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1. SUMMARY AND INTRODUCTION

1.1 SUMMARY

Section IV of the Facility Description and Safety Analysis Report provides a general description of the reactor vessel. Appendix G of that report describes the design and fabrication requirements for the reactor vessel. A study of the feasibility of shipping a shot assembled reactor vessel to the Monticello, Minnesota site has led to the conclusion that the major subassemblies should be fabricated in the shop with final assembly and erection to be accomplished at the plant site.

The purpose of this report is to:

(a) Describe the results of a General Electric task force study which led to the conclusion that a reactor vessel can be assembled and erected on the field to the same quality as a shop assembled vessel.

(b) Outline the engineering requirements for the design, analysis, selection of materials and fabrication of the reactor pressure vessel.

(c) Describe specific details for executing the design and the major fabricating techniques which will be utilized for the reactor pressure vessel.

(d) Describe the frame work of procedures, inspections, tests and approvals to assure the engineering requirements are satisfied.

Based on the above, General Electric, Chicago Bridge and Iron Co. and the Northern States Power Company have concluded that the Monticello Nuclear Generating Plant reactor pressure vessel may be site-assembled to the same quality or better than a shop assembled vessel and the reactor operated without endangering the health and safety of the public.

1.2 STUDY

In early 1965 General Electric's Atomic Power Equipment Department established a Task Force to study the feasibility and merits of various degrees of on-site assembly and erection of reactor pressure vessels of the sizes being forecast for boiling water reactor power plant for sales in the 1966-70 period.

The need for this study was brought about by the growing nuclear power industry and the desirability or opening up a large number of potentially highly attractive nuclear power plant sites which were not available by water transportation necessary to ship large and heavy shop assembled reactor vessels.

This study included a technical evaluation of the fabrication processes involved in assembling a BWR reactor vessel to determine if there were any limitations in accomplishing all or any part of these operations at the reactor plant site. The Task Force concluded that the answer to this question was economic rather than technical. The most economical approach to providing reactor vessels to sites not now open for fully shop

assembled vessels is to accomplish as many tasks in the shop consistent with normal transportation available to the plant site.

One of the major conclusions of this study was that there is no technical basis for not being able to site assemble and erect a reactor vessel of the diameter and wall thicknesses evisioned for large BWR's which has the same quality as a similar vessel fully assembled in the fabrication shop.

This Task Force not only utilized the best technical manpower available in the General Electric Company but also utilized sources in the large diameter, heavy wall pressure vessel fabrication industry. Uses of industry sources included a review of the large diameter, heavy wall pressure vessels which have been assembled and erected at the site.

Based on the favorable conclusions of this Task Force, the General Electric Company offered for sale nuclear power plants to be located on sites which required partial assembly and erection of the reactor vessel at the plant site. The Northern States Power Company's Monticello, Minnesota plant is to be the first GE-BWR to utilize this method of vessel fabrication.

Additional details of the Task Force study are included in Appendix A.

II. FEASIBILITY OF SHIPPING A SHOP ASSEMBLED REACTOR VESSEL TO MONTICELLO SITE

2.1 GENERAL

A study was conducted during May-June, 1966 to determine the feasibility of transporting a shop assembled reactor vessel to the Monticello Site. The study included reviewing alternate routes by personal inspection, contacting pertinent sources of information and reviewing resulting possibilities with the appropriate municipal, state and federal agencies.

A shop assembled vessel would have to be delivered to the head of navigation on the Mississippi River at Minneapolis by September 1, 1968. The move from the head of navigation to the Monticello Site would be accomplished in three phases:

1. River transport by barge to the docking site which would be about four miles upstream from the head of navigation.

2. Docking the barge and unloading the vessel to a transport vehicle.

3. Road transportation from docking site to the Monticello Site.

The major problems in the first phase include dredging a channel four miles, and crossing a pair of City of Minneapolis submarine water mains. Crossing the water mains would require special techniques and must be accomplished at high water when there would be approximately four feet of water over these lines. High water occurs for a very brief period about September 1. The barge would have to be at the docking site by November 11--the end of the navigation season for the Minneapolis Upper Harbor.

The principal problems for the second phase include securing sufficient land and local approval for a docking and unloading site.

The third phase has many obstacles besides the economic considerations, but the most serious one involves obtaining permission to travel on village roads. The only feasible route for the majority of road transport (about two-thirds of the distance) is over a new Interstate Highway now under construction. The State Highway Department would permit use of this highway at a point in construction when the subgrade is complete, but before paving, and when it is thoroughly frozen. This would mean movement over this highway in January-February, 1969.

The earliest a shop assembled vessel could be completed and delivered to the head of navigation in Minneapolis is about March 1, 1969, thus for all practical purposes ruling out delivery of a shop assembled vessel to the Monticello Site. Additional details of this feasibility study can be found in Appendix B.

III. REACTOR VESSEL DESIGN

3.1 DESIGN REQUIREMENTS

The Monticello Nuclear Power Plant reactor vessel shall be designed in accordance with the ASME Boiler and Pressure Vessel Code, Section III, 1965 Edition, and addenda and applicable ASME Code Case Interpretations in effect on the date of the contract July 18, 1966, local jurisdictional requirements and General Electric, APED Specification. The State of Minnesota has no requirements for the reactor vessel design beyond the requirements of the ASME Code. The requirements for the design of Monticello reactor vessel as contained in the ASME Code and the General Electric APED Specification are identical to other reactor vessels currently being designed for General Electric, including those for Quad Cities I and II Nuclear Plants being designed by the Babcock & Wilcox Company and the Millstone Point Nuclear Plant being designed by Combustion Engineering. The loading conditions, of course, vary due to the difference in plant size.

3.1.1 The principal design requirements of the ASME Code are as follows:

1. A Registered Professional Engineer experienced in pressure vessel design must certify that the General Electric specification is a "specification of functions and design requirements including its classification, related to operating conditions in such detail as will provide a complete basis for design, construction, and inspection" in accordance with the ASME Code.

2. A detailed stress analysis is required for all pressure containing parts of the reactor vessel. A stress report must be prepared which contains a complete set of the stress analysis calculations and design drawings of the pressure parts of the reactor vessel. A Registered Professional Engineer experienced in pressure vessel design must certify that the design complies with all requirements of the design specification and the ASME Code.

3. A fatigue analysis is required to demonstrate the suitability of all reactor vessel components subjected to cyclic application of loads and thermal conditions. Unless the amplitude of loading or range of temperature change of cyclic conditions can be demonstrated to be within acceptable limits by conservative approximations as prescribed in the ASME Code, either a detailed transient stress analysis or a fatigue test must be performed. The stress or strain concentrating effects of structural discontinuities, and the cumulative effects of different types of stress cycles on the same part must be taken into account in the fatigue analysis.

4. Maximum shear stress theory is used to establish stress limits applied to the detailed stress analysis. The stress intensity defined as the largest absolute value of the differences between the principal stresses (twice the maximum shear stress) must be within the stress intensity limits prescribed by the Code. The stress intensity limits allowed depend on the type of loading producing the stress. Primary stresses are those stresses which must be developed to satisfy the simple laws of equilibrium. Their basic characteristic is that they are not self-limiting, and if they considerably exceed yield strength gross distortion or failure will occur. Secondary

stresses are those stresses developed by the constraint of adjacent parts or by self-constraint of a structure. Their basic characteristic is that they are self-limiting and local yielding or minor distortion limit the stresses and failure should not occur as a result of their exceeding yield strength in one application.

5. The maximum allowable stress intensity (twice the maximum shear stress) must be no greater than the following depending upon the category of the stress:

   Primary general membrane stress is limited to the lesser of:

   1/3 Ulitmate Tensile Strength at design temperature or the specified minimum at room temperature whichever is less.

   2/3 Yield Strength at design temperature or the specified minimum at room temperature whichever is less. (Except in the case of austenitic steels, 90 percent of Yield Strength at design temperature applies instead of 2/3 Yield Strength at design temperature.)

   Combined primary general membrane plus primary bending stress intensity is limited to 1.5 times the allowable stress intensity for primary membrane stress intensity.

   Combined primary plus secondary stress intensity range is limited to 3 times the allowable stress intensity for primary membrane stress intensity.

6. The maximum allowable alternating stress intensity including stress concentration (or fatigure strength reduction factors) and localized thermal stress is established separately for (1) carbon and alloy steels and (2) 18-8 stainless steels and Nickel-Chromium Iron Alloy (Inconel) depending on the number of cycles. The allowable alternating stress intensity was determined using a factor of 2 on stress (strain) or 20 on cycles whichever was greater from fatigue tests to failure performed on polished speciments of these materials. Cyclic tests performed on pressure components have not resulted in failure at less than twice the allowable number of cycles.

7. The minimum thickness of pressure parts are prescribed by the membrane stress limits resulting from pressure loading.

8. Openings in pressure parts must be reinforced by replacement of the area of opening within prescribed proximity limits from the opening.

9. Pressure containing welds are required to be full penetration welds of a design to facilitate radiography to Code standards except for specifically controlled small nozzle connections. Where nozzle weld configurations are such as to make radiographic examination or interpretation difficult supplemental ultrasonic examination is required.

10. The transition between sections of unequal thickness is limited to be no more abrupt than a 3:1 taper.

3.1.2 In addition to the ASME Code, the following design requirements are included in the General Electric Specification:

1. All of the reactor vessel design drawings and stress analysis calculations must be submitted to General Electric for an independent review and approval by an engineer experienced in pressure vessel design.

2. A calculation of relative flange rotations and bearing loading on flange faces is required to predict flange closure seal operation. Empirical criteria are established to assure satisfactory seal performance during operation.

3. Fillet radii between two parts must be at least half of the thickness of thinner of the two parts being joined.

4. If reinforcement for openings (except the control rod drive and incore flux monitor nozzles) requires local added thickness of the vessel shell, such added thickness shall extend at least 1.5 times the diameter of the opening from the center of the opening.

5. Dissimilar metal welds in nozzle ends must be at least 1.25 times as thick as the connecting pipe wall thickness. The weld and nozzle for prescribed lengths on either side of the weld are of constant thickness.

6. Spherical washers are used under the main closure head nuts to reduce stud bending stress. The radii at the crest and root of stud threads are controlled to result in lower stress concentration factors than standard screw threads.

7. Weld seams are located to avoid, in so far as practical, the area of highest neutron flux opposite the core and vessel penetrations.

3.2 PERFORMANCE OF REACTOR VESSEL DESIGN ANALYSIS

The reactor vessel for the Monticello Nuclear Generating Plant is being designed by the Chicago Bridge and Iron Company (CB&I). A portion of the detailed stress analysis is being performed by the General Electric Co., Atomic Power Equipment Department. The detailed division of responsibility for the design and detailed stress analysis is as follows:

Responsibility	Item Description
CB&I	Detailed Design Drawings
CB&I	Part sizing and Detailed Configuration
CB&I	Primary Stress Analysis
GE	Steady State Thermal Stress Analysis

Responsibility	Item Description
GE	Transient Thermal Stress Analysis
GE	Certification of Steady State and Transient Thermal Stress Analysis
CB&I	Certification of Design Report per ASME Code
CB&I	Overall responsibility for design, fabrication and testing in accordance with ASME Code and General Electric Specification.

Thus, Atomic Power Equipment Department is providing a calculational service to Chicago Bridge & Iron. This arrangement is not typical, but was utilized in order to obtain timely completion of the analysis since CB&I manpower was not available to complete the entire analysis. In the actual performance of this analysis CB&I has temporarily assigned two stress analysis engineers to work with and under the direction of General Electric engineers.

Since a portion of the stress analysis for the Monticello reactor vessel is being performed by General Electric, consideration is given to having an independent party review the design analysis. A comparison of the review and approval process on a typical reactor vessel design and the Monticello reactor vessel design is shown schematically on Figure III-1.

In the typical case in the past, the design drawings and complete stress analysis calculations would be prepared by the reactor vessel supplier and submitted to General Electric for review and approval. A General Electric design engineer, experienced in pressure vessel design has the sole responsibility for this review and approval. This review and approval would typically include:

1. Verification that all applicable loading conditions have been taken into account.

2. Method of analysis including thermal and stress models realistically represent the part under consideration.

3. Assumptions, boundary condition, physical constants, and stress concentration factors are appropriate.

4. Spot checks of mathematical manipulations.

5. Verification that ASME Code stress criteria and fatigue evaluation criteria have been fulfilled.

6. Comparative evaluation for gross similarity with analyses of similar components of other reactor vessels.

The design engineer has at his disposal a material engineering unit and a stress analysis unit which can provide assistance in specialized areas. All design drawings which pertain to fabrication and inspection procedures are reviewed by the materials engineer responsible for the applicable fabrication and inspection procedures. The stress analysis unit is available to comment on stress analysis techniques and for the performance of independent detailed stress analyses. It is the practice of General Electric not to perform

a complete independent analysis, but only on a first-of-a-kind basis and then only when the design detail or loading condition makes the analysis non-routine and complex.

As shown on Figure III-1, the design drawings and primary stress analysis for the Monticello reactor vessel will be completed by CB&I and submitted to the design engineer just as described in the typical case described above. Upon review for functional and fabrication requirements, the design engineer would approve the design drawing subject to completion of the steady state thermal stress and analysis and the transient stress analysis by the stress analysis unit. This analysis is submitted to the design engineer for an independent review and approval identical to the review of analyses typically submitted by suppliers as described above. The completed and approved analyses performed by General Electric is certified by a General Electric Registered Professional Engineer experienced in pressure vessel design and furnished to CB&I for inclusion in their stress analysis report.

The only difference between the typical review and the review performed for the Monticello reactor vessel design is that a part of the stress analysis function is transplanted from the supplier to General Electric, and this means that there is no provision for a complete independent stress analysis of components. However, none of the design details or loading conditions of the Monticello reactor vessel are expected to be of a category which would require a "first-of-a-kind" independent analysis. Therefore, it has been General Electric's conclusion that an independent review of the design analysis is not required. If, during the course of design, any new or unusual design considerations develop, the need for an independent review of those design analyses will be re-evaluated.

The only difference about the reactor vessel design for Monticello Nuclear Generating Plant and other plants is not in the vessel itself, but in the supporting structure. The base of the reactor vessel support skirt will be welded to a steel supporting cylinder rather than to a flange. In the past, shop assembled vessel support skirts have terminated at a flange which was held down on sole plates on a reinforced concrete support pedestal with anchor bolts cast into the concrete. The Monticello vessel support skirt will be welded to a steel cylinder rising from the secondary containment vessel as shown in Figure III-2, is used to support the vessel during field erection. This steel cylinder will be designed to withstand the imposed loads resulting from the weight of the vessel, test water and other construction and test loads.

The final reactor vessel support structure is shown in Figure III-3.

The pedestal concrete will be placed with the minimum possible load on the vessel skirt (head removed, no water in vessel, no pipe attached to vessel nozzles, etc.).

Shear rings or other means will be provided to transfer the additional vessel loads resulting from the weight of fuel, water, piping, etc., to the concrete pedestal and to make the vessel skirt and pedestal act as a composite structure.

The final vessel support, consisting of the pedestal and biological shield wall will be designed to resist seismic and jet forces in addition to the operating and dead loads. Lateral support for the top of the vessel and shield wall is provided by means of the stabilizer, truss and shear lugs shown in Figure III-3.

3.3 MATERIAL SELECTION

The materials selected for the Monticello reactor vessel are the same materials used in vessels currently being made as shop fabricated vessels for other General Electric Company plants. The main pressure parts shall be made of the following materials:

1. Cylindrical shell and heads shall be made from low alloy steel plate in accordance with ASME SA-533, Grade B, Class 1 per ASME Code Case 1339-2. (This material was formerly designated ASME A302, Grade B modified per ASME Code Case 1339-1).

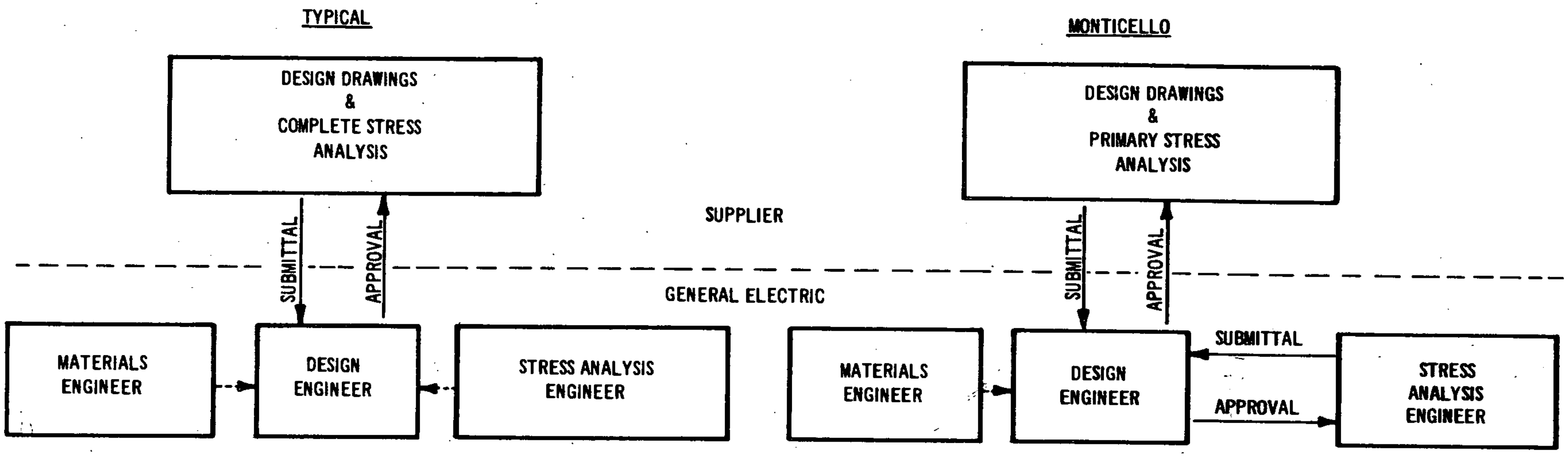
2. The main closure flanges and the principal nozzles shall be made from low alloy steel forgings in accordance with ASME SA-508, Class 2, per ASME Code Case 1332, paragraph 5.)

3. The studs, nuts, bushings and washers for the main closure flange shall be made from alloy steel in accordance with ASME SA-540, Grade B24, Class 3 for studs and Class 5 for the nuts, bushings and washers, per ASME Code Case 1335-2. (This is SAE 4340 material as was formerly designated ASME SA-320, Grade L43 per ASME Code Case 1335, paragraph 4.)

The material for the core structure support has tentatively been selected as Nickel-Chromium-Iron Alloy (Inconel 600) in accordance with ASME SB-168 per ASME Code Case 1336.

3.4 APPENDIX MATERIAL

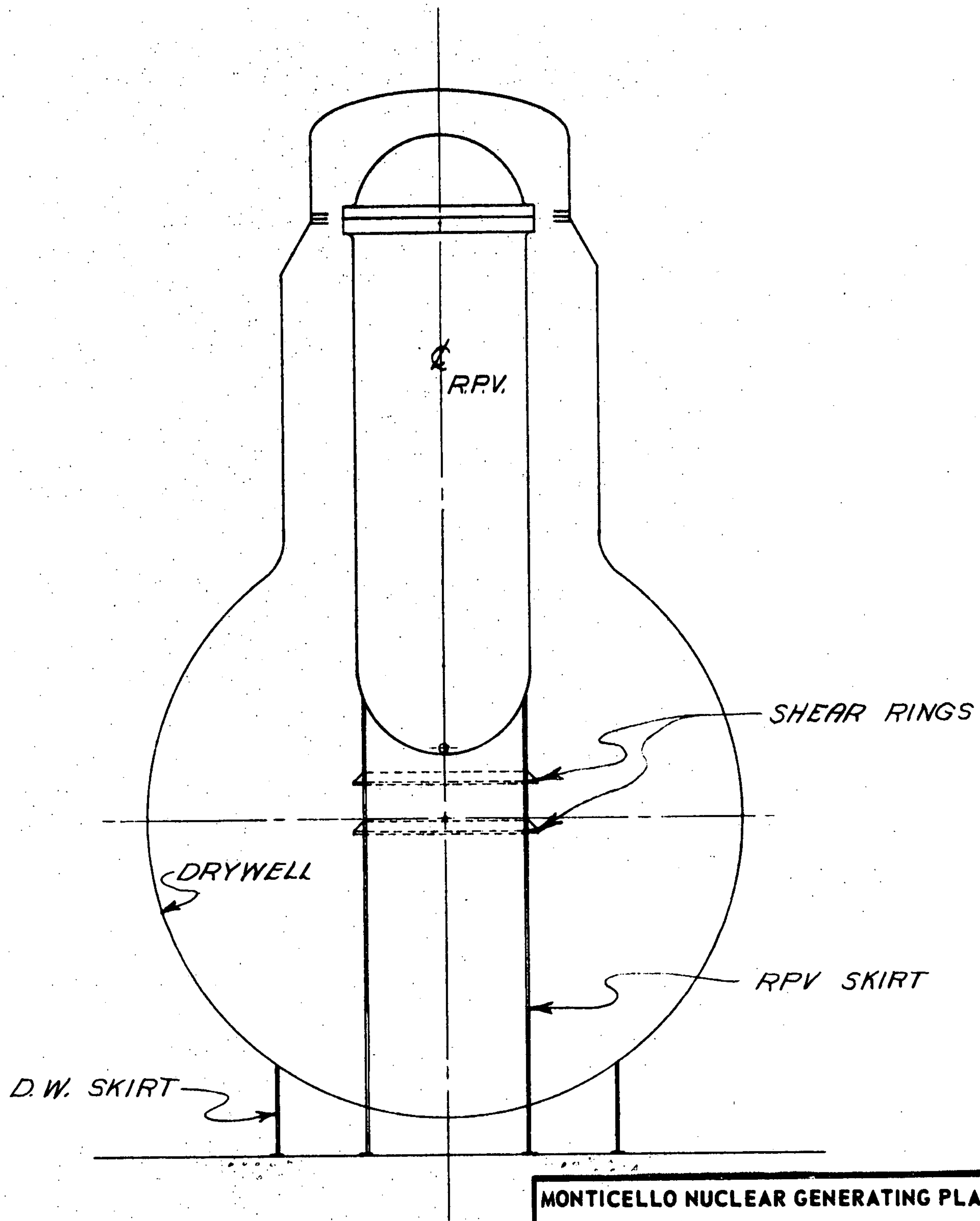
The specific General Electric "Engineering Requirements" for the Monticello Reactor Vessel are included in Appendix C.



MONTICELLO NUCLEAR GENERATING PLANT

Comparison of Review and Approval Process

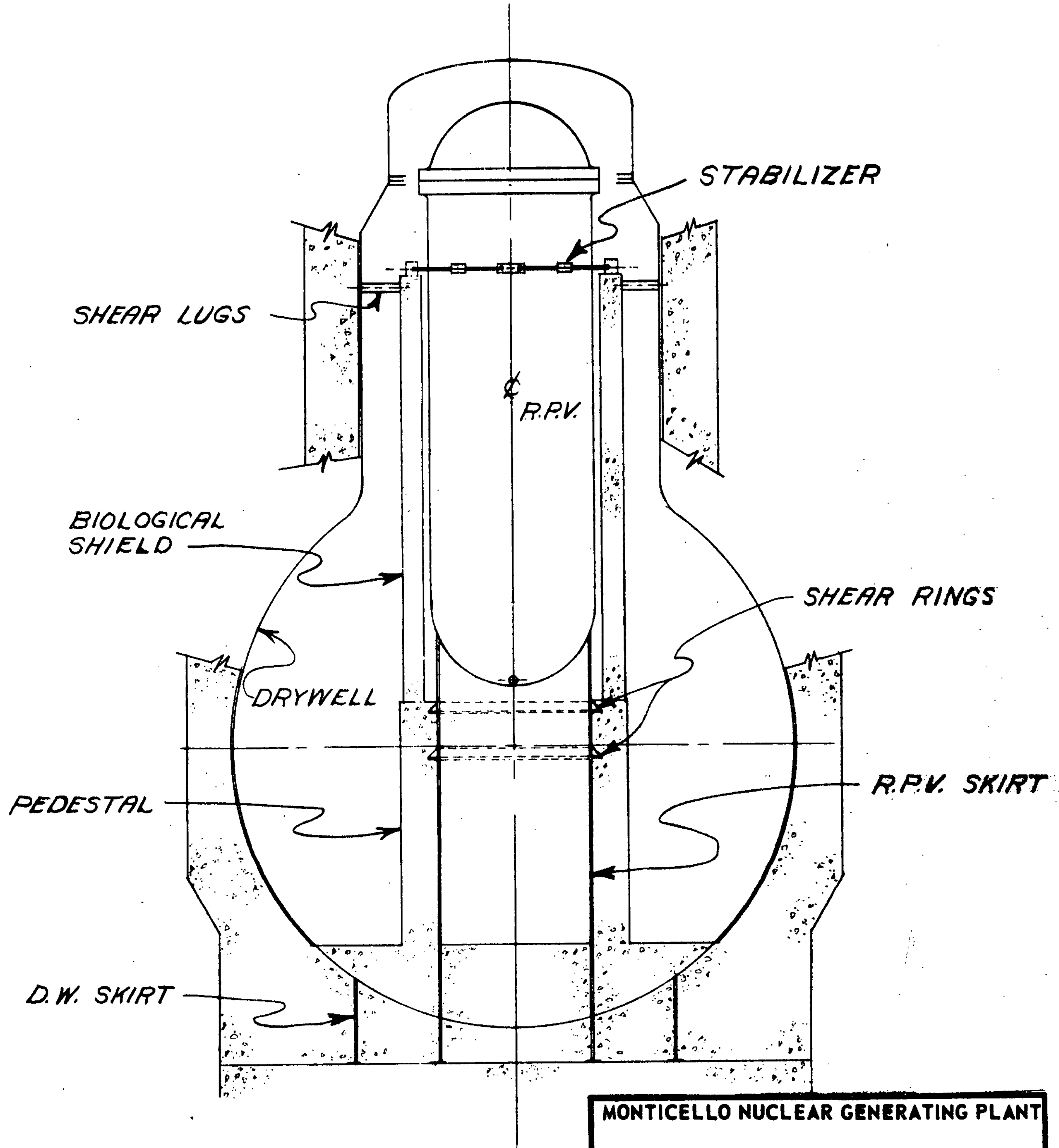
FIGURE III-1



MONTICELLO NUCLEAR GENERATING PLANT

Field Erection Vessel Support Structure

FIGURE III-2



MONTICELLO NUCLEAR GENERATING PLANT

Final Vessel Support Structure

FIGURE III-3

IV. VESSEL FABRICATION AND ASSEMBLY

4.1 DIVISION OF WORK AND PROJECT ORGANIZATION

A significant portion of the vessel fabrication will be performed in the shop, just as though the vessel were to be final assembled and tested before shipment. This work will be entirely in accordance with the Code and GE fabrication and quality control requirements. The balance of the fabrication and assembly at the site will be performed, utilizing proven techniques and equipment without any compromise whatsoever in the design, quality, or functional requirements of the vessel.

The project organization chart is shown in Figure IV-1. It clearly delineates (as is discussed in Section 4.5 the line responsibilities of the Project Manager and the Quality Control Manager. Overall control of the project is the responsibility of the Central Regional Operations Manager, F. E. McAtee, whose office is in Chicago, Illinois.

A detailed critical path method network schedule has been developed so that the critical path flow of materials is known and an on-time completion of the reactor vessel by February 1, 1969 is assured.

A typical site assembly area is shown in Figure IV-2 and an artist's rendering of the completed composite reactor and containment vessels is shown in Figure IV-3.

4.2 SHOP FABRICATION AND SUBASSEMBLY WORK

As much fabrication and subassembly work as possible will be performed at CB&I's Birmingham, Alabama manufacturing plant. The overall job economics favor this approach because of the convenience of overhead handling equipment, utilization of the existing shop labor pool and facilities for machining, heat treatment, etc. Restriction on shipping dimensions (not weight) was the determining factor in considering how much of the vessel assembly work could be performed prior to shipment.

An effort was made to clear complete shell rings 18 feet 2 inches diameter by 10 feet 11 1/2 inches long, weighing 140,000 pounds. While these rings could be barged to Minneapolis, the interconnecting railroad (Minneapolis, Northfield and Southern Railway) could not move the shipment from Port Cargill to the Great Northern Cedar Lake yard interchange. The Great Northern services the Monticello area. Overland truck handling clearance checks, to date, have also been unsuccessful in finding an open route to the Great Northern Railroad; therefore, half ring sections will be shipped from the shop. Figure IV-4 shows the proposed shop assembled pieces for the Monticello reactor vessel.

A 17 foot diameter support skirt extension with leveling devices attached will be shipped in one piece to the site. It will splice the stub skirt on the vessel bottom head to the long skirt constructed with the drywell, as shown in Figure IV-3.

It is planned that cold forming procedures will be utilized to press the bottom head, shell and top head plates. All plate material will be detailed to the maximum length and width dimensions that can be delivered from eastern mills and porperly handled by the fabricating facility. The shell plates will be purchased in the quenched and tempered condition and cold formed utilizing approved procedures.

Before commencing fabrication, all plates will be inspected for size, thickness, surface condition and the mill stamps properly identified. Ultrasonic testing of material will be done by trained, well-qualified personnel in accordance with Code specifications. Certified mill test reports and all quality control measures will be reviewed by CB&I engineers to assure compliance with material specifications.

After the plates have been marked and flame cut to approximate size, they will be pressed to shape on a 6,000 ton hydraulic press, designed by CB&I. Any minor deviation from curvature tolerances found in checking with box templates and sweeps will be corrected by sizing the plates on this press. Each plate will when be marked and cut to size and edges beveled with semi-automatic cutting torches. In order to insure proper dimensions and alignment, shop assembled weldments will be fit up and match-marked prior to shipment to the job site for assembly and welding together there.

A procedure developed to qualify this shop fabrication technique is referred to in Section 4.5, CB&I Quality Control Plan, and is included in the Appendix F.

The bottom head will be shipped in two sections consisting of (1) the knuckle course of plates with the stub skirt attached and (2) the dollar plate assembly. The dollar plate assembly will be predrilled in the shop to accommodate the 121 control rod drive sleeves. The initial holes will be approximately 5 inches in diameter, large enough to pass a boring bar cutter assembly used in the final in-place boring for the sleeves at the site. This assembly and pre-drilling work will be performed at CB&I's Greenville, Pennsylvania plant because of the availability of machining equipment there. The final drilling will be performed in place at the site. At the site, these holes will be enlarged and countersunk to accept the 7 1/2" outside diameter sleeves, which are welded to the bottom head, and subsequently bored out in-place to the nominal diameter of 6".

The bottom head knuckle course shop weldment will be positioned and two overlay weld metal build-ups will be applied (indicated schematically in Figure IV-5) in the two areas where the shroud support field welds to the bottom head. These weld build-ups will be shop machined to the contours shown in Figure IV-5.

The Monticello vessel shell will be made up of four rings, approximately 11 feet wide. Each ring will be made from two formed plates. The half ring sections will be temporarily joined together, thus allowing a complete ring to be placed on a roller bed. The complete ring

will then be preheated and the overlay weld metal deposited, utilizing automatic equipment similar to that shown in Figure IV-6. All shell fittings, with the possible exception of the 36 by 28-inch recirculation outlets, will be shop installed. Post weld heat treatment will be performed and inspection of the overlay weld deposit and insert seams will be made after cool-down.

All shop work will be subjected to the rigid quality control program described in Section 4.5, CB&I Quality Control Plan.

The shell and cover flanges will be shipped directly to the site as rough machined, nondrilled, seamless forged rings from the Ladish Company plant in Cudahy, Wisconsin. The weld ends will be prepared at the forge works (Ladish) for fit-up and welding to the adjacent No. 4 shell ring and top head weldments.

The top head plate assembly will be shipped in one piece. It will be welded together from six knuckle plates and a one-piece dollar plate assembly, as shown in Figure IV-7.

The internal shroud support skirt will be completely shop fabricated at Greenville and shipped as an integral ring assembly to the site where it will be welded to the bottom head in place.

The completely fabricated stud bolts, washers, and gaskets will be shipped directly from General Electric qualified manufacturers to the job site storeroom.

4.3 SITE SUBASSEMBLY AND ERECTION

The reactor will be erected initially, concurrent with the containment drywell and suppression vessel. Site subassembly of the reactor vessel will commence about the same time work starts on the containment vessel. Erection of the reactor bottom head cannot proceed until the lower section of the drywell is erected, including the reactor support skirt, to which the intermediate skirt extension is joined, which in turn welds to the reactor vessel stub skirt.

Unlike the case for determining the maximum size of subassemblies at the shop, weight of the lifts, or derrick capacity dictates what can be subassembled at the site. The closure seams between subassembled sections will be made in place, similarly as they are on the containment vessel.

The post weld heat treatment zones are established by the location of penetrations with respect to circumferential weld joints and the adherence to safe thermal gradients through adjacent vessel materials.

Methods of achieving the machined surface requirements and drilling, tapping and boring operations have been developed by CB&I engineers using commercial equipment where available and designing and building custom-made devices where necessary.

Suitable weather protection devices will be provided that will shelter the vessel weldments during site fabrication, both during ground assembly and during final welding, post weld heat treatment, etc., in place.

A series of erection sequence illustrations of the major assembly yard and in-place welding erection, post weld heat treatment, and machining events is contained in Appendix D. The step-wise activities listed thereon will not be repeated in detail in this narrative.

Double use of the post weld heat treatment furnaces will be made, since they also make excellent environmental housings for the welding and radiograph work. Figure IV-8 shows typical post weld treatment of the longitudinal ring welds. Figures IV-9 and IV-10 similarly show post weld heat treatment of the bottom head and stub skirt assembly and the top head and flange assembly.

Temperatures from thermocouples will be permanently recorded on a multiple point potentiometer type instrument. Adequate thermocouples will be used to obtain representative readings from all parts of the section being heated.

The various parameters for heat treating, such as heating and cooling rate, variation of temperature during the holding period, etc., will be in accordance with Section III of the ASME Boiler and Pressure Vessel Code and other requirements of the General Electric specifications.

4.3.1 Site Subassembly

The basic assembly yard fabrication process will proceed as follows on head and shell components: (a) join shell halves into rings, bottom head to skirt extension, top head to flange on level work tables; (b) preheat to 300° to 400° F and weld sections together, i.e., four shell rings, one bottom head with skirt and one top head with flange; (c) magnetic particle check weld periodically during deposition of metal as preliminary inspection step and replace any unsound material found therein; (d) hot ultrasonic test welds before post weld heat treatment; (3) post weld heat treat at 1150°F; (f) cool and radiograph welds; (g) ultrasonic welds again; (h) manual overlay welds; (i) post weld heat treat; (j) cool and ultrasonic overlay; (k) dye check overlay.

4.3.2 Assembly and Machining in Place

The bottom head and stub support skirt assembly will be set in place on a 17-foot diameter tubular support skirt furnished in the drywell base of the containment structure. The bottom head/skirt assembly will be leveled using the devices on the stub skirt and intermediate skirt extension provided.

The vessel centerline will be established as a vertical line of sight using a precise jig transit instrument located underneath the bottom head and sighting on a target in the geometric center of the dollar plate. The bottom head and skirt assembly will be adjusted so that the top edge of the head assembly is level and its center is on the plumb line described above.

