are reported.*

## 1. Introduction

Many of the large coastal steel works in Japan were constructed around the 1960s, and equipment has now been in operation for 50 years since startup. Even with proper maintenance, aging facilities undergo progressive deterioration when equipment is operated under severe environments characterized by large loads, high frequency of operation and high temperatures, like the environment of steel making machinery. As an additional problem, that deterioration degree has now reached unknown territory, and in some cases, unexpected deterioration has a large impact on operations. In recent years, JFE Steel has carried out large-scale equipment renovation projects, focusing particularly on strengthening its production base and realizing tough, resilient manufacturing capabilities.

Since it is necessary to stop production by the equipment undergoing renovation in order to carry out a renovation project, methods for shortening the construction period are demanded. Even when similar backup equipment is available, a production stop will be necessary if trouble occurs in the backup equipment. Thus, shortening the construction period is unavoidable requirement from the viewpoint of minimizing risk. However, unlike the initial construction, when construction is carried out while surrounding facilities continue to operate, there are large restrictions on the shape and installation positions of the new equipment, particularly in the renovation of large-scale facilities. Since the general practice is to divide large equipment into smaller component parts, which are then assembled at the site, a lengthy construction period is inevitable. Moreover, with today's higher safety levels, which reflect the painful lessons of past industrial accidents, it is also necessary to implement sure safety measures at every stage of construction, and dangerous work omitting those measures is not allowed.

On the other hand, accompanying advances in information technology, the environment surrounding new equipment can be acquired as the 3-dimensional (3D) coordinates of a large point cloud by irradiating a laser in the full 360° range from the measuring instrument around whole circumference and measuring the distance and angle, and this data can be acquired with measurement error of 1 mm or less, within a time of

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[*1] Staff Deputy Manager,
Plant Engineering Technology Sec.,
Plant Engineering Dept.,
East Japan Works(Keihin),
JFE Steel

[*2] Manager,
Steelmaking Plant Maintenance Sec.,
Plant Engineering Dept.,
East Japan Works(Keihin),
JFE Steel

[*3] Staff Assistant Manager,
Steelmaking Plant Maintenance Sec.,
Plant Engineering Dept.,
East Japan Works(Keihin),
JFE Steel



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only several minutes. Moreover, a virtual factory can also be reproduced on a computer from the point cloud data with a data size of several 100 GB obtained in this manner[1].

This paper presents a report on renovation of a deteriorated water-cooling duct of a steelmaking shop converter exhaust gas treatment facility at JFE Steel East Japan Works (Keihin). Conventionally, when large blocks of equipment were to be carried into a site, a study of drawings and an actual carrying-in test using a simple model with an external shape similar to the actual objects were necessary. However, with the aim of improving efficiency, we searched possible delivery routes by using virtual equipment using a point cloud and CAD model. It was also possible to minimize repair work at the site by deciding the positional relationship with the reused equipment outside the scope of the renovation in advance, thereby shortening the construction period.

## 2. Efforts for Application of Large Block Construction Method

### 2.1 Outline of Converter Exhaust Gas Treatment Facility

In the converter process, pig iron is refined into steel by decarburization by blowing an oxygen jet into the molten pig iron from a water-cooled tube called a lance. Because this process generates a high temperature, flammable exhaust gas with a high dust content, exhaust gas treatment equipment is necessary. As part of this exhaust gas treatment equipment, the water-cooling duct that carries the high temperature gas to the venturi scrubber recovers the heat of the exhaust gas as energy in the form of steam. This duct generally consists of a panel-type water cooling wall (membrane wall), in which several 100 boiler tubes aligned in the exhaust gas flow direction connected by fins, as shown in **Fig. 1**. Unlike the boilers in electric power plants, etc., in a converter exhaust gas treatment facility, the tubes undergo cyclical heating and cooling with a cycle of several 10s of minutes, corresponding to the conditions of the steel refining process, and this causes thermal fatigue cracks. Since the tubes are deteriorated by these cracks and erosion by dust, which consists mainly of iron oxides, renovation of the water-cooling duct becomes necessary at roughly 10 years.

