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Sisältö:

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MANUFACTURE OF NUCLEAR REACTOR VESSELS AT ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO.

1. INTRODUCTION

Ishihawajima-Harima Heavy Industries Co. (IHI) has been engaging in manufacturing nuclear equipment from the early stage of nuclear industries in Japan.

The early nuclear products of IHI were mostly for test or demonstration reactors and testing facilities. IHI started fabrication of its first heavy nuclear reactor pressure vessel for a power reactor in June, 1967 and completed in May, 1969. IHI has delivered seven (7) nuclear reactor pressure vessels (RPV) and has five (5) RPVs in shop or on order now.

RPVs manufactured by IHI are listed in Table-1. In addition to RPV, IHI has many experiences in manufacturing primary containment vessels, heat exchangers, piping and other nuclear equipment, including installation at site.

IHI Yokohama No.3 Works, which is especially designed and equipped for the manufacture of heavy pressure vessels of high quality, was first in operation partially in 1967. After series of expansion, the current facilities were completed in 1971, including a shop especially designed and equipped for the manufacture of piping assembles and heat exchangers.

For the manufacture of critical components, such as RPV, it is essential to perform complete advance planning and verification of manufacturing techniques.

For the verification of manufacturing techniques, full or large scale mock-up tests should be carried out simulating actual operations in addition to the parametric laboratory tests. IHI carried out a series of full size mock-up tests prior to the fabrication of the first RPV, and has performed mock-up test every time a new technique is used.

2. DESIGN

In the design stage, the required quality level which shall be built in the vessel is to be decided in accordance with the customer's specifications and applicable codes and regulations. The required product and process quality is to be translated into drawings, procedures and other design documents performing functional and stress analysis.

Most dimensions of vessels are usually determined by rather simple design calculations, except main flanges, support skirt connection and local complex parts, such as termal sleeve connections on nozzles. Dimensions of main flanges, support skirt connections and complex parts should be determined after carrying out a series of parametric stress analysis. In determining dimensions of main flanges, sealing effect considering flange rotation due to bolt up should be taken into account in addition to stresses.

The determined dimensions of the vessel must be verified for its integrity and strength by detail stress analysis for all operating conditions, and it may be necessary to impose some limits on the operating conditions in some case. Analytical stress analysis methods should be highly developed so that stress values can be obtained at a high accuracy for all operating conditions. Experimental stress analysis methods should be utilized or supplement the analytical methods for the complex parts for which an analytical method is not readily available.

IHI has developed many computer programs for analytical stress analysis and has performed experimental stress measurements to analyze the complex parts and also to verify the analytical methods. Examples of the complex parts are control rod penetrations of head and nozzle connections.

A outline drawing of typical 1100 Mwe RPV is shown in Fig. 1.

It is very important to design a RPV suitable for the available fabrication techniques and facilities and planned examination and testing methods. Considerations should be given to the inservice inspection after operation.

Major parts of RPV for boiling water reactors are bottom head, cylindrical shell, shell and top head flanges, and top head. The bottom head consists of a central disk and 4 or 6 petal plates. The central disk is one piece or welded two or three pieces. The cylindrical shell consists of 4 shell courses which are welded 2 or 3 formed plates. The shell and top head flange are one piece forging. The top head consists of a central disk and 4 or 6 petals.

3. MATERIALS

For pressure retaining major parts of RPV, the following materials are currently exclusively used.

Plate: Manganese - Molybdenum - Nickel Low Alloy Steel

Japan Industrial Standard (JIS) SQV 2A
American Society of Testing and Materials (ASTM9
A-533 B Cl.1

Forging: Chromium - Molybdenum - Nickel Low Alloy Steel

JIS SFVV2
ASTM A-508 Cl.2

For control rod penetration nozzles and small partial penetrantion weld nozzles, the following material is used.

Nickel - Chromium - Iron Alloy

JIS NCF B
ASTM B-166

Chemical Compositions and mechanical properties of these materials are shown in Table 2.

In order that the materials are used for RPV, they must have appropriate tensile strength, yield strength, fatique property, high ductility and excellent impact property. Further, they are required to have good weldability, low crack sensitivity and not to be sensitive to neutron radiation.

Max. thickness 300 mm, max. width 4800 mm, max. weight 75 tons plates and max. outside diameter 7200 mm, max. forged weight about 200 tons forgings are currently available.

4. FABRICATION

4.1. General

In addition to required high quality, special features for fabrication of RPVs are such that RPVs are extra heavy in weight and large in outside dimensions; precise dimentional control is required; extensive machining is required; and it is required to go through many complex fabrication and inspection steps to complete the vessel. It usually takes 2 years or more to shop fabricate a RPV for large boiling water power reactors.

What is the most important in applying fabrication techniques to actual fabrication processes, is that they have been fully developed in the laboratory and also that they either have been proved in actual applications of same type or have been fully confirmed with respect to workability, adaptability in actual operations, and predictability of possible problems.

Therefore, detail planning for the fabrication processes and sequence prior to the fabrication and tight process control during the fabrication are very important.

An outline chart of the typical fabrication sequence is shown in Fig. 2.

4.2. Forming

The first operation in the shop is to form a plate to the specified dimensions. IHI Yokohama No.3 Works has a 8000 tons hydraulic pressing machine and a 3000 tons hydraulic bending roll for the forming of heavy plates. The pressing machine can handle a 6 meter wide plate inside the four poles. The bending roll can bend a 120 mm thick plate in cold and a 300 mm thick plate in hot.

For forming of plates of cylindrical shell courses, IHI uses the bending roll in hot condition. Plates for spherical heads are hot formed by the pressing machine using male and female dies. The heating temperature for hot forming is 850°C to 900°C and the forming operation is usually done between 800°C and 600°C.

Mechanical properties of the plate at elevated temperature are shown in Fig. 3 as a basis of hot forming temperature.

4.3. Quench and Temper Heat Treatment

After hot forming, the formed segments are quenched and tempered to enhance the mechanical properties especially impact property. If cold forming is performed using already quenched and tempered plates, the quench and temper after forming are not necessary, but degrade of the impact property due to plastic straining must be confirmed. The quenching operation consists of heating to above austenitizing temperature, 860°C to 900°C, and forced cooling down to 300°C. Quenching is followed by tempering heating to 650°C to 680°C and cooling in still air. The forced cooling for quenching is done in a water pit, 10.5 m in diameter and 6.1 m in depth, agitated by recirculating water.