The leveling and plumbing procedure will be repeated after each of the four shell rings is placed. The centerline for the bottom head and skirt assembly is shown in Figure IV-11. The No. 1 shell ring, assembled and welded in the assembly yard, complete with the 36 by 28-inch diameter recirculation and other nozzles, is placed as an integral ring in position atop the bottom head. The girth seam will be fit, preheated, and the hand welding started. The No. 2 ring will then be placed, fit and welded before any post weld heat treatment is done in place on either ring. Temporary weather protection will be provided by the multipurpose post weld heat treatment furnace structure. The preheat will be maintained on the bottom head to No. 1 ring girth seam until the No. 1 to No. 2 girth seam is ready for post weld heat treatment. The shroud support skirt will be installed. At this time, the two rings will be stress relieved simultaneously in this temporary furnace. Steps (b) through (k) used for site subassembly (paragraph 4. 3. 1) will also be used for assembly in place.

Nondestructive testing procedures in the field will be essentially the same as those performed in the shop. Radiography will be performed utilizing a 100 or 150 Curie Gamma source with appropriate shielding. This work will be performed on the third shift or on weekends. Usage of the source will be in accordance with the applicable Federal and State regulations.

Concurrent with erection of the vessel shell, the vessel top head weldment will be fit and welded to the cover flange in the assembly yard area. After completion of all the welding, post weld heat treatment and examination steps, the top head will be positioned for drilling the 5 1/4-inch diameter hold down bolt holes, as shown in Figure IV-12. With the cover in this same position, the grooves for the two 1/2-inch diameter stainless "O" ring gaskets will be machined with the portable CB&I equipment shown in Figure IV-13.

After the No. 1 and No. 2 girth seams have been post weld heat treated, the temporary furnace will be converted into an air-conditioned and ventilated work room around the bottom head and No. 1 shell ring. A temporary cover will be installed above this work area so that the balance of the vessel can be erected without interfering with the bottom head work (other than for in place radiographic work on the closure girth seams of subsequent rings). The holes and sleeves for the 121 6-inch diameter control rod drive thimbles and the 40 - 2-inch diameter holes for the in-core flux sensors will be provided utilizing precision-bored guide templates, optically aligned in a temperature controlled housing to guide a vertical boring bar and cutter head, as shown in Figure IV-14. These procedures will not only assure that the holes will be on accurate centers but that they will be plumb as well.

As the containment vessel is completed, it will form a perfect weather enclosure for the balance of the in-place assembly of the reactor vessel. In-place post weld heat treatment of the Nos. 2 and 3 shell rings is shown in Figure IV-15.

The vessel closure flange having been welded to the No. 4 shell ring in the assembly yard, will be drilled and tapped in place to receive the bushings and holddown bolts, as shown in Figure IV-16.

The gasket sealing face on the vessel flange will be machined in place using the equipment shown in Figure IV-17.

Performing this work in place assures a truly horizontal flange surface and stud holes that will be plumb. These are inherent advantages considering the operational task of removing and replacing the reactor cover during refueling.

While the in place assembly of the vessel is proceeding, internal thermocouple attachments, etc., will be installed.

Drilling of the control rod drive sleeve holes, welding in the sleeves and boring them out to the final precise dimension proceeds in parallel with the work on the vessel described above.

4.3.3 Hydrostatic Test

Upon completion of the in-place machining work on the vessel flange and control rod sleeves, the reactor cover will be attached and the vessel prepared for test. A hydrostatic overload pressure test will first be performed, following which the cover will be removed and the service gaskets installed, the cover replaced and a leakage rate test will be conducted at the design pressure rating.

These tests will prove out the vessel only, as no interconnecting piping will be attached at this time.

4.4 DETAILS OF WELDING AND INSPECTION

4.4.1 Joint Categories

All main joints in the pressure vessel except the control rod penetrations (partial penetration weld connections) will utilize joints of Category A and/or B (Paragraph N-462 Section III, ASME Code, 1965 Edition). Control rod penetrations (partial penetration weld connections) in the bottom head (Category D joints) will utilize one of the permissible details in Figure N-462.4 (d) Section III, ASME Code, 1965 Edition. Present engineering details have resulted in the selection of the detail in the lower left-hand corner of the above figure.

The bottom draw off or drain attachment weld utilizes a Category D joint also. Attachment of the connection will be made using deposited weld metal as compensation and is illustrated in Figure 462.4(c)(3), Section III, ASME Code, 1965 Edition.

Category D joints utilizing butt welded attachments for the nozzles will be in accordance with Figure 462.4 (a)(5), and as further illustrated in Figure I-613(a) of the ASME Code. Present plans indicate that all Category D joints using butt welded attachments can be performed in the shop fabrication sequence. There is a possibility that certain clearances may dictate the field installation of the recirculation nozzles to reactor vessel wall.

4.4.2 Joint Design

The joint design for both shop and field welding of the main joints of the pressure vessel will be as shown in Figure IV-18. This is a double beveled joint which utilizes a square bar as a spacer and temporary back up bar for welding. The edge preparation will be made by flame cutting or machining. If machining is used it will be performed upon sections that will permit the temporary bar to be machined in place. If a square bar is utilized, it will have a chemical composition which meets the requirements of the base metal specification. In both instances the square bar will be completely removed by a back gouging operation.

The desigu for the Category D joints installing the penetrations into the shell plates comprising the No. 1, 3 and 4 rings shall utilize the joint in Figure IV-19. This is a single beveled joint which uses a square bar as a spacer and temporary back up bar for welding. The bevel will be on the inside of the vessel. Again, the square bar will have a chemical composition which meets the requirements of the base metal and will be completely removed by a backgouging operation. (Note, if present engineering plans cannot be completed as a result of certain clearances and the recirculation nozzles must be installed in the field, the joint detail for such an installation will be Figure IV-18. As stated earlier, all indications are that these nozzles can be installed under shop conditions.)

Weld edge preparation will be accomplished in the shop by flame cutting the desired bevels and land upon the plate edges followed by gringing. In certain instances edges will be prepared by machining and the bar will be machined in place. The edges will be inspected by magnetic particle inspection methods prior to fitting up the edges to be welded. If the weld joint being prepared is to be welded in the shop, the edges will be inspected by magnetic particle in the shop; otherwise this inspection will be performed in the field.

4.4.3 Welding Sequence

A typical Category B joint is indicated in Figure IV-20. Spacer bars will be placed on the bottom edge of the top plate for all circumferential joints. Approximately 1 1/2 inches of weld metal will be deposited on the inside before removing the spacer bar completely by arc gouging from the outside surface of the vessel. The arc gouged groove as well as the weld surface inside shall be magnetic particle inspected before welding from both sides progresses simultaneously. By placing the spacer bar to the outside of the joint it is possible to weld the inside of the joint and arc gouge from the outside which eliminates some welding debris from inside of the vessel, especially with respect to the stainless steel overlay surface.

It is anticipated that in order to deposit the first 1 1/2 inches of weld metal, a total of 30 passes will be required. These passes will be made with 5/32-inch and 3/16-inch diameter electrodes. Upon completion of the arc gouging operation, the joint will be welded using 5/32, 3/16 and 7/32-inch diameter electrodes as the groove size permits until a number of passes approaching 220 have been made to completely fill the groove.

Category A joints will be welded with a joint detail and welding sequence as indicated by Figure IV-21. Again, a square bar to act as a spacer and temporary back-up bar will be utilized. Welding will be performed with 5/32-inch diameter electrodes and about 1 1/2 inches will be welded before removing the spacer bar by arc gouging. Weave passes will be used for the various layers until the width of the groove becomes so wide that a weave of 3 times the electrode diameter is exceeded. When this width is exceeded, then a multipass per layer technique will be employed. Edge preparation and inspection, preheating, fitting, welding, supervision, etc., will be performed on all joints utilizing control procedures that have been previously set up and approved. The backgouged weld groove and the weld surface will be magnetic particle inspected before completing the weld joint from both sides simultaneously and at each 1 inch layer of thickness.

Joints welded to form subassemblies on the ground, in addition to the assemblies welded in place, will be provided with temporary enclosures as protection against weather. A typical installation varying only as a result of reactor job site conditions is illustrated by Figure IV-22.

4.4.4 Out of Roundness

The plate edges for all category A and B joints will be held in place by fitup lugs welded securely in position. Out of roundness tolerances will be in accordance with Figure IV-7. These lugs and bars, when attached directly to the pressure vessel shell, will be fabricated from material similar to the base metal. All temporary lugs, bars and gadgets will be removed. It should be noted that heavy walled pressure vessels do not have "welded in" flat spots because the forming operations and wall thickness preclude such an occurrence.

4.4.5 Low Hydrogen Low Alloy Electrodes

The shielded metal arc process was selected for all of the welding of the major joints in the pressure vessel. Certain areas (such as the weld metal build-up on the bottom head knuckle for attaching the skirt knuckle) may be welded with the submerged arc process, with a wire and flux combination to yield the desired base metal properties in the deposited weld metal.

A special low alloy steel coated electrode will be utilized for the welding. This electrode was developed to match closely the physical and chemical properties of the base metal. Typical physical and chemical properties of the weld metal are listed below.

Chemical Analysis Deposited Weld Metal

C	Mn	Ni	Mo	Si
.05	.97	1.03	.49	.41

All Weld Metal Tensile Properties

Vertical Weld
Postweld Heat Treated at 1150°F (+25°F; -50°F)

Yield (ksi)	Tensile (ksi)	% Elong. 2"	% Reduction of Area
82.3	91.5	25	69

This low hydrogen iron powder coated electrode has the advantages inherent with this designation and results in a deposited weld metal that has the notch toughness advantage from added nickel and the high temperature strength advantage from added molybdenum. A review of the typical results indicates a close matching of the base metal properties. Multiple pass techniques with this electrode have the affect of producing good sound welds without reducing any of the physical properties of the base metal below the standards required by Section III, ASME Code. In fact, the Charpy Vee impact values and NDT values of the deposited weld metal will exceed the minimum requirements of Paragraphs N331 and N332, Section III.

4.4.6 Electrode Care

All low alloy low hydrogen electrodes will be stored in a dry place 2 to 3 inches above the floor in storage houses. They will not be stored directly on concrete but sufficient space between the floors and walls will be provided to permit circulation of air. All electrodes will be removed from the hermetically sealed tins and baked at 800° F for one hour before using. After the 800° F baking cycle, the electrodes will be stored in holding ovens maintained at 250 to 350"F until used. Welders will be permitted to remove only that amount of electrode that can be used in a 2 hour period.

All low hydrogen iron powder coated low alloy electrodes (E8018-X) are manufactured with a maximum permissible moisture content (by weight) of 0.40 percent in the electrode coating. CB&I feels this moisture content is excessive in this type of electrode when making high tensile strength weldments under highly restrained conditions and, therefore, require the electrodes to be baked at 800° F for one hour in order to lower the moisture content below 0.20 percent. They are stored in holding ovens between 250° F and 350° F in order to maintain the moisture content below 0.20 percent. The requirements for electrode handling and storage are over and above any Code requirements.

4.4.7 Preheat

Preheating for welding shall be accomplished in such a manner to provide a uniform temperature within the preheat range. The use of insulation, metal foil and electric preheating equipment to accomplish this close control of the preheat range is illustrated in Figure IV-23.

Strip heaters will be utilized to maintain a uniform and even preheat temperature range. This preheat will be applied before any welding begins and shall continue until the part or parts being welded has/or have been given a postweld heat treatment before allowing the weldment to cool to ambient conditions.

4.4.8 Welding Supervision

Welding will be accomplished with stick electrodes and will be continuous as dictated by job site conditions. Continuous visual inspection will be accomplished by assigning one welding supervisor for every 6 to 8 welders. The welding supervisor has the responsibility to assure that all welding procedures are carefully followed and that any surface irregularities that occur in a weld bead deposit are removed. There will be one project welding supervisor who is responsible for all of the welding that is being performed under the direction of the welding supervisors. The welding supervisors will be under the direct control of the project welding supervisor.

supervisors. The welding supervisors will be under the direct control of the chief welding supervisor.

All welding supervision, electrode care and preheating, together with constant visual inspection will be instrumental in reaching the ultimate objective of no defects when the weldments are subjected to radiographic examination.

A typical CB&I training program for welding supervisors is discussed in Appendix E.

4.4.9 "Hot" Ultrasonic Examination

As a further check to assure a "no defect" condition after the base metal weldments are completed and prior to postweld heat treatment, these welds will be subjected to ultrasonic testing (hot U.T.) which is over and above the requirements of the Code or specifications that have been issued by General Electric. Past experience has indicated that this inspection method (hot U.T.) is an excellent quality control measure. Irregularities that are disclosed by this method permit corrections to be performed before the post weld heat treatment and radiographic inspection.

After ultrasonic (hot U.T.) inspection has been performed and the base metal weldments proven satisfactory, the joints will be given an interstage postweld heat treatment at 1150° F (+25°F; -50° F) for approximately one hour before allowing the weldments to cool to ambient temperatures. Ultrasonic and radiographic examinations of the weld joints will be performed upon the base metal prior to overlay welding the joints with the shielded metal arc process. Preheat will again be provided while overlay welding is being performed.

4.4.10 Overlay Welding

Field overlay welding will be performed using the stringer bead technique with a minimum of two layers to accomplish the full weld overlay thickness. The first layer will be made with 1/8, 5/32, 3/16-inch diameter or a combination of sizes of E309 electrodes and the remainder of the overlay will be accomplished with 1/8, 5/32, 3/16-inch diameter or a combination of sizes of E308 electrodes. Figure IV-24 illustrates a typical stainless steel manual weld overlay. Again, close visual inspection will be performed by the welding supervisors to assure quality. Instruction and training of the welders will have been accomplished in the job site school. The school will also train and qualify welders for the overlay welding of the forgings for the top and bottom flanges that will be shipped to the job site direct from the forging manufacturer. Ultrasonic and dye penetrant examinations will be performed on the overlay in addition to close visual inspection during the actual welding operation.

The majority of the overlay welding will be accomplished in the shop. A shell ring will be overlay welded using the series arc and submerged process for depositing a Type E308 weld deposit, Figure IV-6. The shell plates will be temporarily joined in order to permit this operation. Upon completion of the welding, the overlay will be given an interstage postweld heat treatment.

When design considerations are finalized that require Inconel (INCO 182 or INCO 82) overlays to be made, these overlay deposits will be performed with either the shielded metal arc, metal inert gas arc or submerged arc processes or combination of these processes. Inconel will be deposited directly to the base metal and not on top of a stainless steel overlay. This sequence eliminates the objectionable considerations that develop if an interlayer of stainless steel is between the base metal and the Inconel.

The shroud support overlay build-up as well as the overlay build-ups for the control rod penetration openings will be made with Inconel. The control rod penetration sleeves will be made from Inconel. Figure IV-25 illustrates the overlay detail of the shroud support weld build-up and the control rod penetrations sleeves.

The skirt knuckle will be attached to the bottom head knuckle by means of a low alloy steel weld metal build-up performed upon bottom head knuckle. This weld build-up will be made with a high manganese molybdenum electrode with added nickel and a neutral flux using the submerged arc process in the downflat position. The build-up will be examined and all procedures will be followed to assure the built in quality before attaching the skirt knuckle section. See Figure IV-26.

1.4.11 Postweld Heat Treatment

Erection sequences are discussed in detail in other sections and, therefore, further elaboration is not given.

However, postweld heat treatment of subassemblies in the field will be accomplished several times depending upon the particular welding operations being performed. When these heat treatments are performed upon the ground, temporary furnaces will be utilized to accomplish this phase of the operation, Figure IV-8. Postweld heat treatments will be monitored using thermocouples strategically placed upon the assembly and throughout the entire furnace. Multiple point strip chart recording potentiometers will be used to record the actual heating progress of the assembly during the entire postweld heat treating cycle.

It will be necessary to perform several interstage postweld heat treatments upon the weldments in order to perform the various welding operations and, more importantly, in order to perform the necessary quality control sequences to assure vessel integrity. Typical interstage postweld heat treatment of subassemblies on the ground are illustrated in Figure IV-8.

Assemblies completed in place will be enclosed and postweld heat treated in a similar fashion to those on the ground. Insulation, thermocouples, heating sources, recording instruments, etc., will be geared to assure complete compliance with the Code and General Electric specifications. As with welding, quality control, etc., postweld heat treatment procedures will be made and approved before the work is performed.

Perhaps the most important item to stress is that postweld heat treatment of subassemblies on the ground or completed assemblies in place in the field will be performed with the same limitations and controls as those in the shop. The ability to accomplish these items is discussed in Appendix K; CB&I experience.

Local postweld heat treatment of a girth weld in position is illustrated in Figure IV-15.

1.4.12 Welder Training

To further augment the objective of "building in quality" rather than "inspecting in quality", a welder training school will be set up and conducted by the experienced and qualified welding supervisors assigned ..is project. The field welders will come from a Boilermaker union which requires 100 percent local welders. An agreement has been made with the union to bring 50 percent outside welders from other CB&I job locations in to do the containment vessel, and some of these welders will be interchanged to work on the reactor pressure vessel. A large portion of the welders used in the reactor vessel will be experienced CB&I welders. Every welder will receive training in the job site school using the materials of construction until a proficiency has been attained that will permit the welder to qualify in accordance with Section IX, ASME Code and the General Electric specifications. The training program will be conducted on the same material, including thickness, as the reactor pressure vessel and the material will be obtained during the fabrication of the vessel. The welding program will indoctrinate the welders into what is expected in the form of "built-in quality" following approved welding procedures and of all the necessary examinations to assure "built-in quality". The welding supervisors and welders will be trained and indoctrinated to the fact that weldments can be made to a quality that will not require time consuming repairs after radiographic and ultrasonic inspections are made. This training will be on test plates at the shop or field, not on the actual vessel.

1.4.13 Radiographic Examination

(1) Present Use

At the present time three of CB&I fabrication plants located at Salt Lake, Chicago and Birmingham all have licenses to use radioactive material for use in the examination of welds in heavy thick plates. In addition, the Birmingham plant has a 2 Mev Van de Graff X-ray unit and a 25 Mev betatron. All plants are fabricating vessels to the ASME Code which requires the same quality level to which this nuclear reactor is to be built. The success that the Chicago and Salt Lake plant have had in obtaining this quality level using radioactive sources has eliminated the necessity of purchasing large X-RAY units. The Birmingham plant, due to its large volume of heavy vessel production, has installed the large X-RAY units in order to speed up the weld examination rather than increase the quality level of examination.

Several vessels have been fabricated in the field that were too large to be shop built and these vessels have been radiographed in the field using Cobalt-60 sources. The thickness of these vessels ranged from 2-3/4 inches up to 7-1/4 inches, and were built to the requirements of the ASME Code. No difficulties were encountered in obtaining the quality level required by this code.

FIELD ERECTED VESSELS EXAMINED USING COBALT 60

Contract	Description	Thickness	Location
8-7381	Basic Oxygen Converter	6"	Ecorse, Michigan
8-4409	5 - 20 foot ϕ Spheres	2-3/4"	Wood River, Illinois
8-8482	Penstock Trifurcation	7-1/2"	Yards Creek, N. J.
8-5583/5	2 - 18 foot ϕ Spheres	5-1/2"	Nimbus Station, Calif.
9-2220	14 foot - 11 inch Sphere	3"	Oleum, Calif.
9-1981/4	4 - 108 inch x 68 foot 8 inch TL Reactors	5-5/8"	Ft. McMurray, Canada
9-4137	15 foot 7 inch ϕ x 109 foot TL Digester	3-3/4"	Baton Rouge, La.
8-9460	3 - 150 Ton Basic Oxygen Converters	4"	Gary, Indiana
9-3252	156 foot ϕ x 70 foot TL Reactor	7-1/4"	Philadelphia, Pa.

(2) Procedure to be Used in the Field

Radiographic examination of completed welds in the field will be accomplished using a radioactive source such as Cobalt-60 or Iridium-192. The type of source used will be determined by the thickness of material to be examined. Iridium 192 will be used on steel thicknesses ranging from 1/2 inch up to 3 inches, whereas Cobalt-60 will be used on steel thicknesses ranging from 1 1/2 up to 8 inches. During the exposure the radioactive source will be placed inside of the vessel or ring, Figure IV-27, in order to contain the radiation emanating from the source to an area inside the vessel or ring. In this way the radiation areas outside of the vessel or ring will be reduced to a minimum. The radioactive source will also be collimated to control the radiation to only those areas being radiographed. Whenever areas of high radiation intensity are encountered, radiation shields will be used to lower the intensity level to a safe level.

The type of film that will be used for radiography will be fine grain similar to Eastman Kodak Type AA, or equal. The film will be used in exposure holders which contain lead screens front and back. The thickness of the front screens will be .010 and the back screen will be .020; and when there is a possibility of back radiation affecting the film, a 1/8-inch layer of lead will be placed behind the film exposure holder.

After exposure the film will be processed using the time-temperature method of development using as a base 5 minutes at 68°F. Longer or shorter development time will be used depending upon the temperature of the developer solution with no processing being performed when the temperature of the developing solution is below 60°F, or above 80°F.

A short-stop solution will be used after the developing solution in order to arrest the development of the film.

After the short-stop solution, the film will be allowed to drain and then will be placed in a fixer solution and allowed to remain in this solution a minimum of 2 times the clearing time.

After fixing, the film will be washed in running water a minimum of 30 minutes, or if a fixer-neutralizer solution is used, the washing time will be reduced to 5 minutes.

During processing, the film will be agitated periodically to insure even development over the entire film.

Automatic processing equipment may be used to maintain the temperature of the solutions and the degree of agitation as recommended by the manufacturer of the equipment.

Radiographs of welds shall have a nominal density of 2.5 with a minimum density of 2.0 when compared to a standard density strip or densitometer.

Standard A.S.M.E. penetrameters having 2T, 3T and 4T holes according to ASME Code, Section III, will be placed alongside the weld bead to insure that the proper exposure technique has been used for the radiographic work.

Radiography will be performed using a technique which will provide a quality level as required by the ASME Code, Section III, Paragraph N524.3(h).

The penetrameter used under normal requirements of the ASTM E142-64 provides a level of inspection designated as 2-2T where the thickness of the penetrameter would be 2 percent of thickness of the radiographed weld, and the 2T hole diameter would be 2 times the thickness of the penetrameter. These values for 5-1/2-inch thick steel are as follows:

2 percent of 5.5 inches	= 0.110 inch penetrameter thickness	2T hole diameter = 0.220-inch
		1T hole diameter = 0.110-inch

The ASME Code has changed to a sliding scale on penetrameters so that on 5-1/2-inch thick steel a .060-inch thick penetrameter is used; then for 5-1/2-inch thick steel

Penetrameter thickness = .060"	2T hole diameter = .012"
	1T hole diameter = .060"

It should be noted that the 1T hole of an ASTM penetrameter is approximately the same size as the 2T hole of the ASME penetrameter. In addition, the thickness of the ASME penetrameter is approximately 1/2 that of the ASTM penetrameter.

The quality level that will be used then on this nuclear vessel is approximately equal to a 1-2T level of inspection shown in ASTM E142-64 and classified in Table III as 1 percent sensitivity, whereas ASME code work is generally referred to as 2 percent sensitivity. (Table II)

The high voltage X-ray equipment used in plant fabrication will be used for the same quality level of inspection, however, the radioactive source is more adaptable to work in the field. Therefore, the same quality level of inspection will be used in both plant and field regardless of the type of radiation equipment used.

Acceptance of the film and completed welds will be based on the requirements of the ASME Code, Section III, Paragraph N624.8.

4.5 CB&I QUALITY CONTROL PLAN

4.5.1 Objective

Quality control for the Monticello nuclear reactor is directed by a Quality Control Manager, assisted by two Quality Control Coordinators. The primary objective of this group is to coordinate CB&I's many quality connected functions into a system which will assure that the reactor vessel produced will meet the quality requirements and to document the fact that these quality requirements have been met. Similar groups are used for each nuclear reactor project under contract.

4.5.2 Company-Wide Quality Assurance

More than twenty years ago, Chicago Bridge & Iron Company recognized the need for authority lines of quality assurance to be separated from authority lines for production and consequently set up the industry's first such system for welding supervisors. Periodic schools trained accomplished welders in the art of inspection for later assignment to job sites where pressure vessels were being constructed. This program for training welding supervisors is administered by the Vice President and Manager of Welding and Inspection, whose department also sets Company standards and policies for the 5 major methods of non-destructive examination, namely: (1) visual, (2) magnetic particle, (3) liquid penetrant, (4) ultrasonic, and (5) radiographic. These policies and standards are administered through the plant and construction welding managers and also by the testing and inspection groups, as indicated on the Project Organization Chart Figure IV-1.

4.5.3 Project Quality Control Organization

Authority lines for project management and project quality control are separated by virtue of having both of these managers report directly to the Regional Manager, who, in turn, reports to the Vice President and Manager of Operations (not shown on the chart). Company standards and policies for quality control--or more aptly put, quality assurance--are set by the Quality Control Administrator who also reports to the Vice President and Manager of Operations. The latter is on the same level as the Vice President and Manager of Welding and Inspection. The Q. C. Coordinator for manufacturing is concerned with nuclear reactors only, which will be scheduled so that vessels are offset by at least three months' lag in time.

The Q. C. Coordinator for engineering, purchasing, and construction is concerned with only one vessel, from the inception of contract, continuous through completion.

4.5.4 Q. C. Responsibilities

The Q. C. Team has the responsibility for assuring that:

1. Quality measurements and controls on process and/or materials provide adequate control of quality;

2. Existing and/or new processes have sufficient capabilities to meet requirements;

3. The quality level of purchased materials, components, and the finished product is commensurate with engineering specifications and with the quality plan;

4. The adequacy of quality measurements, and of equipment for evaluating, measuring, and controlling product or process reliability.

Q.C. will also participate in the vendor "in-process" inspection, as necessary; interpret the quality control plan for plant and site forces; participate in a review of engineering drawings and material purchase specifications to assure that quality requirements have been included; prepare special required quality records and reports not usually prepared by other CB&I components; review and audit the inspection and testing functions to assure compliance with requirements; and participate in the final product inspection.

4.5.5 Use of Company-Wide Talent and Experience in Quality Control

CB&I management, being cognizant of the need for adequate control of quality on nuclear reactor vessels, has given the Q. C. Manager authority to enlist the assistance of top Company experts, as needed, regardless of their position. Both Q. C. coordinators are graduate engineers, well experienced in the design, fabrication, construction, and inspection of heavy field erected pressure vessels. CB&I's managers are graduate engineers in all echelons of management. As an example of the use of this talent, consider the program that has been put into effect covering the preparation, review, and approval of process procedure.

Q. C. is responsible for proper procedures. They call upon experienced engineers or technicians to write each procedure (plant personnel for plant processes, construction personnel for site processes, and inspection personnel for inspection). Full use is made of operator experience. Each process procedure is reviewed by an "in-house" review board prior to being submitted to the customer for approval. This review board is as follows:

Vice President and Chief Engineer

Vice President and Manager of Welding & Inspection

Vice President and Southeastern Regional Manager

Central Regional Manager (for contract)

Eastern Regional Manager

Quality Control Administrator

General Construction Administrator

General Manufacturing Administrator

Materials Engineer

Metallurgical Consultant

Contract Estimator

Manufacturing Manager (for contract)

Construction Manager (for contract)

Other technicians, as needed

During the time that a procedure is undergoing the in-house review, informal discussions may be held with the customer to assure acceptance of the procedure upon formal submittal. A similar review program is in effect for the review and submittal of material purchase specifications and for engineering drawings. These programs assure that all drawings, specifications and procedures for the contract will receive the attention of all responsible managers and also receive the benefit of the vast experience acquired by the Review Board members.

4.5.6 Verification of Procedures

For the most part, written procedures for the Monticello project will be normal standard operating procedures, adjusted to the contract requirements where needed. Where required by the Code or the customer, procedures are verified with a test or demonstration program. In this category is the cold forming of the shell and head plates. A procedure, "Cold Forming Effects on A533 Material", was prepared to qualify CB&I's cold forming in accordance with Paragraph N-515 of the ASME Code, Section III, and to demonstrate CB&I's ability to cold form this material.

Copies of approved procedures are included in Appendix F as follows:

Figure F-1 - Cold Forming Effects on A533 Material

Figure F-2 - Cold Forming Procedure (Shell & Head Plates)

Figure F-3 - Post Forming/Welding Heat Treatment

Figure F-4 - Ultrasonic Examination of Plates

Figure F-5 - Liquid Penetrant Testing Procedure

Figure F-6 - Magnetic Particle Testing Procedure

Figure F-7 - Plate Material Specifications

Figure F-8 - Ultrasonic Test Procedure (Hot UT for Welds)

4.5.7 Compliance with Specifications

By using check-off type records, spot checking operations as the work progresses, and by auditing all inspections, plant and site Q. C. Coordinators are able to assure that:

1. Approved procedures will be used;
2. these approved procedures are being followed;
3. required inspections are being properly performed;
4. inspections are being witnessed by the customer's Q. C. representative; and
5. the material or part meets the required level of quality before it is further processed.

Each item or piece of material received at the shop (or at the site) is to be covered by a Work Order and Traveler Card which lists in sequence all of the operations and inspections which that particular item or piece must undergo (see Figure F-9). Each operation or inspection is given a unique reference number so that it can be referenced to the report of record. Each operation is referenced to the applicable approved procedure, with special notations for witness points, or points beyond which further progress must be halted until clearance has been obtained. Provision is made for sign-off and date by the supervisor after the operation has been completed, by the inspector after the inspection has been performed, and in addition, by the Q. C. Coordinator as well as the customer's Q. C. representative after each item or piece has been reviewed and passed. Consider the sample Traveler Card shown in Figure F-9 which depicts the sequence of operations and inspections that the bottom head plate must undergo.

(a) All plate material is to be quenched and tempered at the mill, in accordance with an approved heat treatment procedure which has been reviewed by CB&I and GE Q. C. personnel prior to actual heat treatment. Test specimens are to be inspected and approved prior to being tested, and the actual tests are to be witnessed. Each plate must undergo two ultrasonic examinations at the mill: one in accordance with the code upon which the mill bases its rejections; and the other a more restrictive examination as required by CB&I for quality control.

(b) The initial inspection at CB&I's plant occurs at the receiving yard, where inspection personnel visually inspect each plate for gross defects, identification of heat and slab numbers, UT reference marks, CB&I contract number, piece marks, and top of ingot identification. The piece is also checked for dimensional conformance: width, length, thickness, and diagonals. CB&I's Q. C. Coordinator witnesses this inspection on a first part basis and audits such inspections thereafter.

(c) The Ultrasonic inspection charts are then reviewed by Engineering, Fabrication and Welding, and the Quality Control Coordinator to determine if the plate meets acceptability standards and to what extent repairs are necessary. It should be noted that all repairs permitted by the Code as well as repairs required to raise the quality level above code requirements, are to be made in CB&I s plant in accordance with General Electric approved procedures using qualified welders under strict welder supervision and quality control.

(d) Certified Mill Test Reports are then verified by CB&I inspection personnel. The plate will be released for fabrication only after this report has been reviewed by both CB&I Q. C. Coordinator and the General Electric Q. C. representative.

(e) Assuming that the plate is acceptable to CB&I, lifting lugs are then attached, and the plate is removed from the railroad car. The "blind side" is then visually inspected, and any excess material is cut off. These operations are to be witnessed by CB&I Q. C. Coordinator on a first part basis.

(f) The General Electric Q. C. representative is then notified as to the date CB&I intends to perform the required Magnetic Particle and Liquid Penetrant Examination of the plate surfaces, so that he can witness these examinations on a first part basis. On subsequent parts, the CB&I inspector releases the plate for fabrication upon successful completion of these examinations, and the reports are audited by CB&I and GE Q. C. representatives.

(g) Similarily, the initial press forming will be witnessed on a first part basis by the customer, and thereafter this operation will be checked and audited by CB&I Q. C. Coordinator and reviewed by the GE QC representative.

(h) The initial post forming heat treatment operation will be witnessed on a first part basis by the customer, and thereafter this operation will be checked and audited by CB&I Q. C. Coordinator and reviewed by GE QC representative.

(i) After removal from the heat treating furnace, and if any repairs to the plate material are required to increase the quality level above code requirements, plate defects will be removed and repaired by welding in accordance with approved welding procedures. During this operation, CB&I "in house" added quality control measures such as "Hot" ultrasonic and "Hot" magnetic particle examinations will be performed. CB&I's Q. C. Coordinator will witness all such repairs, and the inspector will release the plate only upon successful completion of these examinations.

(j) The plate will then be press-formed to final radius, and returned to the furnace for the final post forming heat treatment. CB&I Coordinator will check and audit these operation as indicated in (h) above.

(k) The plate used for this illustration is to be used for code qualification of cold forming, and to demonstrate CB&I's ability to cold form A533 material. In view of this, a special test program has been prepared as indicated in the "Cold Forming Effects on A533 Material" procedure. Test coupons are removed next and prepared for the GE QC representative on a first part basis as indicated.

(l) At this point, the plate will receive a dimensional inspection for deviation from true circular form, and will be sent back to the press for cold sizing, if required. This inspection will be

witnessed on a first part basis by the CB&I Q.C. Coordinator, and subsequently periodically checked.

(m) Non-destructive tests are required on all formed plates; a 100 percent volumetric UT examination (more restrictive than required by the code), and a magnetic particle inspection of both the inside and outside surfaces (not required by the code). In addition, the bottom head plate used to qualify cold forming will be liquid penetrant and magnetic particle examined on all six surfaces (not required by code). Further, repair welds will be radiographically examined. All of these examinations will be witnessed on a first part basis by the GE QC representative and thereafter the test reports will be reviewed. The CB&I Q. C. Coordinator will witness these examinations on a first part basis, and thereafter they will be periodically checked and the test reports will be reviewed.

(n) At this stage, the excess stock will be removed from the plate, and the plate edges will be prepared for welding. A magnetic particle inspection of the plate edges will be made which will be witnessed on a first part basis by the GE QC representative and the CB&I Q. C. Coordinator. A dimensional inspection will also be performed to assure that the individual plate has been made within dimensional tolerances, including chords, diagonals, finish radius, and thickness. The plate, having passed all the specified inspections, is ready to be fit together with its adjoining piece. Sequence operations and inspections for these operations are given on another traveler card.

Prior to each inspection or operation that is covered by a written procedure, inspection and Q.C. personnel are required to review the applicable procedures, calibration of measuring equipment, and other variables which might have an effect upon the ultimate quality of the item or piece. Familiarization seminars are held weekly (more if necessary), at the lowest practical level for plant and site forces to assure complete understanding of the quality requirements.

A positive system is in effect for the receipt of revised documents whereby voided documents are withdrawn and destroyed. For ready reference, each technician, supervisor, area foreman, and general foreman is provided with a complete and up-to-date set of specifications, drawings, procedures, and administrative instructions including the detail plan for control of quality - all in a binder.

4.5.8 Documents and Records

In addition to the usual records required for pressure vessels built to Section III of the ASME Code, CB&I Quality Control Coordinators will maintain a Daily Progress Record, a complete Thermal History of all parts (see Figure F-10), and a quality control Spread Sheet (Figure F-11). Written nondestructive test reports are to be prepared for each Radiographic, Ultrasonic, Magnetic Particle, and Liquid Penetrant inspection (see Figures F-12, 13, 14 and 15). The latter 3 Figures provide for a detailed plot of all defects that require repair. Welders' performance qualification certificates and test results will be available for review.

The Daily Progress Report is a summarization of the Traveler Cards showing completed progress and status of all material to date. Coupled with the CPM diagram, this report will draw attention to areas or items of concern to production management and/or to quality control in sufficient time so that proper corrective action can be taken.

The Thermal History is a sequential record of date and number of hours each piece of material has received heat treatment at, or above, 1100°F. Each such heat treatment is to be referenced to the actual furnace chart records. Running totals are to be carried for post forming and post welding heat treating temperature, and for other higher heat treating temperatures, commencing from just prior to initial heat treatment for development of mechanical properties.

