METHOD FOR SHORTENING THE CONSTRUCTION PROCESS OF A LARGE-SCALE LNG RECEIVING TERMINAL

METHODE DE REDUCTION DU DELAI DE CONSTRUCTION D'UN TERMINAL DE RECEPTION GNL D'UNE GRANDE ECHELLE

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ABSTRACT

Chubu Electric Power Co., Inc. has recently constructed, along with an extension of No. 3 and No. 4 units of high-efficiency combined cycle power generation system (total output 3,300MW) at its Kawagoe Thermal Power Station, a new terminal for receiving approximately 3 million tons of LNG annually from first project in Qatar, the Near & Middle East.

This terminal, which includes 1 unit of unloading facilities for receiving 135,000 m^3 LNG tankers, 4 LNG tanks of 120,000kl capacity (above ground metallic double-shell type), 4 LNG evaporator units, etc., was constructed starting in 1993 and commissioned to initial cooling down on 10th January, 1997. Construction work included laying long runs and a large volume of control cables, because it was decided to use a remote-controlled monitoring & operation system. The monitoring operation is carried out from the control room of adjacent power generation facilities.

In the construction of those systems, it was necessary to maintain the working schedule steadily while ensuring quality and safety so as to provide a stable power supply to cope with growing demand. The construction method has some characteristics.

This paper describes an effective method for shortening the construction period of such equipment and facilities.

RESUME

Avec la construction de nouveaux trains No. 3 et No. 4 (puissance totale de 3300 MW) dans la centrale thermique KAWAGOE, installations de production électrique du cycle combiné de rendement élevé, Chubu Electric Power Co., Inc. a construit dans la même centrale, un nouveau terminal qui reçoit environ 3 millions de tonnes de GNL par an en provenance du premier projet au QATAR dans le Moyen-Orien.

Le terminal, composé d'un quai de réception de métaniers de 135.000 m^3, de 4 bacs GNL de 120.000 kl (type terrestre à double paroi métallique) et de 4 évaporateurs GNL, a amorcé la construction en 1993 et, le refroidissement initial étant achevé le 10 janvier 1997. Etant donné que le terminal a adopté un mode d'opération de surveillance de la commande à distance à partir de la salle de contrôle des installations de production électrique se situant adjacente au terminal, les câbles de commande sont devenus longs et abondants.

Vu la nécessité d'assurer la qualité et la sécurité des travaux tout en assurant consciencieusement le délai de construction, la méthode de construction de ces installations porte des caractéristiques ci-dessous afin d'assurer une alimentation stable pour répondre à la demande d'électricité croissante.

Cette thése porte sur l'aperçu et l'efficacité de la méthode utilisée pour réduire le délai de construction.

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1. INTRODUCTION

Chubu Electric Power Co., having 5 prefectures situated in the central part of Japan as supply area, is ranked in the third position among the 9 electric power companies in Japan with a sold amount of electric energy of 115.6 billion kWh in 1996.

Chubu Electric Power Co. started introducing LNG as fuel for power generation from 1978 by paying attention to its features of cleanliness and reliability of supply and, as of 1996, 31% of the power generating equipment capacity was represented by thermal power equipment using LNG as fuel, and as much as approximately 34% of the generated electric energy was covered by LNG.

Moreover, the total annual amount of LNG supplied to Chubu Electric, which was about 5.5 million tons all from Indonesia and Australia in 1996, is expected to increase to approximately 9 million tons in 1999 and after, including the supplies from Qatar started in 1997.

The company currently owns 3 LNG bases i.e. Chita terminal, Yokkaichi terminal and Kawagoe terminal, and the Kawagoe terminal constructed in the precinct of the Kawagoe Thermal Power Station is the latest terminal put into operation in 1997.

Sufficient reliability must be secured for those LNG receiving terminals because they are located rather close to urban areas and handle a large amount of LNG. At the same time, it is also requested that the terminals be constructed within a limited period of time and put into operation at prescribed time, in line with the construction of the power generation equipment. The company therefore adopted some new methods for shortening the construction period while securing the required quality, in the construction of the Kawagoe terminal. Explanation will be given on those methods hereafter.

