# IMPROVEMENT OF DESIGN & CONSTRUCTION TECHNOLOGY IN JAPANESE NUCLEAR POWER PLANTS

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## ABSTRACT

Nuclear power generation currently offers economic merits superior to those of other methods dependant on such thermal power generation as petroleum, LNG, or coal. However, it is essential for the nuclear power generation continuously to retain economic superiority through concurently maintaining its high safety features and outstanding reliability. For achieving this purpose, taking into account of importance explained above, we have been developing and improving those of technologies such as design, engineering, and construction regarding the both field of management and techniques useful for plant construction.
This paper covers the several instructive matters which Hitachi has accomplished throughout having had his hand in the project jobs.

## INTRODUCTION

Construction of the first commercial LWR (Light Water Reactor) plant in Japan was started in February, 1967 at Tsuruga 1 (375 MWe, BWR Plant) for the Japan Atomic Power Company. Its commercial operation commenced in March, 1970. For the first several commercial LWR plants, the main contractor was a foreign company, with Japanese plant makers participating in the work. After gaining experience, domestically designed nuclear power plants, with a Japanese company as their main contractor, were built. Original design improvement and development of design and construction techniques were achieved through the cooperation of electric power companies, plant makers, and construction companies under the Japanese government's guidance, so-called Japanese style technical development. This paper covers, for your presentation, especially regarding technical development and improvement of plant design and construction useful for reduction of construction period in which we have a lot of experiences now.

## DESIGN DEVELOPMENT

The nuclear power plant consists of many and various units of equipment such as reactor, turbine, pump, valve and control, and can demonstrate the functions as a power generating plant by organically connecting them with pipings and cables. Since these units are properly arranged and housed in the buildings in accordance with the applications and purposes, the connectors such as pipings and cables are many and complicated, and how properly they are arranged greatly influence the operationability and maintainability of the plant. For this reason, in the plant layout planning, the layout is fixed by determining the arrangement of the buildings and main units, then planning the main piping routes and generally making additions and corrections through trial and error.

To increase the efficiency of such layout planning, so far the color composite drawing and plastic models have been introduced to make adjustments for interferance prevention and maintainability, but still a lot of manpower is required to quickly make the additions and corrections for the layout.

On the other hand, recently the computer technology is making a remarkable progress, and it was expected that the same or higher effect than that of the plastic model might be obtained by developing CAD system incorporating such uptodate computer technology, we have, therefore, developed and put to practical use a "three-dimensional plant layout planning CAD system" using the uptodate computer technology.

### 1) Model Engineering

The full-fledged introduction of the model engineering method in the nuclear power plant was started in 1977.

In this design procedure, the design models are mainly used, and the main piping route plan, cable tray plan and air-conditioning duct plan are made by using the master plan models with scales of 1/15 to 1/100 and on basis of the primary equipment layout, in the early stage, and after the equipment layout body is investigated in detail, it is reviewed by the customer. In the later stage, the plant planning is done through designing and adjustment of all the equipment using integrated design models with scales of 1/10 to 1/75 or partial design models.

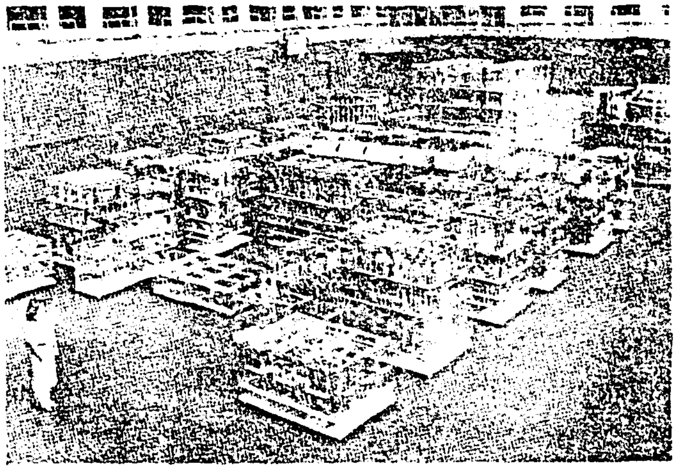

Fig. 1. Design model

At the time of the first completion and second completion of the integrated model, the customer reviewing is done, and after his approval on the model is received, single body plan drawings are prepared.