After the quench and temper heat treatment, the mechanical properties of the plates are tested to confirm the proper heat treatment and the required mechanical properties, taking specimens for the prolongation of the plate.

An example of measured cooling courve is shown in Fig. 4. Examples of cooling rates and impact properties in thickness of plates are shown in Fig. 5 and 6.

4.4. Cold Sizing of Formed Plates

It is difficult to form the plates to the exact specified dimensions in hot condition and some distortion due to quenching can not be avoided. Therefore, cold sizing is required to obtain the exact formed dimensions after hot forming and quench-temper operations.

The cold sizing is performed, using the pressing machine or the bending roll, heating to about 100°C to preclude the possibility of brittle fracture. Since it is difficult to cold size a plate to a larger radius, the hot forming should be to a little larger radius than the final specified radius. The maximum fibre strain due to cold sizing should be less than 0.5%.

The shape and dimensions of the plate are checked by templates during the cold sizing, but the final acceptance of the dimensions is done after the detail dimensional check on a leveling platform. It is very important to obtain a formed plate of exact specified dimensions at this stage for precluding possible dimensional problems in later stages, even though it takes much time and labour.

After finishing the cold sizing, the base metal is ultrasonically examined for full volume by longitudinal wave and is examined by magnetic particle for entire surfaces.

4.5. Welding of Longitudinal Seam

After the cold sizing, weld edges for longitudinal seams are prepared by machining. The longitudinal seams of the cylindrical shell courses are welded by submerged arc welding process. Each 1/3 thickness of a seam should be welded in turn to minimize the distortion due to welding. The longitudinal seams of the petal section of head are welded by manual shielded metal arc welding process. In this case, four or six seams are welded simultaneously by the same number of welders as the seams to minimize the distortion.

For the longitudinal welding, it is also very important to use a strong restraining structure to minimize the distortion and to keep the good roundness.

Pre-heating, 150°C to 250°C, is performed during welding and is kept until an interstage stress relieving heat treatment (ISR). The keeping of the pre-heating until ISR and ISR are performed to avoid possible hydrogen delayed cracking. It is also desirable to finish the weld surfaces before the ISR to avoid possible stress relief cracking eliminating stress concentration such as undercuts.

The weld edges and back shipped area are examined by magnetic particle method. The weld is examined by radiographic and ultrasonic methods for full volume and by magnetic particle method for both surfaces, after ISR. IHI has a linear accelerator, a beta-tron and Co-60 isotopes for radiography of heavy wall welds.

4.6. Cladding

The inside surface of RPV is weld overlay cladded with 18-8 stainless steel or Ni-Cr-Fe alloy.

A single layer, 75 mm wide strip type, submerged arc welding process is used for cladding of major parts. For inside of nozzles, 37.5 mm or 25 mm wide trip type submerged arc welding is used, and for inside of small nozzles and local back cladding, manual shielded metal arc welding is used.

Strip type overlay cladding of cylindrical shell courses is done using turning rolls for positioning, whereas the cladding of spherical heads is done using welding positioners. 255 tons and 75 tons welding positioners are available at IHI. The maximum capacity of the turning rolls which IHI has is 800 tons.

Prior to the actual application of the strip overlay cladding, extensive parametric laboratory tests and a full size mock-up test were carried out to assure the stable and uniform chemical compositions as well as precluding of defects such as slag inclusions and undercuts.

Cladding is examined by ultrasonic and liquid penetrant methods.

A couple years before, micro cracks under the overlapped area of high heat input overlay cladding, such as strip and multiwire cladding, were found on the forged material after taking off the cladding. This under-clad cracking has been widely discussed and investigated in the world. IHI has also carried out extensive investigations on the under-clad crackings and has successfully developed a technique to eliminate the cracking using high frequency induction heating on the clad before stress relieving.

4.7. Nozzle to Shell Weld

All nozzles, except small instrumentation nozzles, are welded to the shell with full penetration welds. The weld joints should be located outside of nozzle outside corner radius so that effective ultrasonic inspection of the weld can be done. The welding process currently used is either manual shielded metal arc or submerged arc welding. The weld edges are prepared by machining.

Since the restraint for full penetration welds of nozzles is very high, pre-heating during welding, maintenance of preheating until ISR and finishing of weld surfaces before ISR are important to avoid any cracking.

4.8. Circumferential Weld

The circumferential welding of shell courses is done using submerged arc welding on turning rolls. Dimensional check of the shell courses should be done carefully before preparing the weld edges by machining, and dimensions should be adjusted by the weld edge preparation.

Dimensional check before edge preparation is especially important for the final circumferential joint, and fitting-up dimentions such as alignment of the center lines and azimuth of both shell should be carefully checked and measured prior to the start of welding.

4.9. Control Rod Drive Penetrations

The bottom head, which has control rod drive (CRD) penetrations, is the most complex part of a boiling water type RPV and time consuming to fabricate. The weld design of CRD penetration nozzles is shown in Fig. 7. Ni-Cr-Fe alloy is usually used for nozzle stub material. The socket type design is easier for welding but harder to prepare weld edges then the set-on type. IHI uses the set-on type usually.

For the set-on type, weld backing rings are used and 3 ~ 7 mm of root layers is removed by machining. In addition to difficult access for welding, distortion of CRD stubs due to unsymmetric configuration of weld edges is to be carefully controlled. CRD stubs, especially outer ones, tend to incline to hill side after welding, if proper control is not done. To control the distortion, control of weld bead sequences should be done in addition to use of heavy restraint jizs. In the extreme case, the welding of hill size is done after finishing the welding of valley side. It may be necessary to control the distortion within 3 mm at the top of CRD stubs. Extensive mock-up tests had been carried out to confirm the weldability and the control method for distortion.

The root layer and each 1/3 thickness of the weld are liquid penetrant examined and ultrasonic examination is performed for full volume of the weld.

The welding of CRD stubs to the bottom head is usually performed at the stage of bottom head assembly and at vertical position.