2. OUTLINE OF KAWAGOE THERMAL POWER STATION

The Kawagoe Thermal Power Station, where the Kawagoe terminal is constructed, is divided into 2 zones by a canal passing through the central part of the site, and has power generation equipment in the western zone and LNG equipment in the eastern zone.

The power generation equipment is composed of generators Nos. 1, 2 which were put into operation in 1989 and 1990 respectively and groups Nos. 3, 4 supplemented in 1996 and 1997, all of which being fueled with LNG.

The generators Nos. 1, 2 are conventional steam power generating equipment by boiler and steam turbine, but have improved efficiency with the adoption of ultra-super critical steam conditions of 31.0 MPa, 1050°F. On the other hand, the groups Nos. 3, 4 are ultra-modern combined cycle power generation systems composed each with 7 power

trains, each train comprising a pair of heat exchangers for recovering exhaust heat and steam turbine, and have a high efficiency of 48% or over.

The output of the generators Nos. 1, 2 is 700 MW each, and that of the groups Nos. 3, 4 is 1,650 MW each, with the total output of 4,700 MW which is the second largest in the world and the largest in Japan.

The Kawagoe LNG terminal is planned to receive about 3 million tons of LNG annually from Qatar and make vaporization and transmission of gas as fuel for the power generating equipment of the groups Nos. 3, 4 for a total energy of 3,300 MW.

The fuel for the existing generators Nos. 1, 2 is supplied through gas pipeline installed in undersea tunnel from our LNG base in Yokkaichi City about 3.7 km away from the Kawagoe Thermal Power Station.

3. OUTLINE OF KAWAGOE TERMINAL

The Kawagoe terminal is constituted by one unit of LNG receiving berth, 4 units of LNG tank plus LNG vaporizing system, BOG treating system, etc.

The LNG receiving berth, which was designed for adaptation to the LNG vessel of 135,000 m^3 class of the Qatar Project, is realized as steel pile supported dolphin type berth with an overall length of 460 m and a water depth of 14 m.

The hard arm for receiving LNG is composed of 3 pieces of 16-inch arm for liquid and 1 piece of 16-inch arm for return gas, and is available for receiving LNG at the rate of 12,000 m^3/h to complete unloading of full volume from a 135,000 m^3 LNG vessel in 12 hours. Moreover, each arm is provided with an emergency shut-down (ESD) device and a ball valve type emergency uncoupling device.

The LNG tank is an above-ground type metallic double-shell tank with a capacity of 120,000 m^3 and 4 units of such tank are installed with a total storing capacity of 480,000 m^3. This tank has an inside diameter of about 73 m and a height of about 46 m. As ground type metallic double-shell LNG tank, it is currently the third largest in the world and the largest in Japan.

Around the tank is installed a liquid preventive dike securing an internal volume equivalent to the total tank capacity for protection against expansion of leakage in case of any such accident. Furthermore, as disaster prevention equipment, high-foaming equipment for controlling vaporization of leaking LNG, water screen system, water spraying system for protecting the tank from radiated heat as well as powder fire extinguishing system are installed and, in addition, we also have inflammable gas detector, low-temperature detector, monitor TV, etc.

Next, the LNG vaporizing system is composed of LNG pump for boosting LNG from LNG tank to approximately 4.9 MPa necessary for using it as fuel for gas turbine, open-rack type vaporizer for heating & vaporizing LNG, etc.

The LNG pumps include 2 units of primary pump with a head of 380 m installed for each tank or 8 units in total, and 5 units of secondary pumps with a head of 610 m. For proper maintenance of those LNG pumps, a monitoring system is installed for directly monitoring the vibrations of the bearings and diagnose anything unusual about the pumps.