### 2.2 Issues in Conventional Construction Method

The overall layout of the converter exhaust gas facility at East Japan Works (Keihin) is shown in **Fig. 2**. The water cooling duct consists of the skirt, lower hood, upper hood, No. 1 radiation part and No. 2

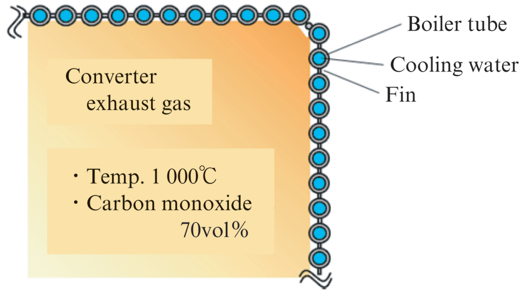



Fig. 1 Schematic diagram of converter exhaust gas treatment facility water cooling duct

radiation part. Installation was possible when the plant was originally constructed, as the water cooling duct equipment was carried in large blocks in order from above before installation of the converter itself. At present, however, with the equipment in operation, it is not possible to use the original method due to the presence of belt conveyors, hoppers and their instrumentation equipment and wiring. For this reason, it was necessary to divide the panels of the water cooling duct. However, if the panels of the water cooling duct are divided, it is necessary to connect several 100 boiler tubes by butt welding at the site, and this would require much time for position correction in millimeter units, as well as the actual welding work.

Among the water cooling duct equipment, at Keihin it was possible to use the preassembled unit renewal method for the skirt and lower hood, as those parts were comparatively small in scale, but the No. 2 radiation part was located in the innermost part of the building and was surrounded by adjoining equipment that was in operation. Therefore, a renovation method in which the panels were divided based on transportable size was selected. First, the idea of preassembled unit renovation had also been proposed for the upper hood in the past. However, there was no margin in the clearance (passage) between the dimensions of the building and the assembled dimensions of the upper hood, and there was also a real risk that it might be necessary to stop construction if passage of the hood was found to be impossible after construction had started. Considering these problems, the preassembled unit method was rejected. Preassembled installation of the No. 1 radiation part was also impossible since that part was even larger than the upper hood, but in order to shorten the construction period, it was necessary to reduce the number of blocks as much as possible.

In order to carry out a renovation by the preassembled unit or large block methods, all of the objects that may interfere with carrying in or installation work must be identified. Because the original drawings of the building and equipment had been done by hand, data unifying those drawings was prepared, and a study