2) Three-Dimensional Plant Layout Planning CAD System

In order to establish the optimum layout plan of the nuclear power plant, it became necessary to draftically improve the conventional drawing planning and plastic model method through utilization of the computer. For this reason such uptodate technologies as knowledge engineering, CAD/CAM and computer graphics were adopted in the layout planning of the nuclear power plant and the three-dimensional plant layout planning CAD system was developed as a through system for integrated design and production.

This system features a through system to automate the piping, tray and duct routings through the three-dimensional simulation and knowledge engineering method including the piping FA.

(1) Automatic Routing

In this system the rich design criteria accumulated by the designers are stored as knowledge in the computer and reflected directly on the routings by the knowledge engineering method, and the procedure to determine the optimum routing by the three-dimensional layout space searching method and the procedure to infer from the criteria stored in the knowledge base and to set the conditions to be the guideline for route searching are combined by describing the knowledge in the hierarchical data structure called frame, thus realizing the introduction of the knowledge into the routing.

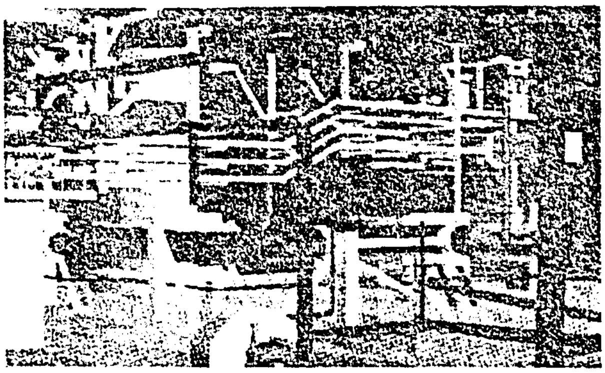

Fig. 2. Computer model

(2) Interactive Layout System

This system aims at interactive processing between designer and computer and it is required that the three-dimensional graphic processing is fast and that the data structures is compact. Therefore, the high speed was promoted by preparing a special plotting program for basic three-dimensional unit. To make the data structure compact, the CSG (Constructive Solid Geometry) method to describe the three-dimensional shape through combination of basic solid units was adopted.

(3) Layout Evaluation System

When the planning is completed, the layout must be ganerally evaluated. For this reason, through the graphic model simulation and high-speed graphic processing to replace the conventional plastic model, such three-dimensional shapes as body, equipment, and piping are expressed realistically and recorded in the VTR, and then highly detailed and realistic "computer model" (Fig.2) is projected on a large screen (72 in), thus making general adjustment of the layout possible.

(4) Execution Designing CAD and Piping FA/CAM System

The data constructed by the planning designing CAD are successively used for piping stress analysis and by the production/execution designing CAD and piping FA/CAM system for large bore piping, small bore piping, supports, buried hardware and operation platform, thus using the three-dimensional data effectively.

3) Example of Application to Actual Machine Designing

A conspicuous feature of the CAD system is that all the works are done interactively between the designer and computer which possesses a rich collection of data concerning the nuclear power plant, through the CAD system. The following will show some application examples of the computer model engineering, especially introduce on general adjustment of 3D-CAD.

(1) General Adjustment

As the divisional detailed designing proceeds, the stage of general adjustment to collate the data with one another and investigate mutual relations starts.

Various equipment and piping data called from the data base are expressed three-dimensionally as shown in Fig.3 and are color-coded so that the systems and applications can be known at a glance.