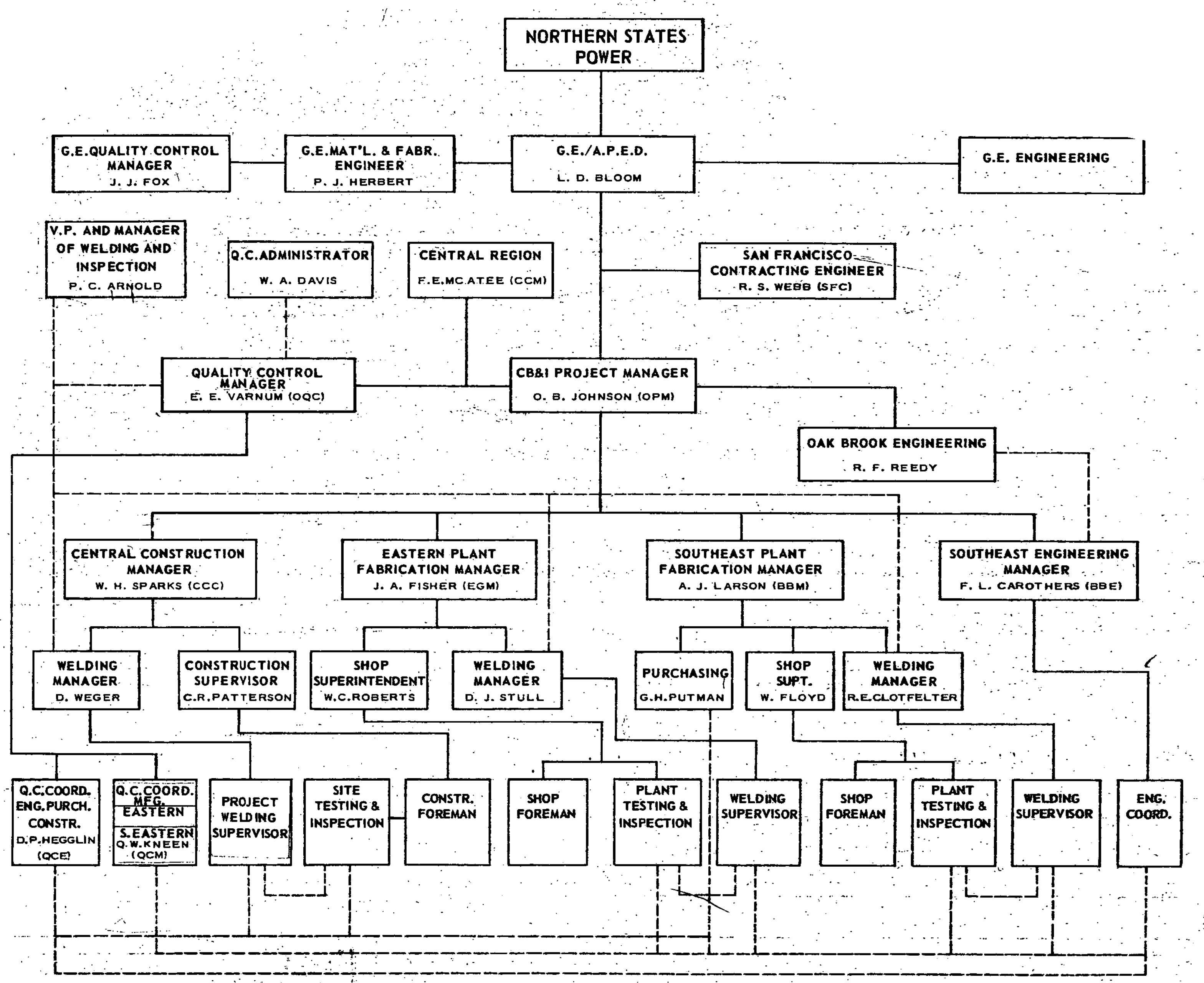
The Spread Sheet depicts material location and identification, weld joints, and weld overlays. Sequential numbers are to be assigned to each welding operation. Provision is made for tabulating the following information:

1. Weld number, approved procedure, and qualification date.
2. Weld joint completion date.
3. Date of post weld heat treatment and total hours at temperature to the date of entry.
4. Radiography identification numbers and date of review and results for each joint.
5. Magnetic particle inspection report number date and results.
6. Ultrasonic inspection report number, date, and results.
7. Approved repair procedure and date of repair, as required.

CB&I's Quality Control Coordinators are to initial and date each entry. Space is also provided for the customer's Q. C. representative to initial each completed date entry. In effect, the spread sheet is an authenticated summary record of all welds, and repairs, keyed back to the approved welding procedures, repair procedures, and inspection procedures by which they were welded or inspected.

During the various stages of material procurement, fabrication, and construction, all welds, material, cladding, and certain surfaces such as bolt holes, flange faces, etc, will be given numerous examinations and inspections in order to assure that the quality required is in fact there. In addition, CB&I has quality requirements which exceed the Code and also are above General Electric's requirements. Whenever defects are disclosed, the GE QC representative must concur with CB&I's defect description, classification, and recommended disposition prior to submittal to General Electric Engineering for final approval. Defects may be classified as either major or minor, and prior approval of repair procedures is required for both classifications. A major repair is defined as (1) a repair of material other than weld metal which requires an excavation greater than 3/8-inch deep or 10 percent of the wall thickness, whichever is less; (2) the repair of any cracks other than crater cracks, in any material or weld metal; and (3) the repair of any defect which is indicative of either a fundamental material problem or a process out of control. A minor repair is defined as all other repairs.

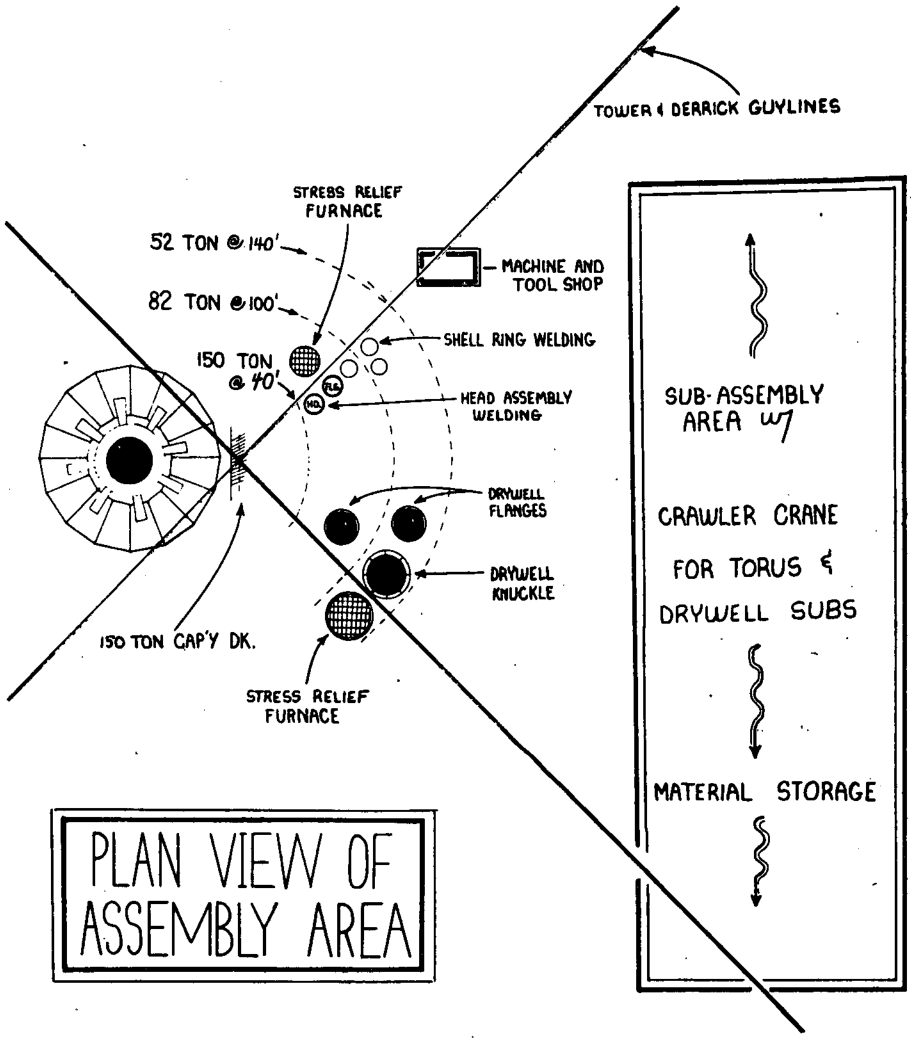
The same record, report, inspection or process procedure is used for similar operations, regardless of whether performed at the shop or at the site. Traveler Cards, Thermal History, and Spread Sheets are initiated in the shop but are carried through to completion of the job site. Further, CB&I's total facilities and combined talent are available to the Monticello project team---they are not restricted to the facilities and talent of a single shop.



MONTICELLO NUCLEAR GENERATING PLANT

Project Organization Chart

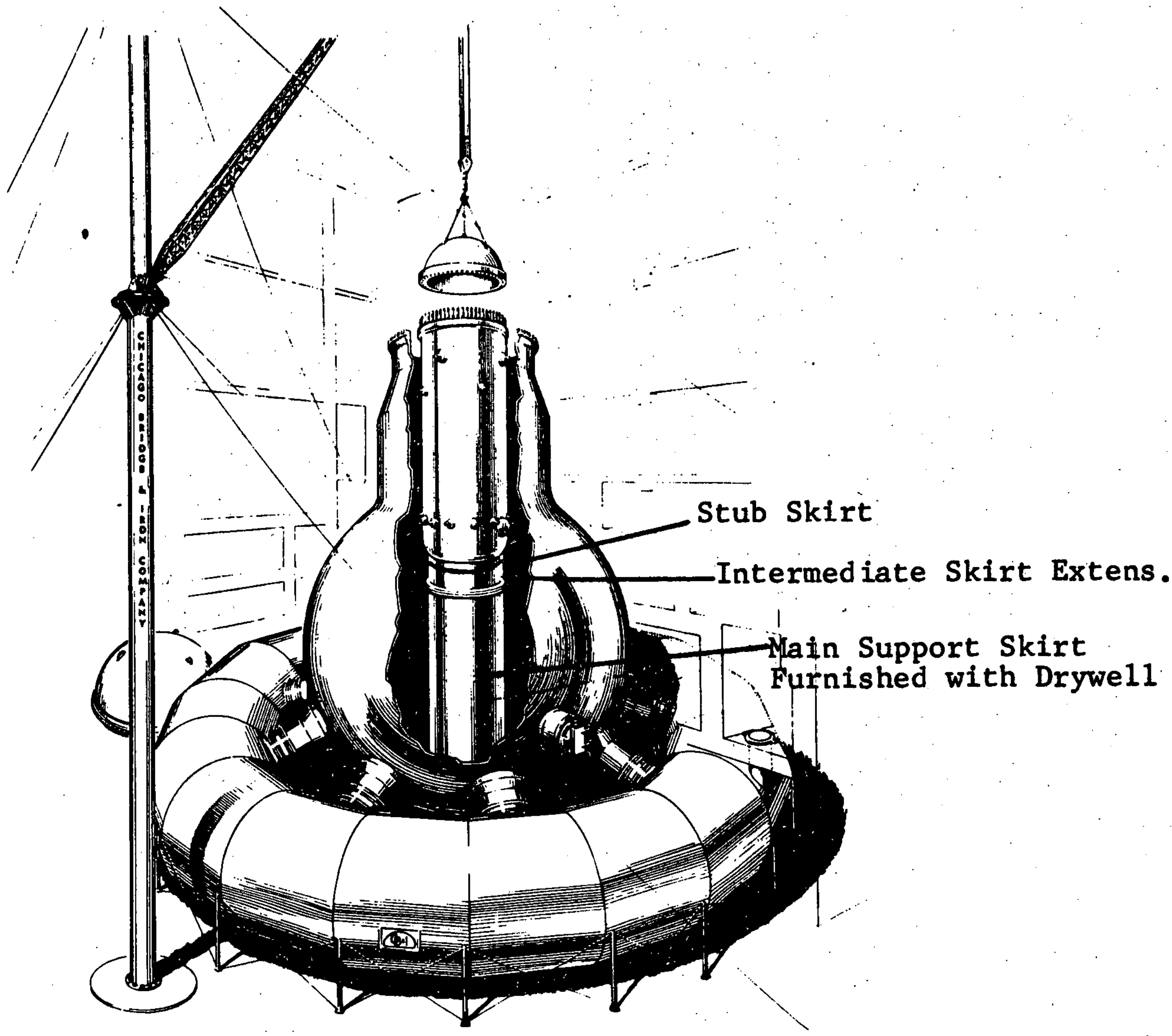
FIGURE IV-1



MONTICELLO NUCLEAR GENERATING PLANT

Site Assembly Area

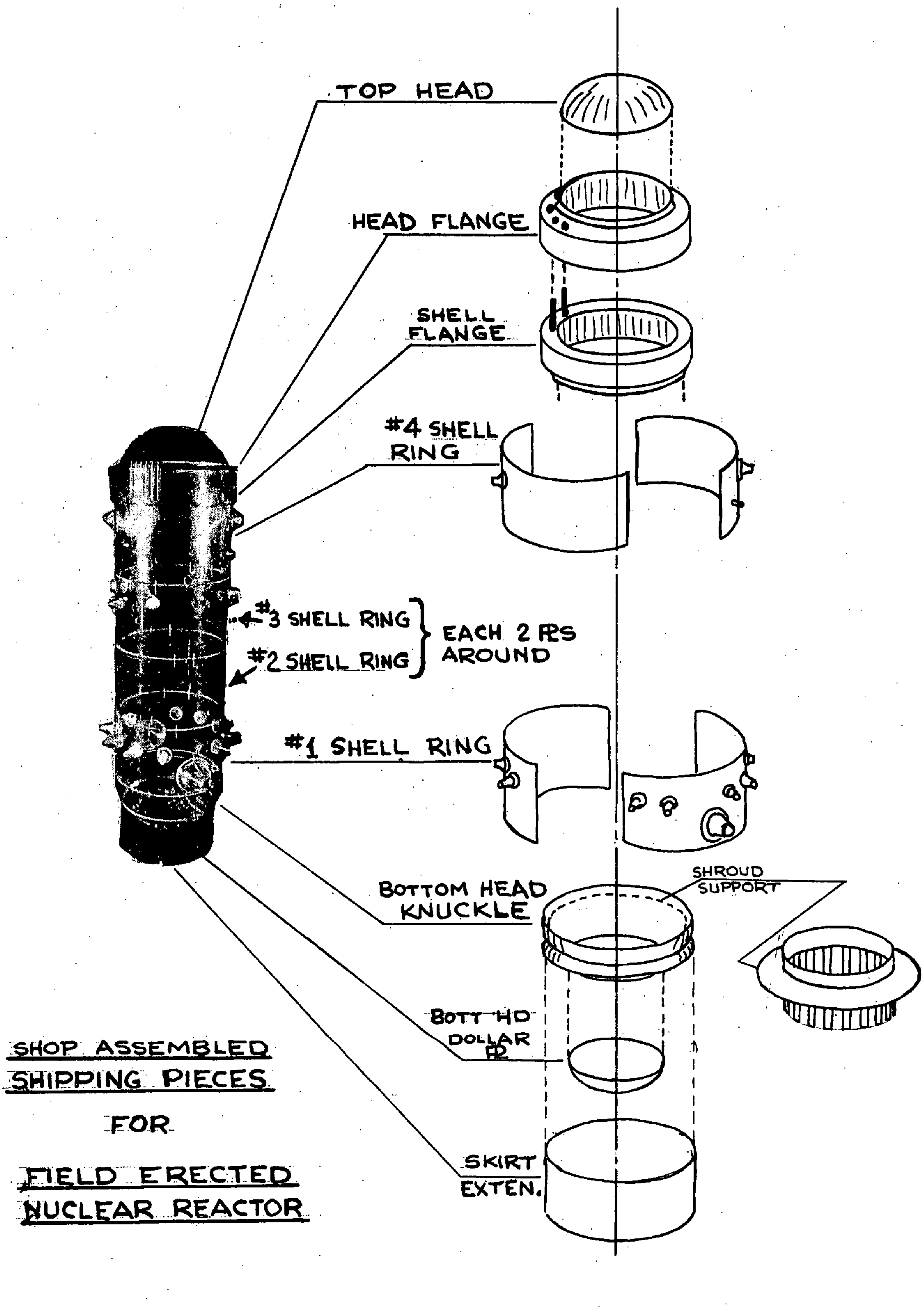
FIGURE IV-2



MONTICELLO NUCLEAR GENERATING PLANT

Composite Reactor and Pressure Vessel

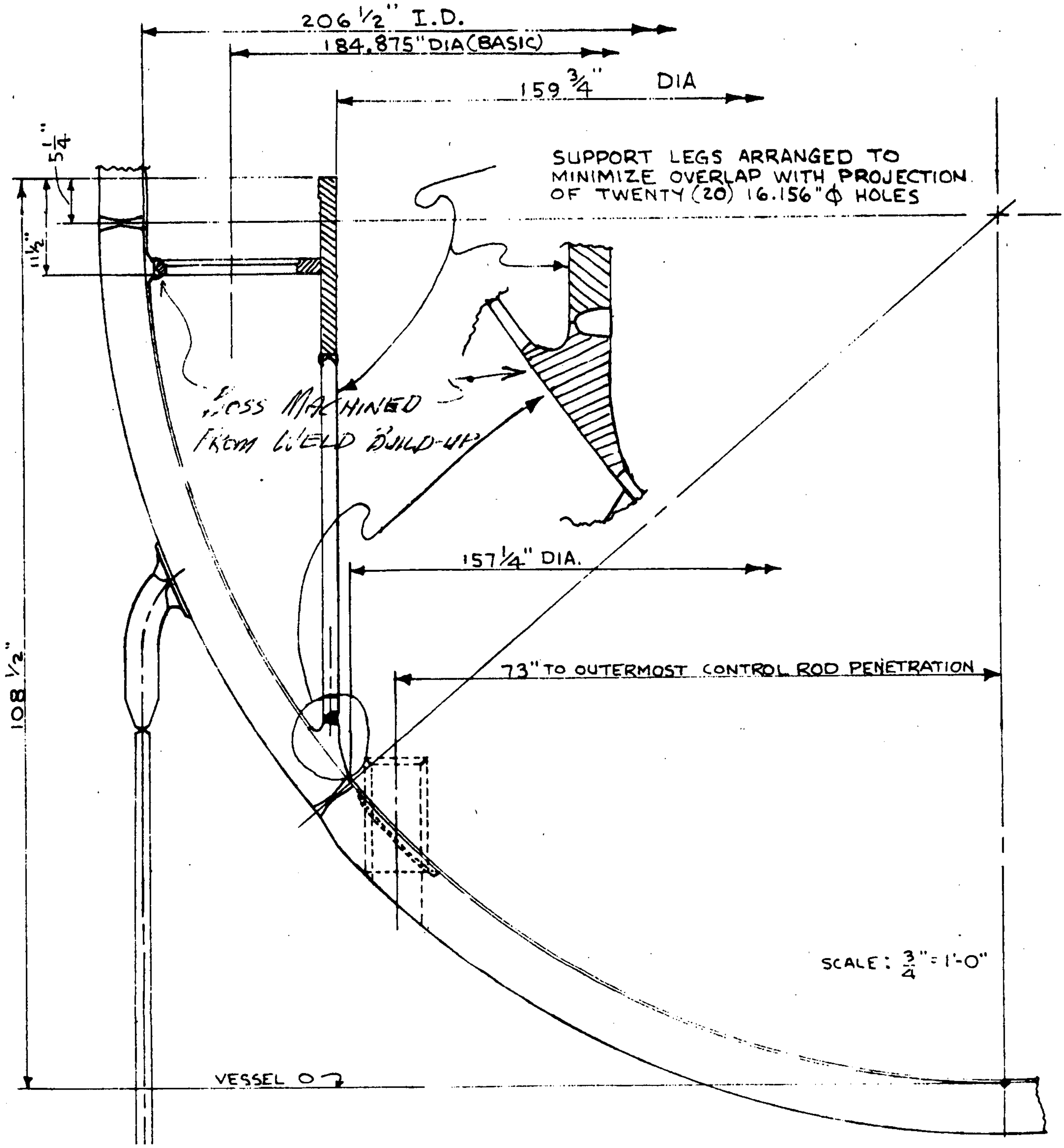
FIGURE IV-3



MONTICELLO NUCLEAR GENERATING PLANT

Shop Assembled Shipping Pieces

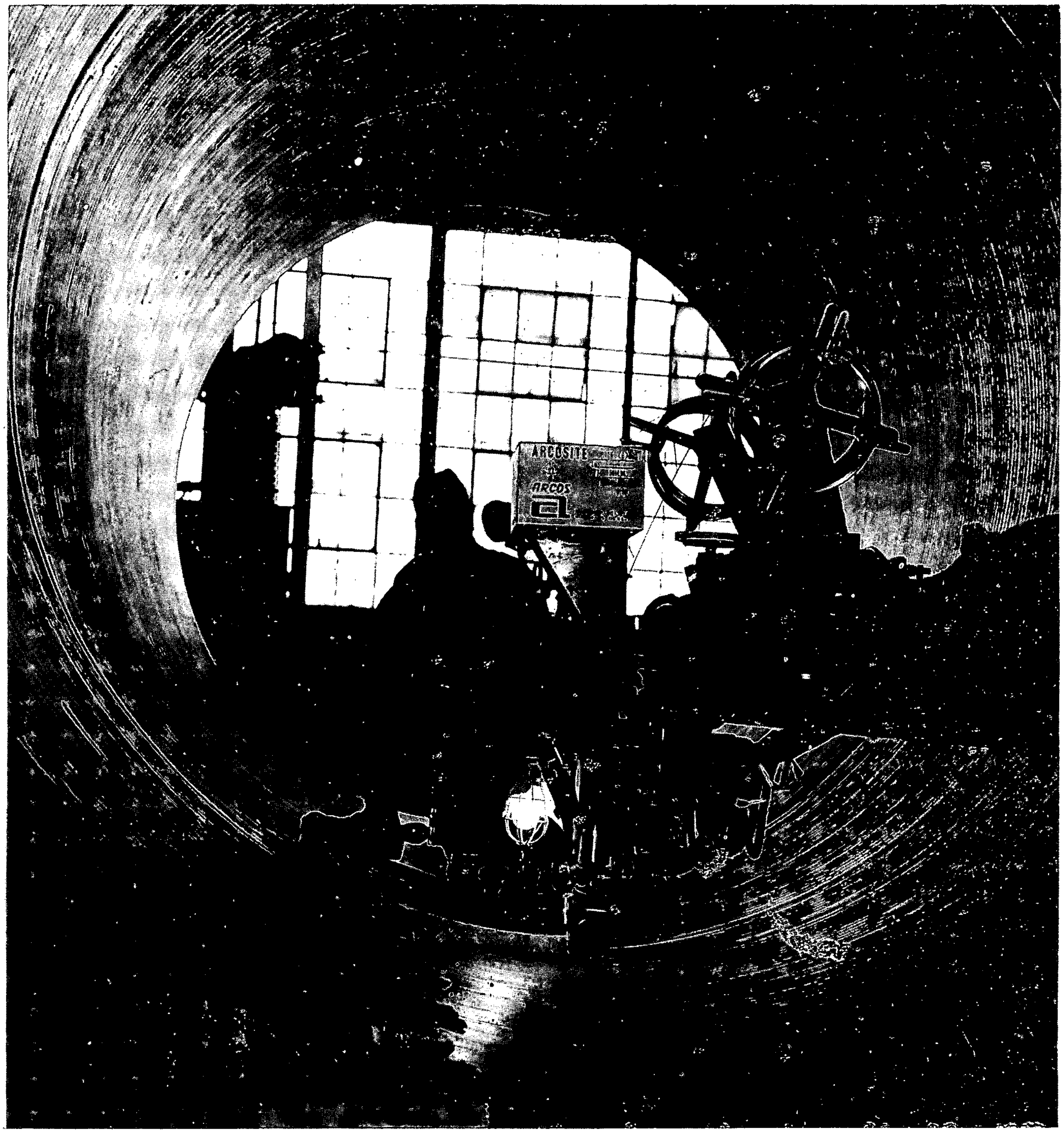
FIGURE IV-4



MONTICELLO NUCLEAR GENERATING PLANT

Shroud Support Details

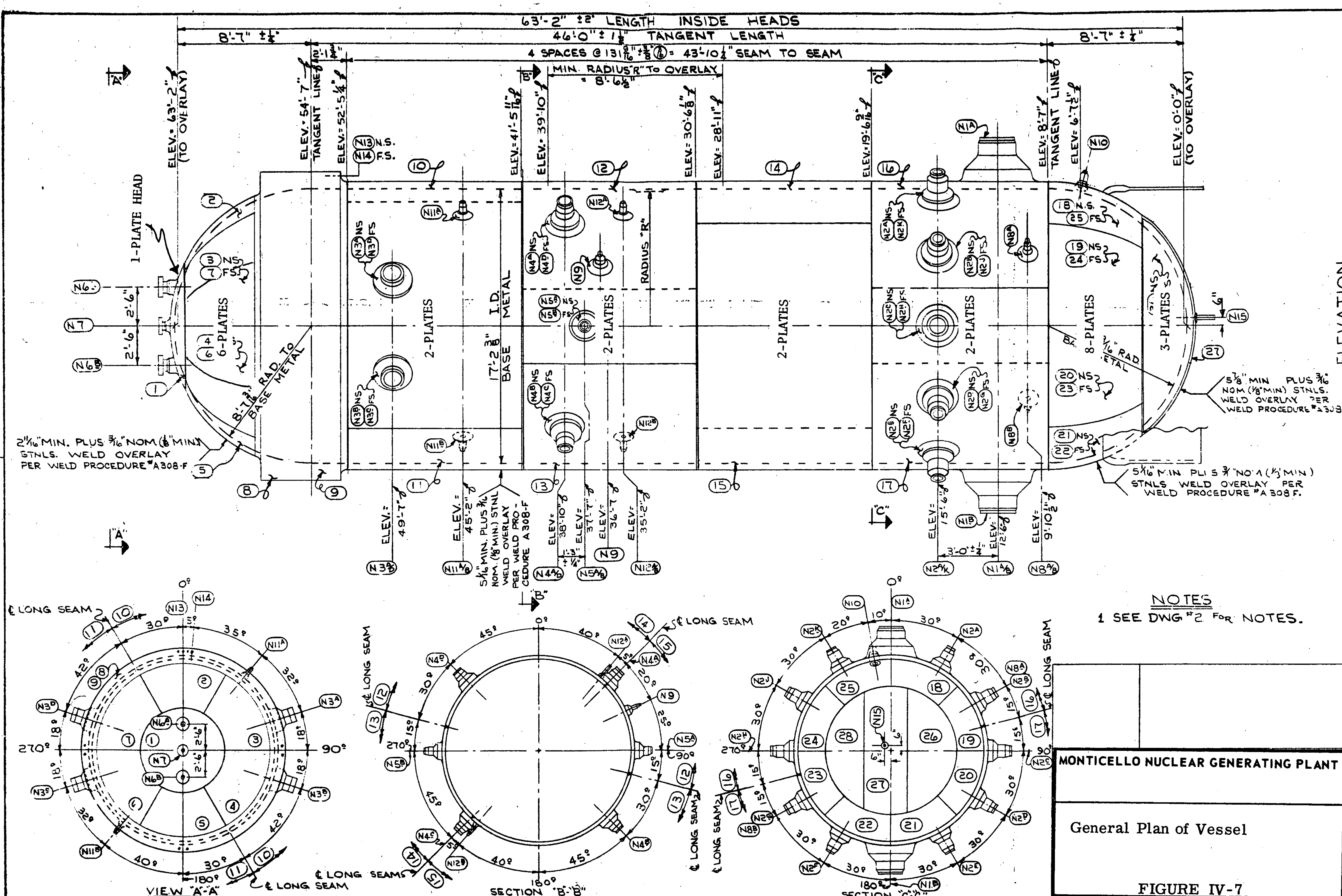
FIGURE IV-5



MONTICELLO NUCLEAR GENERATING PLANT

Stainless Steel Overlay of Pressure Vessel

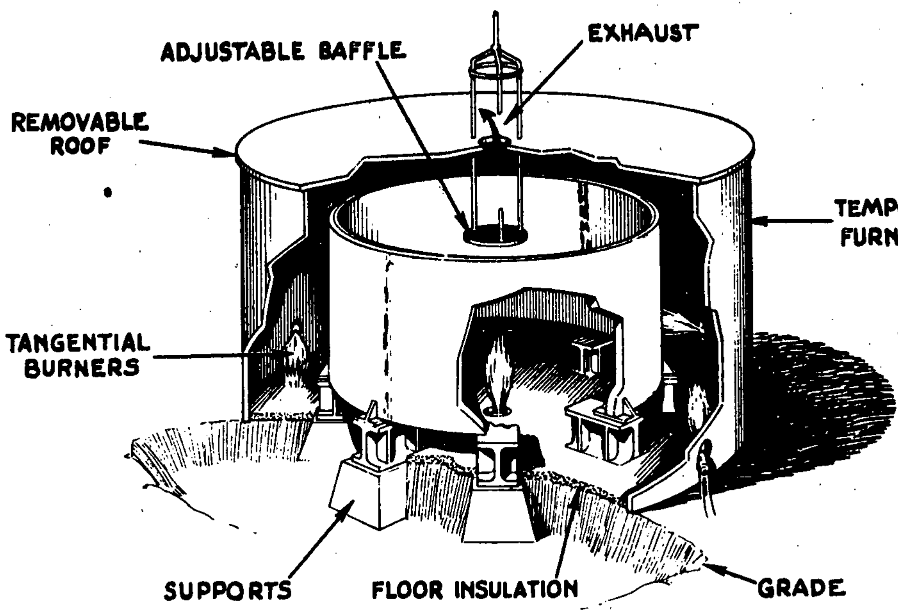
FIGURE IV-6



MONTICELLO NUCLEAR GENERATING PLANT

General Plan of Vessel

FIGURE IV-7

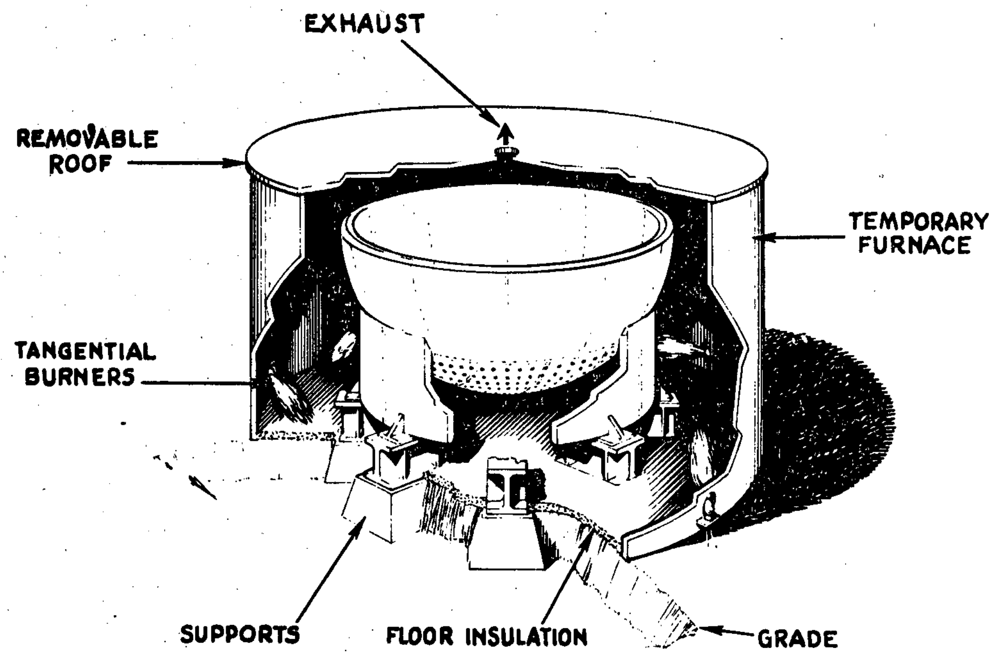


POST WELD HEAT TREATMENT
LONGITUDINAL WELDS
TYPICAL SHELL RING

MONTICELLO NUCLEAR GENERATING PLANT

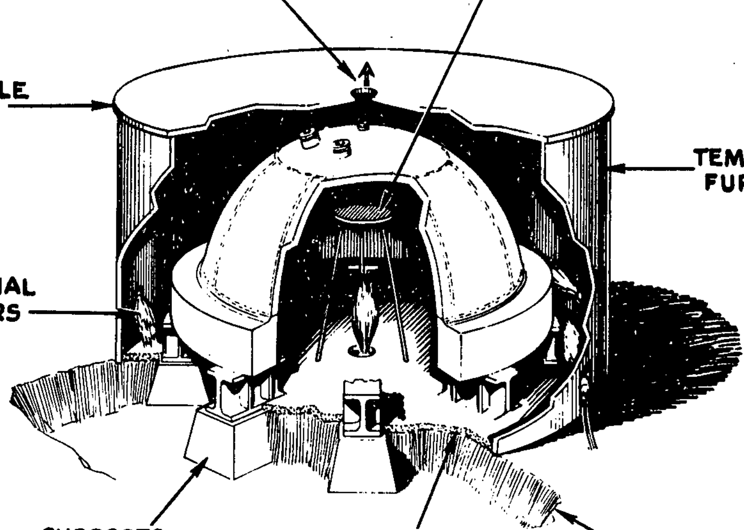
Post Weld Heat Treatment of Longitudinal Welds

FIGURE IV-8



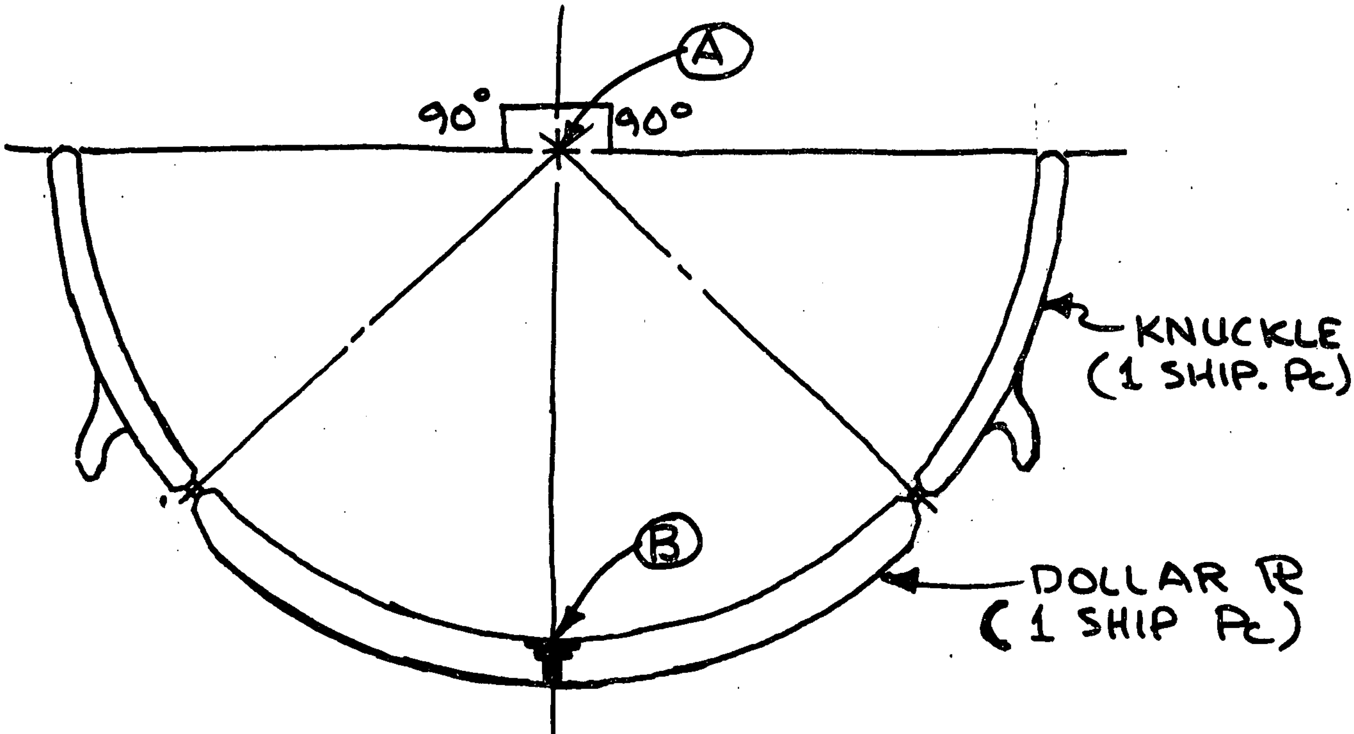
POST WELD HEAT TREATMENT
BOTTOM AND HEAD TO SKIRT WELDS

MONTICELLO NUCLEAR GENERATING PLANT
Post Weld Heat Treatment of Bottom Head and Skirt Welds FIGURE IV-9