4.10. Stress Relief Heat Treatment

Stress relief temperature and holding time are 595°C to 635°C and minimum 15 minutes for the interstage stress relief (ISR) and 1 hour per 25 mm of weld thickness for the final stress relief. The final stress relief is done by either of the following methods. A method is to stress relieve the complete vessel in the furnace as a whole. The other method is to stress relieve upper and lower shell assemblies in the furnace separately and the final circumferential joint locally. IHI has 9.4 m x 9.4 m x 20 m long gas furnace to stress relieve a whole vessel. IHI has also performed local stress relieving at vertical position in a pit using electric heating elements with automatic control.

The local stress relieving method has an advantage of shortening the shop fabrication schedule, because time consuming machining of CRD penetration of vessel bottom and stud holes of shell flange, which must be done after final stress relief, can be done concurrently before the local stress relief. Another advantages of the local stress relieving method is that it does not require so large furnace.

For temperature measurement during stress relief, a several thermo-couples should be attached directly to the vessel. For local stress relief, more than 100 thermo-couple are atteched inside and outside of the vessel to measure heat treatment temperature itself and temperature gradient beyond the heat treated local area.

4.11. Final Machining

After final stress relief, the vessel must be checked for overall dimensions at vertical position and the center line and azimuth of the vessel must be established and marked clearly. Then, final machining is performed. For the bottom part of the vessel, CRD and in-core monitor penetration holes and bearing surface of support skirt are machined to exact dimensions and levels. For the shell flange, tapping of stud holes and machining and finishing of flange seal surface are done. IHI has a gantry type, numerical controlled vertical boring machine, specially designed for the final machining of RPV. This machine can travel over 4 m and 18 m deep pits and the final machining is done with excellent accuracy and speed at vertical position with this facility. Horizontal boring machines and special portable machines can be used for the final machining.

For the final machining of the top head, a rotary table is necessary to machine grooves for metal "O" rings and a slight taper of flange seal surface. IHI has a large vertical lathe with 250 tons rotary table.

Stainless steel part such as vessel to pipe transition pieces and internal bracket are welded after final stress relief to avoid furnace sensitization and machined, if necessary.

4.12. Cleaning, Hydrostatic Test and Shipping

After the final machining, the inside surface of the vessel is cleaned with wet sandblasting to remove oxide film on the cladding and followed by high pressure rinse with demineralized water. All openings are capped with mechanical seals and the vessel is filled with demineralized water for hydrostatic test.

Main flanges are bolted up using specially designed bolt tensioners. The water is heated so that the metal temperature of the vessel is higher than 36°C to preclude possibility of brittle fracture.

After the hydrostatic test, required non-destructive examinations are carried out and cleaned with high pressure water rinse. Hydrostatic caps are replaced with shipping caps. Shell flange and support skirt are sealed with blind plates. The outside surface is sand blasted and painted.

Nitrogen gas is purged inside of the vessel to protect from contamination of Chrodide or other harmful elements during shipment.

The vessel is shipped from the shop by sea way and loading on a boat is done by a floating crane.

TABLE - 1 MANUFACTURING EXPERIENCES OF REACTOR PRESSURE VESSELS (1/2)

ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.

LOCATION	OPERATING COMPANY	TYPE	MWe	DESIGN PRESSURE PSIG	DIMENSIONS ID MM	DIMENSIONS THICK MM	DIMENSIONS HEIGHT MM	MATERIAL	CODE	YEAR BUILT	REMARKS
FUKUSHIMA-1	TEPCO	GE BWR	460	1250	4,796 NOM. (188")	160 MIN.	19,681	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	ASME III ASME VIII MITI	1969	
FUKUSHIMA-2	TEPCO	GE BWR	780	1250	5,570 NOM. (218")	138 MIN.	21,921	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	ASME III MITI	1971	
FUKUSHIMA-3	TEPCO	GE BWR	780	1250	5,570 NOM. (218")	138 MIN.	21,847	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	ASME III	1972	
BROWNS FERRY-II	TVA	GE BWR	1075	1250	6,375 MIN. (251")	155.6 MIN.	23,214	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	ASME III	1971	Subcontracted by [illegible] Co.
BROWNS FERRY-III	TVA	GE BWR	1075	1250	6,375 MIN. (251")	155.6 MIN.	23,214	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	ASME III	1971	DO

TABLE - 1 MANUFACTURING EXPERIENCES OF REACTOR PRESSURE VESSELS (2/2)

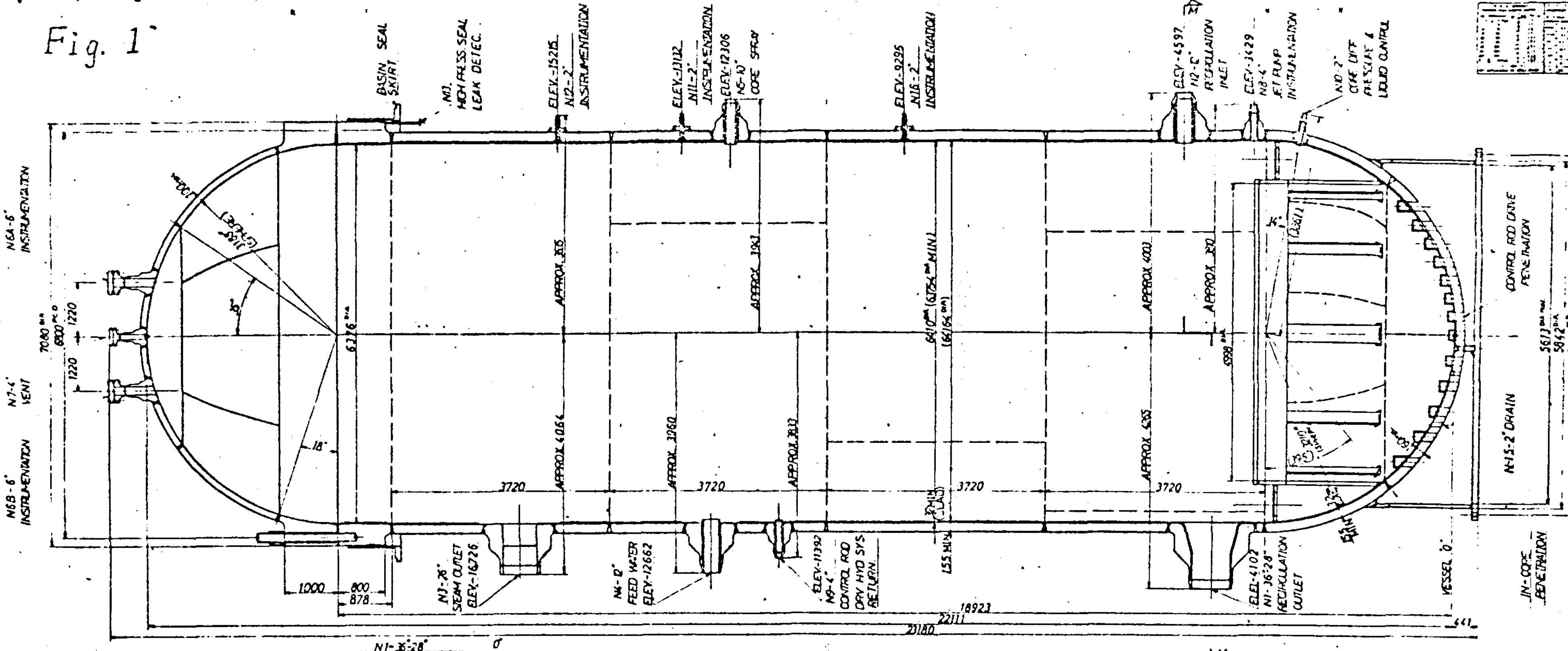
ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.