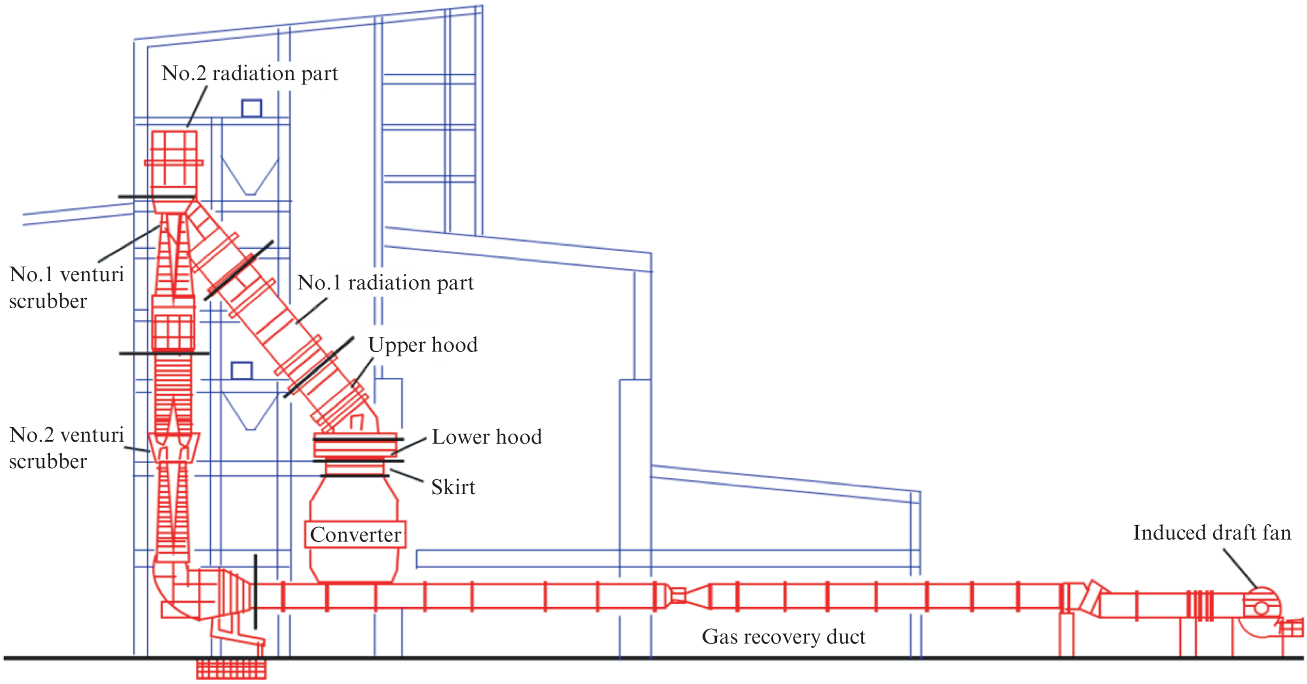



Fig. 2 Schematic diagram of overall converter exhaust gas treatment facility

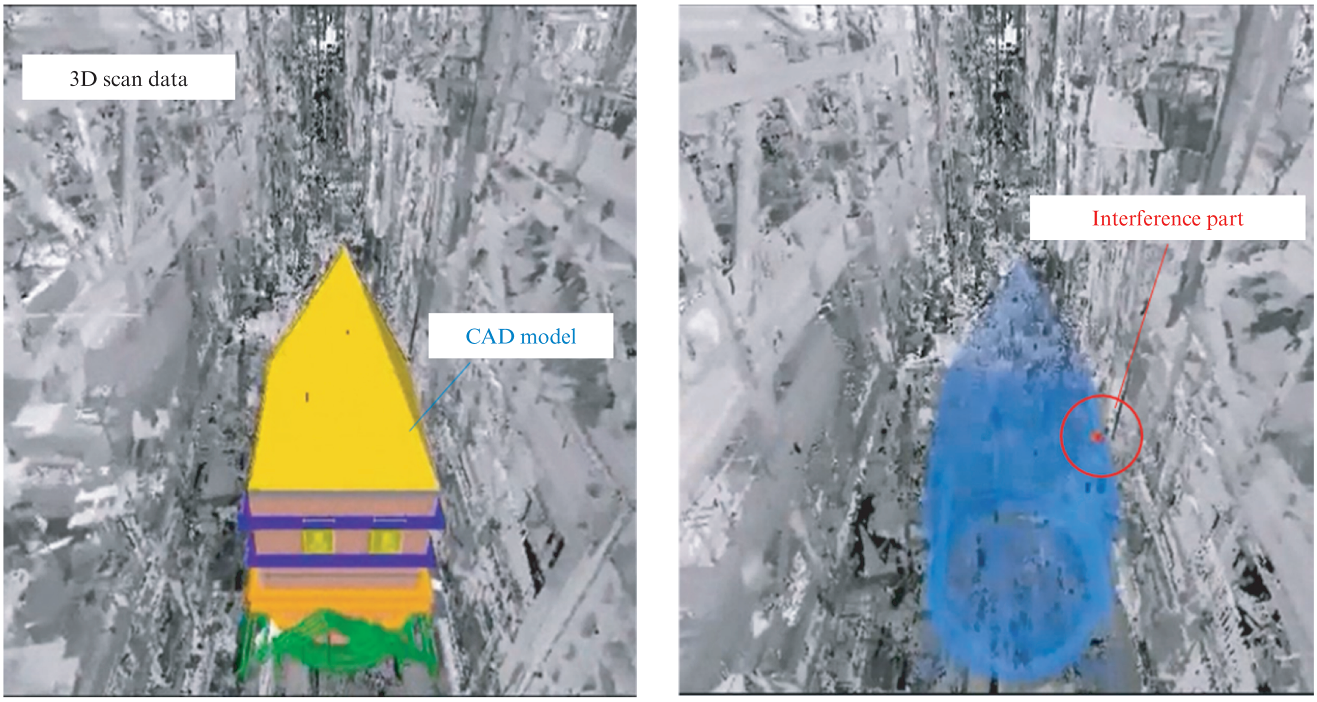
was carried out by continuously changing the position and attitude of the new equipment. This process required an enormous amount of work. On the other hand, carrying-in tests had been carried out in the past by constructing actual-scale welded models using shape steel, but the high cost and large amount of labor were issues.