The LNG vaporizers, which are all of open-rack type with a capacity of 155 t/h each and installed in the number of 4 units, are designed to deal with the fuel of 13 of the total number of 14 power trains of the groups Nos. 3, 4 with 3 units of vaporizer.

The sea water for vaporizers is taken in at an exclusive water intake, and the sea water after exchange heat with LNG is discharged to the water intake for the generators Nos. 1, 2.

The BOG (boil-off gas) produced in this base is compressed to approximately 0.9 MPa by means of a BOG compressor, to be used as fuel for generators Nos. 1, 2 using low-pressure gas, for saving the compression power.

4. DESIGN FEATURES

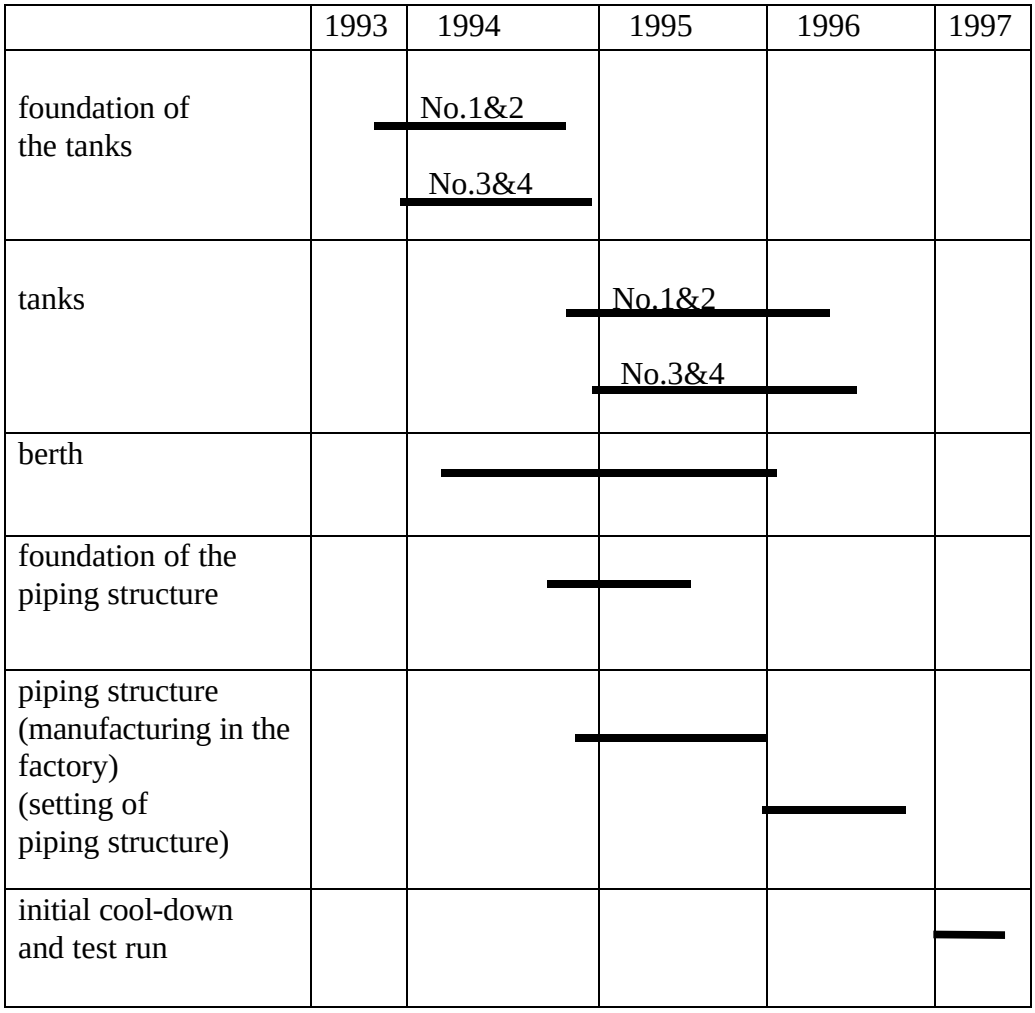
The entire terminal was arranged in the eastern part of the site to enable eventual expansion of the power generation equipment and the base in the future, and 4 units of 120,000 m^3 tank were installed there to secure a storage volume of LNG necessary for the groups Nos. 3, 4. As type of LNG tank, we selected above-ground type metallic double-shell tank with an inner tank of 9% Ni steel which has a lot of positive achievements and high reliability and is also advantageous from the viewpoint of both construction period and costs.