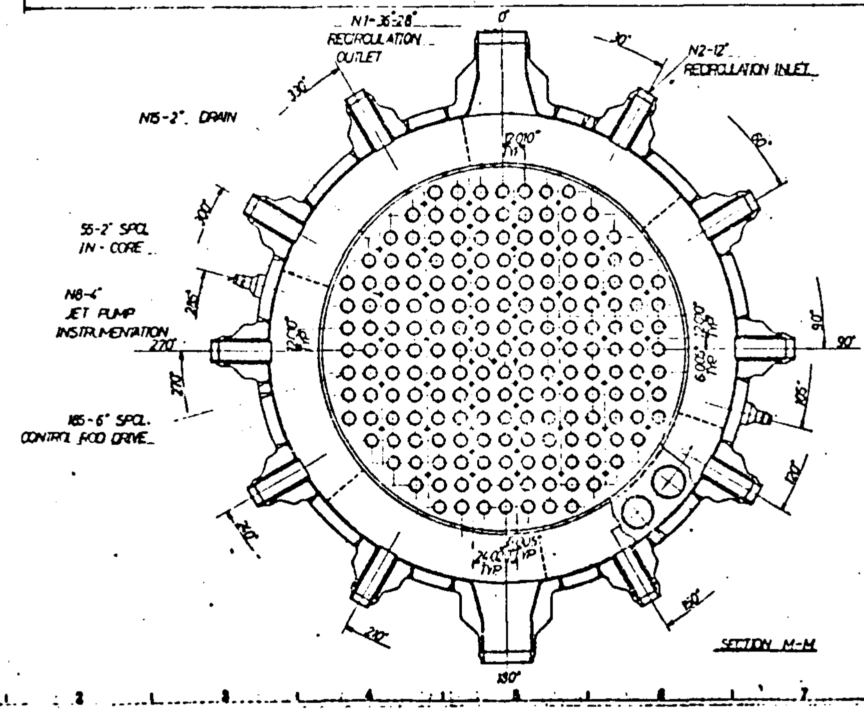
LOCATION	OPERATING COMPANY	TYPE	MWe	DESIGN PRESSURE PSIG	DIMENSIONS ID MM	DIMENSIONS THICK MM	DIMENSIONS HEIGHT MM	MATERIAL	CODE	YEAR BUILT	REMARKS
RINGHALS-I	SWEDISH STATE POWER BOARD	ASEA BWR	750	1233	5,950 NOM.	143 MIN.	21,335	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	SWEDISH CODE	1971	Subcontracted by B&W Ltd.
HAMAOKA-I	CEPCO	GE BWR	515	1250	4,680 NOM. (183")	114 MIN.	21,106	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	ASME III MITI	1973	
B -I	TOHOKU-EPCO	GE BWR	515	1250	4,680 NOM. (183")	114 MIN.	21,106	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	ASME III MITI	1974	
FUKUSHIMA-5	TEPCO	GE BWR	780	1250	5,570 NOM. (218")	138 MIN.	21,847	ASTM A533 GR.B,CL.1 ASTM A508 CL.2	ASME III MITI -	1974	
FUKUSHIMA-6	TEPCO	GE BWR	1100	1250	6,400 NOM	158 MIN.	23,[illegible]	"	"	1975	
NS-3	CEPCO	GE BWR	800	1250	5,570 NOM	133 MIN	21,847	"	"	1975	
2F-1	TEPCO	GE BWR	1100	1250	6400	158 MIN	23,[illegible]	"		1976	

Table-2 Chemical Compositions and Mechanical Properties

	A-533 B Cl.1	A-508 Cl.2	B-166
C max	0.25	0.27	0.15
Mn	1.15-1.50	0.50-0.80	1.0 max
P max	0.035	0.025	-
S max	0.040	0.025	0.015
Si	0.15-0.30	0.15-0.35	0.5 max
Ni	0.40-0.70	0.50-0.90	72.0 min
Cr	-	0.25-0.45	14.0-17.0
Mo	0.45-0.60	0.55-0.70	-
V max	-	0.05	-
Fe	-	-	6.0-10.0
Cu	-	-	0.5 max
Tensile Strength kg/mm	56.2-70.3	56.2 min	56.2 min
Yield Strength kg/mm	35.2 min	35.2 min	24.6 min
Elongation %	18 min	18 min	30 min