POST WELD HEAT TREATMENT
TOP HEAD

MONTICELLO NUCLEAR GENERATING PLANT
Post Weld Heat Treatment of Top Head to Flange Weld
FIGURE IV-10



ESTABLISHING REACTOR ℄

1. THE REACTOR ℄ IS ESTABLISHED IN THE SHOP.

2. POINTS (A) & (B) ESTABLISHES REACTOR ℄.

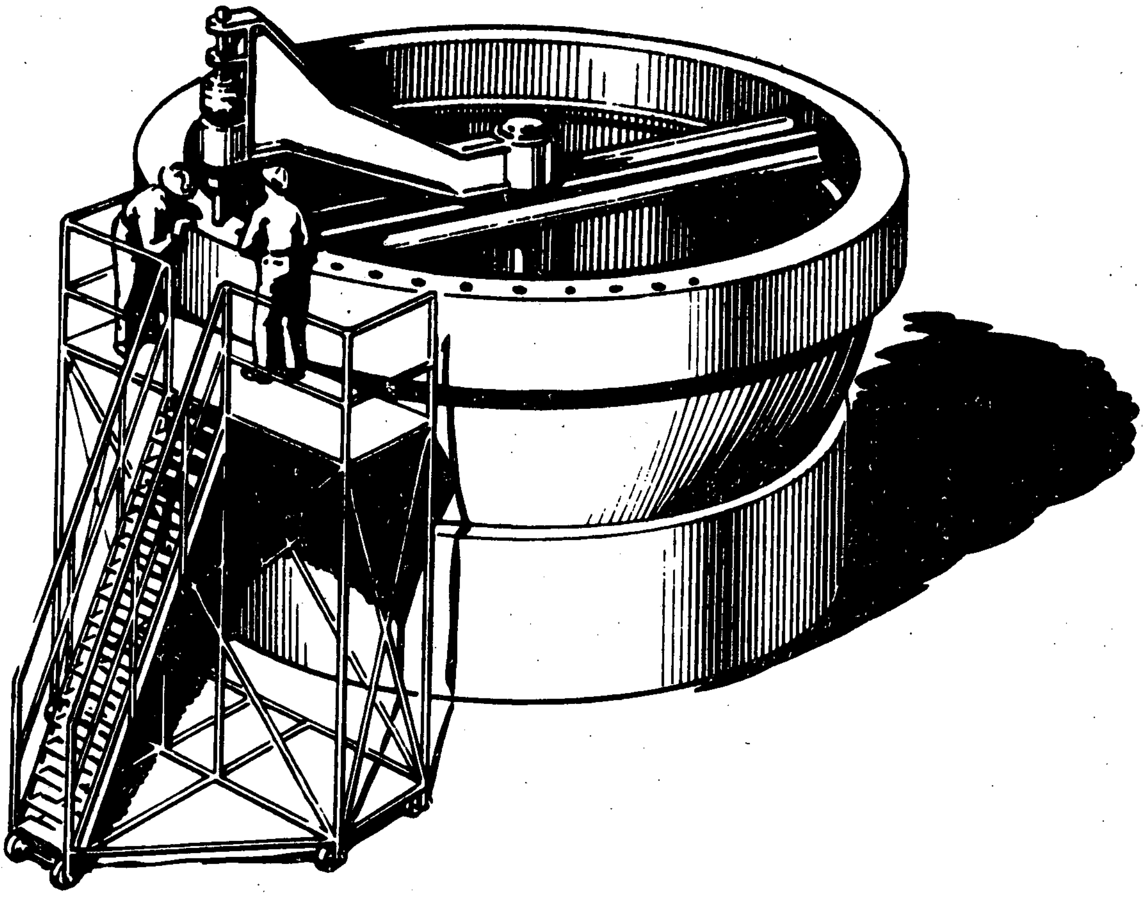
3. WHEN FIELD ASSEMBLES BOTTOM HEAD, THE REACTOR ℄ SHOULD NOT CHANGE APPRECIABLY BECAUSE OF FOLLOWING SHOP PROCEDURES:
   a) CIRCUMFERENTIAL JOINTS ARE MACHINED
   b) CONTROL ROD PENETRATIONS ARE ACCURATELY LAYED OUT & SUB BORED

4. WHEN FIELD ERECTS BOTT HD ASSEM, THE FIELD WILL LEVEL SECTION (WITH LEVELING DEVICES ON REACTOR SKIRT) SUCH THAT PTS (A) & (B) ARE IN A VERTICAL LINE.