Moreover, this terminal is characterized in that its normal operation and monitoring are made by remote control from the central control room of the power generation system considering labour saving and ease of operation, because of the fact that the terminal is located in the same site as the power generation equipment although they are separated from each other by a distance of about 500 m. For that reason, necessary automation, remote control and monitoring systems are also installed.

In the central control room, full CRT operation and large screen are adopted, enabling one-man operation at normal times.

As it was foreseen that remote control & monitoring requires a large amount of control cable, the control system was installed in the terminal and only the operating terminals were installed in the faraway central control room, for the purpose of cost reduction by reduction of cables. In addition, we adopted optical cable for the transmission of signals to improve reliability against noise and reduce the amount of installation work.

The Kawagoe terminal, the construction of which was started in 1993 together with that of power generators of Nos. 3 & 4 groups, received the first LNG vessel in January, 1997 and, after going through initial cooling down and subsequent test run of the respective equipment units, started its commercial operation in June, 1997. The general process of its construction was as follows:



5. NEW UNIT PROCESS OF LNG PIPING EQUIPMENT

In the Kawagoe terminal, a new unit process of LNG piping equipment was adopted as one of the techniques leading to shortening of the construction period.

This new unit process of LNG piping equipment consists in manufacturing single-piece block with a maximum weight of 250 tons including bridge and completing up to painting in the factory by further advancing the conventional piping unit process, and transporting the unit to the field in the state of almost finished product for installation. The contents of this process are described hereafter.

① Specifications of LNG piping

An enormous volume of piping is required for a LNG receiving terminal. The specifications and quantities of the main LNG piping constructed in the Kawagoe LNG terminal are the following:

	Diameter	Thickness	Material	Quantity	Piping length
LNG receiving piping	800mm	8mm	SUS304	2	1400mm
Return gas piping	450mm	6mm	SM400B	1	1300mm
High-pressure feed gas piping	650mm	22mm	SM400B	2	800mm
Low-pressure feed gas piping	650mm	8mm	SM400B	1	800mm
BOG piping	1000mm	8mm	SUS304	1	350mm

② Conception of new unit process

In the new unit process adopted this time, a large unit in the state completed up to final painting is assembled in the factory together with bridge and piping, and transported on platform by the sea. In the state where the platform boat remains alongside the pier, the height of the platform is adjusted and the piping equipment unit is rolled off onto a dolly which directly gets aboard the platform boat. The unit is carried to the site on that same dolly, placed on the foundation of the piping bridge, and then lifted down for installation.

③ Technical problems to be cleared for the adoption of the new unit process

The following measures were taken to solve various technical problems to be cleared for the implementation of the new unit process:

Item	Concrete contents
• The prescribed strength must be secured for the structural steel in the split and independent state, because the structural steel is split for assembling.	Added braces necessary for each unit.
• It is necessary for a dolly to get in under the unit to directly lift it up, at the time of rolling off from the platform boat and transportation to the site.	Adopted rigid frame structure without vertical braces in the direction perpendicular to the shaft.
• Reinforcement of quality control at the time of manufacturing in the factory for securing the accuracy of bridge dimensions and the accuracy of piping installation on the structural steel.	Reinforced the quality control, because the accumulation of each error in each part would influence the position of last part of welding of piping. The target of the quality control is as follows. • error in the position of the structural steel <3mm • error in the distance of welding face of the piping <0.8mm • error in the position of the center line of piping <1.5mm • decline of the structural steel <1/1000
• Matching of the structural steel and the foundation at site .	• canceled the error in foundation work at site by the feedback of the result of the measurement of the foundation

④ Situation of application of new unit process

The scope of application of the new unit process in the construction of the Kawagoe LNG terminal was as shown in the drawing below, representing approximately 90% of the overall length of main LNG pipelines and approximately 92% of the total weight, and the total number of piping units was 65.