Fig. 1





NOZZLE NO	QUAN	SIZE	FUNCTION	AZIMUTH ±0°7'	DISTANCE FROM VESSEL "0" ±13	REMARKS
N1A, N1B	2	36"-28"	RECIRCULATION OUTLET	A:0°, B:180°	4,102	
N2A THRU N2K	10	12"	RECIRCULATION INLET	A:30°, B:60°, C:90°, D:120°, E:150°, F:210°, G:240°, H:270°, J:300°, K:330°	4,597	DESIGN PRESSURE 1565 PSIG
N3A THRU N3D	4	26"	STEAM OUTLET	A:72°, B:108°, C:252°, D:288°	16,726	
N4A THRU N4F	6	12"	FEEDWATER	A:0°, B:30°, C:150°, D:210°, E:270°, F:330°	12,662	DESIGN PRESSURE 1475 PSIG
N5A, N5B	2	10"	CORE SPRAY	A:120°, B:240°	12,306	
N6A, N6B	2	6"	INSTRUMENTATION	A:0°, B:180° ON TOP HEAD Φ36"	—	6" FLG. SMALL GROOVE FACING
N7	1	4"	VENT	ON ℄ OF TOP HEAD	—	4" FLG. SMALL GROOVE FACING
N8A, N8B	2	4"	JET PUMP INSTRUMENTATION	A:105°, B:285°	3,429	
N9	1	4"	CONT. ROD DRV. HYD. SYS. RETURN	146°	11,392	
N10	1	2"	CORE DIFF. PRESS. & LIQUID CONTROL	180°	—	10" FROM TANG. LINE OF LWR. HEAD
N11A, N11B	2	2"	INSTRUMENTATION	A:40°, B:220°	13,132	
N12A, N12B	2	2"	INSTRUMENTATION	A:40°, B:220°	15,215	
N13	1	1"	HIGH PRESS. SEAL LEAK DETECT.	BETWEEN HEAD BOLTS 0° APPROX.	—	3000LB SOCK. WELD FITTING
N15	1	2"	DRAIN	SEE SECTION M-M	—	
	185	6" SPL.	CONTROL ROD DRIVE	SEE SECTION M-M	—	
	55	2" SPL.	IN-CORE	SEE SECTION M-M	—	
N16A, N16B	2	2"	INSTRUMENTATION	A:40°, B:220°	9,296	

NOTE:
DIMENSIONS ARE IN MILLIMETER UNLESS OTHERWISE INDICATED

MATERIALS

1. SHELL PLATES: ASTM A533 GR.B, CLASS 1.
2. MAIN CLOSURE FLANGES AND NOZZLES: ASTM A508 CLASS 2
3. N-11,12 INSTRUMENTATION NOZZLES: ASTM B166
4. MAIN CLOSURE BOLTING: ASTM A540 B24 CLASS 3 AND CLASS 4.
5. CONTROL ROD DRIVE PENETRATION SLEEVES: ASTM A508 CL 1 WITH INCO-82 CLAD
6. CORE SHROUD SUPPORT: ASTM B168 AND A240 TP 304
7. SUPPORT SKIRT: ASTM A533 GR. B. CL 1.

WEIGHT

HEAD CLOSURE 89.5 ton.
MAIN VESSEL 576 ton
BOLTING MATERIAL 23.4 ton

Fig 1 OUTLINE OF R[illegible]
(1100 MWe BWR)