MONTICELLO NUCLEAR GENERATING PLANT

Establishing Reactor Centerline

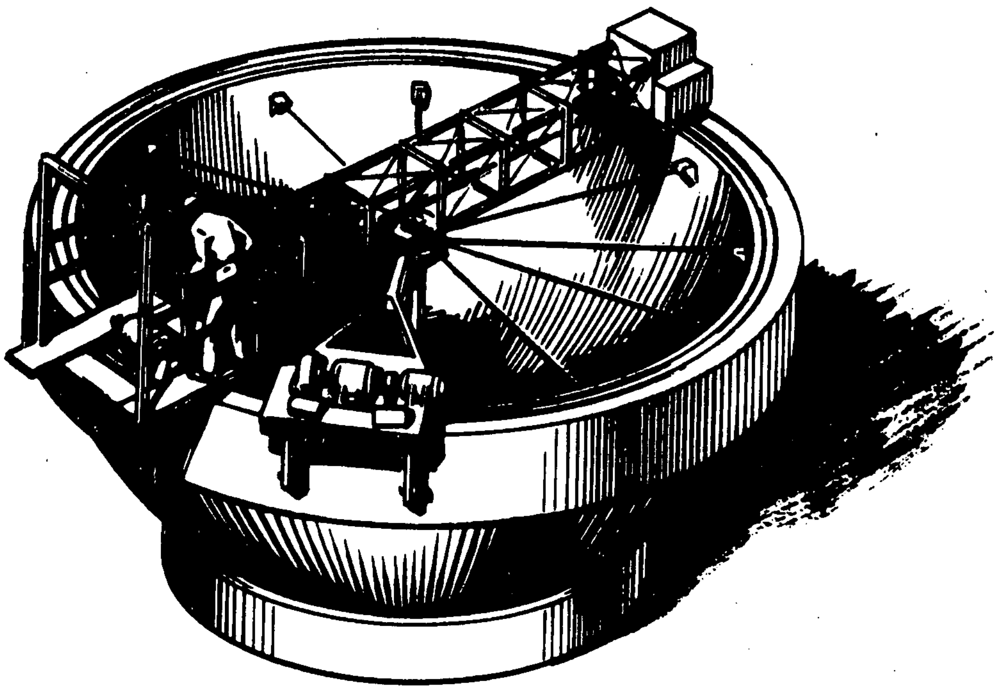
FIGURE IV-11



MONTICELLO NUCLEAR GENERATING PLANT

Top Head Flange Drilling

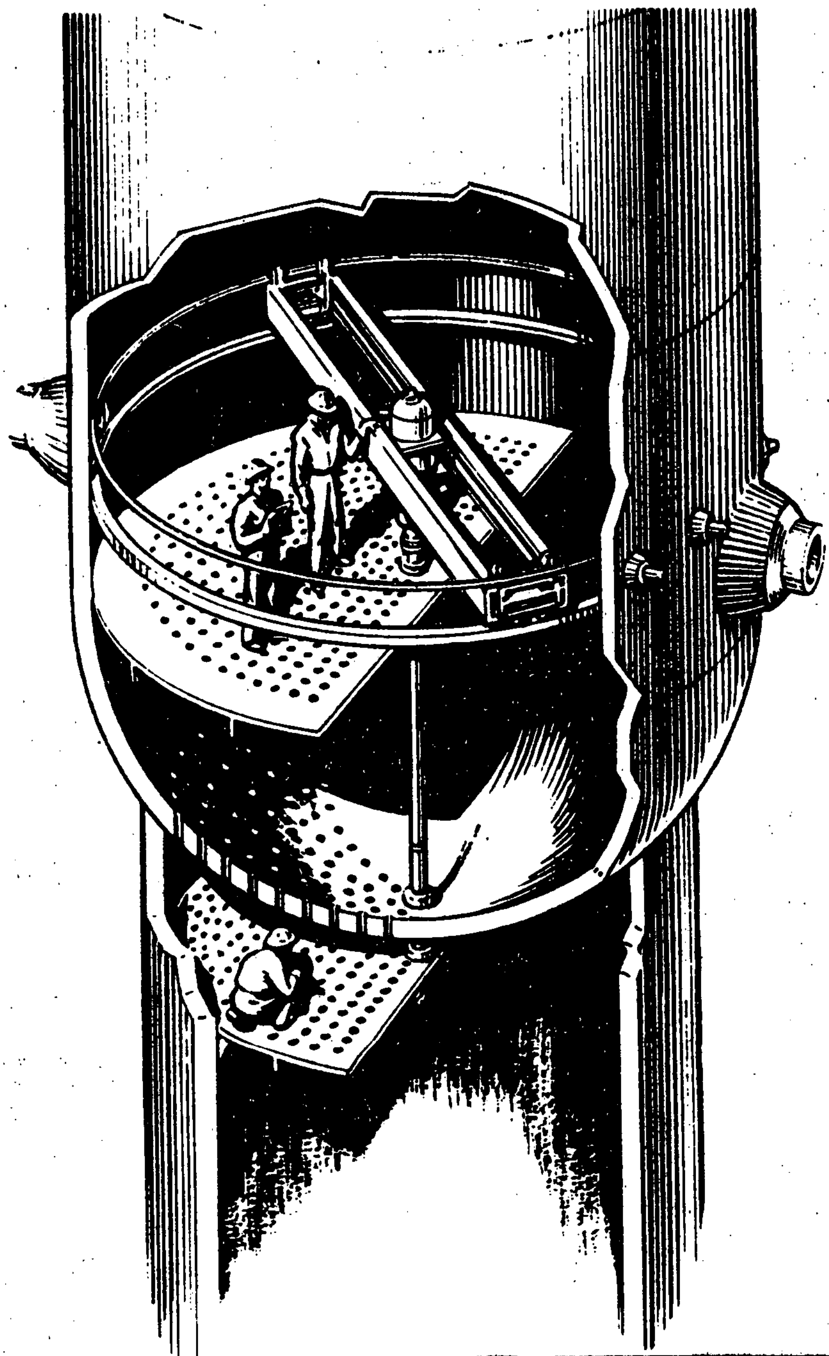
FIGURE IV-12



MONTICELLO NUCLEAR GENERATING PLANT

Top Head Flange Machining

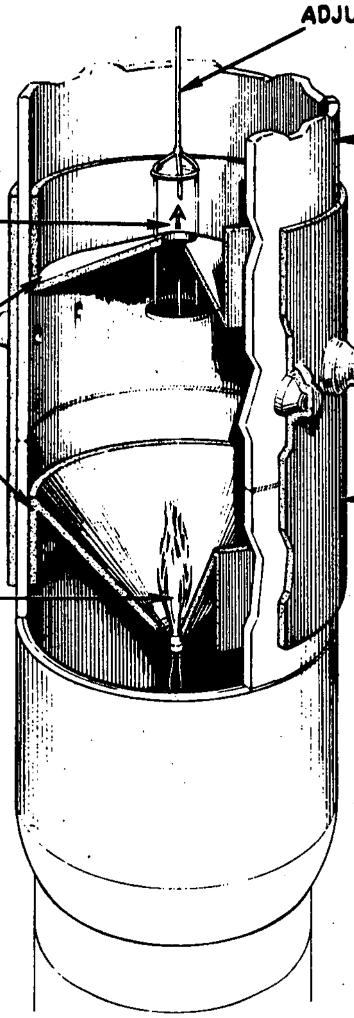
FIGURE IV-13



MONTICELLO NUCLEAR GENERATING PLANT

Boring Bar Cutter Drilling Control Rod Drive Sleeves

FIGURE IV-14

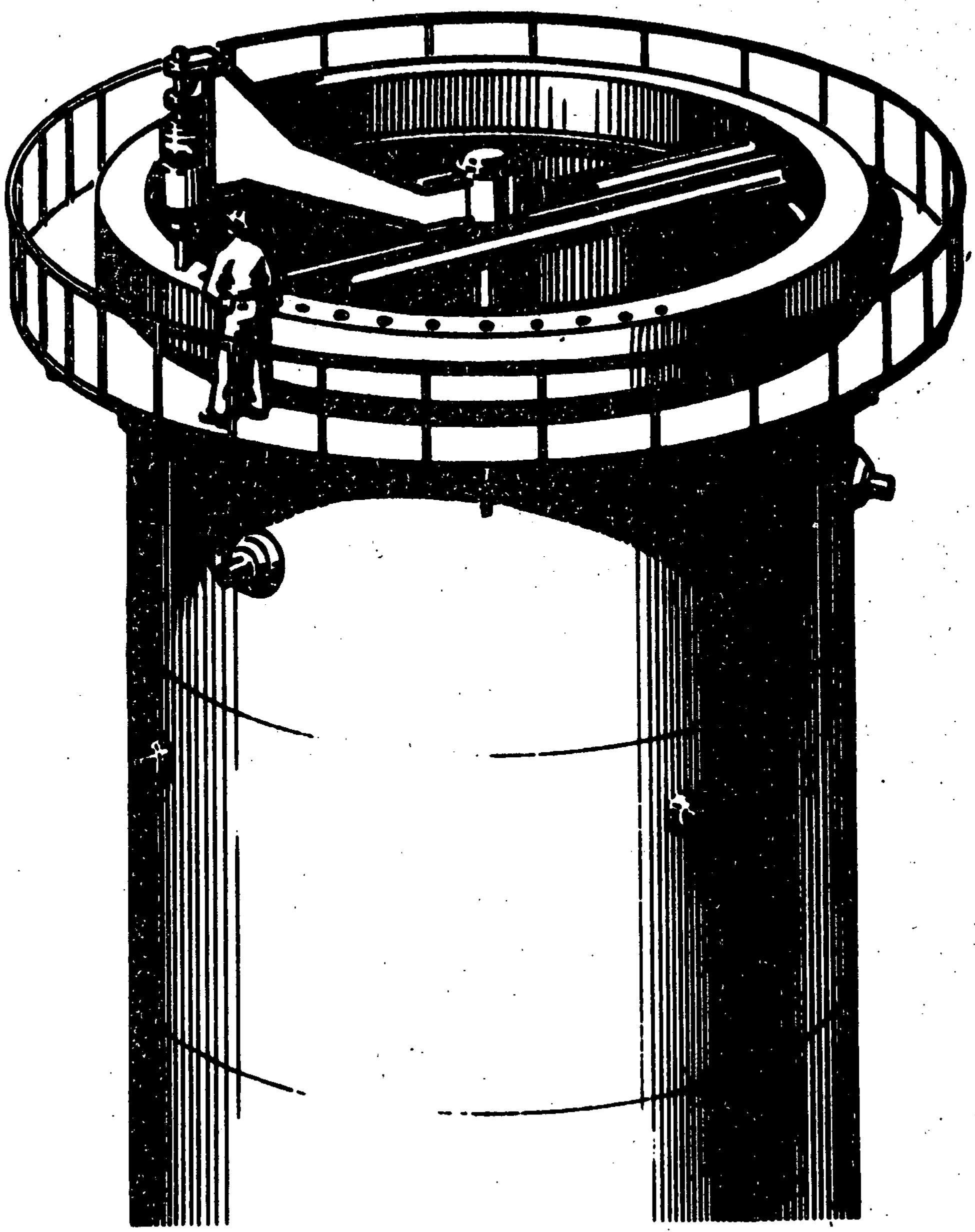


LOCAL POST WELD HEAT TREATMENT
GIRTH WELD - IN POSITION

MONTICELLO NUCLEAR GENERATING PLANT

Post Weld Heat Treatment of Girth Weld in Position

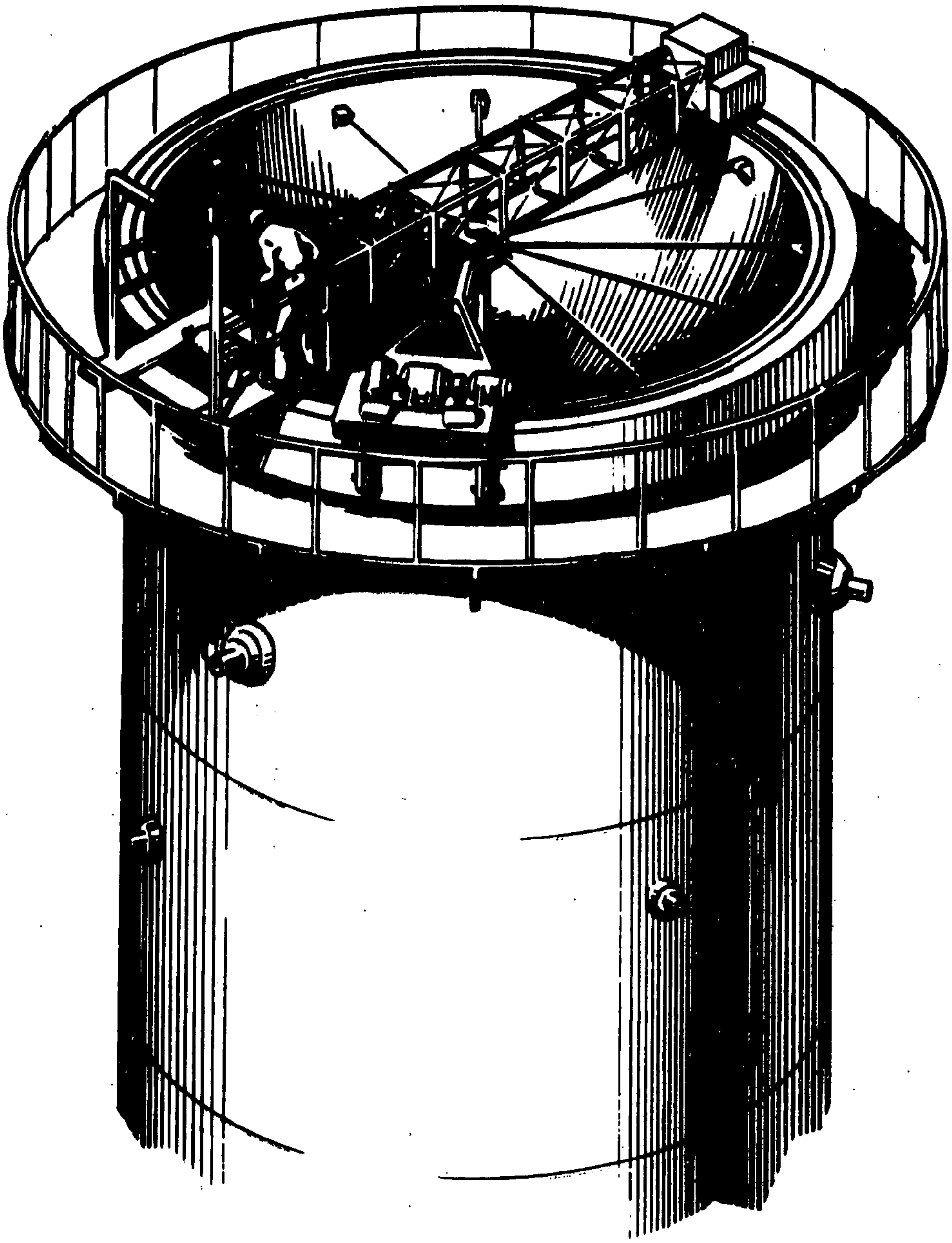
FIGURE IV-15



MONTICELLO NUCLEAR GENERATING PLANT

Vessel Closure Flange Drilling

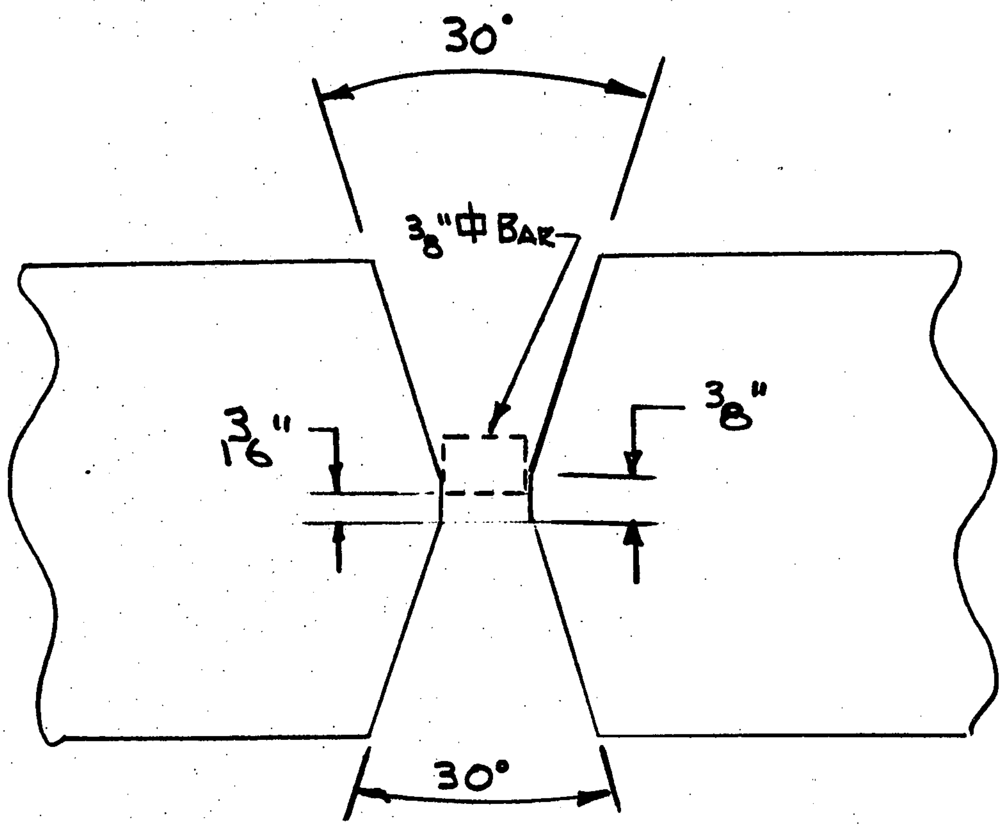
FIGURE IV-16



MONTICELLO NUCLEAR GENERATING PLANT

Vessel Closure Flange Machining

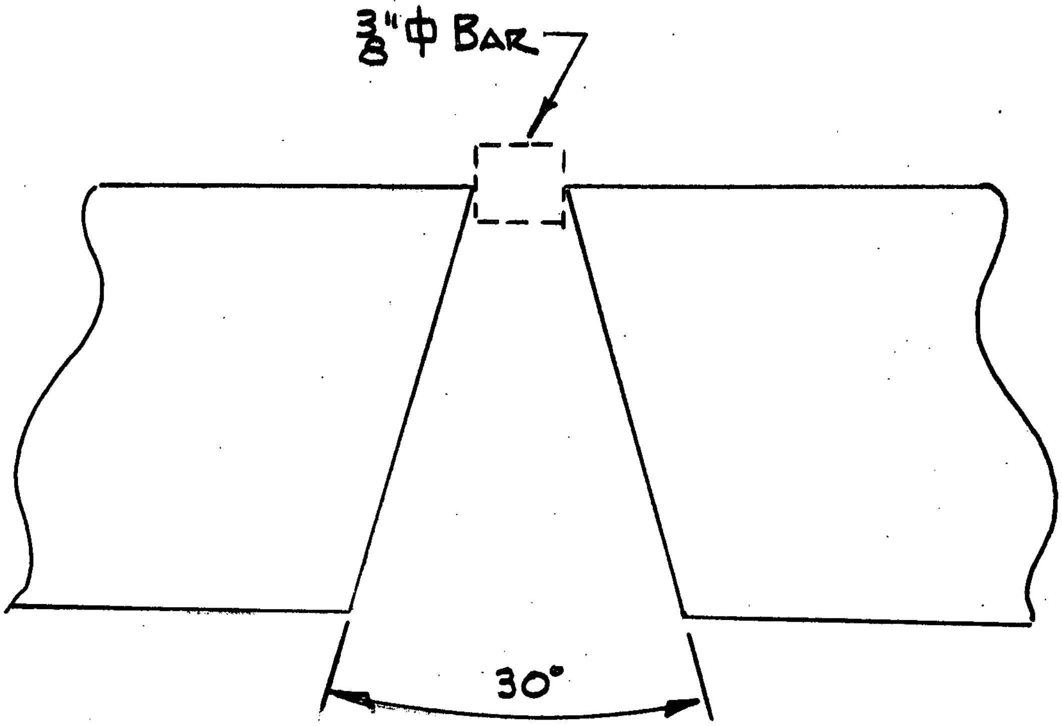
FIGURE IV-17



MONTICELLO NUCLEAR GENERATING PLANT

Category A and B Joint Detail

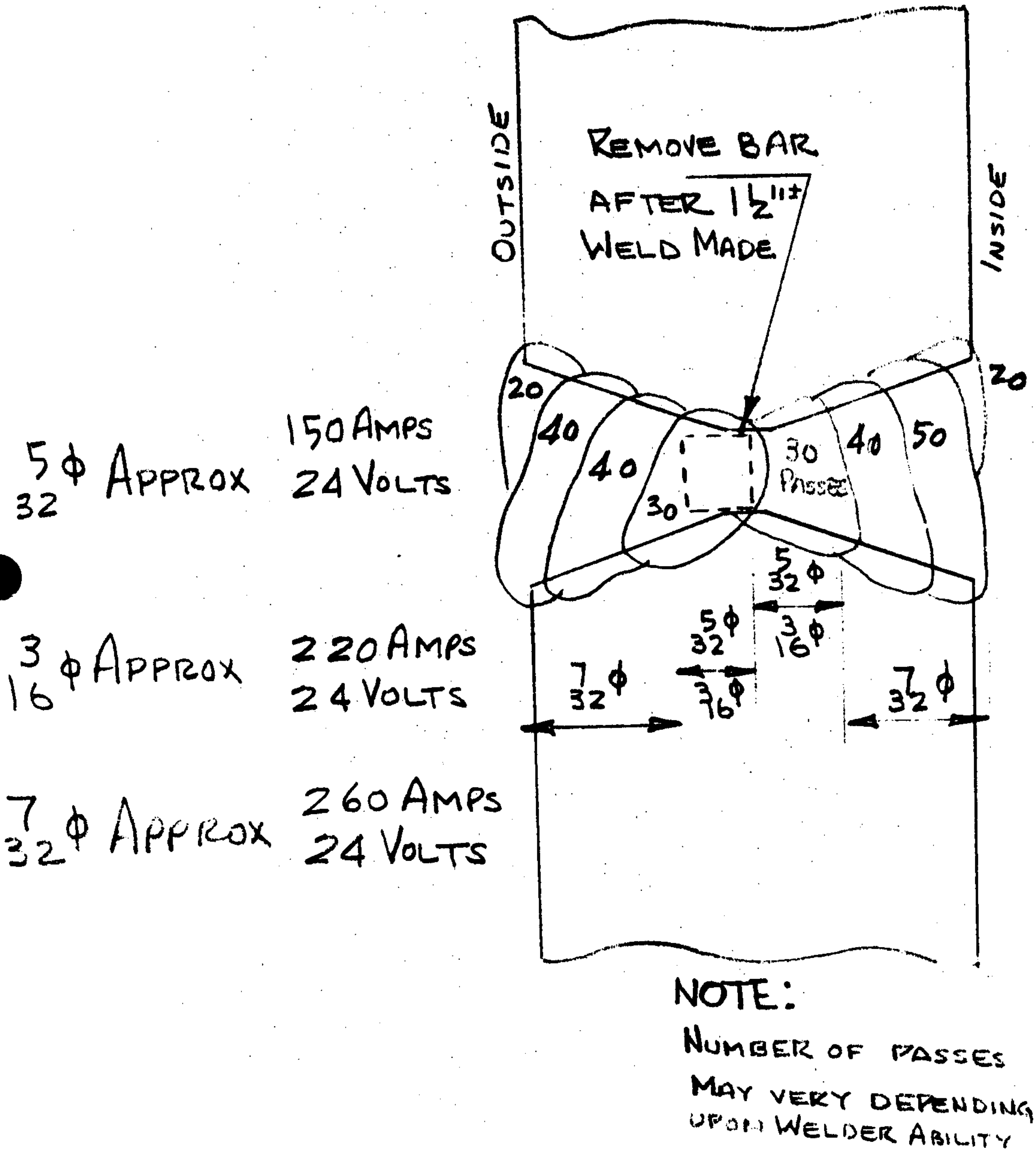
FIGURE IV-18



MONTICELLO NUCLEAR GENERATING PLANT

Category D Joint Detail

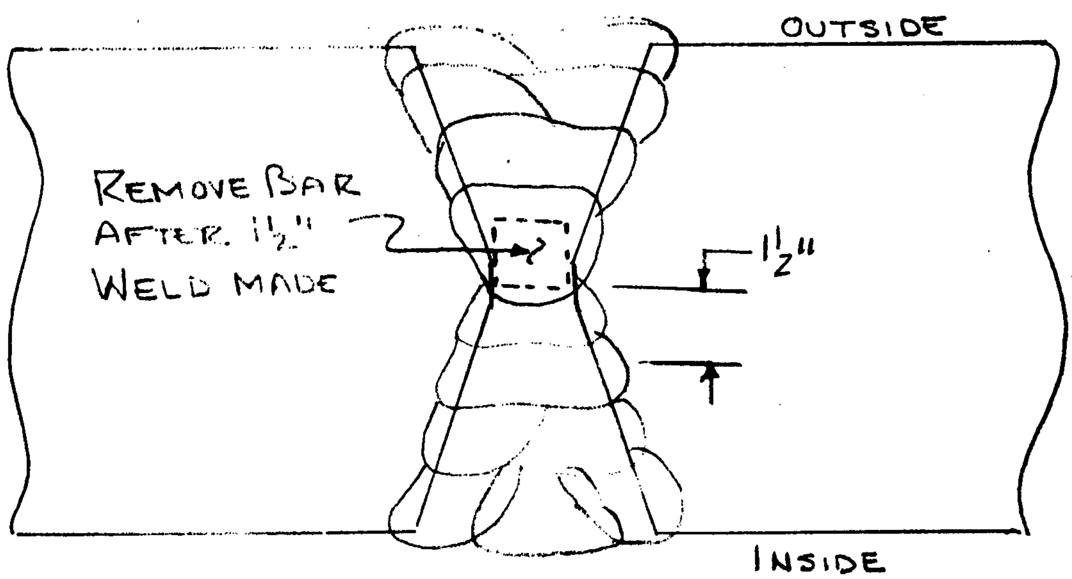
FIGURE IV-19



MONTICELLO NUCLEAR GENERATING PLANT

Category B Joint Weld Sequence

FIGURE IV-20



5/32 φ APPROX

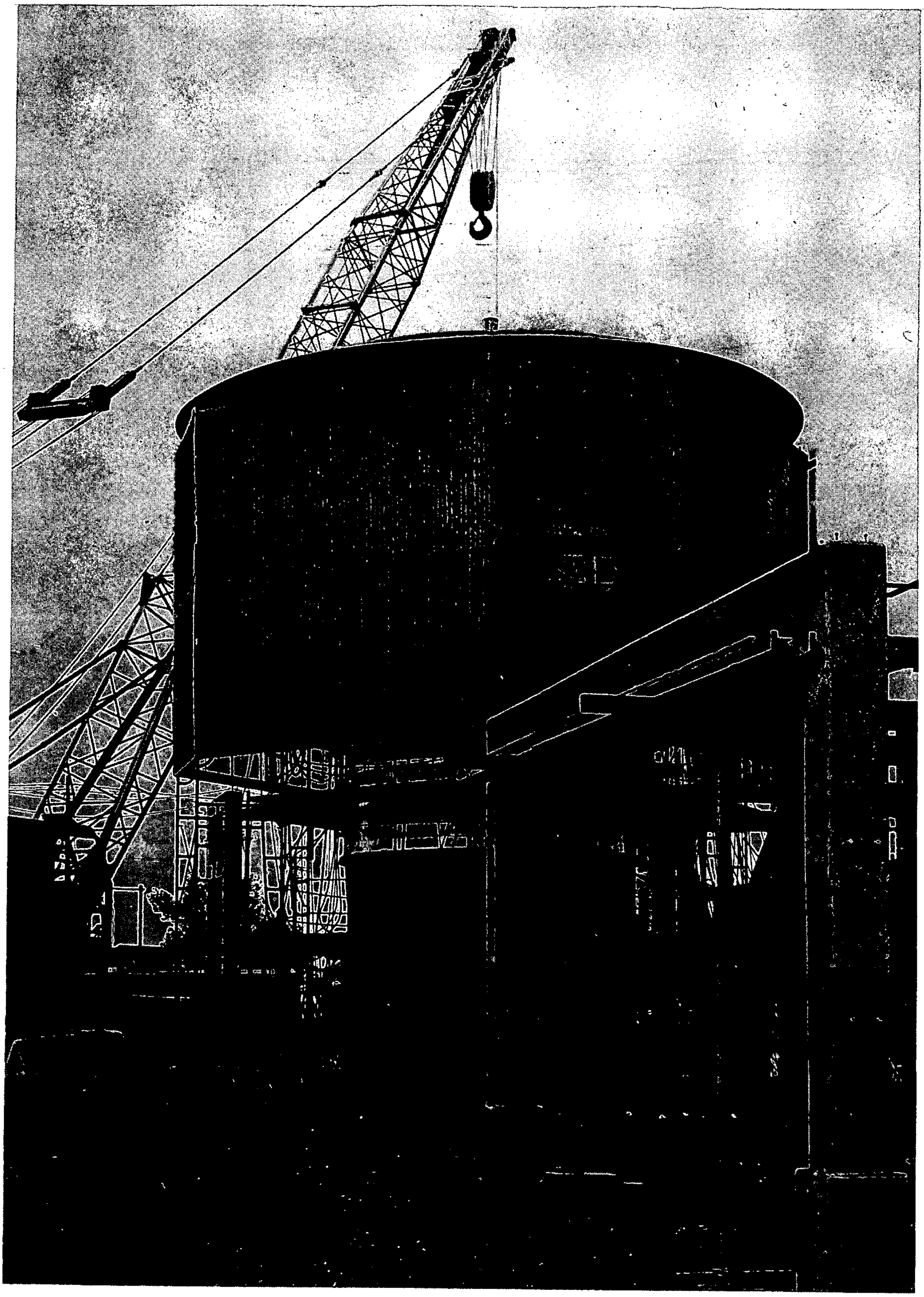
160 AMPS
24 VOLTS

NOTE:
NUMBER OF PASSES MAY VARY DEPENDING UPON WELDER ABILITY

MONTICELLO NUCLEAR GENERATING PLANT

Category A Joint Weld Sequence

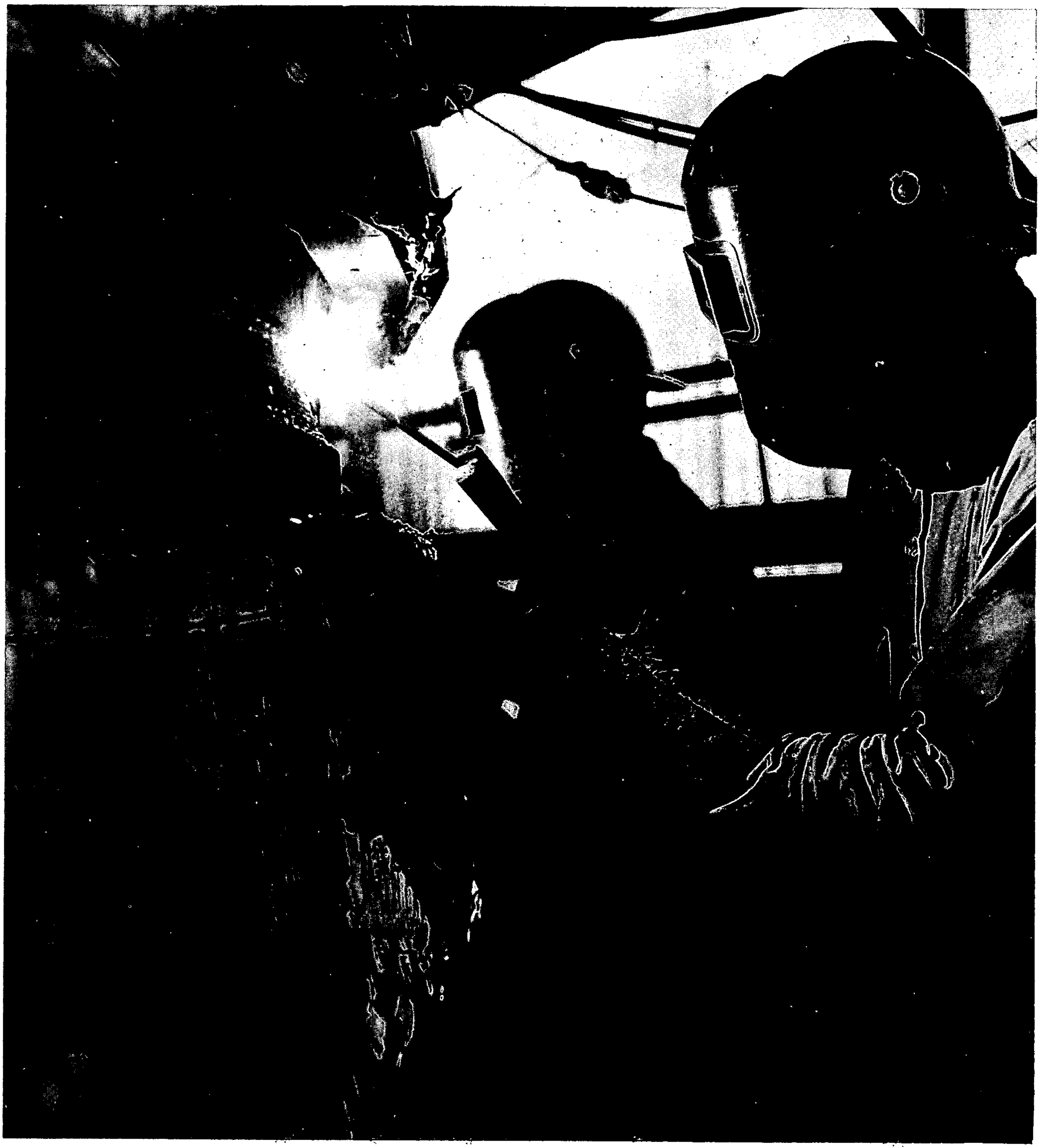
FIGURE IV-21



MONTICELLO NUCLEAR GENERATING PLANT

Weather Protection for Welders

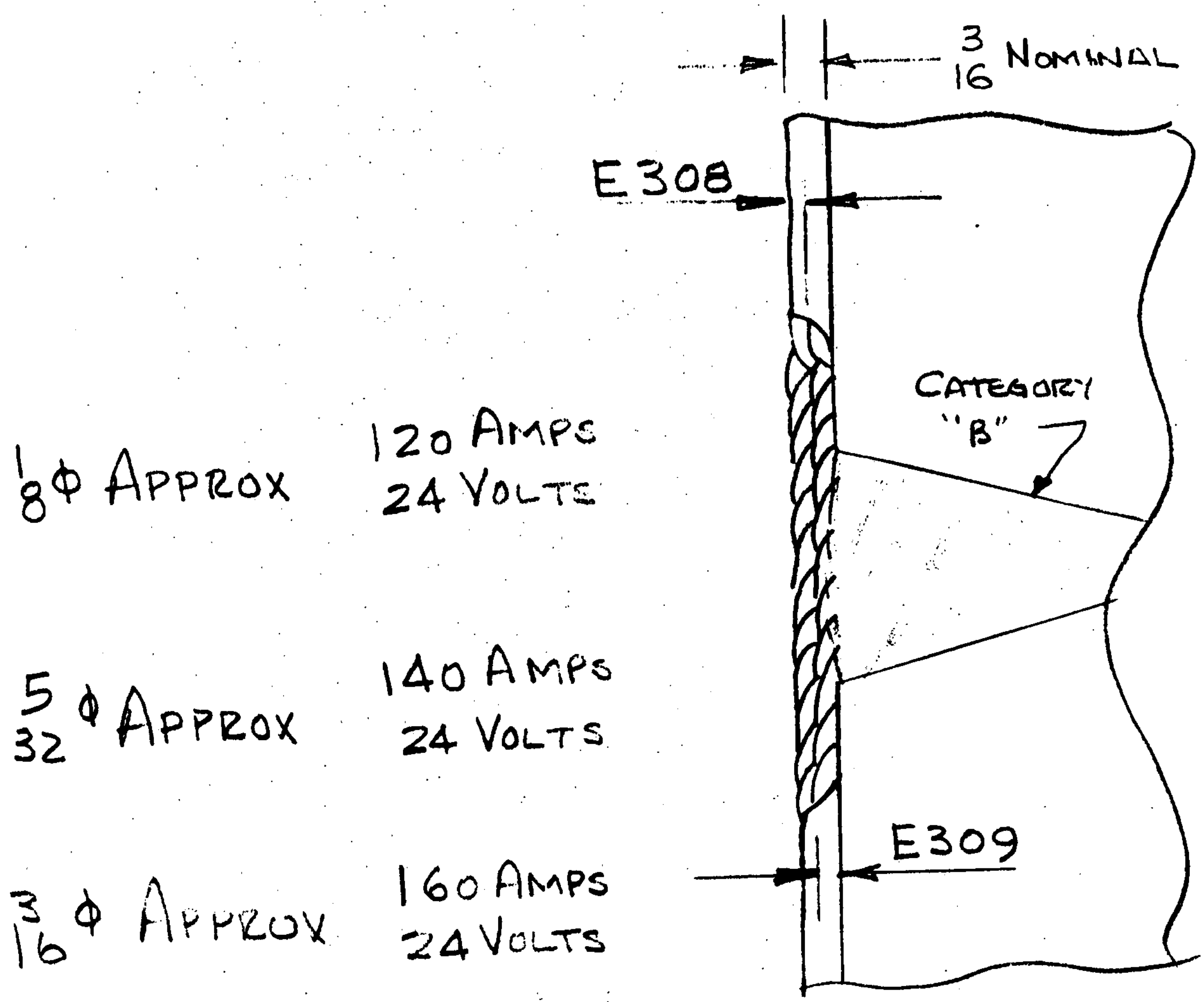
FIGURE IV-22



MONTICELLO NUCLEAR GENERATING PLANT

Typical Field Pre-Heating Arrangement

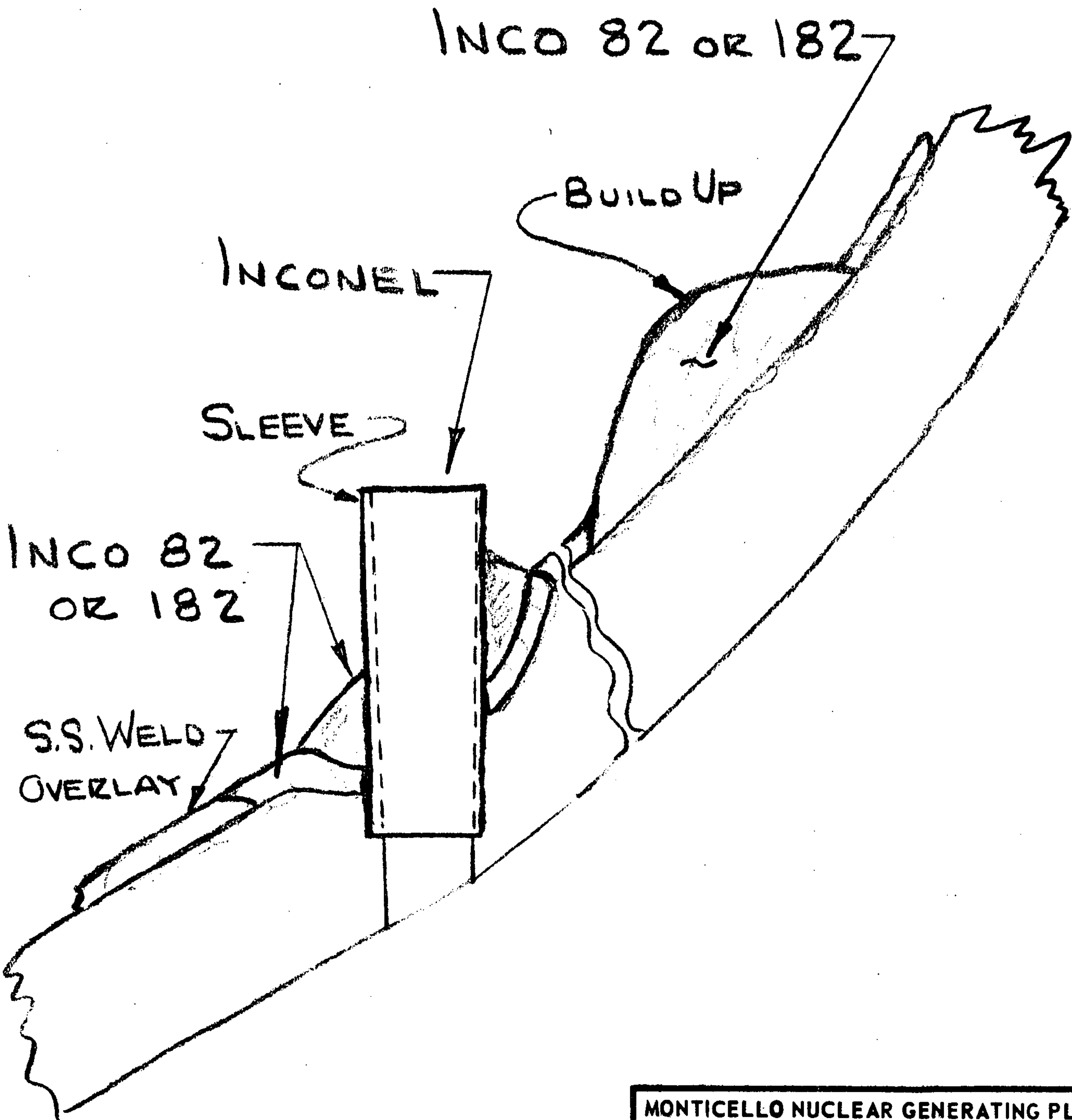
FIGURE IV-23



MONTICELLO NUCLEAR GENERATING PLANT

Typical Stainless Steel Overlay - Manual

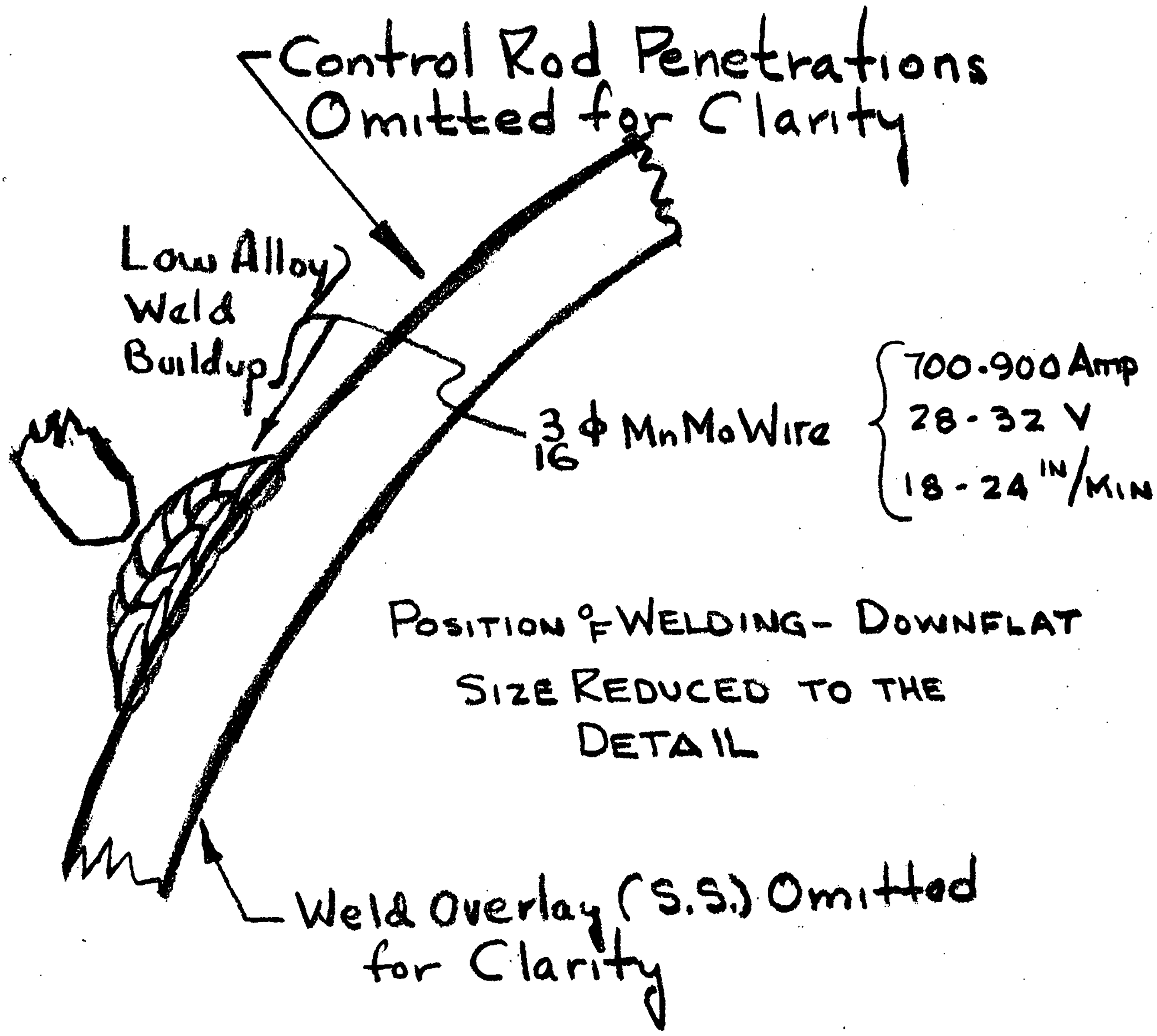
FIGURE IV-24



MONTICELLO NUCLEAR GENERATING PLANT

Shroud Support Buildup Control Rod Penetration Sleeves

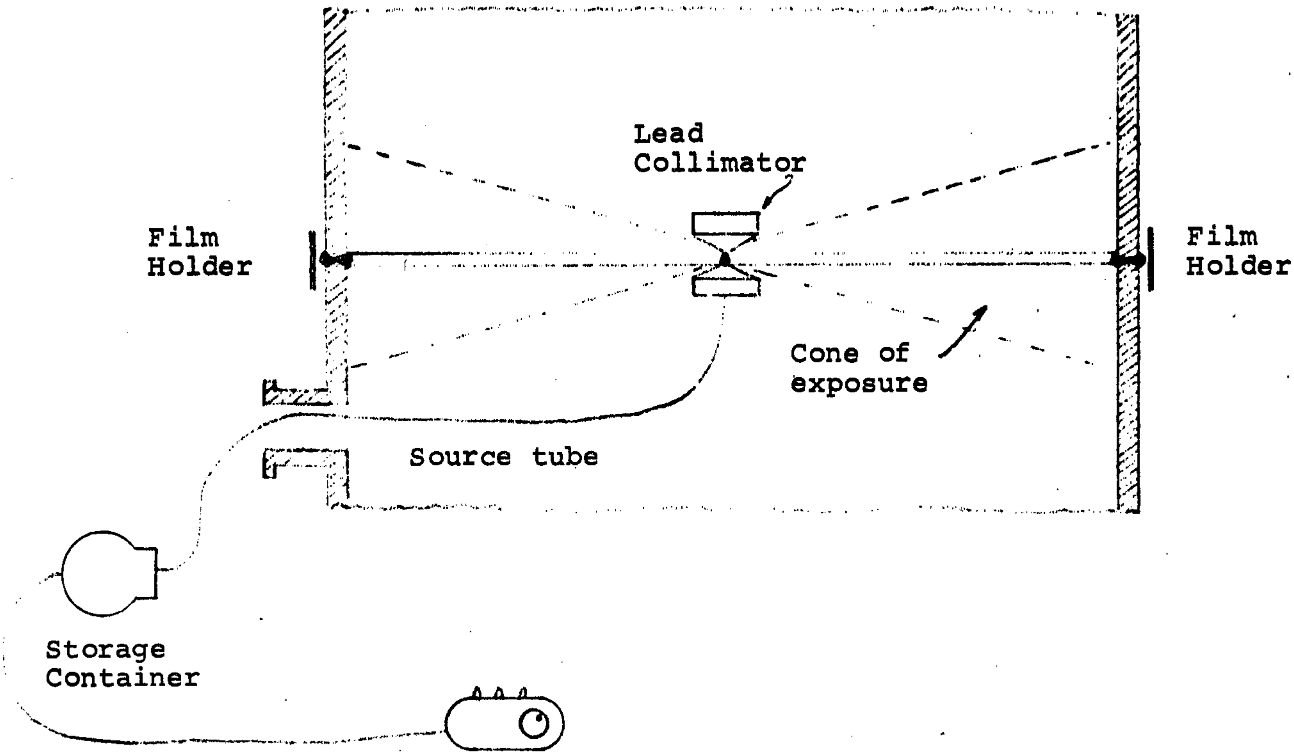
FIGURE IV-25



MONTICELLO NUCLEAR GENERATING PLANT

Skirt Knuckle Weld Buildup on
on Bottom Head Knuckle

FIGURE IV-26



Radiographing girth joint - entire joint exposed at the same time.

Figure

NOTE:

Vertical or longitudinal joints will be radiographed in the same manner, however, it may require several setups to cover the entire joint.

MONTICELLO NUCLEAR GENERATING PLANT
Typical Field Radiographic Setup FIGURE IV-27

V. GENERAL ELECTRIC REVIEW, EVALUATION AND APPROVAL OF CB&I PROCEDURES

5.1 GENERAL

The "Engineering Requirements" for the Monticello reactor vessel requires specific written procedures to be prepared by CB&I and approved by General Electric Company to provide a check and balance system between fabricator and purchaser in addition to the high-level check and balance system within CB&I described earlier. Furthermore, a check and balance review system is provided within General Electric Company between Engineering and Quality Control. The approved procedures then become the basis upon which Quality Control inspects for performance and control of the process.

Each written fabrication, inspection and test procedure submitted by CB&I is reviewed and commented upon at General Electric for completeness, technical adequacy and resolution of any differences between the two companies prior to General Electric approval for construction.

5.2 TYPES OF PROCEDURES TO BE REVIEWED

The specific procedures requiring review and approval are given in Appendix C, Sections VII, VIII and X and may be summarized as follows:

5.2.1 Fabrication Procedures

Fabrication Sequence
Forming
Heat Treating
Welding
Cleaning
Ferrite Control
Repairs

5.2.2 Inspection Procedures

Radiography
Ultrasonic
Magnetic Particle
Liquid Penetrant
Special dimensional inspections

5.2.3 Test Procedures

Material Acceptance tests
Code & special weld tests
Fabrication tests
Hydro test
Seal Leak test

The detail into which each of these procedures is reviewed and approved by General Electric is listed in Appendix G, which outlines the minimum information to be contained in each procedure. Appendix H deals specifically with the basis for review of radiographic inspection procedures.

The procedures shall be reviewed with the objective of performing the work with controls and equipment easily capable of meeting the engineering requirements with known and proven techniques. Either successful past experiences or demonstrations are required of any technique suspected of being "marginal".

5.3 DIFFERENCES IN FABRICATION PROCEDURES AND CRITERIA FOR ACCEPTANCE

The Monticello reactor vessel fabrication will have the following differences compared to a vessel totally assembled in the shop:

5.3.1 Temporary Weather Protection Instead of Permanent Weather Protection.

Criteria: Sturdy structure to withstand wind, rain and snow with heating and insulation to provide local protection equal, to or better than shop.

5.3.2 Temporary Post Weld Heat Treatment Furnace for Total Post Weld Heat Treatment of Components.

Criteria: Sturdy structure to withstand wind and control of heating, holding and cooling rates and instrumentation to measure the process.

5.3.3 Source of Welders

Criteria: Demonstrated proficiency with same materials and instruction on electrode controls. Close supervision and inspection of the quality of production work as it progresses.

5.3.4 Construction at Two Locations Instead of One.

Criterion: Provide equal supervision, inspection and standards at both locations.

5.3.5 More Manual Welding

Criteria: See "Source of Welders" above.

5.3.6 More In Place Machining

Criteron: Demonstrated proficiency to meet Monticello tolerances.

5.3.7 More Local Post Weld Heat Treatment.

Criteron: Demonstrated proficiency to control temperatures to specification requirements (including code) without harmful thermal gradients and with adequate control and instrumentation. Harmful thermal gradients are those which cause stresses exceeding the yield point at temperature.

5.3.8 More gamma ray radiography

Criteria: Meet code. Quality procedure with gamma radiographs showing hole in penetrameter

with a diameter equal to the thickness of the penetrameter.

Other procedures are the same in the field as in the shop and shall meet the following General Electric criteria: The fabrication sequence shall provide for:

1. All steps and sequences required by engineering requirements (including code) and experience are accounted for, particularly the heat treatment, welding and inspection steps, and that they are sequenced in an acceptable order.
2. Access for work and inspection of subsequent steps;
3. Minimize probability of damage by succeeding steps, such as from welding, heat treating and cleaning operations.

The forming procedure shall provide for:

1. Known temperature time strain cycles;
2. Hot forming furnace atmospheres which are compatible with the material;
3. Adequate controls on the process.

The heat treating procedure shall provide for:

1. Furnace atmospheres which are compatible with the material;
2. A temperature time cycle which is known to produce a favorable balance of mechanical properties.
3. Maximum temperature gradients and support of components which prevent distortion.
4. Adequate instrumentation to measure the process and proper furnace controls.
5. Special attention to the adequacy of temporary furnaces and local post weld heat treatment.

The welding procedures shall provide for:

1. Compatibility of materials
2. Adequate access and joint design for position and process;
3. Proper preheat and post weld heat treatment;
4. Moisture control of welding materials;
5. Proper cleaning and back chipping.

The cleaning procedure shall provide for:

1. Removal of harmful soils and oxides
2. Compatibility of materials
3. Adequate rinsing

4. Controls on the process for chemical cleaning: temperatures, times, mixing, depletion, and rinsing.

The ferrite control procedure shall provide for some detectable ferrite from periodic measurements.

The repair procedure for minor repairs shall provide the basis for leaving small cavities "as-is" and controls on re-welding and re-inspection before and after filling a cavity. The repair procedure for major repairs shall additionally provide for recording the repair and an analysis of the cause of the defect.

The ultrasonic test procedures shall provide for:

1. Equipment and techniques to engineering (and code) requirements with known or demonstrated sensitivity;
2. A system for recording results
3. Removal of any deleterious couplant.

The radiography procedure shall provide for:

1. Either known techniques and processing methods or demonstrated adequacy to meet code requirements;
2. Processing techniques which preserve the sensitivity of completed films over long periods of storage.
3. Identification and recording the results
4. Special qualification of gamma-ray procedures.

The magnetic particle and liquid penetrant procedures shall provide for:

1. Meeting engineering (and code) requirements;
2. Known or demonstrated techniques
3. A system for identification and recording of results.

The special dimensional inspection procedures shall provide for:

1. Accuracy of measurement within the required tolerances;
2. The accuracy of measurement shall be added to the measured dimension in the least favorable manner;
3. A meaningful method of recording the results.

The procedures for Material Acceptance tests, code and special weld tests, Fabrication tests and Surveillance tests shall provide for:

1. Meeting engineering (and code) requirements regarding material condition, orientation and location of specimens and test conditions;

2. Any special qualification conditions relating to unknown or uniform conditions.

The hydro test and seal leak test procedures shall provide for:

1. Meeting engineering (and code) requirements
2. Adequate instrumentation;
3. Temperature control in relation to NDT temperature
4. Documentation of test results.

In summary, the review and approval by General Electric of the CB&I procedures for the Monticello reactor vessel provide a detailed, critical check and balance of the technical adequacy methods and process control which will be used at Monticello. It is estimated that a total of 30 to 40 individual, detailed procedures will be reviewed and approved.

VI. GENERAL ELECTRIC QUALITY CONTROL PLAN

6.1 GENERAL

General Electric has developed a Quality Control organization with the responsibility and authority to assure that purchased material and equipment conforms with design and quality requirements.

The quality level and acceptance criteria are established in the following order:

1. The Purchase Contract

2. The General Electric Specification (includes applicable Code requirements)

3. The General Electric Quality Control Plan

4. Approved drawings and calculations

5. Approved Manufacturing Procedures

The above documents are established prior to fabrication and are subject to formal review prior to issue.

6.2 ORGANIZATION

The General Electric Quality Control organization is shown in Figure VI-1. The Quality Control-Direct to Site Procurement organization will be responsible to assure supplier conformance with the established requirements on the Monticello Reactor Pressure Vessel. The detailed organization chart is shown in Figure VI-2.

The Quality Control Engineer is responsible to plan and direct the General Electric Quality Control activity on Reactor Pressure Vessels. The General Electric Quality Control (Field) Representatives for the Monticello Reactor Vessel will be assigned in residence at the CB&I plant in Birmingham, Alabama, and at the Monticello site in Minnesota. In addition, GE plans to utilize its experienced Quality Control Representatives in Chicago, Philadelphia and Boston to cover Quality Control work at CB&I material suppliers, such as Ladish (flange forgings), Lukens Plate, Midvale Heppensthal (nozzles) and Advance Products ("O" Rings). GE's practice is the same for shop assembled vessels.

6.3 TYPICAL EXPERIENCE

6.3.1 Quality Control Engineer: In addition to an engineering degree, the vessel Quality Control Engineer must have five to ten years experience in Design, Manufacturing or Quality Engineering work on Nuclear Steam Supply Equipment or equivalent. His experience must include specialized training in nondestructive testing and welding and metallurgical engineering. He must be expert on ASME Code quality requirements.

6.3.2 Quality Control Representative: The Quality Control Representative must have an Engineering degree plus five to ten years experience in Design, Manufacturing or Quality Engineering work on Nuclear Steam Supply Equipment or equivalent - or, in the absense of the Engineering degree, he must have ten to 15 years related experience. His experience must include specialized training in non-destructive testing, welding and manufacturing of heavy fabrications. He must be thoroughly familiar with ASME Code quality requirements. At least one year of vendor quality engineering work is required.

Each of GE's present Quality Control Representatives has a minimum of 15 years related experience.

6.4 QUALITY CONTROL PLAN:

The General Electric Quality Control Plan is established prior to the purchase of the reactor vessel and is modified, if necessary, during the contract. The General Electric mandatory witness points are detailed on the supplier's traveler cards which accompany each piece or lot of vessel material. A copy of the current Quality Control Plan is shown in Appendix J.

6.5 GENERAL ELECTRIC QUALITY CONTROL ACTIVITY

The following lists are representative of the Quality Control work which has been or will be performed by General Electric on the Monticello Vessel.

6.5.1 Quality Control Engineer Activity:

a. Review the conceptual design to assure adequate provision for quality.

b. Preliminary and final drawing and specification review to assure clear delineation of requirements.

c. Development of Vessel Quality Control Plan delineating General Electric requirements.

d. Participation (with design and project engineering) in technical review of bids to resolve questions or interpretations of quality requirements.

e. Pre-production reviews with supplier design engineering, manufacturing engineering and Quality Control management to assure clear mutual understanding of requirements.

f. Independent review of detail drawings and manufacturing procedures submitted by supplier.

g. Technical direction and support of Quality Control Representatives. (This involves daily communication by phone and frequent written instructions).

h. Audit of the supplier quality system.

i. Audit of the Quality Control Representative.

j. Daily contact with Design and Materials Engineering.

k. Continuous objective review of fabrication sequence to assure that the resultant quality conforms with requirements.

6.5.2 <u>Quality Control Representatives Activity:</u>

a. Independent review of all General Electric drawings and specifications.

b. Pre-production reviews with supplier design engineering, manufacturing engineering and Quality Control management to assure mutual understanding of quality requirements.

c. Review of supplier detail drawings, Manufacturing and Quality Control procedures. (Supplier drawings and procedures are approved by General Electric).

d. Review of suppliers detailed fabrication process sheets to assure proper sequence and adequate in-process inspection and control.

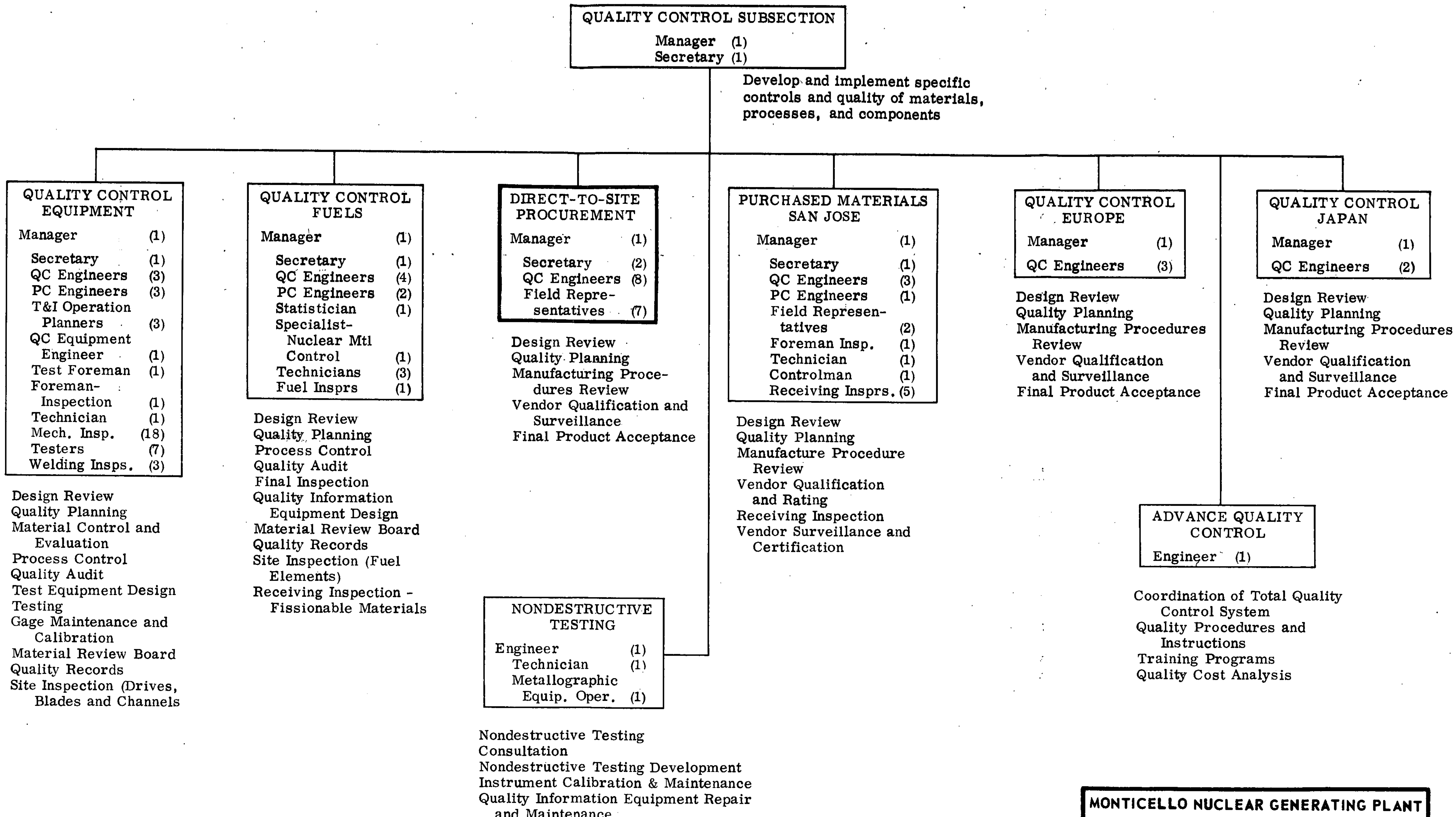
e. Frequent audit of suppliers conformance with established quality control procedures such as:

(1) Document change control
(2) Calibration control
(3) Material identification and control
(4) Deviating material control

f. Review of supplier purchase orders to assure clear delineation of quality requirements.

g. Review of all chemical and physical properties reports and the total quality control records including welder qualifications, ultrasonic, radiographic, magnetic particle, liquid penetrant, heat treatment, hydrostatic and dimensional inspection reports.

h. Scheduled and unscheduled witness and audit of any manufacturing process, test, or inspection and reporting of results to General Electric.