⑤ Construction period shortening effect of the new unit process

The adoption of the new unit process made it possible to basically eliminate the installation work of bridge and to also reduce the amount of cold insulation & painting work, thus shortening the construction period on the site by approximately 3 months.

The adoption of the new unit process led to expansion of the scope of execution in the factory, and made it possible to execute the work under better equipment conditions and improve the work efficiency because of reduction of processes subject to weather conditions. This contributed to not simply shorten the construction period on the site but also reduce the entire construction period including both the construction period in the factory and the construction period on the site.

⑥ Other merits of the new unit process

In addition to the shortening of the construction period, the adoption of the new unit process also produced the following effects:

- Improvement of quality
  Expanded scope of manufacturing in the factory with favorable working environments as well as mechanization and automation improved the quality of welding work, etc.
- Improvement of work safety
  The safety of the field work improved thanks to reduced amount of work in high places and reduced use of large construction machines on the site.

6. MOBILE X-RAY INSPECTION SYSTEM

Regarding the construction of the LNG tanks, high-energy mobile X-ray inspection system was adopted to improve the efficiency and reliability of the inspection of welds of the thick steel plate.

① Radiographic inspection at the time of construction of LNG tanks

A particularly high reliability is requested of LNG tanks which store a large amount of LNG. Especially for the inner tank to be directly in contact with low-temperature LNG made of 9% nickel steel, thorough quality control on welding is also required. Therefore, we make it a rule to perform radiographic inspection on all weld lines of the inner tank to verify their soundness. In recent years, increase of LNG tank size is also increasing the amount of work and the construction period required for the inspection of LNG tanks.

The specifications regarding welding of the inner tank side plates of the 120,000 kL LNG tank constructed in the Kawagoe LNG terminal are the following:

Tank dimensions	Diameter 73.2m, Height 43.9m
Thickness of inner tank plate	Lowest stage 36.8mm, Top stage 12.0mm
Length of weld line	Circumferential direction 1,610m, Vertical direction 465m

② Outline of mobile X-ray inspection system

The mobile X-ray inspection system adopted this time, realized by providing X-ray camera lifting and rotating mechanism, automatic sight adjusting mechanism and remote controlled unit with monitor camera on a mobile stand travelling in the circumferential direction by inverter controlled electric motor on the tank side plate by semi-automatic operation.

This system has the following features:

- Shortened exposure time
  The exposure time has been reduced to approximately 1/10 (case of a plate thickness of 40 mm) compared with the conventional process, thanks to increased energy strength of the X-ray camera.
- Improved workability by introduction of semi-automatic camera
  In the past, operations such as setting of camera in respective places of photographing, etc. used to be made manually. With the adoption of a system which travels on the side plate for taking pictures by semi-automatic operation, the work efficiency improved and, at the same time, it has become possible to execute the photographing, which used to be made by 3 to 4 members in the past, by only a single operator.

③ Process shortening effects by mobile X-ray inspection system

The mobile X-ray inspection system can be applied to both horizontal part and vertical part of weld lines on the side plate. Examples of improvement of photographing efficiency for each of them are indicated below.