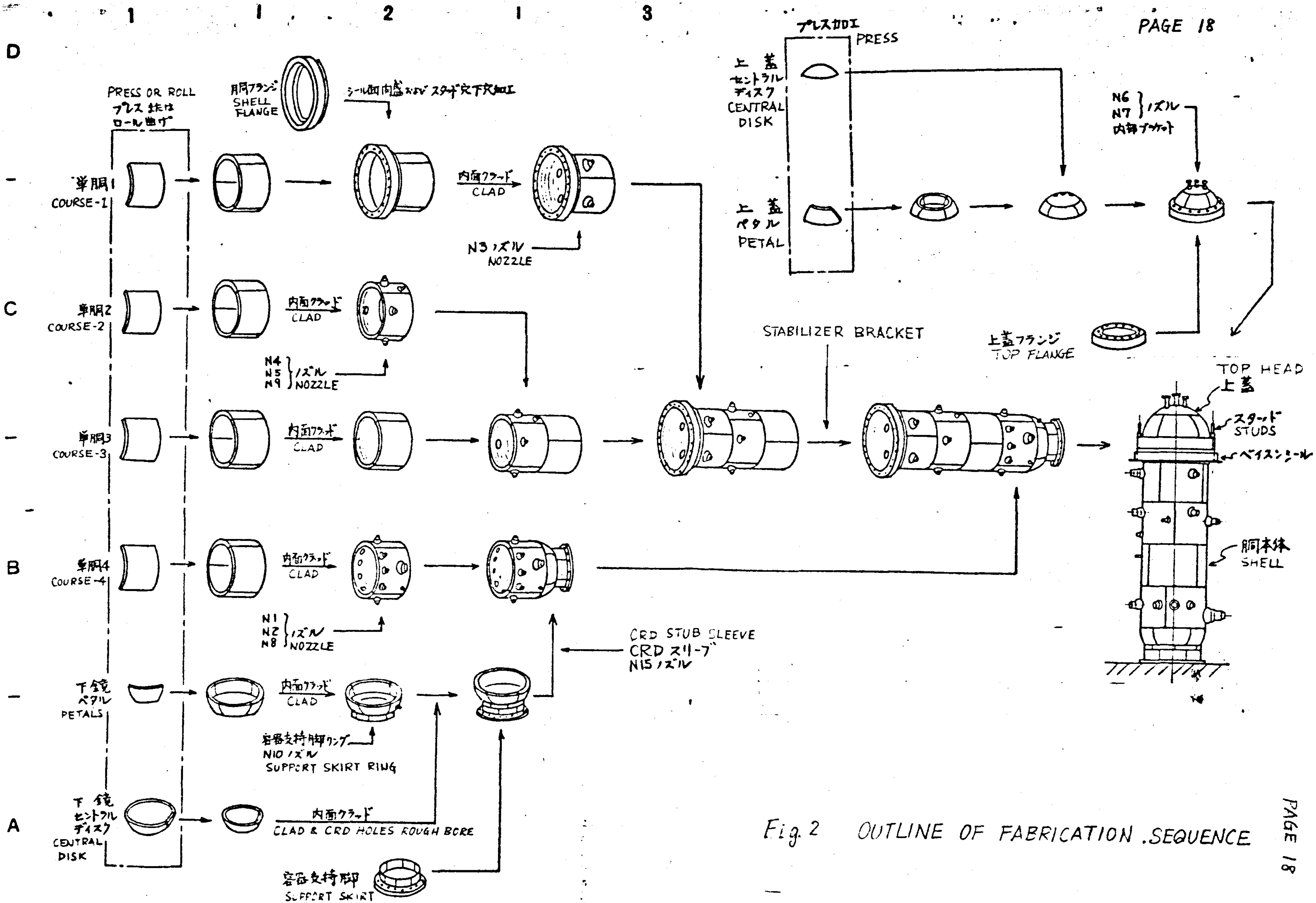


Fig. 2 OUTLINE OF FABRICATION .SEQUENCE

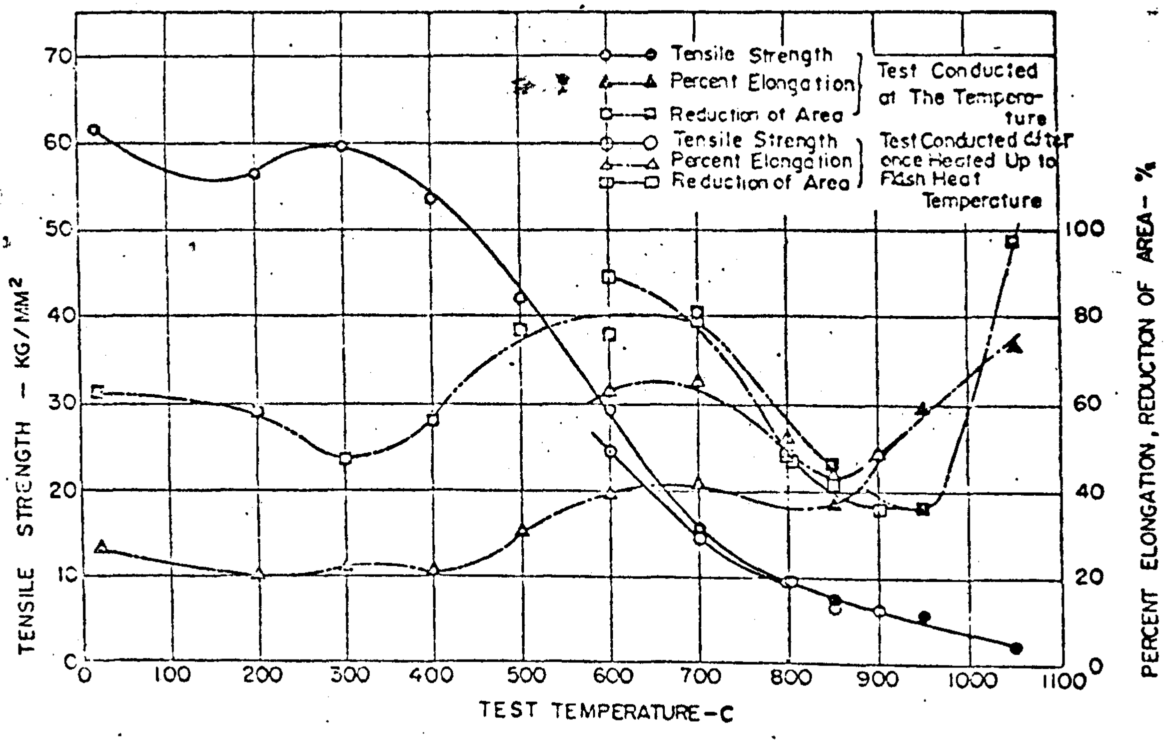


FIG.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE

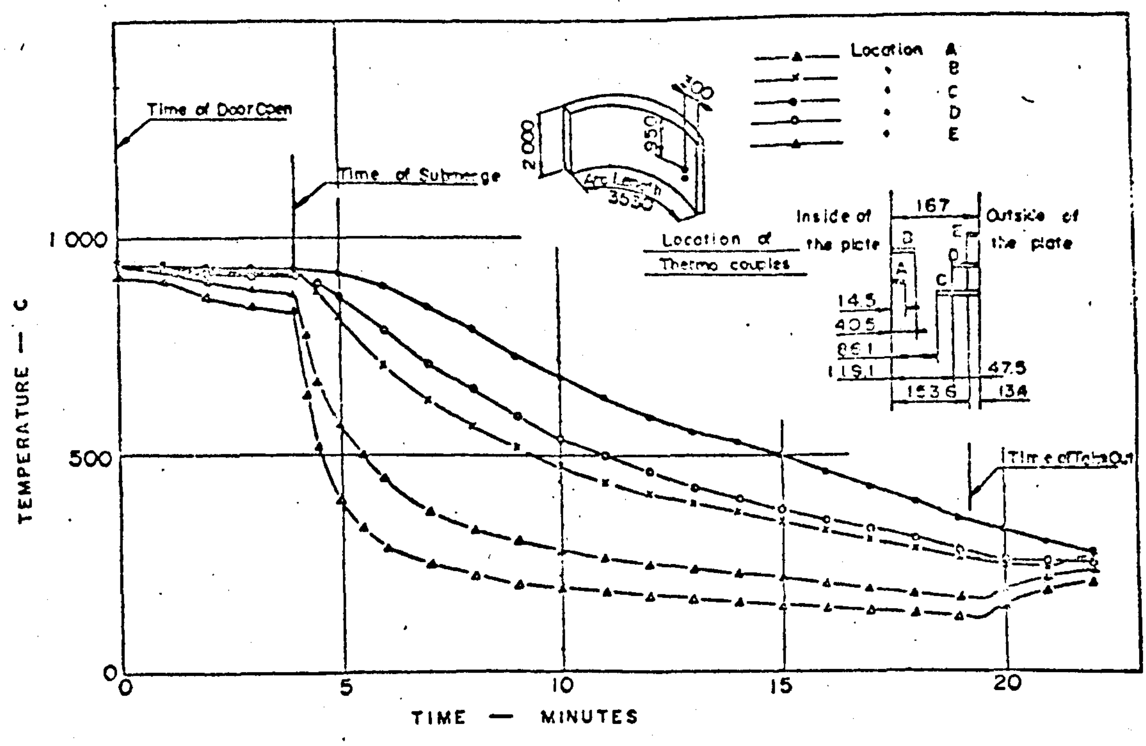


FIG. 4 COOLING CURVE OF PLATE DURING QUENCHING

Fig. 5 Cooling rate and location in plate during quenching

