Installation of Condenser for Steam Turbine by Large Block Construction

—Hokuriku Electric Power Company’s Shika Nuclear Power Station Unit 2—

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OVERVIEW: The power market has seen rapid deregulation and liberalization, and this has strongly motivated the power industry to streamline equipment costs and reduce construction schedules. This calls for a radically new construction method that can respond and accurately target these needs. The conventional approach has been to construct heavy equipment such as condensers in fabrication shops and deliver the finished equipment to the site, which involves a number of restrictions. To overcome these restrictions, Hitachi built the Futo Factory at the 4th wharf of Hitachi Port in September 2000 specifically to fabricate condensers. A permanent crane capable of lifting up to 500 t is situated near Futo Factory and is capable of shipping condensers implemented as large blocks. Using this facility, the time frame needed to fabricate and install equipment for the Hokuriku Electric Power Company’s Shika Nuclear Power Station Unit 2 (SU2) has been substantially reduced.

INTRODUCTION

WORK began on the Hokuriku Electric Power Company’s Shika Nuclear Power Station Unit 2 (SU2), a 1,358-MW capacity ABWR (advanced boiling water reactor), in August 1999 and is scheduled to begin commercial operation in March 2006.

The world’s largest class mobile crawler crane with a lifting capacity of 30 m by 930 t is being used to install the condensers, etc., and construction is proceeding by assembling large blocks.

Condensers for nuclear power plants are massive in size so typically the lower shell is fabricated in a number of blocks while the upper shell is implemented in panels at a fabrication shop then delivered to the

Fig. 1—Large Mobile Crawler Crane Lifts Lower Shell Block (left) and Upper Shell Block (right) onto Turbine Generator Base.
Installation work of installing a condenser is greatly reduced by fabricating the equipment in a shop specialized in condensers, then installing the condenser in large blocks onto turbine generator base columns.

site and assembled as the blocks are lifted into position by a crane.

For the SU2 project we adopted a different approach: the lower shell block was assembled with all of the tubing welded into place and two heaters were installed in the upper shell block, and these were assembled at the fabrication shop into large 270-t blocks. This substantially reduces the on-site construction time that would normally be required to install a condenser of this magnitude.

What makes such large block construction possible is the availability at Hitachi, Ltd. of the world's largest class crawler crane. Using this large crane, we are able to assemble blocks of unprecedented magnitude in the construction of a condenser for the world's largest class nuclear power plant. Not only does this approach greatly reduce the on-site construction time, it also contributes significantly to improved quality and construction safety at the construction site (see Fig. 1).

This paper gives an overview of the large block construction method that was used in fabricating and installing the steam turbine condenser for SU2 ABWR of Hokuriku Electric Power Company in Ishikawa Prefecture.

CONDENSER SPECIFICATIONS

The condenser for Hokuriku Electric Power Company's SU2 ABWR and houses 12 low-pressure heaters. Table 1 summarizes the main specifications.

With a cooling surface of 102,000m^2 and over 1,100 km of titanium tubes (length × number of tubes), this is the largest class condenser available anywhere. Anticipating that we would be using a large block construction approach, we employed SMA490AP, a higher tensile strength material than that used before for the main sections and this permitted thinner walls which made the equipment lighter.