### 2.3 Study of Construction Method of 3D Measurement

To obtain a convenient, detailed understanding of the positional relationships between the cooling duct structure and the surrounding equipment, a 3D laser scan was applied to the converter building. Unlike the information in drawings, a 3D scan acquires the surrounding environment as an aggregate of fine points having 3D coordinates, and can measure actual objects. For this reason, it is an excellent technique for digitizing facilities, including even hoses and cables, small diameter piping, traps in building columns, and spare equipment and various devices located on each floor, which are not necessarily shown in drawings. However, fine airborne dust is a significant problem in converter buildings. If that dust reflects the 3D scan laser, an interfering object will be generated in the data, even in spaces which are completely empty. Superimposing several iterations of scan data and having a responsible person with a good knowledge of the site make noise judgments are effective approaches for removing this data as noise.

**Figure 3** shows images from the study of carrying equipment into the building using the overhead traveling crane, which was carried out with the aim of applying the large block construction method to the renovation of the No. 1 radiation part. Here, a CAD data model of the new equipment, including 4 hanging wires, was introduced in the virtual space constructed from the scan data. With the software used here, the CAD model of the new equipment changes to transparent blue if the scanned point cloud intrudes into the model, and the intruding point cloud is displayed in red. This makes it possible to judge which objects that interfere with the equipment being carried into the actual plant can be removed, and which are necessary for operation. If it is possible to remove an interfering object, that object is removed in advance, and if an object is necessary, the data is searched for a route that avoids that object. This greatly reduces the risk of a critical situation in which it is impossible to pass some unexpected obstacle during actual construction at the site. Moreover, study of drawings is often limited to only a few angles, even when the attitude is changed during installation at the site, but with the technique using a 3D scan, a detailed check, including interference between the hanging wires and the surrounding equipment, is possible by continuously changing the angle.

If these data are presented to the construction company and the construction method is studied while viewing those images, sure execution of the construction work is possible by assigning monitoring personnel to spots where care is necessary to avoid interference during carrying-in work, selecting more appropriate hoisting gear and the like. Furthermore, since the work




(a) No interference case

(b) Interference case

Fig. 3 Study of bring in using 3D scan data and CAD model

procedure could be presented in the form of a video, this also contributed to a deeper understanding by the individual construction workers and safe construction work.

At East Japan Works Keihin, preassembled unit renovation of the upper hood and large block renovation of the No. 1 radiation part were carried out using this technique, achieving a large reduction in the construction period in comparison with the conventional technique and 100% accident-free completion of all work.

## 3. Efforts for Efficient Installation Position Adjustment

### 3.1 Efficient Position Adjustment of Upper Hood

Because the upper hood is designed to cover the top of the converter body, it has a structure that is retracted horizontally during refractory brick relining work in the converter. The hood also has a lance hole, a probe hole for the converter sampling probe and a flux chute for supply of lime and other materials, as shown in **Fig. 4**, and these must be at the correct positions when the hood is returned to the operation possible after the renovation. This also includes the joints with the adjoining parts of the water cooling duct (i.e., the lower hood before and the No. 1 radiation part after the upper hood). Adjustment is comparatively easy when the hood is in the operation position, since the position can actually be measured against the target object. However,