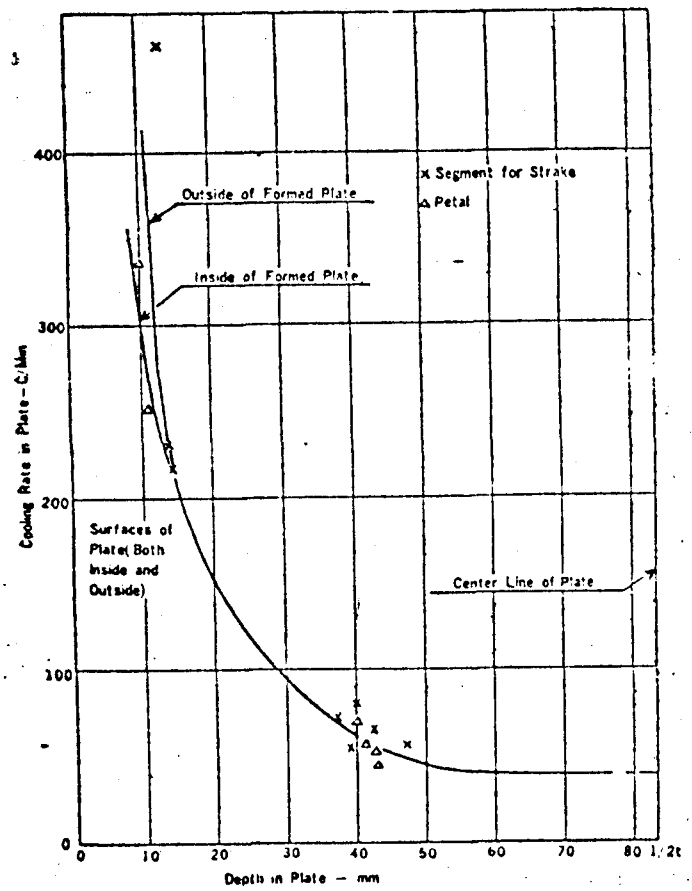
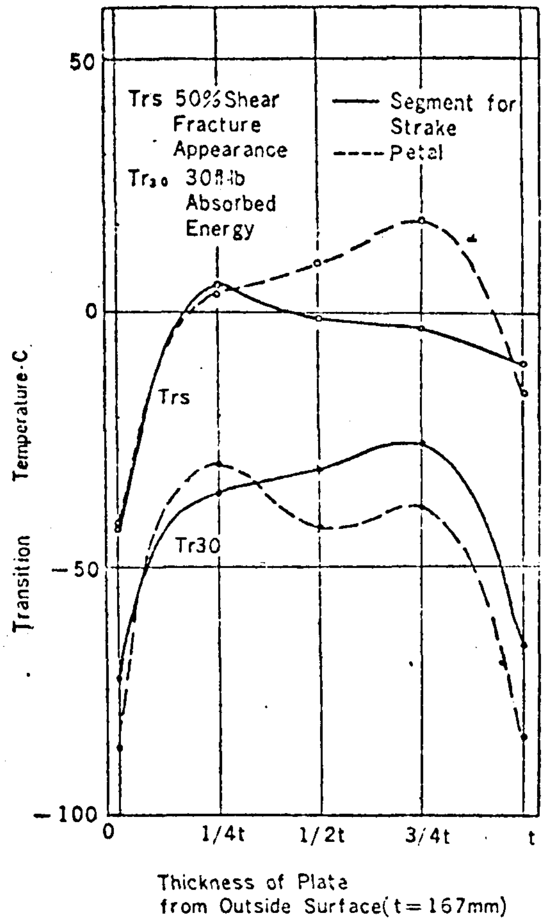


Fig. 6 Impact property of plate after heat treatment



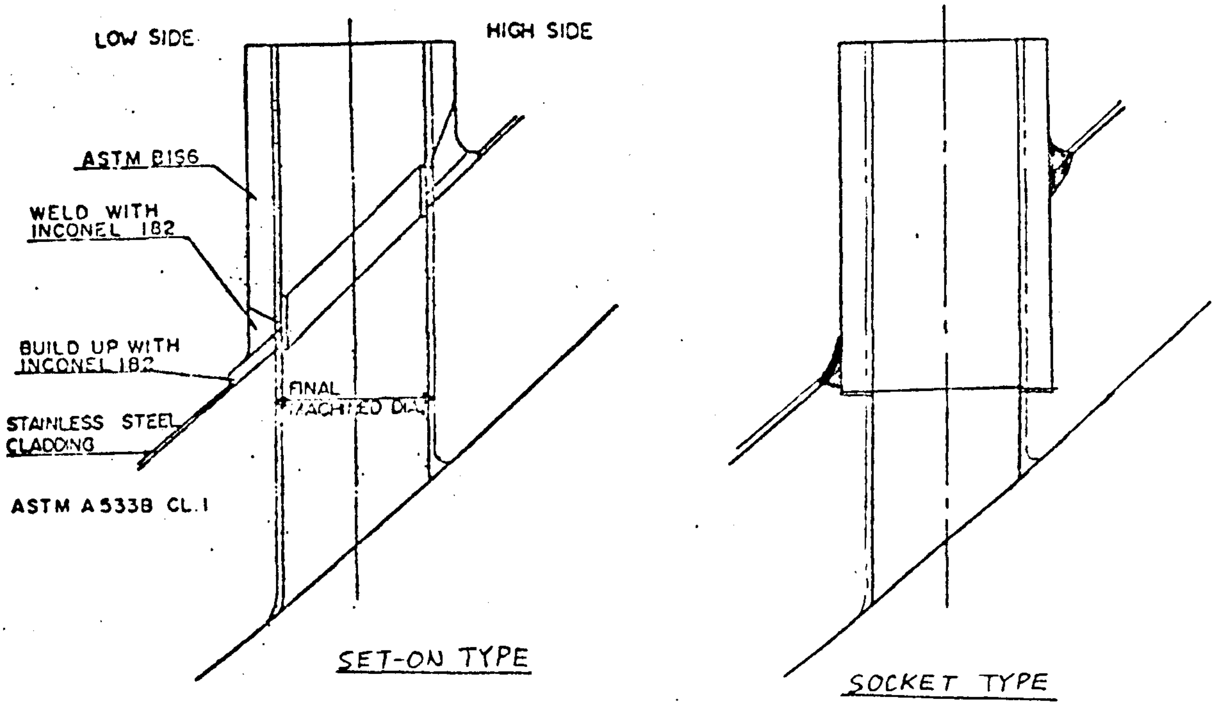


FIG. 7 TYPICAL CRD STUB TUBE

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QUALITY ASSURANCE AT ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO.