In this stage of general adjustment, especially important effect is demonstrated by the three-dimensional simulation. The following will detail the method.

a) Access Simulation
Along the access passage, the viewpoint is moved and the scene at each point is dynamically displayed on the screen, and the accessibility and operationability of valves, etc. are confirmed.

b) Human Walking Simulation
Along the passage a dummy person is moved and interference with piping, equipment, etc, is checked to confirm the passability. (Fig.4)

c) Equipment IN/OUT Simulation
Along the equipment path, the equipment is moved to check if equipment in/out movement is duly considered in the piping plan.

d) ISI Checking Simulation
ISI robot model is displayed at the welding place and through the operation display, whether the ISI space is secured or not is checked.

e) Valve Operation Simulation
A dummy person is displayed at the valve position and the valve operationability is checked.

f) Valve Disassembly Simulation
While the valve is moved, any interference with surrounding pipe, equipment, etc. is checked to make sure that a sufficient space for valve disassembly and inspection is secured.

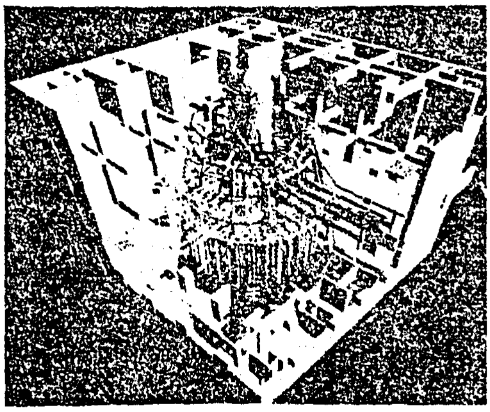

Fig. 3. Equipment and piping data base in three-dimension

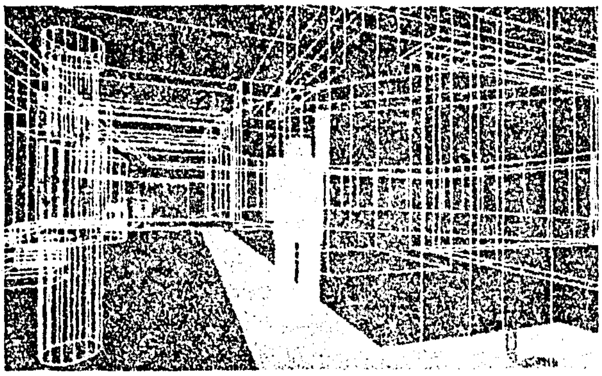

Fig. 4. Human walking simulation

As a new designing method adopting such newest technologies as knowledge engineering, CAD/CAM and computer graphics for the nuclear power plant layout planning, a three-dimensional layout planning CAD system was developed. Application of this system to the actual plant designing is expected to produce the following effects.

(1) Through the automatic layout system, the designing can be speeded up, various case studies in the planning stage can be made, and systematic and optimum layout planning is realized.

(2) The interactive layout system facilitates three-dimensional graphic processing of piping, trays and ducts and creation, modification and addition of computer model.

(3) The layout evaluation system makes it possible to extract problems in the planning stage through functional evaluation on matching with P & ID and operationability evaulation on valve disassembly and inspection.

(4) By using the graphic model simulation for the general adjustment evaluation and reviewing, alterations and additions can be quickly made, thus reducing the designing time.

(5) Since the plan design data are successively used by the production designing CAD, CAM and FA systems via the data base, troubles due to design data copying error can be prevented.

The above is expected to increase the efficiency of plant layout planning and designing.

## DEVELOPMENT AND IMPROVEMENT OF CONSTRUCTION TECHNIQUES

Nuclear power generation currently offers economic merits superior to those of other methods dependent on such thermal power generation as petroleum, LNG, or coal. However, it is essential for the nuclear power generation continuously to retain economic superiority through concurently maintaining its high safety features and outstanding reliability. In this chapter, the typical examples on technique for construction developed or imploved shall be introduced hereafter.

## IMPROVEMENT OF CONSTRUCTION AND INSTALLATION

Plant construction commences civil work such as excavation, and building construction follows. And after that, the plant maker's installation work begins.

The trio of plant maker, construction company, and electric company is engaged in development of various new construction techniques on critical plant work based on the following viewpoints: expansion of simultaneous work, reduction of work volume, and improvement of work productivity.