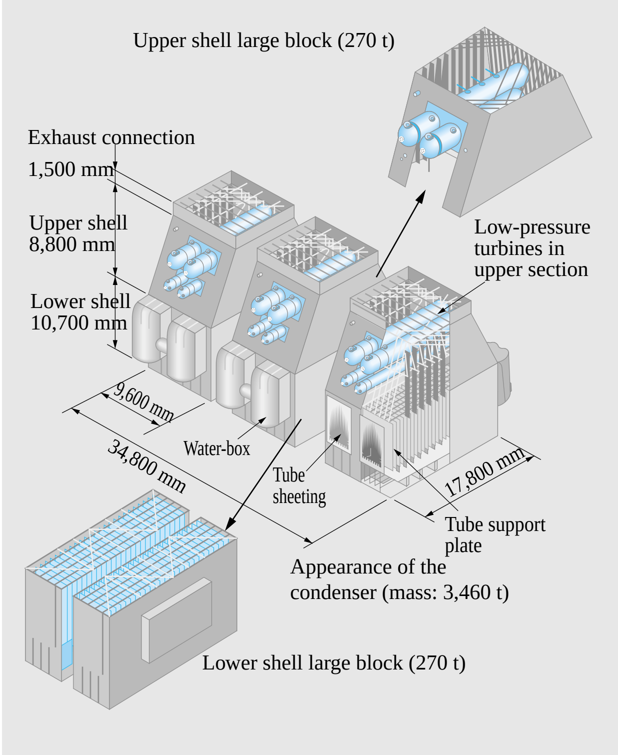

Fig. 2—Condenser's Cut-away View and Division into Large Blocks.
The lower shell making up the bulk of the condenser's 3,460-t mass is divided into two sections (assembled tubes at a shop), and the upper shell housing two heaters is implemented as a single block.

The condenser consists of following sections:
(1) the lower shell is the core where the tubes are located,
(2) the upper shell housing the low-pressure heaters, and
(3) water-boxes that feed seawater into the tubes and exhaust connection fixed to the low-pressure turbines (see Fig. 2). The water-boxes and exhaust connections are relatively smaller and less massive than the other

TABLE 1. SU2 Condenser Specifications
One of the largest condensers ever manufactured with 102,000 m^2 of cooling surface and over 1,100 km of tubing (length × number of tubes).

Item		Specifications (3 shells)
Type		Surface contact 3 shells
Cooling surface		102,000 m^2
Tubing	Outer dia.	28.58 mm
	Thickness	0.5/0.7 mm
	Effective length	17,790 mm
	Number	63,864
Material	Tube	Titanium (JIS TTH340)
	Tube sheets	Titanium grade sheets (JIS TP270 + SMA490AP)
	Shell	Corrosion resistant steel (JIS SMA490AP)
	Water-box	Steel sheets (JIS SS400) + rubber lining
Weight		About 3,460 t (including built-in heaters)

TABLE 2. Comparison of Specifications for Fabrication, Delivery, and Installation of Condensers
We are now able to handle much larger blocks with completion of a dedicated fabrication shop for condensers, and using a large crawler crane for installation and a temporary crawler crane for off-loading the blocks.

	Former	Current (SU2)
Shop fabrication	Overhead traveling crane (no practical mass limitations)	Same
Transport at site	Rollers (no practical mass limitations)	4 multi-roller chassis Max. capacity: 400 t
Transport to ship	Floating crane Max. lift capacity: 200 t	Permanent crane Max. lift capacity: 500 t
Ocean transport	Ship or barge (no practical mass limitations)	Same
Off-loading at site	Permanent crane Max. lift capacity: 150 t	Temporary crawler crane Max lift capacity: 450 t
Transport at site	Multi-axial trailer (no practical mass limitations)	Same
Installation	Large tower crane Max. lift capacity: 130 t (some use of giant crawler crane)	Large crawler crane Able to install upper shell Max. 91 m × 341 t

sections and block construction has been used for this section in the past. The challenge of the SU2 project is that the lower and upper shells (which have always been constructed in the piecemeal conventional way) are also being implemented in large blocks for this project.

EQUIPMENT SPECIFICATIONS AND LARGE BLOCK ASSEMBLY

Specifications of Manufacturing Equipment and Installation Equipment

Up to now the permissible upper limit on the size and mass of blocks has been constrained by equipment capacity at each stage of the process: fabricating and shipping the blocks from the shop, off-loading the blocks near the site, transporting the blocks at the site, installation of the blocks, etc. Due to these limitations, large blocks have always been kept under 150 t in weight.

With Hitachi's recent completion of a shop specifically set up to fabricate condensers measuring up to 32-m wide by 240-m long (7,680 m^2), we are capable of delivering condensers weighing up to 500 t using a permanently installed crane. Some of the restraints including economical matter of the past have been eliminated by using a large crawler crane for installation so we can now handle much larger blocks than in the past. Table 2 shows a comparison of new equipment for the SU2 project and conventional equipment.