1. INTRODUCTION

It is the policy of Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) to provide products and services of a quality that meet the requirements of the applicable codes, regulartory authorities and our customers. To meet this objective, a systematic and planned control system of quality is established and executed for manufacture of nuclear equipment. A written quality assurance manual which describes the established quality system is prepared to be understood and used by all members concerned, and all quality related activities must be performed in accordance with the quality assurance manual.

IHI established a quality assurance system for manufacture of nuclear equipment, which was comparable to the current system, and prepared a quality assurance manual in 1967 at the start of manufacture of the first reactor pressure vessel for a large nuclear power station. Since then, the quality assurance system has been modified and strengthened through the experiences of actual performance.

IHI quality assurance system is established based on the requirements of ASME Boiler and Pressure Vessel Code Section III and USAEC 10 CFR (Code of Federal Regulations) 50, Appendix B, Quality Assurance Criteria for Nuclear Plants.

2. QUALITY ASSURANCE ORGANIZATION IN IHI

IHI has the Nuclear Power Division which is responsible for all activities relative to manufacture of nuclear equipment, including design, engineering, procurement, manufacturing and quality assurance. The General Manager of the Nuclear Power Division has the responsibility and authority for the over all operations of the Division and reports to the Executive Vice-President.

The Nuclear Power Division has the Design Departments Nuclear Equipment Quality Assurance Department (NEQAD), the Project Department and the Yokohama No.3 Works. The Yokohama No.3 Works has two Workshops for manufacturing and the Production Control Department. The interrelation of these Department and Workshops is shown in Fig. 1.

The authority and responsibility of persons and organizations performing quality assurance functions are clearly established. Such persons and organizations have sufficient, well-defined responsibility, authority and organizational freedom to identify quality assurance problems; to initiate action which results in solutions; and to verify implementation of solution to those problems.

NEQAD is independent of organizations directly responsible for performing the specific activities, and is responsible for checking, auditing, examination, test or otherwise verifying that an activity has been performed correctly.

NEQAD consists of the Quality Assurance Office and the Inspection Sections. The Inspection Sections are responsible for performance of quality control such as non-destructive examinations. The Quality Assurance Office is responsible for establishment of the over-all quality assurance system and preparation of the written quality assurance manual with the assistance of the department, workshops, offices concerned. The Quality Assurance Office is also assigned the responsibility for auditing and verifying that over-all quality assurance program has been correctly performed as established.

The Technical Review Board (TRB) are established under the General Manager of the Nuclear Power Division to foresee and resolve technical and quality problems on products and program. TRB plays key role in the quality assurance system, and has following three important functions.

(1) When employed new or special design, material, fabrication process, examination, test or other control systems, which will be necessary to control specially and more strictly, the technical and quality problems shall be discussed and resolved in advance in TRB. This fuction is necessary to prevent occurence of the anticipated problems in advance and to fabricate the high quality equipment.

(2) TRB is responsible for making the disposition of nonconformities.

(3) TRB shall discuss and recommend the corrective action to prevent recurrence of nonconformity including the deficiencies found in the audit.

The member of Board consists of the Managers or representatives of NEQAD, the Design Departments, Workshops and the Production Control Department. Specialists of the Research Institute or other organizations are called on TRB for consultation, as necessary. The position of the chairman of the Board is taken by the Manager of the Quality Assurance Office. TRB is called by the Quality Assurance Office at least once a month and as needed to review problems.

3. QUALITY ASSURANCE SYSTEM

1) Quality Planning

To assure the required quality of the products in the customer's specifications, applicable codes and regulations, correct interpretation, clear definition shall be made during the earliest stage of planning and required systems, facilities and personnels are reviewed, evaluated and provided to obtain the planned quality adequately.

The quality of the product will be planned from the raw material to the final stage of the product and will be correctly translated into drawings, specifications procedures, instructions and all the documents including those for shop use, which shall be reviewed by individual groups and shall be authorized by the management.

2) Procurement

All materials are procured from the suppliers who have been evaluated and qualified by IHI for their engineering, manufacturing and quality assurance capabilities and their past experiences. The suppliers is required to establish the quality assurance program to assure the proper quality levels specified in the purchase specifications. The product quality and the quality assurance activities are inspected and audited by IHI inspectors.

3) Material Control

After the receiving inspection of materials, identification numbers of every material will be marked to identify and control them throughout the fabrication in the shop. When a material is found defective or not conforming to the quality requirements, it is to be identified, documented, segregated and disposed to prevent its erroneous or inadvertent use.

4) Distribution of Drawings

A drawing distribution system in a manner which assures timely issuance and distribution of the drawing is maintained. In the system, it is also assured that only the latest issue is effective when some revisions are made due to design change or etc.

5) Process Control

Process control system shall be established and maintained to assure that each process meets quality requirements; the quality assurance program is properly understood and followed; parts and assemblies are identified; qualified personnel are employed in the welding and nondestructive examination processes; correction of non-conformance are properly performed, and only parts and assemblies meeting the quality requirements are released to proceed with next process.

The fabrication sequence and status are controlled with the Process Sheets. The Process Sheets are shop travellers and placed in shop and signed-off by the personnel responsible for each work step.

6) Welding Control

Welding is very important process for quality of the product. For welding materials, qualification test records and identification of heat or lot number, trade name and combination of heat number of welding wire and batch number of flux shall be maintained throughout storage, baking, issurance, welding and re-turning for re-baking. The welding materials are baked prior to issue and unused materials are returned after allowable exposure time for moisture control. Welding procedures must be qualified and qualified welders are employed in the welding and identified. Welding parameters actually used are recorded.

7) Calibration and Measurement of Test Equipment

All gauges, measuring and test devices are calibrated at periodic interwals determined on the basis of stability, purpose, and frequency of usage.

8) Audit System

Periodic and routine audits are carried out to assure the planned quality with all aspects of Q.A. system and to evaluate the effectiveness of the system. The results are reported to the management so that immediate corrective action will be taken when necessary and that the proper execution of quality system is verified.

9) Record Control System

As the evidence of compliance with the planned quality, complete files of records for all materials; fabrication, examination and inspection taken throughout the manufacturing are prepared and compiled systematically with full reference and identification to the procedures, specifications, stress reports and drawings applied to the manufacturing.

Fig. 1 ORGANIZATION CHART