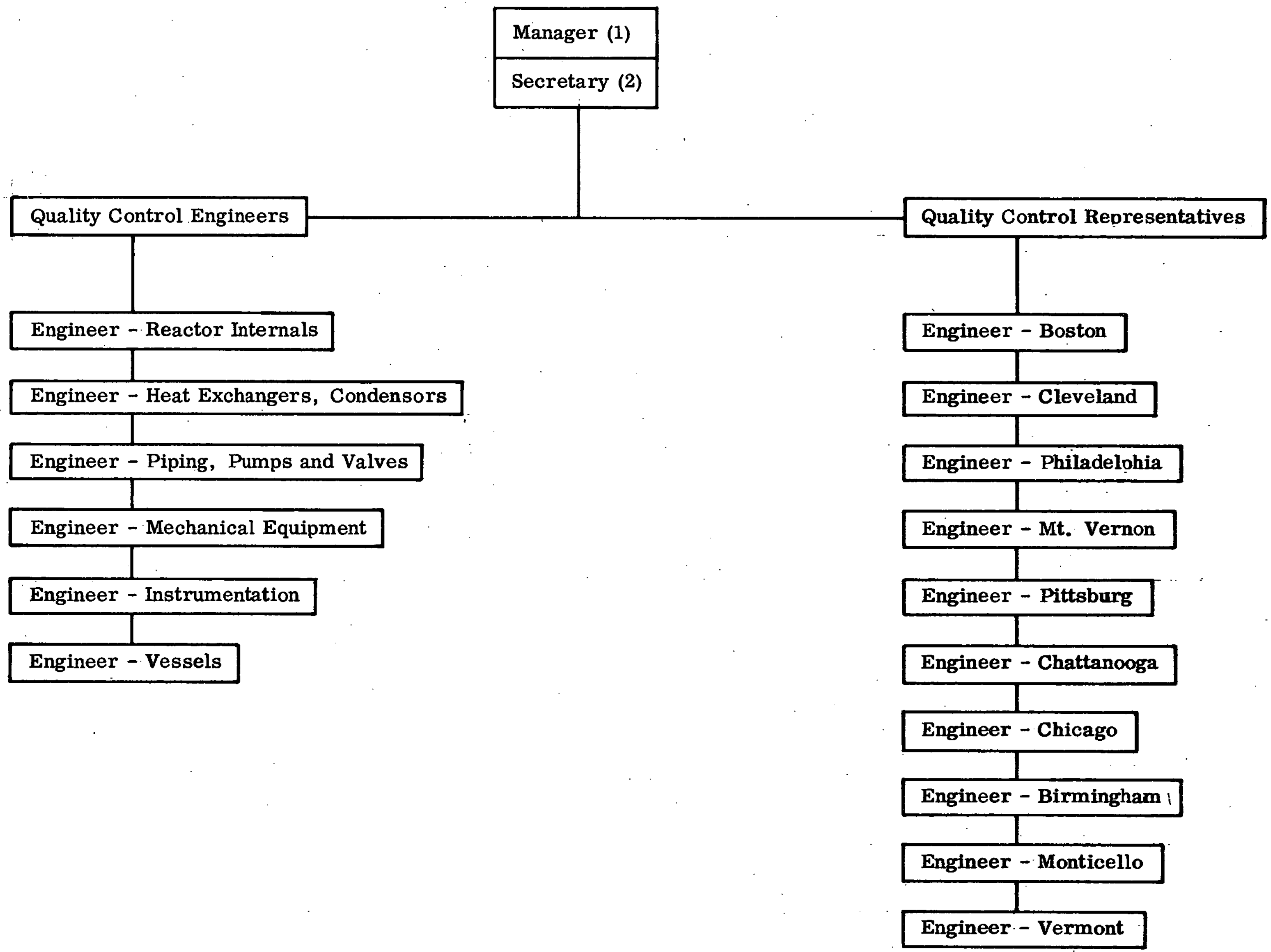


MONTICELLO NUCLEAR GENERATING PLANT

General Electric Quality Control Organization

FIGURE VI-1

QUALITY CONTROL DIRECT TO SITE PROCUREMENT



MONTICELLO NUCLEAR GENERATING PLANT

Direct-to-Site Procurement

FIGURE VI-2

VII. FIELD ORGANIZATION

7.1 GENERAL

A field organization is being established at the Monticello plant site to handle assembly and erection of the reactor vessel. Both General Electric and CB&I will have "production" organizations at the plant site. CB&I's Construction Supervisor reports through the Construction Manager to the CB&I Project Manager. The General Electric Site Manager reports similarly to the General Electric Project Manager. The CB&I Construction Supervisor is responsible for assembly and erection of the reactor vessel in accordance with approved procedures issued by higher organizational levels in his company. CB&I has a Quality Control organization which is separate from the "production" organization and is responsible to assure that all work is done within previously approved written procedures. The "on-site" Quality Control inspectors have authority to stop work when, in their opinion, it is not in accordance with procedures or where proper procedures are not in existence for the work being performed.

The General Electric site organization consists of a Resident Manager and a staff of engineers and specialists who continuously review the progress of work on the reactor vessel and may request the CB&I Construction Supervisor to stop work when, in the opinion of the General Electric site engineer, the work is not progressing in a satisfactory manner. The General Electric site organization keeps the General Electric design engineering organization informed on the progress of work at the site.

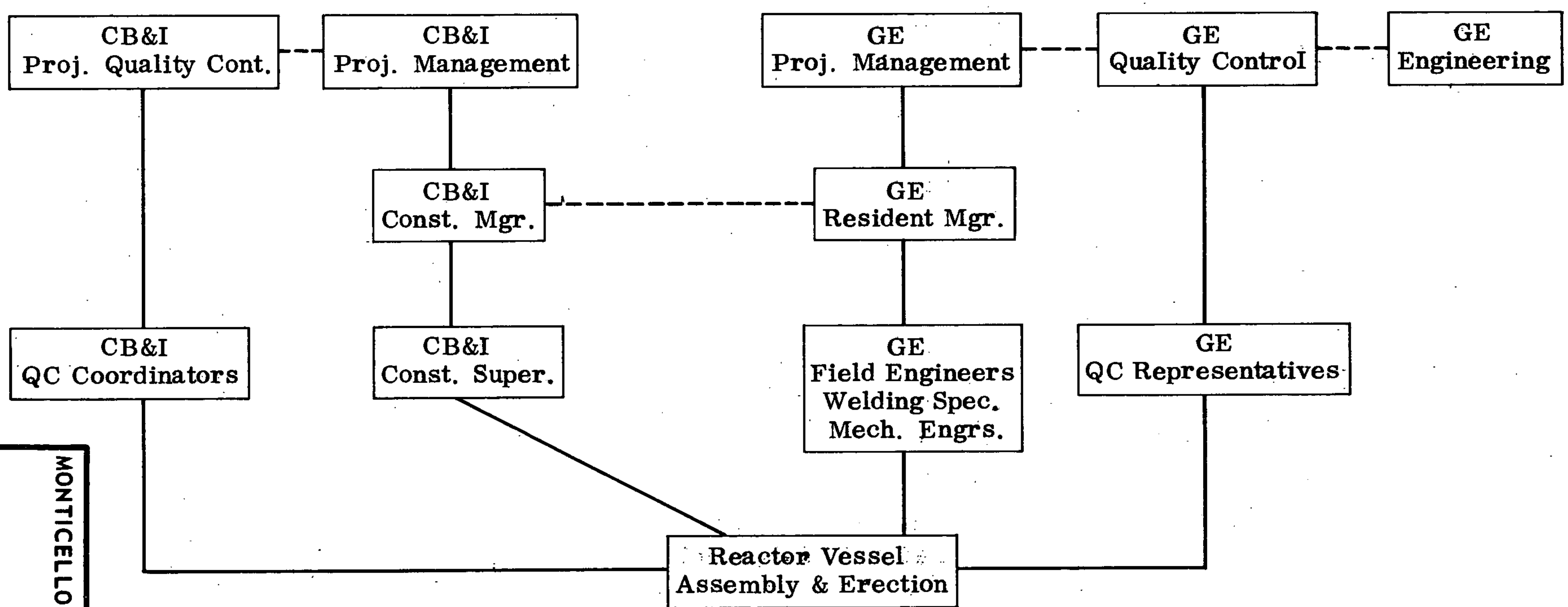
General Electric also maintains a Quality Control organization which is separate from both the General Electric project management organization and the engineering organization. There will be a resident General Electric Quality Control representative at the Monticello site as well as at CB&I's Birmingham plant. The site representative assures that General Electric engineering requirements are being met and can effectively stop work on the job since he must personally approve all final inspections after each significant assembly and erection operation. Frequent site visits will also be made by both CB&I and General Electric design engineers.

In addition to the CB&I and General Electric Quality Control representatives at the plant site, a ASME approved code inspector must approve all radiographs and other inspeotion reports to certify that all requirements of the ASME Boiler and Pressure Vessel Code, Section III, Class A vessels, have been met.

Thus, while there is a "production" organization for both CB&I and General Electric to assure timely execution of the assembly and erection of the reactor vessel, within approved procedures, both companies also have Quality Control organizations with proper authority to assure that these procedures are properly followed. This type of "check and balance" system provides the necessary assurance that a very high quality reactor vessel will be assembled and erected at the Monticello site.

Figure VII-1 shows the Monticello field organization.

MONTICELLO NUCLEAR GENERATING PLANT



MONTICELLO NUCLEAR GENERATING PLANT

Field Organization - Reactor Vessel Assembly and Erection

FIGURE VII-1

VIII. QUALIFICATION OF VENDOR

8.1 GENERAL ELECTRIC

General Electric has been actively performing detailed pressure vessel thermal and stress analysis for approximately five years, and reviewing vessel manufacturer analyses since the first commercial nuclear vessels have been built in this country. During this time an evolution of design criteria have been formalized through the first issue of the ASME Section III Nuclear Vessels Code in 1963. Several General Electric engineers are thoroughly familiar with the detail requirements of this code, as well as the rational intent of the code. General Electric has consistently insisted on rational and safe design interpretations of the code where specific wording or intent is vague or inconsistent.

In reviewing vessel manufacturer analyses, it has been recognized that a complete detailed review in many cases is most meaningful if performed independently of the modeling assumptions and specific methods used by the manufacturer. For this reason, General Electric analyses have been performed independently on all of the key structural analysis in typical BWR pressure vessel design. In this manner, results from several sources are compared with results from General Electric methods.

The digital computer has been used extensively by General Electric for thermal, stress, and fatigue analysis. General Electric has a comprehensive library of computer programs and General Electric personnel have accumulated years of experience in using these programs to model pressure vessel components. In many cases, several computer programs have been compared to determine the best program for a given type problem solution.

The four engineers assigned to the Monticello vessel analysis are experienced in pressure vessel design and analysis, and three of the four are licensed professional engineers. The training of these people has been academically at the Masters degree level or equivalent through General Electric training courses.

8.2 CB&I EXPERIENCE

Chicago Bridge & Iron Company was founded in 1889, primarily as a bridge building firm. Some five years later, the Company branched into the steel plate field - designing, fabricating and constructing ground and elevated steel tanks for water storage.

Bridge building was discontinued shortly after World War I, as opportunities grew in the steel plate field. With the discovery of great oil fields in the 1920's, CB&I quickly established itself as a leading supplier to the industry--desiguing and building many types of storage tanks and processing structures.

CB&I's performance for the petroleum industry led to the challenging requests from other fields. Soon the Company ranked as an international leader in specialized steel and alloy plate structures.

When the technology of arc welding became accepted in the 1930's, CB&I immediately established a welding research department to develop the methods whereby steel plates of various thicknesses and chemical composition could be joined together at the job site, welded in all positions and at such distant locations as South America and the Middle East.

Welding research and training at CB&I are more active today than ever before. The Welding Research Department's programs and CB&I Vice President, P. C. Arnold and his staff are highly respected throughout the industry. (An American Welding Society paper by Mr. Arnold, describing this work, is included in the Appendix E.)

CB&I is an active member of the American Welding Society. The late Harry C. Boardman, former CB&I Director of Research, was chairman of the Welding Handbook Committee in 1953.

Paralleling CB&I's continuous development efforts in welding techniques and the use of special metals were Company programs in design, fabrication, and special erection equipment.

For years, the American Petroleum Institute had its own pressure vessel Code, recognized by the boiler authorities of some states; and the American Society of Mechanical Engineers' Boilder Code also was a recognized standard by various states and insurance agencies. CB&I design and research engineers have always played a key role in subcommittee and task force groups in both API and ASME, involving matters of design, welding, materials, and fabrication procedures. (A partial list of current Code Committee assignments of CB&I personnel is contained in the Appendix K.) At the time of his death, in 1956, H. C. Boardman was Chairman of the Main Committee for the ASME Boilder and Pressure Vessel Codes.

Under the direction of George T. Horton, son of the founder, and H. C. Boardman, CB&I developed and patented the use of various pressure vessel configurations, such as the Hortonsphere, Hortonspheroid, Hemisperoid, Noded Hortonspheroid, Multisphere, and others for the storage of volatile liquids. It was natural then for CB&I designers to help write the Code Specifications covering the design, fabrication and testing criteria of these special structures.

CB&I employs over 600 graduate engineers today. The nuclear design group, under the direction of Vice President and Chief Engineer, Leonard P. Zick, is located at the Company's staff offices in Oak Brook, Illinois.

CB&I was part of the pioneering effort by the AEC, GE and CB&I which resulted in the successful construction of the world's largest spherical pressure vessel in 1952 as part of the SIR reactor test program at West Milton, New York. The design, quality control, inspection and testing of this gigantic 3,500-ton containment structure was the first in a series of 30 housings CB&I has constructed over a 14-year span for the nuclear industry.

Having heavy plate fabrication presses and heat treating facilities at the Birmingham, Alabama manufacturing plant, it was natural that CB&I was solicited to construct nuclear reactor vessels as early as 1952. Having carefully reviewed the overall business investment, then and in subsequent years, CB&I management had concluded that: (1) Since the Birmingham plant could not ship large diameter heavy vessels (the plant is not on water), and (2) since the manufacturing facility's principal function was to furnish fabricated materials for site constructed vessels, no effort should be made to compete for shop fabricated nuclear reactor vessel work.

However, in view of the experience gained to date in site assembling heavy nuclear containment vessel and refinery vessel components and the need for site assembled nuclear reactor vessels. CB&I management has concluded this work can be done and should be actively pursued as a new Company product line. It is clear to CB&I that large steel reactor vessels, requiring special site assembly, fabrication and field construction can be furnished today without compromising design, quality or functional requirements. Site erecting of thick plate, post weld heat treatment, radiographing and the machining of large closures have been performed to date on vessels for other industries.

As early as 1958, CB&I was site assembling heavy sections for containment vessels utilizing precise welding, postweld heat treatment, and radiograph procedures in accordance with Section VIII of the ASME Boiler Code and applicable Code Cases. Heavy site assembled nuclear containment vessel components were being furnished because they were too big to ship as assembled units.

For many years, thick (2-inch to 4-inch) wall refinery vessels have been site assembled from low alloy steel requiring welding, inspection, post weld heat treatment and overload pressure testing. A 7-inch thick, 575-ton hydrocrac reactor and several vessels of slightly smaller proportions are currently being site constructed by CB&I. They will operate at pressures and temperatures in the range of 1800 psig and 800° F.

CB&I's successful experience in welding these site assembled heavy wall hydrocracker vessels in Canada and the U. S. A. is an understandable step in the constant progress that has been made in the development of site fabrication techniques over a 30-year period.

8.2.1 13-FOOT DIAMETER BY 70-FOOT REFINERY SITE ASSEMBLED HYDROCRACKER REACTOR VESSEL

CB&I is currently assembling a 13-foot diameter by 70-foot tall ASME Section III designed hydrocracker reactor, 7-1/6 inches thick, weighing 575 tons, at an oil refinery in the Philadelphia, Pennsylvania area. The material is 2-1/4 percent chrome, 1 percent moly, overlayed with Type-347 stainless steel. Its configuration is shown in Figure VIII-1.

Figure IV-23 shows welders at work on a typical girth seam weld at the site. This is the same facility visited and inspected by various members of the AEC and ACRS groups.

The vessel was shipped in ten shell ring sections, 14-foot, 2-inch outside diameter and 6-foot, 7 1/4-inches high, weighing approximately 42 tons each. The top and bottom head and the support skirt were also shipped as separate shop assembled sections. All inside surfaces except the areas adjacent to the field weld seams were shop overlayed with Type-347 stainless steel.

Ten of the eleven field welded girth seams are completed, including ultrasonic testing and radiographing. These welds were made under the close supervision of qualified welding supervisors and the results were outstanding. Not one single field welded seam required repair!

The same success story can be told about four-foot diameter by 69-foot tall hydrocrackers erected at a remote site in Canada. Those vessels were 5-3/8-inches thick and overlayed with Type-347 stainless steel.

The Philadelphia vessel is described in Line 10 of the tabular summary in Figure VIII-2, and the Canadian vessels are listed in Lines 4 and 5 in the same summary.

In addition to the welding and post weld heat treatment of thick plate assemblies, site fabrication of a reactor vessel requires special machining work to supply (a) the control rod drive sleeves; (b) the internal shroud support skirt; and (c) the closure flange sealing surfaces, including drilling and tapping for the hold-down stud bolts.

8.2.2 MACHINING

CB&I pioneered the development of site machining when it designed and built a portable milling head cutter for supplying large head closures on high vacuum test chambers required by the aerospace industry. Success has been achieved in holding a vacuum of 1 by 10^{-8} torr (mm of Hg) in a 65-foot diameter test chamber utilizing a single elastomer "O" ring on a 40-foot diameter closure.

Figure VIII-3 shows the 3-1/4-inch drywell cover flange weldment for Dresden II being machined at the job site following the welding and post weld heat treatment operations.

CB&I has constructed numerous basic oxygen furnaces (BOF's) having shell plates as thick as three inches and trunnion ring support flanges as thick as 6 inches. Several tables summarizing this work are shown in Figures VIII-4, 5 and 6.

Figure VIII-7 shows a site boring machine setup for field boring 36-inch diameter trunnion ring holes on a basic oxygen furnace at a steel mill site. These holes are 38 inches deep, 35 feet apart and are bored to a diameter tolerance of ± .001 inches, with less than .0005 inches taper. Parallelism between the diametrically opposite holes was held to 0.020 inches!

8.2.3 POST WELD HEAT TREATMENT EXPERIENCE

A paper summarizing CB&I's post weld heat treatment experience is included in Appendix K, and a partial summary of various types of post weld heat treatment is given in Figure VIII-8. The know-how and overall understanding CB&I has developed from having performed over 400 post weld heat treatments at various job sites throughout the world is directly applicable to the post weld heat treatment problems that are encountered in site assemblying a reactor vessel. In many instances, the nature of the refinery vessel materials requires a greater degree of control because of the alloying elements present.

8.2.4 WELDING

CB&I insists on having high quality welders whose work will not require repair on these special thick wall structures. A great deal of procedure preparation time and expense is expended to make perfect welds.

Recent experience in welding the four thick walled hydrocracker vessels in Canada and the 7-inch thick vessel in Philadelphia resulted in all perfect welds. This testified to the effectiveness of the detailed welder training and welding supervisory programs used by CB&I. As a further testimony to the high quality of CB&I welders, a summary sheet is presented in Figure VIII-9 which typifies the high quality work of almost 700 welders who have a "percent good" average of 93.63 percent on 1,028,580 welds made over an 8-year period. Other specific information should be noted on that sheet.

A welder using shielded metallic arc welding equipment to weld up radial seams on a 2-5/8-inch thick drywell transition knuckle section of a containment vessel is shown in Figure VIII-10.

8.2.5 MANUFACTURING

While the facilities at CB&I's Birmingham manufacturing plant are in the final stages of being improved to handle thick wall vessel work, an existing 3,000 ton press, hot forming a 7-inch thick plate is shown in Figure VIII-11 and a thick wall vessel is shown prior to shop assembly in Figure VIII-12.

Automatic welding of overlay stainless steel material on a typical thick wall pressure vessel is shown in Figure IV-6.

The summary of thick wall vessels work by CB&I, shown in Figure VIII-2, is only a partial list of vessels constructed in the past two or three years. However, it is representative of various shop built up vessels (BU) and site assembled vessels (KD) on which valuable experience has been gained that will contribute to the successful construction of site assembled nuclear reactor vessels. Note, that the 48-foot diameter by 2-1/4-inch thick sphere in Line 8 is high strength T-1 steel material, and that two site assembled 19-foot diameter, 5-1/2-inch thick Type-304 stainless steel spheres appear in the last line.

8.2.6 WEATHER PROTECTION

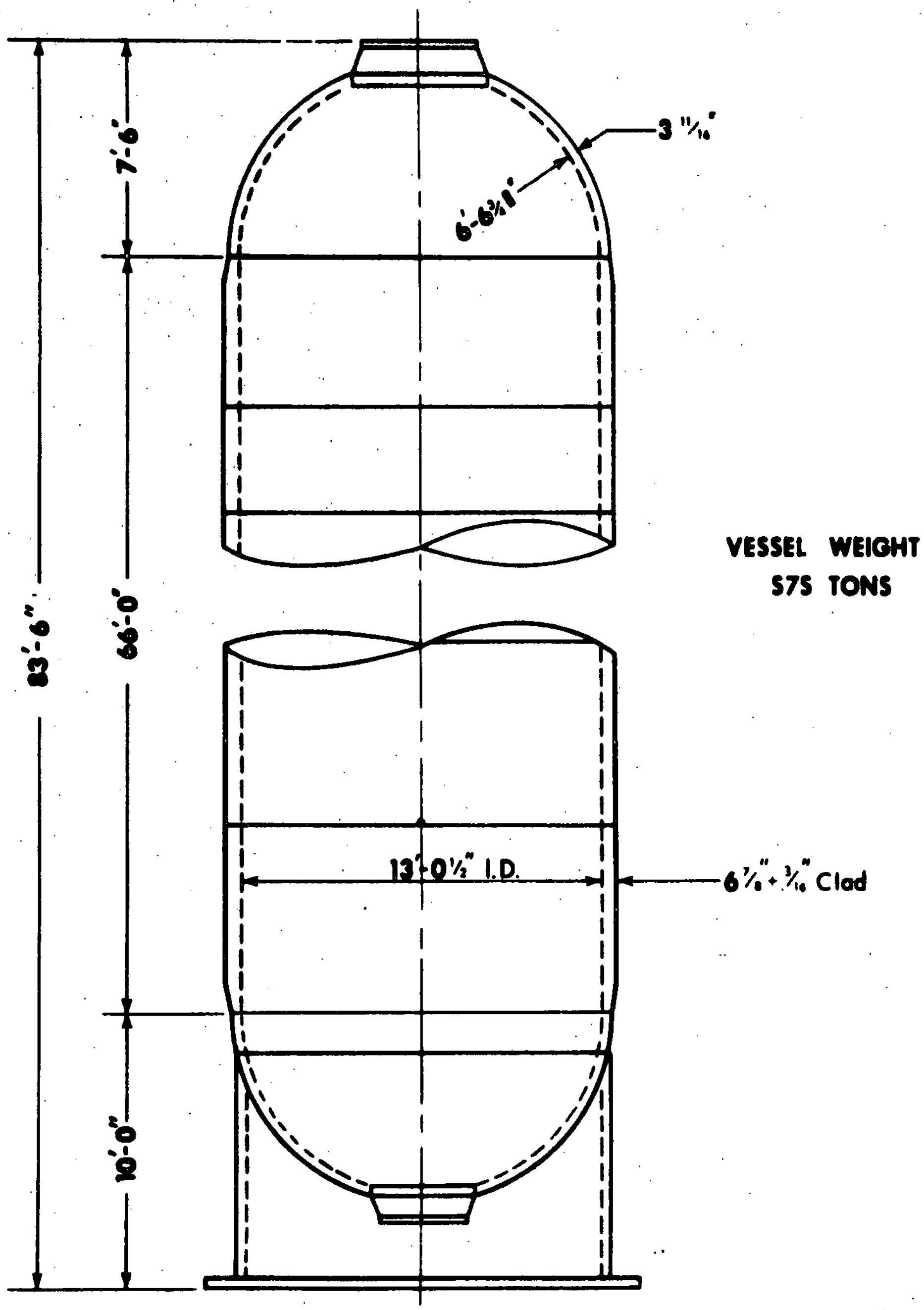
Special attention to weather protection of welders, machining, and heat treatment operations at the job site has always been of prime concern to CB&I. Members of the AEC staff who visited the hydrocracker construction site in Philadelphia were exposed to rainy weather conditions and first hand found how effective the weather protection, shown in Figure IV-22, was at the time. Similar weather protection on an earlier job in Canada is shown in Figure VIII-13. Not only must the welders (and their work) be protected from the outside elements but the vessel material being preheated at temperatures between 300 and 400° F must be insulated so the welders are not exposed to an uncomfortable atmosphere. The reflective cover of such insulation is partially seen in Figure VIII-13, but more specifically in Figure IV-23, where welders are shown at the Philadelphia site hand welding a 7-inch thick girth seam.

Interesting comparable data on the NSP reactor vessel and Dresden II nuclear vessels, as well as the Philadelphia and Canadian refiner vessels are summarized in Figure VIII-14.

8.2.7 RADIOGRAPHY

CB&I has had considerable field experience in working with 100 percent X-ray, thick wall vessel sections. The 6-inch thick girder flanges on a BOF furnace previously described are 100 percent radiographed as are the 3-1/4-inch thick cover flanges on the containment drywell vessel. A gamma source is utilized. Figure VIII-15 shows a typical gamma pill setup. CB&I either subcontracts this work to a reputable firm or may use its own licensed operators in accordance with the Federal and state regulations for handling radioactive materials. A typical site radiographic processing unit complete with temperature control for the processing solutions as required is shown in Figure VIII-16.

The work already performed in site constructing nuclear reactor vessels at foreign locations provides interesting background for the work proposed herein. The British have built several 60- to 70-foot diameter, 3-inch thick spherical vessels for their gas-cooled reactor projects as far back as the late 1950's. The Naval Reactor Branch of the AEC has recently proposed a large seed blanket reactor which the literature reveals to be a 30-foot diameter spherical vessel, approximately 9 inches thick which would require site assembly. Perhaps of greater interest, is information learned at NUCLEX '66 regarding the 15-foot site assembled reactor vessel being built by Skoda Works at Pilsen, Czechoslovakia. This vessel is a 15-foot diameter tall by 60 feet structure with a wall thickness of approximately 6 inches. The vessel is a CO_2 gas-cooled reactor and has a working pressure of approximately 925 psig.



MONTICELLO NUCLEAR GENERATING PLANT

Site Erected Hydrocracker Pressure Vessel

FIGURE VIII-1

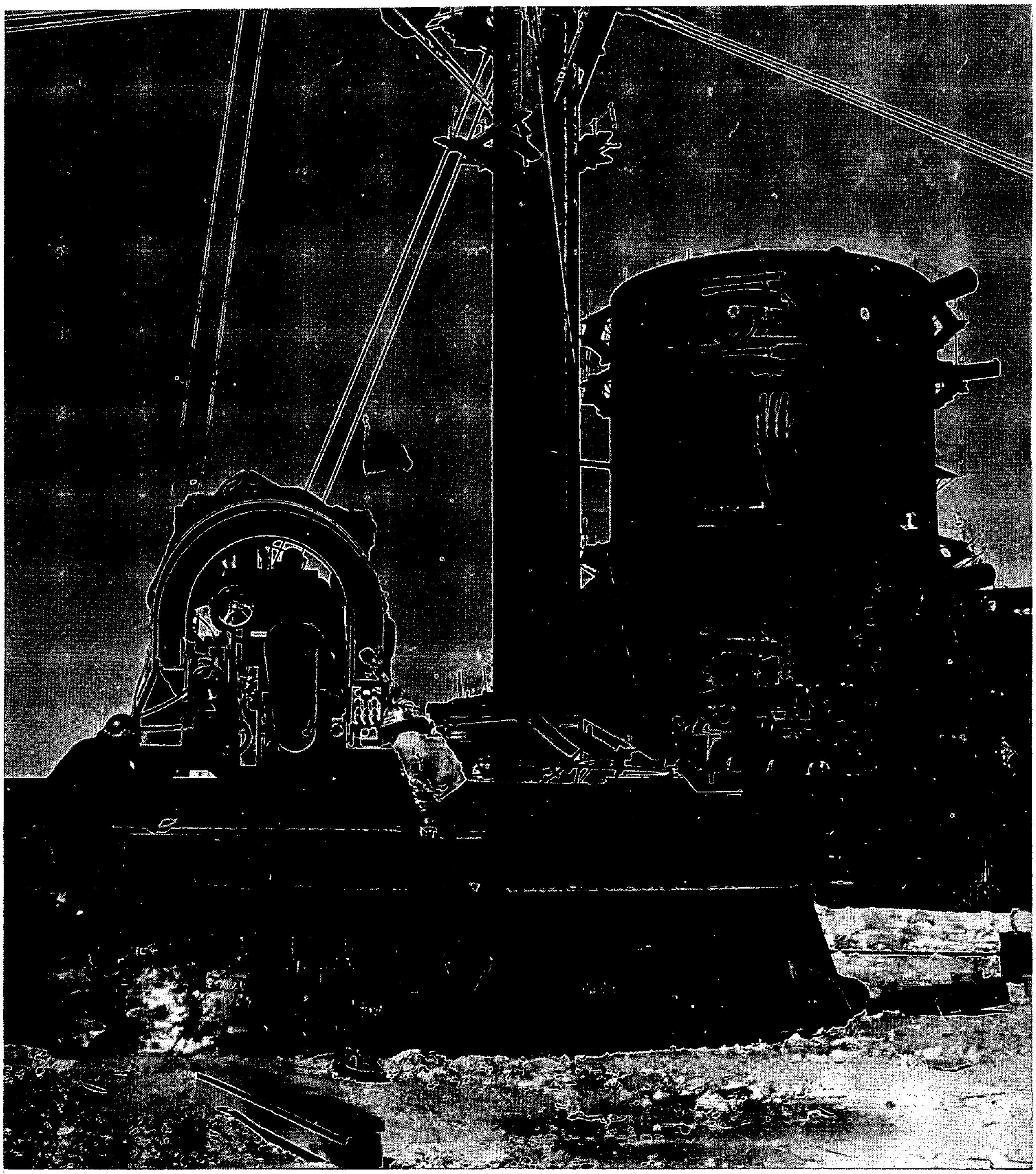
CB&I CONSTRUCTED HEAVY WALL VESSELS

No. & Type Vessel	BU or KD	Diam. Ft.	Lgth. Ft.	"T" Inches	Mat'l	Weight Tons
2 Vert	BU	7	69	5-1/2	A387-D C/W 308	435
4 Vert	BU	9	88	5-7/8	A387-D C/W 347	1880
1 Sph	KD	19		4-3/4	A387-C	138
3 Vert	KD	9	69	5-3/8	A387-B C/W 347	891
1 Vert	KD	9	60	5-1/8	A387-B	232
2 Vert	BU	10	83	5-7/8	A387-D	836
3 Vert	BU	10	86	5-7/8	A387-D	1329
1 Sph	KD	48		2-1/4	CC 1204 T-1	365
1 Vert	BU	10	42	5-3/4	A387-D C/W 347	251
1 Vert	KD	13	70	6-7/8	A387-D C/W 347	576
1 Vert	BU	10	101	6-3/4	A387-D C/W 321	501
1 Vert	BU	11	87	7	A387-D	578
1 Vert	BU	9	61	6-1/2	A387-D C/W 347	300
1 Vert	BU	10	63	7	A387-D C/W 347	350
2 Sph	KD	19		5-1/2	304 SS	290

MONTICELLO NUCLEAR GENERATING PLANT

C B and I Constructed Heavy Wall Vessels

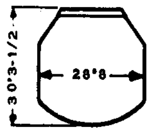
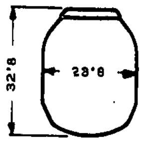
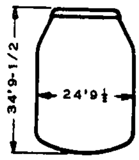
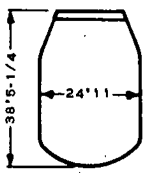
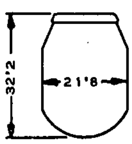
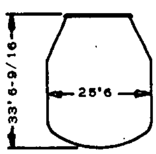
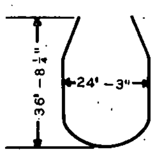
FIGURE VIII-2



MONTICELLO NUCLEAR GENERATING PLANT

Field Machining Drywell Flange

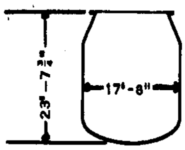
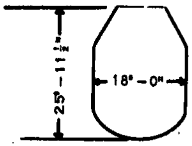
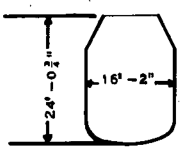
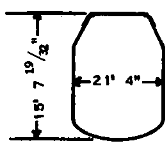
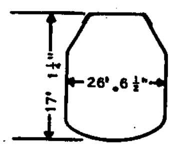
FIGURE VIII-3

Basic Oxygen Steelmaking Vessels	Chicago Bridge & Iron Company			
	Customer & Location	No.	Rated Capacity	Completion Date
	Great Lakes Steel Corp. Ecorse, Michigan	2	300 tons each	1962
	United States Steel Corporation Duquesne, Pennsylvania	2	150 tons each	1963
	Gary, Indiana	3	150 tons each	1965
	Chicago, Illinois	3	150 tons each	1967
	Ford Motor Company Dearborn, Michigan	2	240 tons each	1963
	Bethlehem Steel Company Lackawanna, New York	3	250 tons each	2-1964 1-1966
	Republic Steel Corporation Gadsden, Alabama	2	150 tons each	1965
	Warren, Ohio	2	150 tons each	1965
	Inland Steel Company East Chicago, Indiana	2	230 tons each	1966
	Bethlehem Steel Company Sparrows Point, Maryland	2	200 tons each	1965

MONTICELLO NUCLEAR GENERATING PLANT

Basic Oxygen Furnaces, Sheet 1

FIGURE VIII-4

Basic Oxygen Steelmaking Vessels	Chicago Bridge & Iron Company			
	Customer & Location	**No.**	**Rated Capacity**	**Completion Date**
	Kaiser Steel Fontana, California	1	110 tons	~~1965~~
	Allegheny Ludlum Brackenridge, Pennsylvania	2	80 tons	1966
	Interlake Steel Corporation Riverdale, Illinois	2	75 tons	1965
	Dominion Foundries & Steel, Ltd. Hamilton, Ontario	2*	105 tons	1965
	Jones & Laughlin Steel Corp. Aliquippa, Pennsylvania	3	120/200 tons	1967
	Koninklijke Nederlandse Hoogovens & Staalfabrieken Ijmuiden, The Netherlands	2	250 metric tons	1967

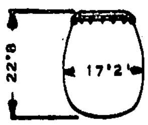
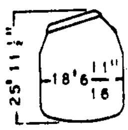
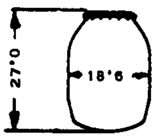
MONTICELLO NUCLEAR GENERATING PLANT

Basic Oxygen Furnaces, Sheet 2

FIGURE VIII-5

Basic Oxygen Steelmaking Vessels

Chicago Bridge & Iron Company

	Customer & Location	No.	Rated Capacity	Completion Date
	Mc Louth Steel Corporation Trenton, Michigan	4*	80 tons each	2-1958 1-1960 1-1965
	Dominion Foundries & Steel, Ltd. Hamilton, Ontario	2**	150 tons	1960
	Colorado Fuel & Iron Company Pueblo, Colorado	2*	1 at 100 metric tons 1 at 100 short tons	1961