Description of Large Blocks

Lower shell block

The lower shell can be implemented as a large block in one of two ways, either with the tubing (bi-block method) or without the tubing preinstalled (integral method). If the block is configured without the tubing, this not only increases the construction steps at the site but also exceeds the lifting capacity of the giant crawler crane for installation. So we opted for the latter approach.

Adopting this approach, there were six lower shell blocks. The largest block measured 6-m wide by 10.9-m high and 17.9-m long, and weighs 270 t which increases to 310 suspension t with the addition of suspension rigging. Then, with the positioning of the giant crawler crane for installation, the maximum work diameter of the lower shell block that is brought in from the far side is 94 m. The weight of this block approaches 250 t so all of the blocks can be installed by the large crawler crane.

Upper shell block

The four sides of the upper shell block are flat panels while the top and bottom are of an open trapezoidal shaped box structure. In the case of completed work, four built-in heaters are arranged inside. The weight of the heaters is approximately 45% of the total weight of the upper shell block. The structure consists of two upper level heaters installed in the upper shell block, and two lower level heaters are installed in the upper part of the lower shell to provide support.

Since it would be difficult to fabricate the upper shell block with the two lower level heaters, they were excluded. This results in an integral structure measuring 10.1-m wide by 9.5-m high and 18.3-m long with a weight of 270 t (a maximum suspension

Fig. 3—Condenser Lower and Upper Blocks under Construction.
The shop building measuring 32-m across was fully utilized. Lower (left) and upper (right) shells are arranged side by side, and the three sections of the condenser were implemented in a total of nine blocks.

weight of 330 t when the suspension rigging is included).

The shapes of the lower and upper shell blocks are shown in Fig. 2, and a view of the shop with blocks under construction is shown in Fig. 3.

TECHNOLOGICAL CONSIDERATIONS

When the large blocks are being delivered, we must consider that different loads from their actual operating state may act on the blocks from the time they are being transported by sea until the blocks are delivered at the site. For this reason we carefully studied the strength of the blocks under different transport and lifting conditions. The main technical considerations are briefly summarized as follows.

Number of Lift Points and Load Adjustment

The number of lift point can be reduced by increasing reinforcement for transportation. However, this is not always an effective procedure considering the amount of additional work involved in adding the reinforcement at the shop then removing the reinforcement at the site. The number of lift points also affects the strength and amount of deformation of all the lift points, so each configuration must be carefully evaluated using the FEM (finite element method) to determine the optimum solution.

The lower shell block is relatively more rigid with less load distribution unbalance, so only requires eight lift points. In this case, each lift point must be capable of holding 30 to 43 t. The upper shell block is quite different. It is open at both the top and bottom, and the two built-in heaters partly overhang. Since the weight of the upper shell block is off-center both side to side and front to back, 19 lift points are required. Four of these lift points are to accommodate the overhang of the built-in heaters. In the actual lifting work, a special lifting beam is employed for both upper and lower shell blocks, and a chain hoist and load cell are used at each lift point to adjust the load.

These lifting procedures are done three times in delivering the large blocks: in shipping, off-loading, and lifting the blocks into position. In each case, the same essential procedures and steps are taken.

Strength Analysis Reflects Acceleration

Dynamic load considerations must be factored into the strength analysis in addition to static loads, so acceleration is set for the strength study. The strength analysis was done assuming about 4.9 m/s^2 (2.0 G) in the lateral direction (to accommodate rolling and pitching during transport in the shop and at sea) and about 19.6 ms^2 (2.0 G) in the vertical direction. Actual measurements of the blocks in transit revealed that the maximum movement in the lateral direction was only 2.94 m/s^2 (0.3 G) and about 9.8 m/s^2 (1.0 G) in the vertical direction, so our allowances were more than sufficient.