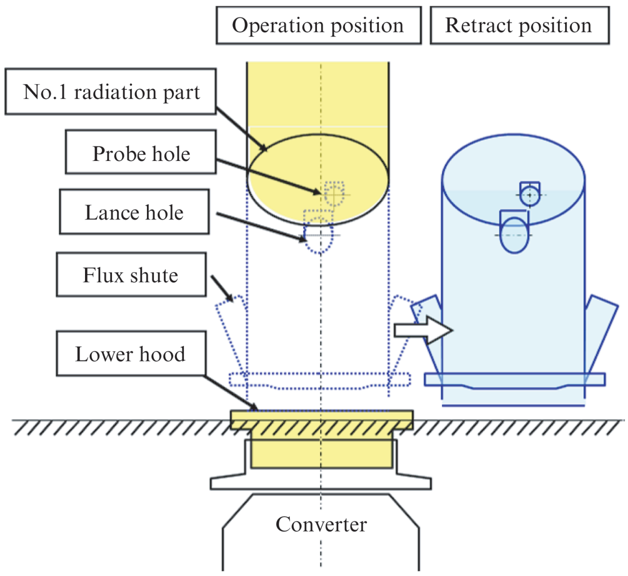



Fig. 4 Various connections of upper hood and retracted position

brick relining work cannot be performed during that period. Therefore, position adjustment is performed with the hood in the retracted position, but large adjustments are not possible, as there is no target object, and final adjustment with the hood in the operation position is ultimately necessary.

To solve this problem, the target object was digitized in advance by a 3D scan, and position adjustment was performed by constructing a virtual target object at the retracted position by changing the coordinates in the direction of hood movement.

This made it possible to perform the brick relining work and the upper hood position adjustment work simultaneously. When the hood was returned to the operation position, no corrections of the various connections were necessary, and the work was completed simply by checking their condition.

### 3.2 Efficient Position Adjustment of No. 1 Radiation Part

Excluding small diameter piping that can be positioned comparatively easily, the only parts that must be connected with the No. 1 radiation part are the upper hood and the No. 2 radiation part. This renovation work was carried out by a large block method in which the No. 1 radiation part was divided into three blocks, and the upper, middle and lower ducts were carried in and installed in order.

In preassembly of each of the blocks of the No. 1 radiation part, the position of the connection between the upper hood and the lower duct, which is installed last, is decided based on the position and attitude of the upper duct, which is connected with the No. 2 radiation part, in order to butt weld the boiler tubes. If the joint is low, the duct will interfere with the upper hood, and if the joint is high or the centers are not properly aligned, converter exhaust gas will leak from the crack. Position adjustment is necessary if the height of the joint exceeds the allowable value, but due to the large scale of the No. 1 radiation part, large amounts of equipment, personnel and time are necessary for adjustment of the installation position after preassembly.

To decide whether position adjustment of the entire No. 1 radiation part was necessary in installation of the upper duct, the middle and lower ducts were preassembled virtually with the 3D-scanned upper duct to determine whether the joint position (seam line) with the upper duct was within the allowable range. **Figure 5** shows an example.

Even though a certain amount of work time was necessary in this stage, position adjustment of the single upper duct is relatively easy. As a result, a total position adjustment after complete preassembly was not necessary, and the construction period could be shortened.

### 3.3 Efficient Determination of Reference Panel Position of No. 2 Radiation Part

In the renovation of the No. 2 radiation part, it is necessary to divide the water cooling duct into about 100 panels with small areas. Since the overall position and shape can be maintained if it is possible to repeatedly remove only the panel parts which are to be replaced, and then install the new panels, position adjustment is not necessary in this case. However, because the old duct remains in place, there is a limit on the size of the panels that can be carried in, and the boiler tubes of the old and new panels must also be connected, resulting in a long construction period.