### 1) Improvement of Civil and Structual Work

Improvement of civil and structural work which form a critical path in the early part of construction are as follows.

(1) Vertical excavation method

The example of "interfacing" between the civil work and mechanical work, that is the soil digging work for building construction. On excavation that requires digging into a considerable depth, a tie-back technique in which vertical excavation is conducted while driving tie-back anchors into the holding walls. This method permits a reduction of soil volume to be dug, while enabling improved accessibility to the construction site and reduction of construction period.

(2) Deck plate system

After completion of the building floor the plant maker starts installation of equipment and piping.

In the conventional method, shoring supports are introduced for slab work, next forms and rebars are fabricated, the shoring supports and forms are removed and plant maker begins the installation work.

One way to avoid this problem is by a deck plate system. After the walls are complted, a steel beam is installed, which is strong enough to support a concrete pouring load, and a steel deck plate is used instead of a form. This method allows installation of equipment and piping can start earlier.

(3) Prefabrication of rebars

Japanese plants, as was mentioned, are required to be highly earth-quake-proof, therefore the number of rebars is large and their fabrication work is complex and takes much time. To facilitate this work, their prefabrication at an on-site prefabrication shop is applied. In this case, an automatic machine for fabrication can be utilized, which increases productivity and offers higher safety. Fig.5 shows a prefabricated T-G pedestal beam rebar, which has a total weight of about 38 tons.

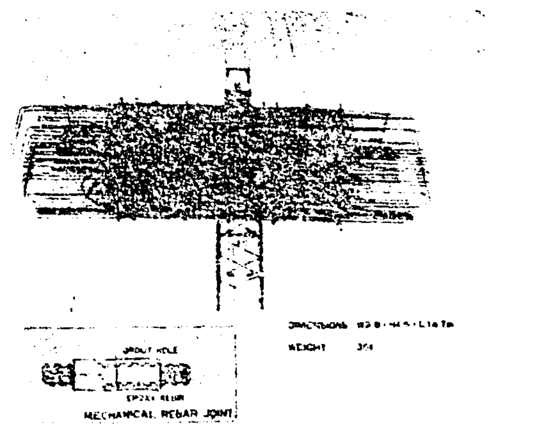


Fig. 5. Prefabricated T-G pedestal beam rebar

To connect a prefabricated rebar to an installed rebar easily and strongly, mechanical joints are normally used.

### 2) Improvement of Equipment Installation Method

(1) Improvement of equipment and piping installation

In the case of first several plants, crane capacities for structural work were small (60-70 tons), almost all work was done at the construction field, and the construction schedule was long. In 1979, a 130 ton derrick crane (6500 ton-meter) was developed and in 1985 a 840 ton crawler crane were introduced for use.

(a) Large block prefabrication of PCV

Fig.6 shown an example of a large block prefabrication of a MARK-II type PCV (1100 MWe). Blocks are prefabricated in a site yard (maximum weight : about 400 tons) and carried by the 840 ton crawler crane. It took about 11 months using the 130 ton tower crane to complete PCV erection, however this is reduced to about 7.5 months by applying the large block prefabrication technique.

(b) RPV placement by large capacity crane

In earlier conventional plants, the RPV was put into place by a fitting device located on the reactor building operating floor, after completion of the operating floor. Therefore, the schedule depended upon the building construction schedule. By applying this large capacity crane, RPV installation does not depend upon the building construction schedule, and interference with structural work can be avoided.