Sea Transport

Given the size of these large blocks, there was really no other way to transport them except by sea. We were able to transport the lower shell block on board a 1,600-ton domestic vessel, but the hatch clearance of the largest ship is only 10-m wide. This meant that the upper shell block, which exceeds 10 m, could not be transported by ship. This block had to be moved using a 3,000-ton capacity (20-m wide by 60-m long) barge. The water portion of the delivery involved eight trips altogether: lower shell large block were carried on six vessels and the upper shell integrated blocks were moved using two barges (two upper shell blocks and one upper shell block per barge). The lower sections delivered by vessel were so high that they had to be moved with the hatch open. As with the upper shell block delivered by barge, the shell block delivered by vessel had to be covered with water- and fire-proof sheets to protect the condenser equipment against rain and seawater.

Off-loading Transport to Plant Site

Permanent cranes for off-loading the equipment near the power station have a limited lifting capacity of 150 t. So for this project we brought in a temporary crawler crane to do the off-loading. Movement range is covered by steel plates that can withstand loads up to 175 kPa. Heavy 680-t capacity multi-axel trailers were used to transport the blocks from the off-loading site to the plant, a distance of about 2 km (crossing a public road at one point).

Lifting Lower and Upper Shell Blocks into Position with Large Crawler Crane

Outfitted for the project with a Mode B auxiliary jib, the rated capacity of the large crawler crane used to lift blocks into position was 30 m × 930 t. However, the maximum work diameters involved in lifting the condenser blocks into place were 94 m for the lower shell block and 91 m for the upper shell block. This required a lifting capacity of 304 t and 341 t, respectively, so the maximum lift weight with added lift rigging was satisfied.

The gap between the condenser lower shell block and turbine generator base is narrowest for the bottom part of the lower shell block, measuring only 40 mm when installed. In order to lift the large block into position after one part of the two-part lower shell block had been put into place, we installed a positioning guide so we could drop the blocks precisely into place with virtually no gap.

CONSTRUCTION TIME MARKEDLY REDUCED

Installation of the condenser proceeded as follows: After lifting the lower shell blocks into place, the blocks were welded together and the strength of welds were verified. Next, the upper shell blocks were lifted into position and the lower and upper shells were welded together. After delivery of the lower shell block commenced on May 17, 2002, the lower shell and upper shell blocks were successively transported to the site. Never leaving blocks on site for longer than two weeks, the work of installing the blocks on the turbine generator base was completed by July 20, 2002 as short as in 64 days. Compared to modest construction project at another ABWR plant that required approximately nine months to complete, the time required for the SU2 project was remarkably short.

EFFECTS OF APPLYING LARGE BLOCK CONSTRUCTION

Here we will highlight the chief advantages of applying the large block construction method for the installation of condensers.

(1) Parts installed on-site and installation work greatly reduced

By adopting the large block construction method, the on-site work was significantly reduced compared to the conventional panel construction method. Moreover, by handling the two built-in heaters as blocks, the work of installing heavy parts in the condenser was eliminated.

(2) On-site area needed for storage and assembly eliminated

In the conventional four block assembly method, the work of installing tubing in the condenser must be done before the condenser can be installed in its permanent position. This requires workers to wait until the installation work on the front of the condenser is finished or set aside an area on site for assembly work, and only after all temporary assembly work of inserting tubing is completed can the blocks be lifted into place. This requires an area must be set aside to keep and assemble the products on site, and also requires equipment to perform the assembly work on site.

These various inefficiencies are eliminated by using the large block construction method.

(3) Tube welding at the shop is far more reliable and efficient.

The work of inserting an extremely large number of tubes and expanding and welding tubes is better done at the shop where environmental conditions are optimum. This not only results in better quality work, but also alleviates congestion at the power plant site.

CONCLUSIONS

This paper presented an overview of the large block installation of a condenser using a Hitachi large crawler crane at Hokuriku Electric Power Company's Shika Nuclear Power Station Unit 2. Adopting the large block approach for the condenser has proved very beneficial for the SU2 project, and the construction work is moving ahead smoothly and according to schedule.

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