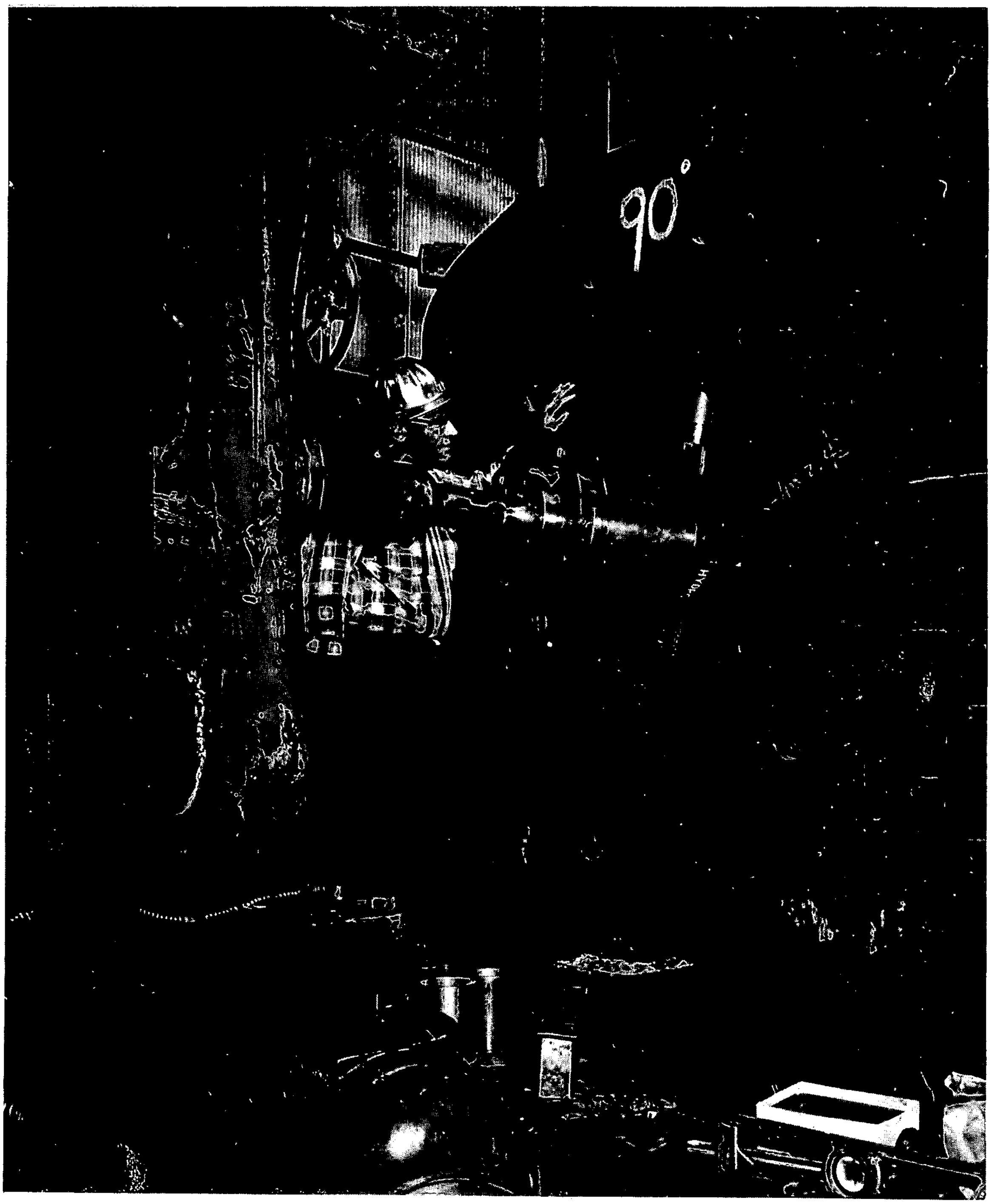
MONTICELLO NUCLEAR GENERATING PLANT

Basic Oxygen Furnaces, Sheet 3

FIGURE VIII-6

*Constructed by CB&I

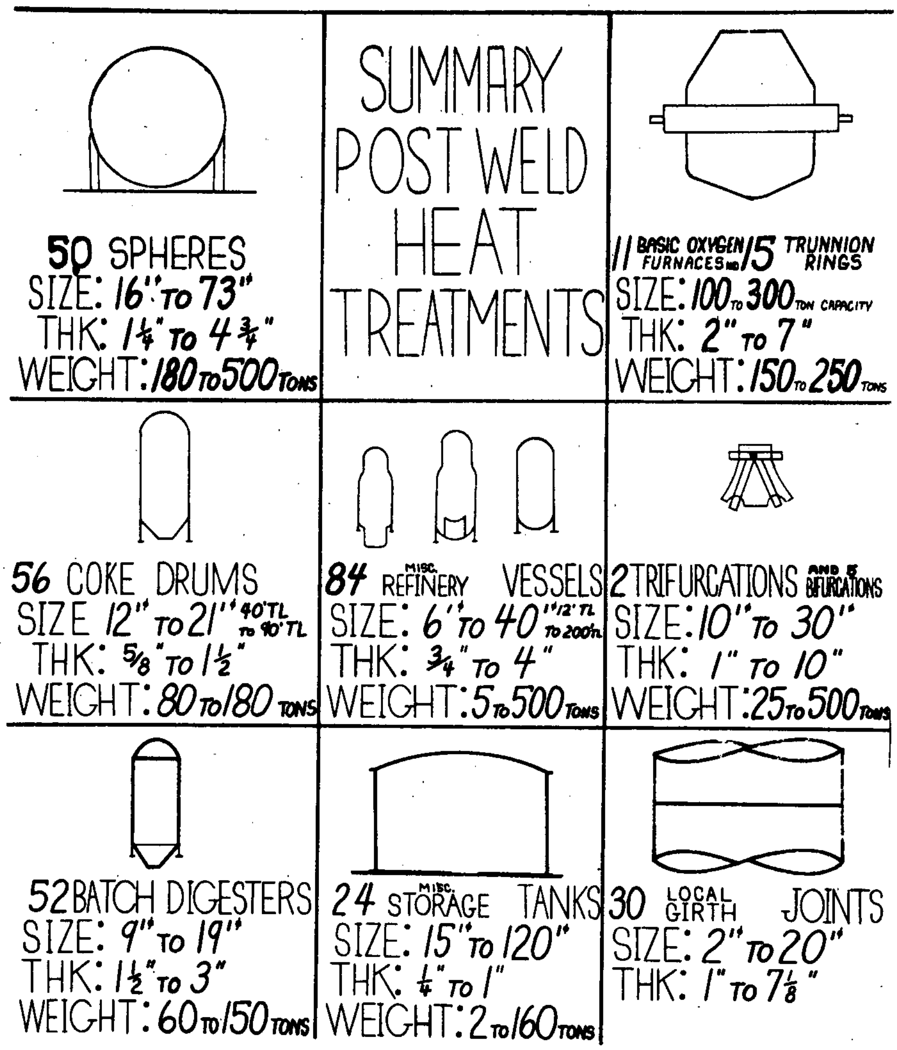
**Constructed by Horton Steel Works, Ltd., a Canadian subsidiary of CB&I



MONTICELLO NUCLEAR GENERATING PLANT

Site Boring 32-Inch Ø Turning Ring

FIGURE VIII-7



MONTICELLO NUCLEAR GENERATING PLANT

Summary Post Weld Heat Treatment

FIGURE VIII-8

WELDERS' 100% X-RAY EXAMINATION RECORD

SIXTIETH LIST

RATING OF WELDERS - PERIOD of 12/16/65 to 6/15/66

345	Class AA Welders	Average of 95% to 100% - AA
242	Class A Welders	Average of 75% to 94% - A
36	Class B Welders	Average of 50% to 74% - B
61	Unclassified Welders	Due to less than 10 X-rays made on their work.

Welders are classified after receipt of 10 or more X-rays from their work.

SUMMARY OF 100% X-RAYS

PERIOD	TOTAL	GOOD	BAD	% GOOD
12/16/58 to 6/15/65	814,767	763,309	51,458	93.68
6/16/65 to 12/15/65	114,320	107,244	7,076	93.81
12/16/65 to 6/15/66	99,493	92,600	6,893	93.07
TOTALS to 6/15/66	1,028,580	963,153	65,427	93.63

This list includes only the welders from whose work we received X-rays during the period of 12/16/65 to 6/15/66. The latest qualification test made by each is noted. The list includes 564 welders who passed our standard welding test, as shown below, and 120 others, for a total of 684 welders.

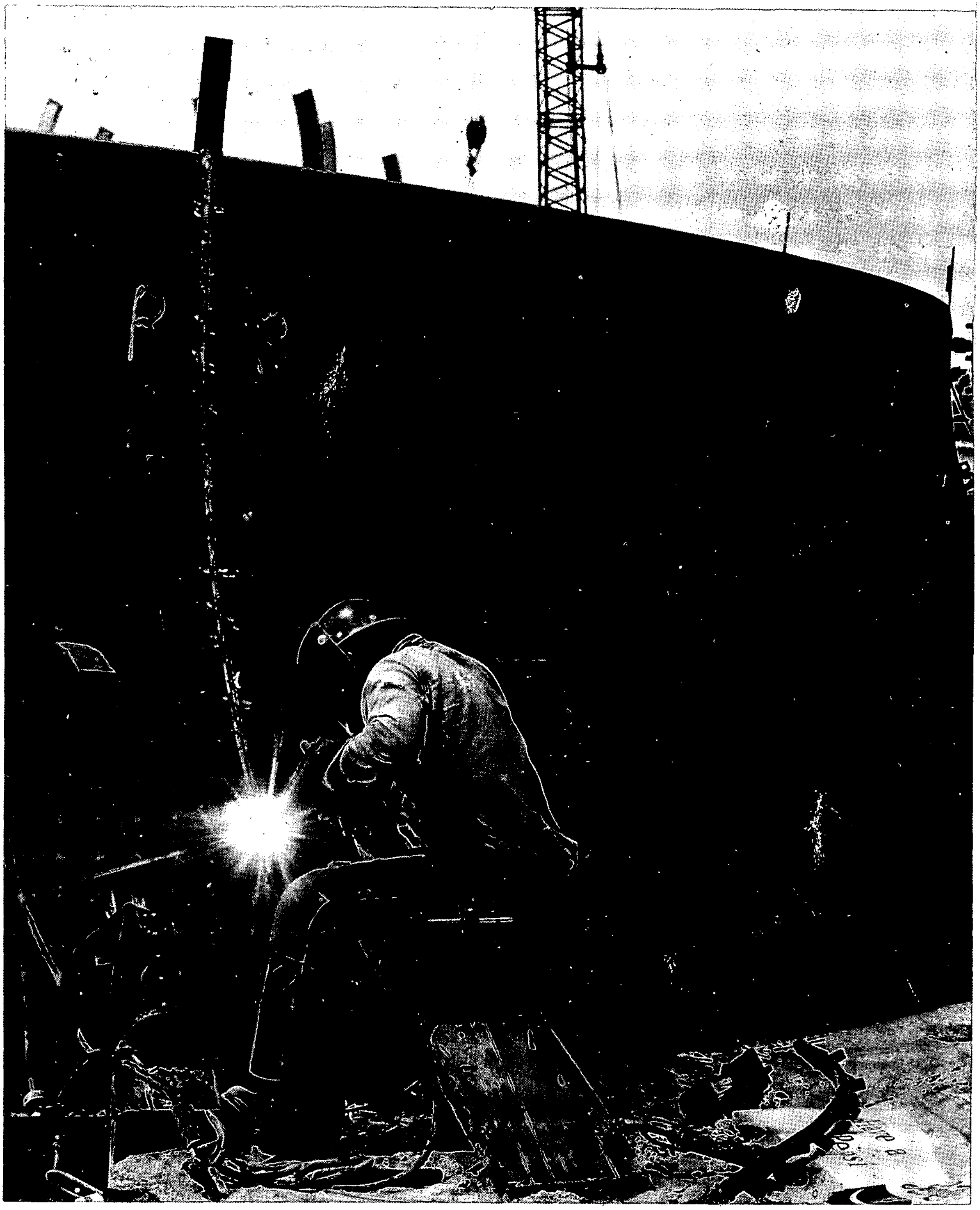
561	Qualified ASME	Permitted to weld on steel of any thickness in all positions.
3	Qualified 1A1	Permitted to weld on steel of any thickness in all positions.
120	Special or Incomplete Tests	Special test to customer's requirements or tests on alloys.

This list represents the total good and bad X-ray pictures regardless of the amount of bad welding in the picture. Repair shots have been excluded.

MONTICELLO NUCLEAR GENERATING PLANT

Welders 100% X Ray Examination Record

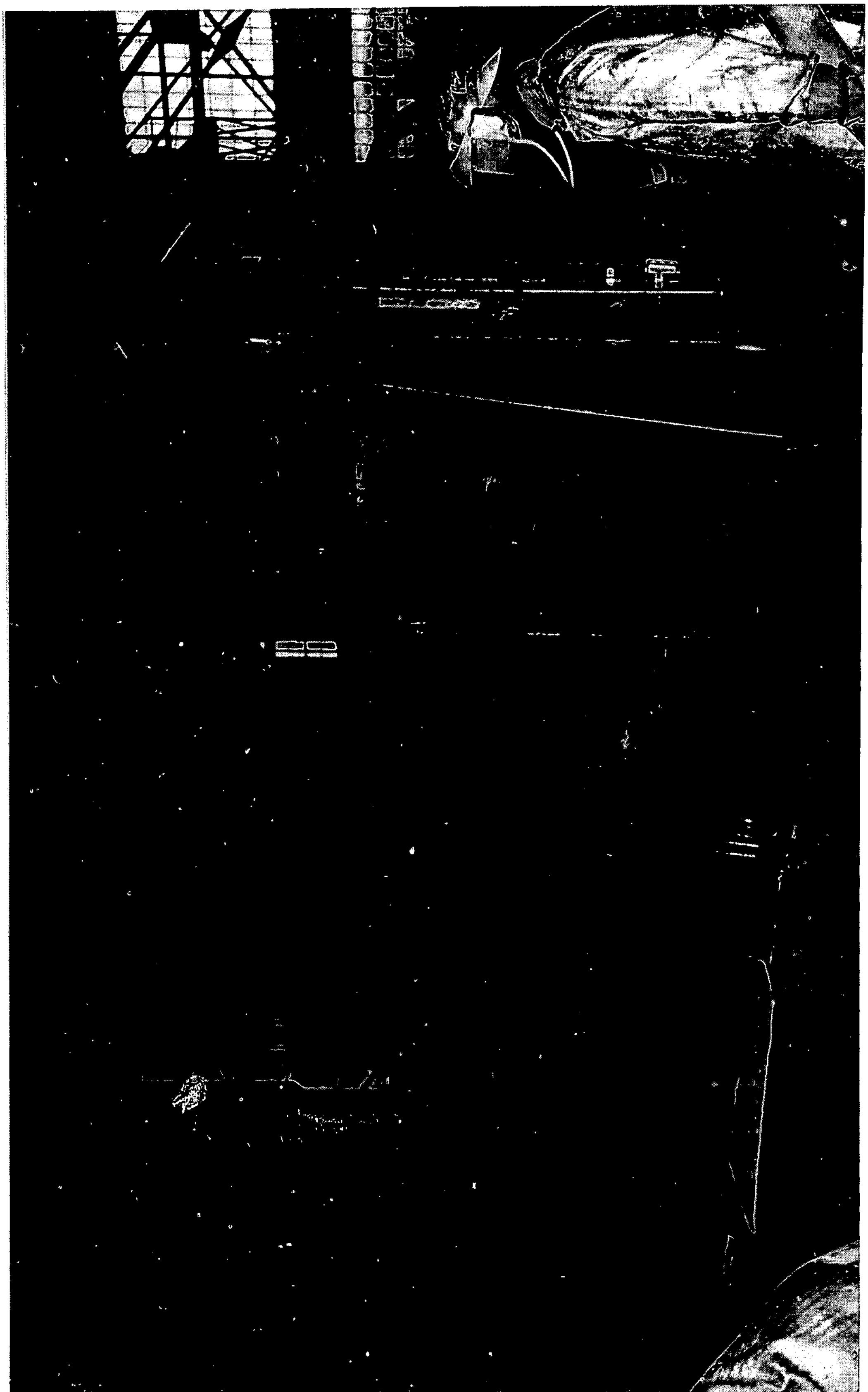
FIGURE VIII-9



MONTICELLO NUCLEAR GENERATING PLANT

Welding 2-5/8 Inch Thick Drywell Transition Knuckle

FIGURE VIII-10



MONTICELLO NUCLEAR GENERATING PLANT

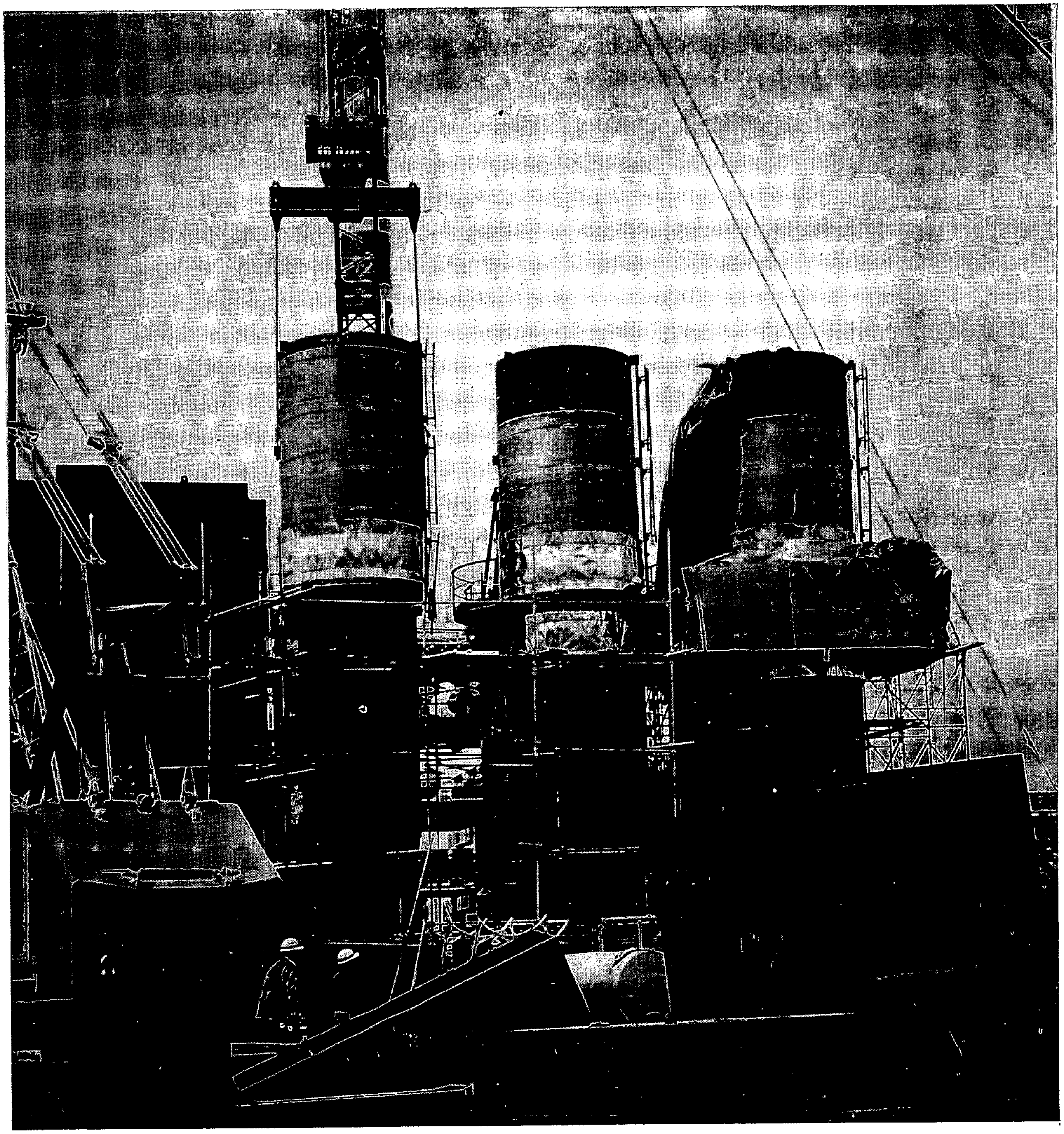
Hot Pressing 7-Inch Thick Plate

FIGURE VIII-11

MONTICELLO NUCLEAR GENERATING PLANT

Shop Assembly of Thick Wall Vessel

FIGURE VIII-12



MONTICELLO NUCLEAR GENERATING PLANT

Site Assembled Refinery Reactors in Canada

FIGURE VIII-13

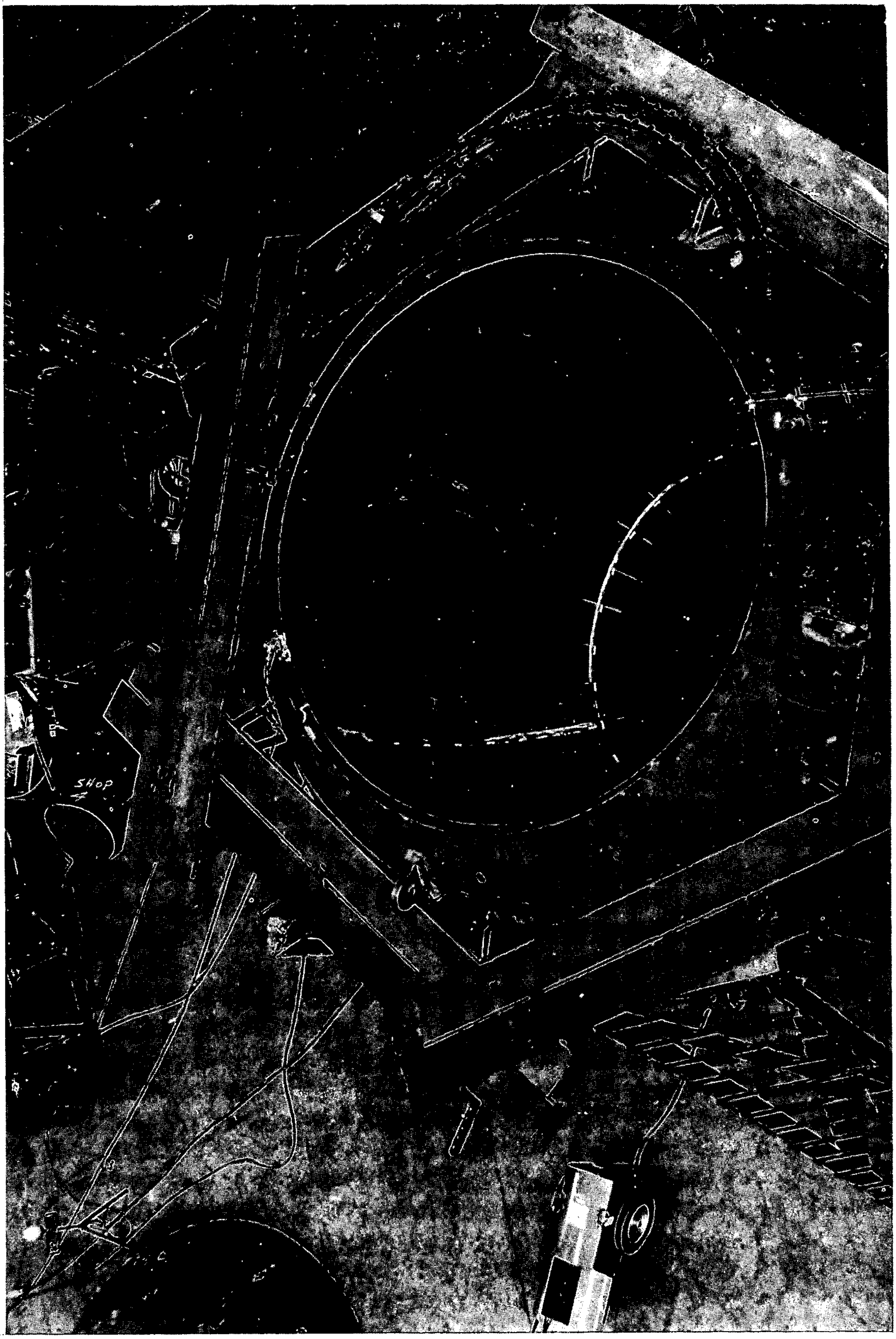
COMPARATIVE DATA: DRESDEN NO. 2 REACTORS AND VESSELS CB+I IS CURRENTLY ASSEMBLING AT SITE.

	PROPOSED		UNDER CONSTRUCTION	
	DRESDEN NO. 2	N.S.P.	PHILADELPHIA	CANADA
SERVICE	NUCLEAR	NUCLEAR	REFINERY	REFINERY
CODE	ASME III CLASS "A"	ASME III CLASS "A"	ASME III CLASS "A"	
PLATE MAT'L.	A302B (A533) M ½ Mo.	A302B	A387D 2¼ Cr, 1Mo	A387B
OVERLAY	308SS (A371)	308SS (A37)	347SS	347SS
INSIDE DIAM.	20'-11"	17'-1"	13'-½"	9'-0"
INSIDE HEIGHT	68'-3"	63'-1½"	79'-0"	77'-8"
THICKNESS TOPHEAD	3¼"	2 13/16"	3 11/16"	3⅜"
SHELL	6⅜"	5¼"	6⅞"	5 7/16"
BOTTOM HEAD	6⅜"-6⅞"	5¼"-6¾"	3 11/16"	3⅜"
WEIGHT-TONS	800	600	575	300

MONTICELLO NUCLEAR GENERATING PLANT

Comparative Data: Dresden 2, Monticello and Vessels CB&I Is Currently Assembling

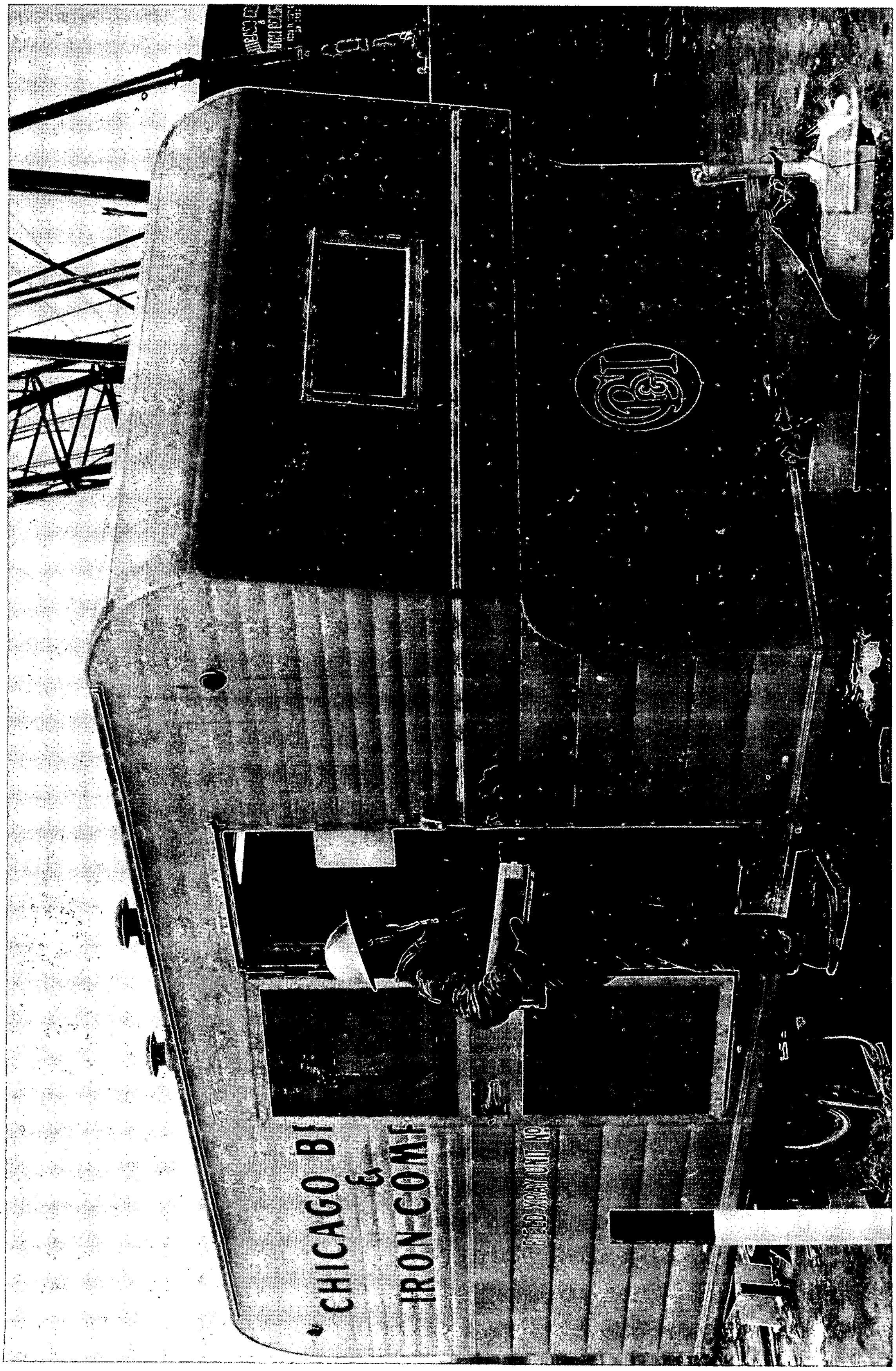
FIGURE VIII-14



MONTICELLO NUCLEAR GENERATING PLANT

Gamma Radiograph Setup

FIGURE VIII-15



MONTICELLO NUCLEAR GENERATING PLANT

Site X Ray Processing Unit

FIGURE VIII-16

APPENDIX A

TASK FORCE STUDY--FIELD ASSEMBLY vs SHOP ASSEMBLY FOR REACTOR VESSELS

I. INTRODUCTION

The largest single piece of equipment shipped to a nuclear power plant site has been the reactor pressure vessel. The competitive position for nuclear power has in many cases been limited to sites that afforded the availability of water transportation for shipment of a fully assembled reactor vessel. Power plant sizes have increased so rapidly in the past few years that truck and rail transportation as a means for transporting a reactor vessel have largely been eliminated.

At the present time, the general line of demarcation between barge and rail shipment in the United States is the 135-inch inside diameter size. All major reactor vessels on order at this time, if shop constructed, are being shipped to site via barge. Land transport from barge point is necessarily via specially built trailers and entails road preparation and utility dislocation planning on an extensive basis.

Land transport of reactor vessels has been surveyed for vessel sizes up to 600 MWe and respective weights of 600 tons for the bare body plus skid supports. These land surveys have been conducted both in the United States and other countries. Feasibility of land transport has been established up to 600 tons for substantial distances. Vehicles for such transport are presently available to tonnages up to 400 tons. Plans for special trailers handling up to 600 tons have been drawn. Spain, France and Italy have trailers with capacities to 400 tons. Therefore, 400 tons is the ultimate present vessel limit on land transport both in the United States and Europe for highway travel. In addition, other limiting factors which play an important part in land transport are:

1. Distances traveled
2. Terrain - mountain grades, etc.
3. Bridge and overpass size limitations.
4. Traverse of metropolitan and suburban areas.

Depending on the locale and terrain, the above factors could possibly result in a lower vessel weight and size limitation than the transport vehicle alone. Water transport capabilities are available for all the vessel tonnages and sizes considered in this report. Ships and barges are available as follows:

Barges -- up to 800 tons.

Ships Deck Cargo -- 250 tons (limited by ship hoist equipment).

LST Ocean-Going Vessels -- 1000 tons.

Water transport equipment is presently available in tonnage capacity for any presently planned vessel size.

Shipping of the reactor vessel then, is a major factor in the competition for sites between nuclear power plant designs and fossil-fueled plant designs. If the restrictions associated with the reactor vessel shipment are taken away or reduced to the same magnitude as the next smaller item which is the generator stator, the shipment problem becomes the same for fossil-fueled plants and nuclear plants. In actuality, the advantage may shift to the nuclear plant because of the fuel requirements of a fossil-fueled plant.

The shipping problem of the reactor vessel can be reduced by site assembling the components of the vessel. Site assembly of the vessel has other indirect advantages. These are:

a. Time saving;

The critical paths of an overall project schedule often follows the reactor vessel. Therefore, a 3-4 month reduction of the reactor vessel cycle will reduce the project duration by the same amount.

b. Risks;

The risks associated with shipping a large shop-assembled reactor vessel are avoided when it is site assembled.

Late in 1964, General Electric actively engaged in tendering a bid to the Central Electricity Generating Board of Great Britain to build a boiling water reactor near Dungeness, England. As a part of this work, bids were solicited from various major British vessel fabricators, and a team of General Electric Company engineers was sent to England to discuss the fabrication of a reactor vessel with the interested bidders. All but one of four bidders intended to field assemble the reactor vessel to varying degrees consistent with their various shop capabilities. The General Electric engineers gained considerable information and insight into methods and potential problems associated with field assembled vessels from these discussions with the technical personnel who at that time were the foremost authorities on the subject. The knowledge so gained was readily applied to the General Electric task force study.

II. TASK FORCE STUDY

Accordingly, the General Electric Company Atomic Power Equipment Department (APED) undertook a comprehensive study to determine the current feasibility and proper course of action to prove the feasibility of a site-assembled reactor vessel during early 1965.

The study was made by key APED personnel representing the functions of Manufacturing, Purchasing, Marketing, and Engineering, Project Management and Finance. The study took the following form:

1. Solicitation of bids for field-assembled vessel.

   (a) Comparison of bid price with estimated cost of shop vessel.

   (b) Evaluation of bid schedule with estimate for a shop vessel.

   (c) Evaluation of methods of fabrication for equivalent quality with shop-fabricated vessels.

2. Seminar Discussions with various fabricators concerning various aspects of field assembly such as:
   (a) Design Details
   (b) Design Analysis
   (c) Fabrication Sequence
   (d) Practices
   (e) Operations
   (f) Supervision
   (g) Inspection and Quality Control
   (h) Vessel Testing

3. Inspection visits to the various fabricators' plants and then current field assembly activities on other types of vessels.

4. Discussions and analyses of the various data resultant from the above proposals, seminars, and inspection.

The results of the task force study will be summarized in the following discussion. The material presented is essentially the same as the non-propriety portion of Report #22A2200 used in a seminar presentation to the AEC and ACRS in Bethesda July 28, 1966.

III. TASK FORCE STUDY RESULTS

1. GENERAL

The design of a field assembled reactor vessel would be the same as a shop assembled reactor vessel. The same quality factors and design margins would be applied since the requirements for material and process inspection and control and acceptance criteria would be identical in both cases and would be equal to or better than requirements of ASME Boiler and Pressure Vessel Code, Section III.

1.1 Design

No design changes were found necessary as a result of this field assembly study.

There is no need to make any special design allowance for plate sizes, seam weld locations, nozzle location, or tolerance for field assembly.

The pressure parts will meet the requirements of ASME Boiler and Pressure Vessel Code, Section III for trueness to form and fit up. These are the same tolerances applicable to a shop assembled vessel.

Machining the vessel flange face in the field with the vessel in its final position will permit maintaining the face more nearly horizontal and the studs more nearly vertical than if the finished machined vessel were placed on a foundation. Again machining rather than erection of the complete vessel would determine the flange face attitude. This would facilitate head removal over the studs.

Building the vessel up on its supports would minimize bow along its axis frequently encountered to some extent when the courses are assembled and post weld heat treated in a horizontal position.

2. DESIGN ANALYSIS

The analysis performed for both a shop assembled and field assembled vessel would be identical. The same loading conditions both steady state and transient would be considered in either case. The design requirements and criteria of ASME Code, Section III would be applied in either case.

3. MATERIAL SELECTION

It is anticipated that the pressure carrying parts of the reactor vessel would be fabricated of the same materials whether the vessel was field or shop assembled. In-place welding might preclude the use of certain materials for some of the internal structure unless welding techniques and electrodes are developed which are satisfactory for all welding positions. The most recent General Electric vessel specifications require that the transition between the vessel and the stainless steel core structure be either Inconel or stainless steel clad carbon or low allow steel. Inconel is not considered suitable for overhead welding.

4. CODE DESIGN

Both the field and shop assembled vessels would be designed to ASME Boiler and Pressure Vessel Code, Section III. The Code requirements for the vessel are identical whether it is field assembled or shop assembled.

5. FABRICATION

5.1 Sequence

The basic fabrication sequence is shown in Figure A-1 and may be summarized as follows:

1. Order, receive and inspect the raw material;
2. Form the material;
3. Weld the material into rings, and heat treat as required;
4. Weld rings together and install nozzles and supports completing all welding requiring post weld heat treatment;
5. Final post weld heat treatment, machining and nozzle installation;
6. Testing the vessel and installation of internals.