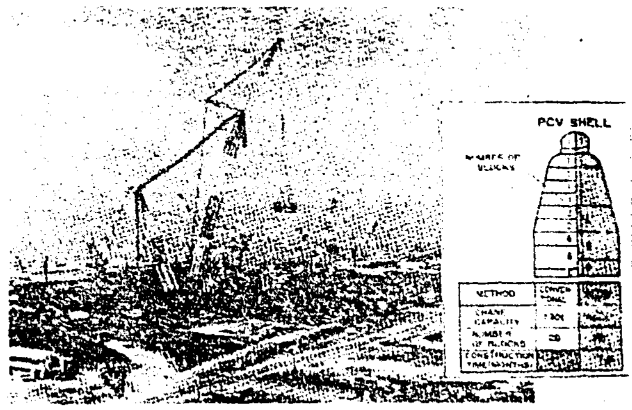


Fig. 6. A large block prefabrication of MARK-II type PCV

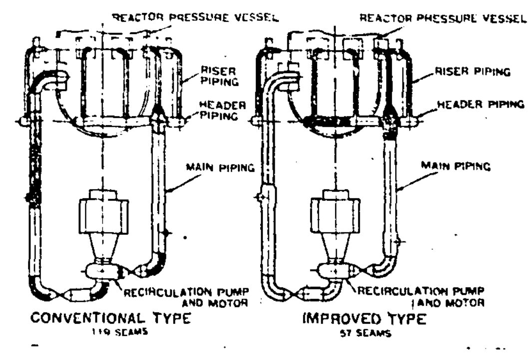


Fig. 8. Reduction welding seams

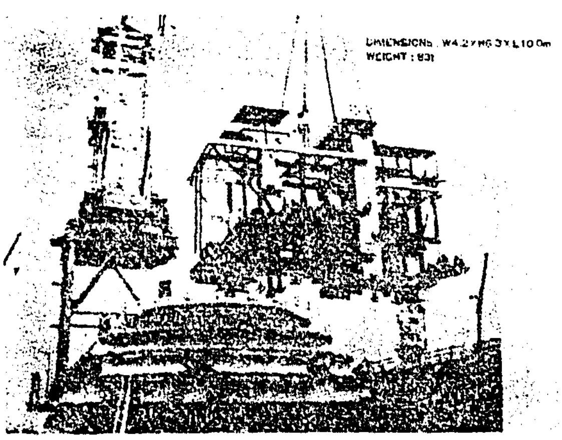

Fig. 7. Equipment and piping modularization

(c) Piping modularization method
Installation of pipings, supports, cable trays and HVAC ducts account for 70% of the plant maker's on site work. To advance this work, a piping modularization method employed. Rather than fabricating piping at construction field as was done initially, piping is fabricated in the factory or a site shop, and transported by cranes. Equipment and piping modularization are shown in Fig.7.
Employing this method more and more brings about not only shorter work time but also improved productivity and safety during site construction.

3) Machinalization of site work

Installation work of piping, support, cable tray and HVAC duct amounts very much, and to reduce man power for these work, machinilization is very important matter for construction.

(a) Application of bent pipe
Bent pipes are applied to reduce the number of welding points made at the construction site. (In-service inspection for pipe welds can also be reduced.) Fig.8 shows an example of a reduction welding seams. These bent pipes are fabricated by using CAM connected with CAD and CAE. Total welding points for large pipes are reduced to 30% now.

(b) Automatic welding machine
By automatization of welding at site, quality improvement and manpower reduction are achieved. Currently, this machine is applied to all welding of PCV shell and 70% of the total pipe welding as our popular procedure.

c) Automatic cable pulling machine
Total length of cable pulled at construction site is about 2500 km. An automatic cable pulling machine has been developed and tested to facilitate this important site work.

4) Cooperation of Structural and Mechanical Work

Structural work and mechanical work are performed under separate contracts. Their coordination is very important especially for the most critical work portion during construction.

(a) Application of packaged control panel system
In conventional plants, designing and installation of the building and electrcial facilities were performed separetely. With a packaged system, cabling space under the electrical room's floor slab is obtained. Terminal boxes can be located and flexibility in the cabling installation schedule is increased, and the installation schedule can be shortened.