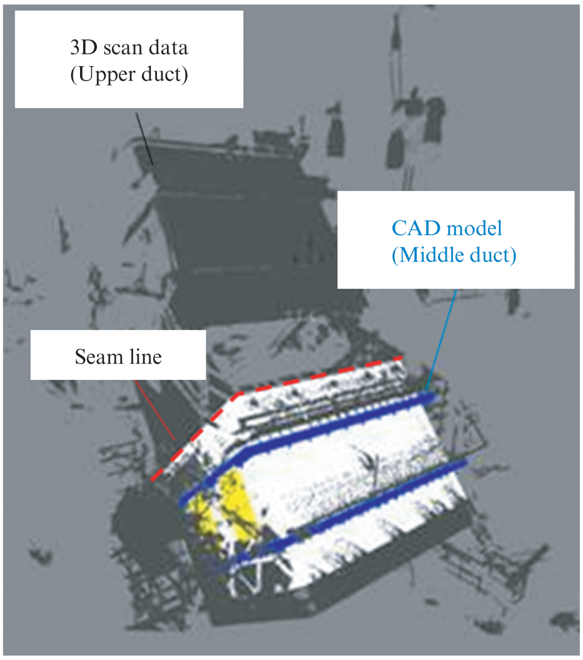
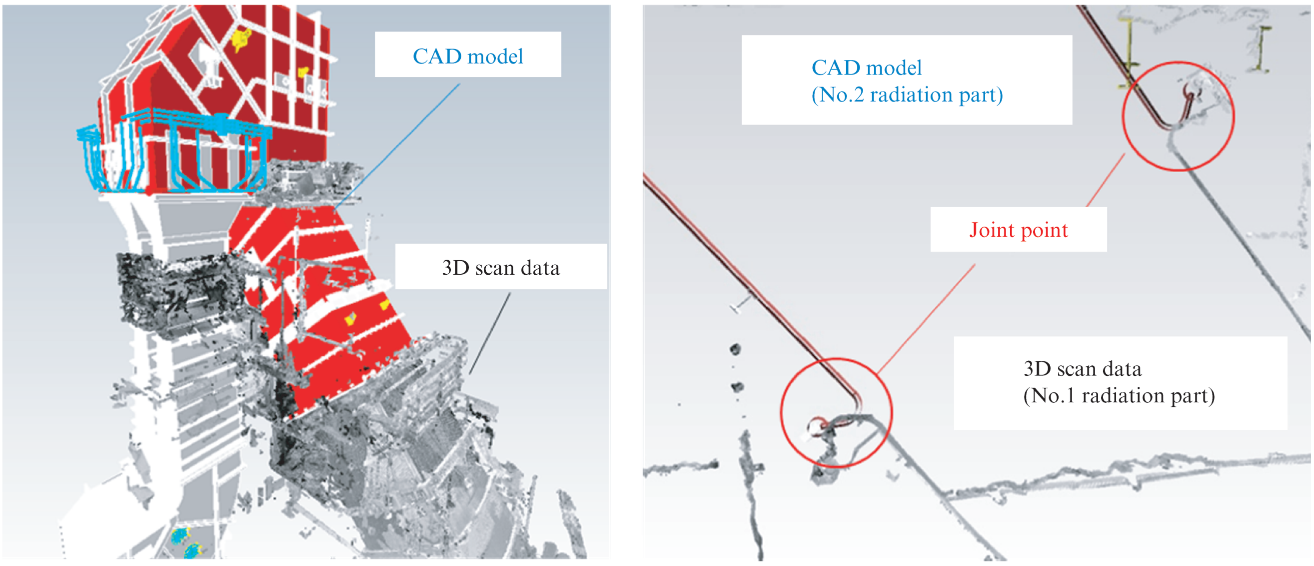



Fig. 5 Position examination of upper duct and middle duct of No.1 radiation part

To shorten the construction period, the entire No. 2 radiation part was removed once, and after installing the panels positioned in the middle part, the new panels were connected simultaneously in parallel in the upper and lower parts. In this case, the possibility of connection with the preceding-stage No. 1 radiation part and the following-stage venturi scrubber is decided by the position of the intermediate panels, which are installed first. Therefore, as shown in **Fig. 6**, the position of the middle panels was decided by using a combination of a 3D scan of the actual object and a CAD model of the new part, which was the same as the technique described up to this point. In equipment that extends over multiple floors, like the No. 2 radiation part, much time and trouble are required to measure the position of the joint part, not only with the traditional method using a tape measure and plumb bob, but even when using a laser rangefinder and laser level. However, a 3D scan is a particularly useful technique because the dimensions and angles of any desired point can be obtained easily. In comparison with the conventional method, the construction period was shortened by approximately 25% by adopting the construction method using 3D scan technology.




(a) Overall study drawing

(b) Connection diagram with No.1 radiation part

Fig. 6 Combination example of scan data of No. 2 radiation part and CAD model

## 4. Conclusion

This article described a technology for shortening the construction period, in which a combination of a 3D laser scan and a CAD model was adopted in a renovation of the water cooling duct of a converter exhaust gas treatment facility.

(1) In construction in a building where neighboring equipment was in operation, the assembly process could be shortened by carrying in the new equipment in preassembled unitary form or divided into large blocks.

(2) In installation of new equipment, position adjustment work in the final stage of construction could be shortened by using data to confirm the positions of connections with various reused equipment in advance.

### References

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