welding line	thickness	photographing time per a sheet		improve-ment (a)/(b)
		conventional method (a)	mobile X-ray inspection system (b)	
vertical	36.8× 36.8	exposure time :21min total time :.42min	exposure time :1.7min total time :.3.7min	11
	32.8× 36.8	exposure time :16min total time :.32min	exposure time :1.1min total time :.3.1min	10
	27.2× 27.2	exposure time :8min total time :.16min	exposure time :0.7min total time :.2.7min	5.9
	22.4× 22.4	exposure time :1.8min total time :.3.8min	exposure time :0.5min total time :.2.5min	1.5
horizontal	32.0× 36.8	exposure time :16min total time :.32min	exposure time :1.1min total time :.3.1min	10
	27.2× 32.0	exposure time :8min total time :.16min	exposure time :0.7min total time :.2.7min	5.9
	22.4× 27.2	exposure time :1.8min total time :.3.8min	exposure time :0.5min total time :.2.5min	1.5

From this result, we can see that, with the use of a mobile X-ray inspection system, the photographing efficiency becomes about 15 times higher compared with the case of conventional method of photographing.

7. USE OF CABLE DRAWING MACHINE

① Amount of cable installation

The Kawagoe terminal is operated and controlled by remote control from the central control room of the power generation equipment in the Nos. 3 & 4 groups located in the same site. Though situated in the same site, this central control room is separated by approximately 500 m from the LNG terminal. For that reason, the amount of cable installation became enormous as indicated below.

Cable name	Specifications	Number of lines	Distance
power cable	SHVV-150sq×1C	12	1100m
control cable	CVV-2sq×24C ,60C	31	1100m
	CVVS-2sq×2C~24C optical fiber	36	1100m

② Outline of cable drawing machine

The cable installation used to be made by manual work and this required a lot of manpower and time. The cable drawing machine adopted this time consists in installing a device for guiding cable in a cable tray or duct in advance and automatically drawing the cable by means of a wire along that guide to install the cable.

The equipment construction and specifications are the following:

Component equipment unit	Specifications	
Driver	Installed length	900m
	Wire drawing speed	Standard 18 ~ 20m/min, Max. 27m/min
Tension transmitter, receiver	Receiving range	Radius 0 ~ 200m
Guiding device	Roller bearing type with Automatically releasing system	

③ Improvement of workability by the use of cable drawing machine

Cable drawing machine was used for approximately 25% of the total amount of cables in the construction of the Kawagoe LNG terminal. As a result, the working efficiency improved by approximately 27% for the portion executed by using the cable drawing machine.

8. RESULTS OF COOLING DOWN AND TEST RUN

The LNG terminal in Kawagoe received the first LNG carrier "Al Zubarah" from Qatar in January, 1997, and initial cooling down was made for it.

The initial cooling down was made by first receiving low-temperature gas at -130 from the LNG carrier and thereby performing pre-cooling down of the receiving piping system and N2 purge of the LNG tanks over a period of 3 days.

After completing the pre-cooling down to the prescribed temperature with the low-temperature gas, we performed cooling down with LNG for 4 days and then stored the LNG in the tanks.

After the initial cooling down, we performed test run of LNG pumps, vaporizers, BOG compressor, etc. as well as various kinds of receiving test, feed gas control test, etc. and obtained satisfactory results in all respects.

As for the receiving test, we implemented a total number of 8 tests during the test run to check the function of various kinds of security devices such as ESD, etc., top receiving from 2 tanks, top receiving from 4 tanks and bottom receiving from 2 tanks and 4 tanks, and confirmed that the equipment is available for use at the prescribed rate in all of the handling services.

As the tests regarding feed gas control, we performed substitution test in case of tripping of one unit, and checked the controllability in case of sudden output fluctuations of the power generation equipment, etc. Especially, the power generation equipment in the groups 3, 4 in Kawagoe Thermal Power Station, which are high-efficiency systems with excellent functions of start-stop and load change speed to follow up changes in the demand of electric power, are requested to have excellent controllability also on the LNG equipment side in corresponding to such characteristics. We made sufficient verification tests also on those functions synchronizing with the test run of the power generation equipment in the groups 3, 4.

After the implementation of the test run, the LNG terminal started its commercial operation on June 13th, 1997 and is working smoothly. This LNG terminal is expected to receive an annual volume of approximately 3 tons in 1998 and after.

9. ACKNOWLEDGMENTS

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