(b) Fabrication of pool liner
Fig.9 shows the reactor well pool liner prefabrication. Pool liner is prefabri-

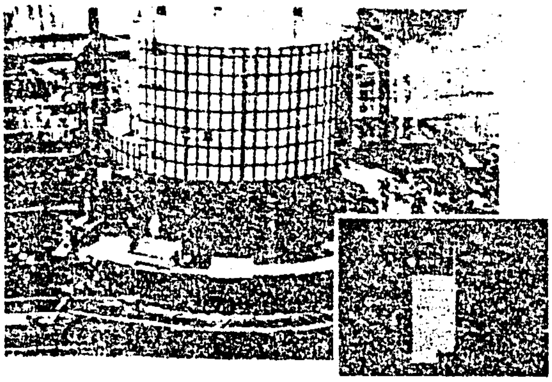

Fig. 9. Reactor well pool liner prefabrication

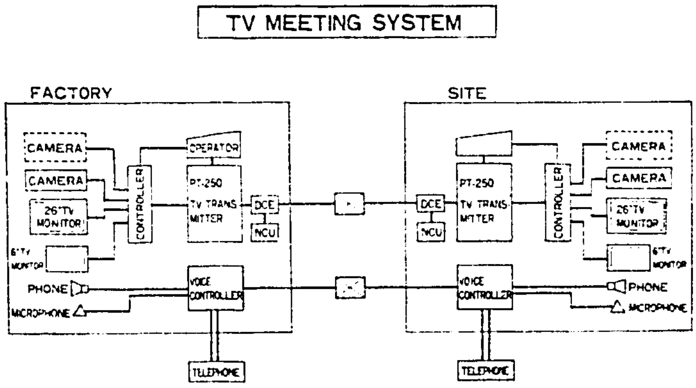


Fig. 10. TV meeting system

cated and positioned prior to pouring concrete. This method is able to reduce both form work and facing work of the concrete.

IMPROVEMENT OF CONSTRUCTION MANAGEMENT

Compared with the thermal power plant, nuclear power plant involves enormously greater project scale as well as incomparably larger volume of materials and items handled at construction site. The construction management performs in attention to minutely conducting construction management, concurrently applying efforts and devising various steps in the schedule control, QC and QA, and site safety control management. The following items are some typical examples regarding improvement of construction site management procedure and tools.

1) Introduction of computer aided management system

To improve efficiency of work-site construction management, both the plant maker and the construction company employ computer aided management system. This system facilitates quick processing of data on delivery date of products, materials, progress report of construction schedule, submission of application for inspections and various other information related to construction.

2) Application of TV meeting

For handling a lot of informations related the project, TV meeting system is now applied on site and works. This system is generally helpful for making consensus quickly among personnel joining construction project and factories. Fig.10 shows the typical TV meeting system in Hitachi Ltd.

3) Construction Survey System

To complete tne best plant construction, plant survey teams are organized timely and dispatched to the construction site. And its purpose are to keep the best plant quality, pointing out problems produced on site in early stage and to solve them. These surveys shall be proceeded with just before reactor vessel installation, just prior to RPV water pressure test proceeded and before fuel loading of the plant.

CONCLUSION

This paper describes the sophistication of design, construction and installation of BWR plants. As result of this progress, the best plant design and engineering and reduction of construction schedule has been achieved.

As summarized in Fig.11, the standard construction schedule, from soil inspection to commercial operation, was 57.5 months for conventional plants, however currently it has been shortened to 52-53 months. In case of advanced BWR plant now being developed achievement of 48 month construction schedule will be feasible for a 1350 MWe class plant.

In conjunction with these circumstances, plan maker searches betterments of reliability, operability, maintenability and economization of LWR plant, and pursues development of new technology.

| PLANT \ ITEM | FOUNDATION BASEMENTS | PCV | MECHANICAL AND STRUCTURAL INSTALLATION | PIPINGS, ELECTRICAL AND INSTRUMENTATION INSTALLATION | PRE OPERATION TEST | START-UP TEST | CONSTRUCTION TIME (MONTHS) |
|---|---|---|---|---|---|---|---|
| CONVENTIONAL PLANT (1100MWe) | 5.5 | 10.9 | 14.6 | 8.5 | 7.9 | 10.1 | 57.5 |
| LATEST PLANT (1100MWe) | 4.7 | 9.7 | 14.4 | 7.8 | 7.2 | 8.8 | 52.6 |

Fig. 11. Reduction of construction schedule