There are three key operations in the sequence which are not detailed on the chart because of their respective nature and the infinite number of variations in which they may occur. These are (a) interstage tempering after welding, (b) "final" post weld heat treatment of some individual welds, and (c) the various inspection steps. These three operations are interspersed throughout the sequence as required by Code, General Electric, and the fabricator. Obviously there are as many variations of the detailed sequence as there are fabricators, but General Electric requires each fabricator to make a detailed fabrication sequence which is subject to General Electric review and approval. The entire detailed fabrication procedure is reviewed by General Electric for proper type and sequence of operations with the built-in quality which The Task Force consider necessary for a highly reliable vessel.

With the vessel design and quality firmly established at a predetermined level by Code, and General Electric specification, the various manufacturing operations must then be performed with the skill and equipment necessary to meet those requirements irrespective of whether the operations are performed in the shop or in the field. Most likely a combination of both shop and field fabrication will occur, such as has already been done with control rod drive housings. The major difference between past shop and future field practice will be the increased quantity of work in the field and less work in the shop.

Assembly and erection of the reactor vessel in the field may have advantage over a shop fabricated vessel in its placement on its foundation. If the vessel is constructed in place, the initial parts of the vessel would be placed on the foundation, and the vessel built up in its final location. Since the initial placement would be a much smaller, less weighty piece, equal loading on the supports and true plumb alignment could be better assured. While true plumb alignment is not essential to reactor operation, it greatly facilitates installation of the critical portions of the internal structure which must be carefully aligned with the control rod drive penetrations in the bottom head. Boring the control rod drive penetrations in place would mean that the attitude of the penetrations relative to plumb would be determined by a machining operation rather than the placement of the pre-machined penetrations of the shop fabricated vessel. Use of specially fabricated fixtures to support boring apparatus above and below the vessel bottom head should result in accuracy equal to or better than usual shop fabrication on a horizontal boring mill. If the fixtures are matoh-machined with the core plate more nearly identical hole patterns may also be attained.

5.2 Practices

It can be shown that all practices for field fabrication will fall into one of four acceptable categories when apparent "differences", are scrutinized closely in context with the General Electric specification. These categories are:

1. Practices which have been proven and used to a limited extent on shop fabricated reactor vessels and which are intended to be used more generally on field fabricated reactor vessels.

2. Practices which have been proven and widely used in the fabrication of other vessels and which are intended to be used on reactor vessels.

3. Practices which will be conducted in the field the same as in the shop.

4. Practices which will continue to be conducted in the shop without change.

More specifically, the manufacturers and distributors of plate, forgings, bar, tubular products, bolting and welding materials for vessel components for both shop and field will all be selected from the same group of qualified vendors. The purchase specifications for the main vessel material will continue to be approved by General Electric Company as has always been its custom.

5.3 Operations

The forming of the vessel components is expected to occur in the shop. The heavy equipment involved in forming shell and head components virtually dictates this approach for economic reasons.

The heat treatment of a vessel fabricated from high strength low alloy materials may be considered as two processes consisting of (1) "High" temperature conditioning heat treatment, and (2) "Low" temperature, post weld heat treatment and interstage tempering. The high temperature heat treatment of the components above 1500°F consists of heating to a relatively high temperature to austenitize, followed by quenching in water to room temperature and then tempering above 1170°F.

Because of the requirement for a high temperature furnace over 1500°F and also for large water quenching facilities, the economics of the process equipment will undoubtedly favor the high temperature heat treatment being performed either at the mill or in the shop. Post weld heat treatment and interstage tempering at temperatures up to 1175°F may be performed equally well in the field as in the shop and has been used for years on many types of vessels. The only difference in post weld heat treatment between shop and field fabricated reactor vessels is that we can expect more local post weld heat treat cycles in the field than we presently have used in the shop. Local post weld heat treatment has been used in the past in the shop and field where facilities and size limitations have required doing so. The ASME Code Section III specifically permits local post weld heat treatment, and since both the Code and General Electric have well developed standards which will not change between shop and field, no change in quality level is expected to occur just because more welds will be locally post weld heat treated.

Local post weld heat treatment consists essentially of heating a circumferential band of the vessel which encompasses the weld joints being post weld heat treated. The permissible temperatures, times, and rates are the same for both local and total post weld heat treatment. The difference between local and total post weld heat treatment is the presence of a thermal gradient between the heated band and the cold section. The General Electric standards for an acceptable local post weld heat treatment procedure are based upon the fabricator providing a detailed written plan which gives particular attention to (1) the type of furnace, furnace controls, and insulation to provide an inherently stable operation which is easily controlled, (2) operating procedures, heating and cooling rates, and temperature gradients in all directions to meet code requirements and to meet General Electric requirements for control of thermal stresses to avoid warpage and distortion, and (3) instrumentation of sufficient type, quality, and location to measure accurately the progress and acceptability of the operation within the specified tolerances.

Total post weld heat treatment of some sub-components such as heads and possibly some nozzle assemblies whose configuration and/or size is not amenable to local post weld heat treatment can be expected. In this event, a furnace will be built in the field which may differ in shape from a shop furnace, but which meets all the functional and technical requirements of a shop furnace. This technique has been used before in the field on other types of vessels.

The methods and techniques of post weld heat treatment of field fabricated vessels therefore represent nothing unique or risky in pressure vessel construction and have been used by reliable fabricators for many years.

The welding and weld cladding of the vessel are expected to be performed with conventional processes involving conventional manual and automatic welding equipment. The major differences between shop and field welding will consist of:

1. Possible differences in experience of field welders which can be controlled by instruction, practice, performance qualification tests, supervision and inspection so that the development of experience is obtained while maintaining an adequate quality level.

2. Possibly more manual welding "out of position" (i.e., other than the flat welding position). This is a matter of degree since some major parts of all reactor vessels are manually welded out of position. Out-of-position welding will be minimized where practical, but where not practical, a General Electric approved welding procedure and joint designs and field supervision will be of a nature which will provide high quality welds.

3. Although no differences are expected between shop and field in protective cover from inclement weather, a difference in ambient temperature and in drafts during inclement weather is possible. The field condition can be expected to be similar to an unheated shop which is not tightly sealed. Attention must be paid to obtaining proper preheat temperatures and for maintaining the preheat temperature until post weld heat treatment. To accomplish this, temporary shielding, insulation, or extra heaters will be provided to maintain control of preheat during welding and prior to post weld heat treatment.

4. The field storage, drying facilities, and handling of coated electrodes and submerged arc welding flux must be equal to shop facilities in their ability to maintain control of the moisture content of the welding material. Field practice is well developed in this regard.

5. Welding processes such as electro slag welding which presently require austenitizing and quenching after welding will be virtually eliminated from consideration for field welding applications during the foreseeable future because of unfavorable economics for obtaining the required heating and quenching facilities in the field.

Any required machining of penetrations and mating surfaces in the field can be performed largely by built-up boring equipment which attaches to the vessel and which may be guided by accurately machined templates in contrast to the huge boring mills usually associated with large shop equipment in which the work is brought to the machine. This approach to machining is not new in reactor vessel construction and has been used in the past on other vessels and has been demonstrated as an acceptable method for construction of larger vessels. Neither is the approach of using equipment such as the gun turret lathes used in shipyard construction.

The use of multiple-piece flanges, if required, will require special evaluation. The tolerances obtainable with this approach to machining will depend largely upon the method of attaching the tooling to the vessel, the accuracy of the templates, the flexure of the boring arm, the tool characteristics, the skill of the machinist, the accuracy of reference point, and the effect of subsequent operations. Most of the effect of this approach is handled by good tooling design. The major difference between shop and field construction is that (1) machinist skill must be provided in the field, and (2) field sequence and accessibility for short, inflexible boring arms and equal tool pressure may require a shift in tolerance from one location to another in any given dimensional system, but a major shift of the overall tolerance envelope within a given system is not expected because system tolerances are set by the requirements of the completed vessel, and not by the equipment of the fabricator. System tolerance envelopes will be relaxed only by changing the design requirements and are independent of shop or field facilities.

5.4 SUPERVISION

The need for adherence to written procedures and dimensional requirements of a reactor vessel must be made apparent to a field erection crew the same as must be done with any new fabricator. A high quality of field supervision will be required to direct the work of the craftsmen and to instruct them regarding the importance of their role in the quality and procedure of the job.

With the prospects of many reactor vessels being field assembled, each at a different site, rather than in a few shops, General Electric will re-evaluate its manpower and training requirements for field supervision and inspection.

6 INSPECTION AND QUALITY CONTROL

6.1 General

Although the requirements for inspection and quality are the same for both shop and field, they may be expected to differ somewhat in method of achievement for the same end result.

With field assembly, the attention of fewer people is directed entirely to one particular vessel under construction, but usually with less formal documentation of specific detailed operations such as found in a shop. Therefore, special effort and emphasis will be directed toward obtaining controls in the field which are equivalent to shop practice where each operational step is detailed on a document sheet called "traveler". The traveler contains formal automatic work steps and checkoffs for inspection, and, in addition, automatically incorporates the details of the approved written procedures. Means must be provided in the field for a quality control system, instruction and diligence, to provide the equivalent of shop practice for assurance of working to approved written procedures and so that proper inspections and quality control are performed at the required times.

The fewer field personnel, including inspectors and quality control inspectors and quality control people, may be less specialized and somewhat broader in coverage than their counterparts in the shop. Therefore, some quality control procedures for dimensional welding and materials controls may be more specific than required for reactor vessels in the shop where standard practices and chain of command are well established.

With all of the responsible people paying attention to one vessel, it is conceivable that the inspection and quality control function may even be better in the field than in the shop.

6.2 Examination

Considering the five major methods of examination given to vessel material, namely; (1) Visual, (2) Magnetic particle, (3) Liquid penetrant, (4) Ultrasonic, and (5) Radiographic, the only difference between shop and field inspection may be the method of radiography and the processing of radiographic films.

Shop radiography of vessel sections may consist of a combination of X-ray and gamma ray; however, more gamma ray radiography may be used on field assembled vessels than heretofore used on shop assembled vessels because the high energy X-ray equipment used in the shop is not readily transportable to the field. Therefore, gamma ray radiography with a relatively large, high energy isotope such as Co-60 may be used more extensively in the field. Special gamma ray procedures which are capable of developing adequate sensitivity must be demonstrated, otherwise high energy X-ray equipments must be provided in the field. There has been a concerted effort to develop ultrasonic examination of welds to the point where it can replace radiograph, but this substitution has not yet received universal acceptance.

Although General Electric requires approval of all inspection procedures, particular attention will be given to gamma ray procedures. Emphasis is placed on developing an average sensitivity which is better than the required Code minimum sensitivity so that the larger size of the gamma ray focal spot and the potentially greater amount of scatter (due to longer exposure times) will inherently produce films which are better than marginal sensitivity.

High quality field processing of radiographic film is neither new nor novel and has been available from selected field fabricators for many years.

The radiographic procedure for welds in multiple-piece flanges, if used, may require development effort to meet specification requirements.

6.3 Vessel Testing

A shop assembled vessel would be hydrostatically tested with temporary closures on all openings in the shop and tested again in the field as a part of the completed system. The hydrostatic test pressure for the vessel test in the shop is not necessarily the same as the system test, since the system test is limited to the maximum test pressure of the vessels or components in the system. With the adoption of ASME Code Section III for the reactor vessel and continued use of ASME Code Section I or the ASA Pressure Piping Code B31.1, the reactor vessel becomes the determining component in setting the hydrostatic test pressure of the system. Section III requires that the hydrostatic test be made at a test pressure of at least 1.25 times design pressure. Section I and the ASA Piping Codes set a maximum hydrostatic test pressure of 1.5 design pressure but has provisions which limits the test pressure to maximum test pressure of any vessel or component in the system.

It is expected that the field assembled vessel would be tested at least once with the complete system. The system hydrostatic pressure test will be performed at the same pressure as would a shop test of the vessel. In addition to the ASME Code test the design pressure test to verify the head closure seal leak tightness would be performed in the field in exactly the same manner as it would be in the shop.

Hydrostatic testing in the field would necessitate scheduling foundation and biological shield pours to permit access to the vessel during the hydrostatic test for inspection. This would not, however, be significantly different than allowing for the placement of the shop-fabricated vessel prior to completion of these concrete pours.

6.4 Interfaces With Construction Activities

There are a number of concurrent activities which must be performed by various organizations to produce a nuclear power plant with a field-assembled reactor vessel. These activities reflect themselves in interfaces which vary in number depending on whether different fabricators are to build the containment vessel and the reactor vessel or whether one fabricator builds the containment vessel and the reactor vessel.

In the former case (as proposed by Chicago Bridge and Iron Co.), one company would correlate within its own organization framework all the interfaces and competing requirements for lifting time of the derrick. The only interface remaining which affects the construction schedule is with the Architect-Engineer-Constructor. To ease this interface problem, it may be necessary to erect a vessel support skirt from the bottom vessel head to the containment bottom plate and to the subgrade concrete below the containment. The skirt would need to be capable of supporting the vessel weight filled with water. Also it would be necessary to have agreement between the vessel fabricator and the Architect-Engineer-Constructor to allow the construction of the main structure to proceed concurrently with the construction of the reactor vessel and the containment vessel. This appears to be no problem provided sufficient space (approximately 5 feet) is left between the containment shell and the civil work.

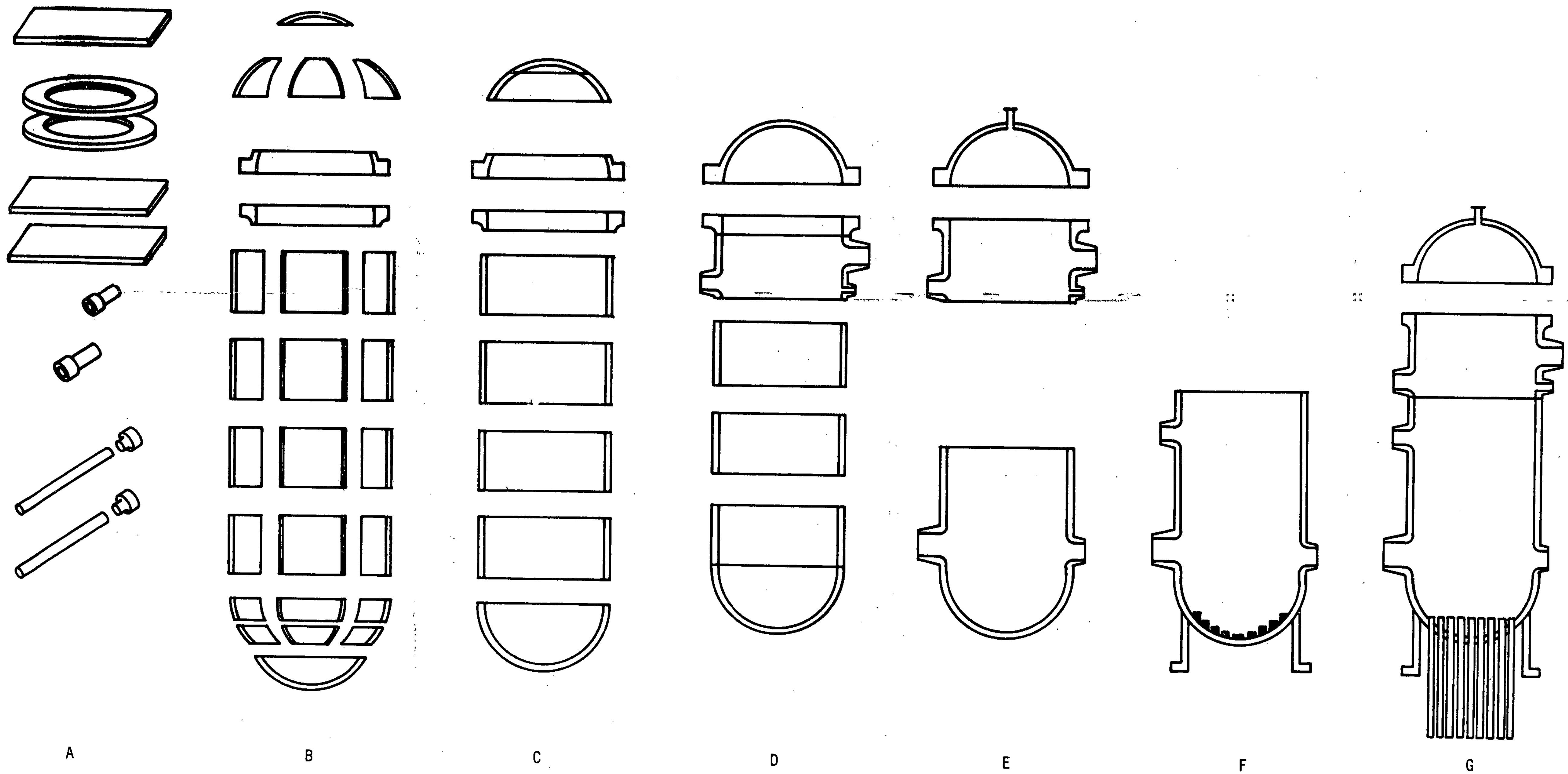
Should separate fabricators be chosen for the reactor vessel and the containment vessel, it appears most feasible to fabricate the pressure vessel adjacent to the reactor building and move it into the building by presently used methods. The main advantage in this case will be elimination of problems of shipping a reactor vessel from vendor's shop to site. In any case, the problems are not insurmountable and reflect only on the schedule aspects of the situation.

IV SUMMARY

The results of the study have shown that there are no technological reasons why a field-assembled reactor vessel should not be equivalent to a shop assembled vessel. The task force concluded that with the proper application of equipment and personnel, a reactor vessel can be assembled in the field in such a manner as to meet all of the exacting requirements of the ASME, Boiler and Pressure Vessel Code Section III, and of the General Electric Company. The Code stamping is equally applicable to shop and field-assembled vessels. In addition, the study has established that there may also be certain schedule advantages, especially if early phases of the vessel fabrication and placement of temporary construction facilities can be commenced before final issuance of a construction permit. By combining and coordinating the fabrication of the reactor vessel with the erection of the containment, sharing of manpower skills and abilities required by both allows better utilization of these skills and in some cases will permit a degree of specialization comparables to that found in large vessel shops. Field fabrication will also provide additional facilities and suppliers in the field of reactor vessel fabrication.

The original mission of this task force was to establish feasibility, evaluate incentive and vendor capability and accumulate adequate data to place this feature in a proposal. This has been completed.

TYPICAL SUB-ASSEMBLIES & SEQUENCE OF ASSEMBLY
REACTOR PRESSURE VESSEL



1. A-B. ORDER, RECEIVE AND INSPECT RAW MATERIAL. PREPARE FABRICATION AND INSPECTION PROCEDURES.

2. B. FORM MATERIAL, MACHINE AND CLAD FLANGES

3. C-D. WELD INTO RINGS, HEAT TREAT RINGS IF NOT ALREADY HEAT TREATED, CLAD AND BACK CLAD WELDS

4. D-E. CONTINUE WELDING INTO RINGS AND INSTALL NOZZLES, CLIPS AND SUPPORTS. MACHINE FLANGES, BACK CLAD WELDS, MAKE C.R.D. THIMBLE SUBASSEMBLIES.

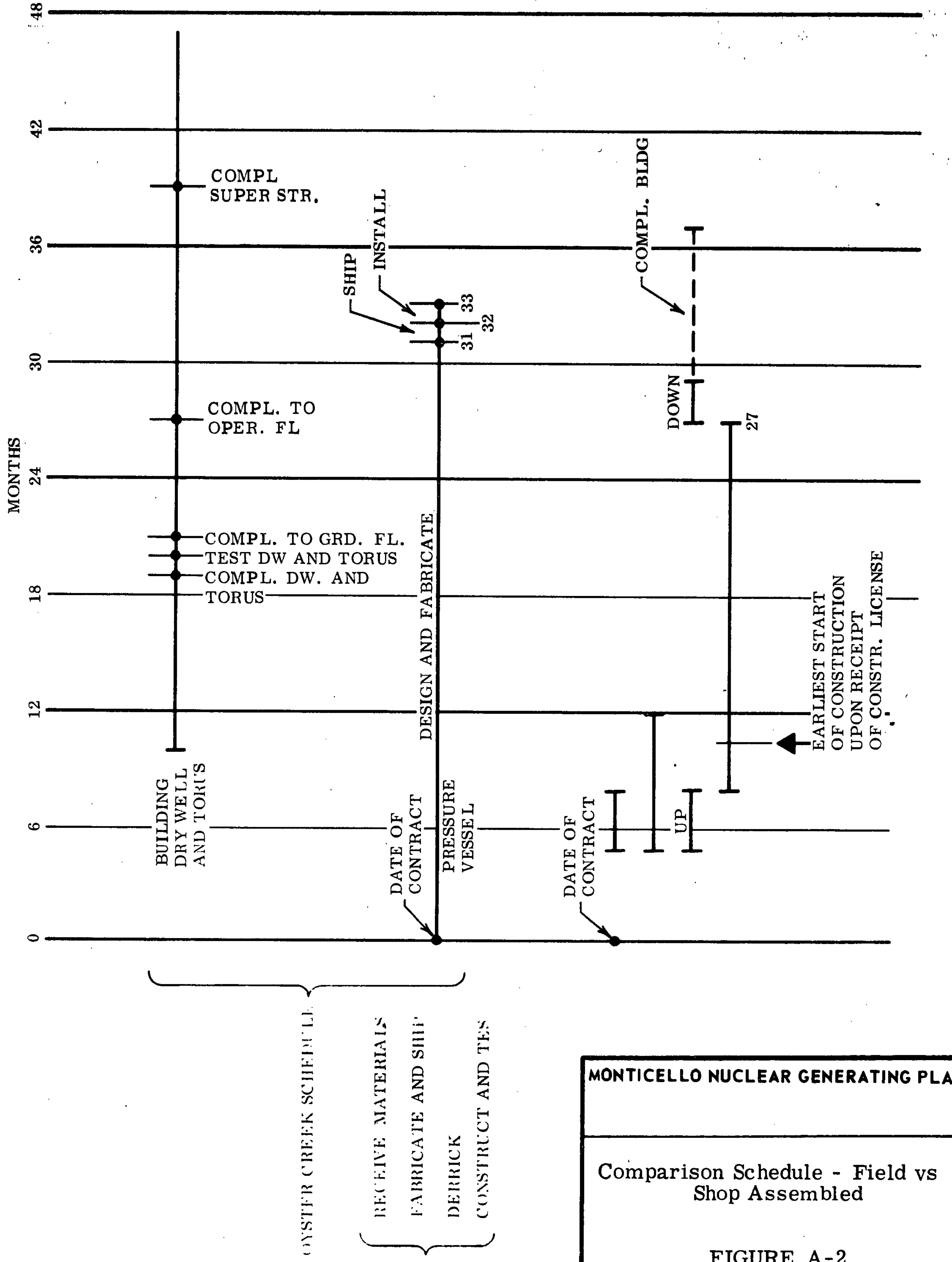
5. F-G. COMPLETE MACHINING AND INSTALLATION OF NOZZLES AND SUPPORTS, COMPLETE WELDING AND BACK CLADDING OF WELDS. FINAL HEAT TREATMENTS ARE COMPLETED.

6. G. HYDROTEST, SEALING TEST, INSTALL INTERNALS.

MONTICELLO NUCLEAR GENERATING PLANT

Typical Subassembly Sequence

FIGURE A-1



MONTICELLO NUCLEAR GENERATING PLANT

Comparison Schedule - Field vs Shop Assembled

FIGURE A-2

APPENDIX B

FEASIBILITY OF SHIPPING SHOP-ASSEMBLED VESSEL TO MONTICELLO SITE

A study was made to determine the feasibility of delivering a shop assembled vessel to the Monticello Site. This study covered river transport from the head of navigation on the Mississippi River to the barge docking site, docking and unloading and land transport to the nuclear plant site.

RIVER TRANSPORTATION

The end of the navigable channel of the Mississippi River is at the Soo Line Railroad Bridge in Minneapolis. The Soo Line bridge is about two miles upstream from the city center and is in the heavily populated area of the city. It is not possible to unload and transport equipment as large as a reactor vessel from this location through the city of Minneapolis. See Figure B-1. Point (1) shows the location of the Soo Line bridge.

The Coon Rapids Dam is located about eight miles upstream from the Soo Line bridge (Point (2) Figure B-1). This dam does not have locks and the stretch of river from this point to the Monticello site is not considered satisfactory for river transportation. This is due to the difficult portage around the Dam and the river rapids and low bridges on this stretch of river.

Other than the expense of dredging the eight mile stretch from the Soo Line bridge to the Coon Rapid Dam, there is one major obstruction to navigation. This is the City of Minneapolis water mains which cross the river at the Fridley Softening Plant. There are other submarine crossings such as gas lines, telephone cables, etc. but whatever solution for crossing the water mains could probably be used for these crossings if the same limiting obstruction is present. The top of the Minneapolis water mains are approximately level with the present river bottom so that necessary dredging to create a navigable channel for the barge would leave the water mains in the direct path of the barge transport. It has been predicted that the depth of the river at the water mains during high water would be approximately four feet. It has been estimated that the loaded barge will draw about seven feet of water and will require a nine foot channel minimum for towing. To pass over these mains will require special barging techniques to reduce the draft to about 2 1/2 feet in order to allow reasonable clearance over the water mains to prevent damage to the mains. It may be possible to accomplish this reduced draft by lashing three barges together. Special techniques would also be required to move the tugs over the water mains.

A river channel must be dredged above the water mains to the final docking site since river depths are in the range of three to five feet. The normal draft of the barge is required to pass under bridges. The exact location of other submarine crossings with respect to the river bottom is not known at the time so that it may be necessary to utilize the same techniques for crossing these obstacles as for the water mains.

A new Interstate Highway (94) running parallel with the river from Minneapolis to Highway 100 bridge will have been built before the vessel could be shipped. See Point(3) Figure B-1. On the basis of discussions with the highway department, the transport vehicle would not be permitted to enter upon or cross this road so that docking of the barge must be upstream of Highway 100 bridge. Shore line property immediately above the bridge is highly residential making docking in this area impractical. In an area about 2 miles above the Highway 100 bridge are possible sites for docking. This area is approximately four miles above the head of navigation. There are several parcels of unimproved shore line property that could possibly be used as docking sites. See Point(4) Figure B-1. A proposed unloading procedure would involve docking the barge parallel to the river bank and utilize an overhead hoisting structure supported on cassions in the river and spanning over the barge to shore to lift and move the vessel to shore and place in on a transport vehicle. Potential problems which have not been investigated include whether local officials would permit this docking facility to be constructed in a residential area.

ROAD TRANSPORTATION

Road travel would involve several types of road beds of varying lengths as follows:

Village Roads - - - - - - - - - - - - - - - - - -	1/2 mile
County Roads - - - - - - - - - - - - - - - - - -	8 1/2 miles
State Highways- - - - - - - - - - - - - - - - - -	2 1/2 miles
State Highways, construction subgrade- - - -	25 miles
On Site Roads - - - - - - - - - - - - - - - - - -	1 mile

Village roads are located in the immediate area of the docking site and are bituminous mats laid on minimum subgrade. The use of these roads through a residential area will probably be subject to serious objections from local officials and property owners and may not be permitted at all. County roads are of similar construction as the village roads. The County Highway Department would give no official opinion on the possible use of these roads at the time this investigation was conducted. The likelihood of receiving permission to use county roads would appear greater than for village roads.

It would be necessary to pass over improved roads of the State Highway system. The present attitude of the highway officials is that such movement would be permitted only if it occurred when the subgrade is well frozen--normally January and early February. From the Osseo area, see Figure B-2, the highway department recommends that the vessel be moved over the subgrade of a new Interstate Highway (94) which will parallel Highway 152. It would not be practical to use Highway 152 because of the many obstructions along its route such as villages, interchanges, utilities, etc. This new interstate highway is to be built during 1968-69. There are several minor obstacles along this route such as road crossings, which may require purchase or lease of private propery in order to move around grade crossing structures. The major obstacle in this highway route is the Crow River crossing. The State Highway Department would not permit the heavy vessel load on this structure nor will they permit shoring the structure to take the additional loads. A temporary trestle could be built to make this crossing but the cost of the trestle plus the difficulties of moving the transport vehicle off of the highway roadbed, cross the temporary trestle and move back onto the road bed

do not appear to be a reasonable solution. Although not economical. the best solution would be to contract with the State Highway Department to design and build the Crow River bridge to carry the vessel loading. The schedule of design and construction of this bridge would have permitted this solution to be pursued.

There are numerous types of obstacles that would be encountered between the docking site and the Interstate Highway road bed although none appear to be insurmountable. These include power lines, house drops, telephone cables and high voltage transmission lines. Lines would have to be disconnected and reconnected by crews working forward and to the rear as the move progresses. Telephone cables would either have to be raised or buried well in advance of the move. High voltage transmission line crossings which do not have sufficient overhead clearance and which cannot be de-energized to permit lifting to permit moving underneath may have to be rebuilt and raised in advance of the move.

ALTERNATE ROUTES

Because of the magnitude of the highway system (state, interstate, county and local), and the many small villages and towns it is not deemed feasible to dock and unload the reactor vessel below Minneapolis and transport it overland from this point to the Monticello Site.

Overland movement from the barge docking site by the most direct route to the Monticello Site was investigated. This overland route would avoid travel over the highway road system by use of a transport vehicle equipped with large rubber tires. This alternative was not considered feasible because of the many creeks and streams which would have to be crossed.

There are two railroad routes from Minneapolis to the Monticello Site. The Great Northern Railroad operates a single track on the west side of the Mississippi River. The Great Northern and the Northern Pacific Railroad jointly own a double track on the east side of the Mississippi River. If the west side route were to be used, rail transport would have to begin about ten miles northwest of Minneapolis. From this point to the Site there appears to be only one major obstacle--the Crow River railroad bridge. This bridge cannot be crossed because of its extreme narrow width and low height. A bypass trestle would have to be constructed to cross the river. If the east side route were to be used it would be necessary to unload the vessel from the railroad car several times to transport it around underpasses which are too low for passage. Bridge crossings near the site are not adequate to carry the loads so either temporary bridges would have to be constructed or the vessel unloaded and barged across the rivers.

CONCLUSIONS

While it cannot be stated unequivocally that a shop assembled reactor vessel cannot be transported to the Monticello Site, there is at least one insurmountable schedule problem that would preclude such a move — the date the vessel would have to be in Minneapolis.

Statistically the navigable season to the Minneapolis Upper Harbor has a latest beginning season arrival date of May 6 and an earliest end season departure date of November 11. These dates are

based on records covering 35 years.

The City of Minneapolis water mains at the Fridley Softening Plant constitute a major obstruction to river travel and can only be passed over during a period of high water which may occur in April and May and during a very short interval about September 1.

The Minnesota State Highway Department will not permit heavy axle loads on the highway system unless the ground is thoroughly frozen. This usually occurs the last weeks of January or early February. The only feasible route to the Monticello Site from the docking site would require use of Interstate Highway 94 subgrade before the road bed is paved. This would require transporting the vessel during January and February, 1969.

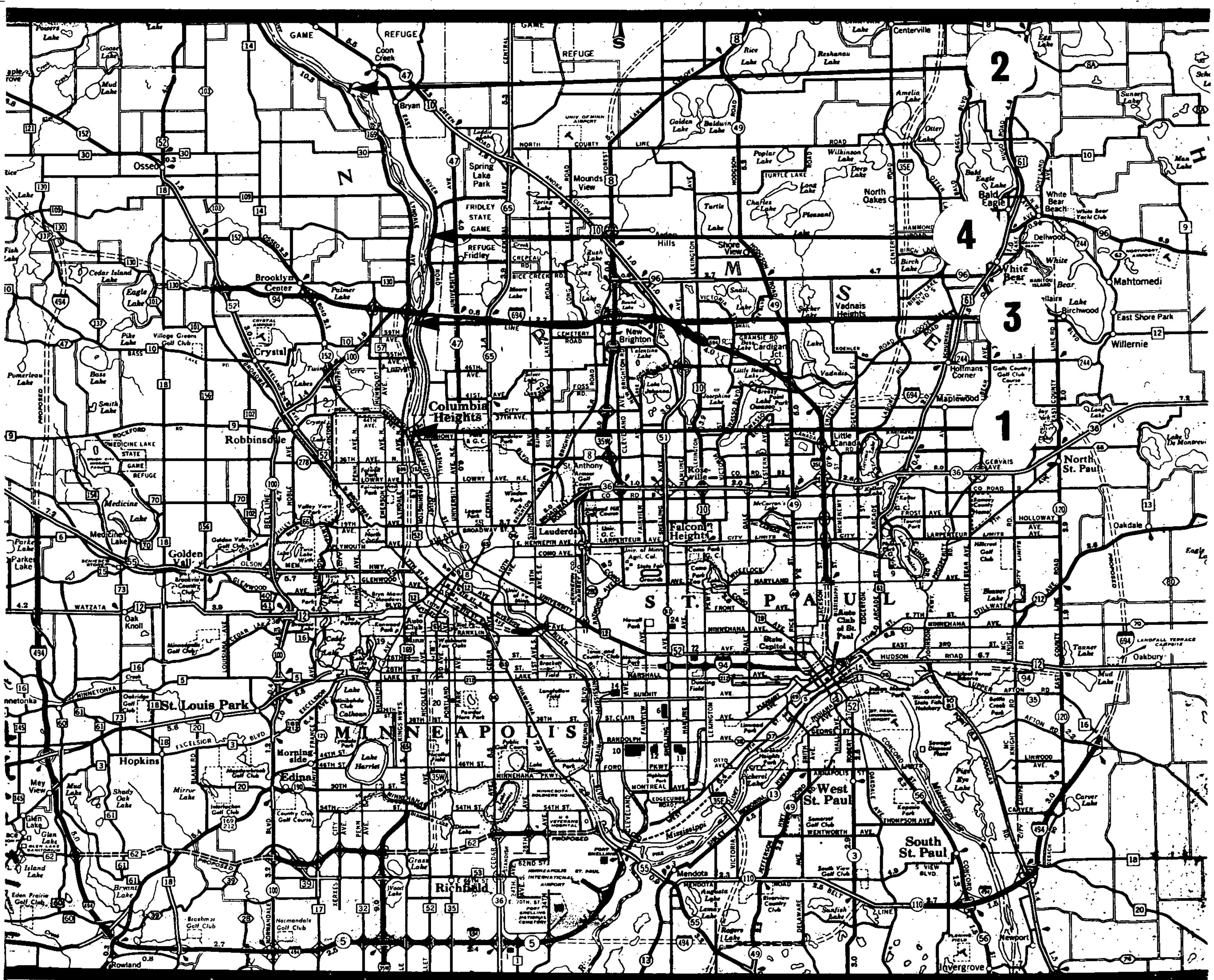
The reactor vessel order was placed in July, 1966. The order could not be placed much in advance of this date because of sizing design time requirements. The most optimistic fabrication cycle would indicate about 2 1/2 years in the shop. For comparison, the Nine Mile Point and Oyster Creek reactor vessels were completed at the fabricator's shop in 2 years, 10 months from the date of award of contract. It would require about 1 1/2 to 2 months to load the vessel on a barge and deliver it to the head of navigation on the Mississippi River at Minneapolis. Thus the earliest the vessel might be expected at Minneapolis would be about March 1, 1969--far beyond several of the limiting dates described above.

There is at least one additional major problem to road transportation which may or may not be insurmountable. This concerns the construction of the unloading facility at the docking site and transport over village roads. Local opposition is expected to be extremely strong and while it may be possible to work out a satisfactory solution with these people the expected delay in arriving at such a solution would be beyond the date for which a decision would be required for placement of the reactor vessel order.

SOURCES OF INFORMATION

The following are the sources of information used for this study:

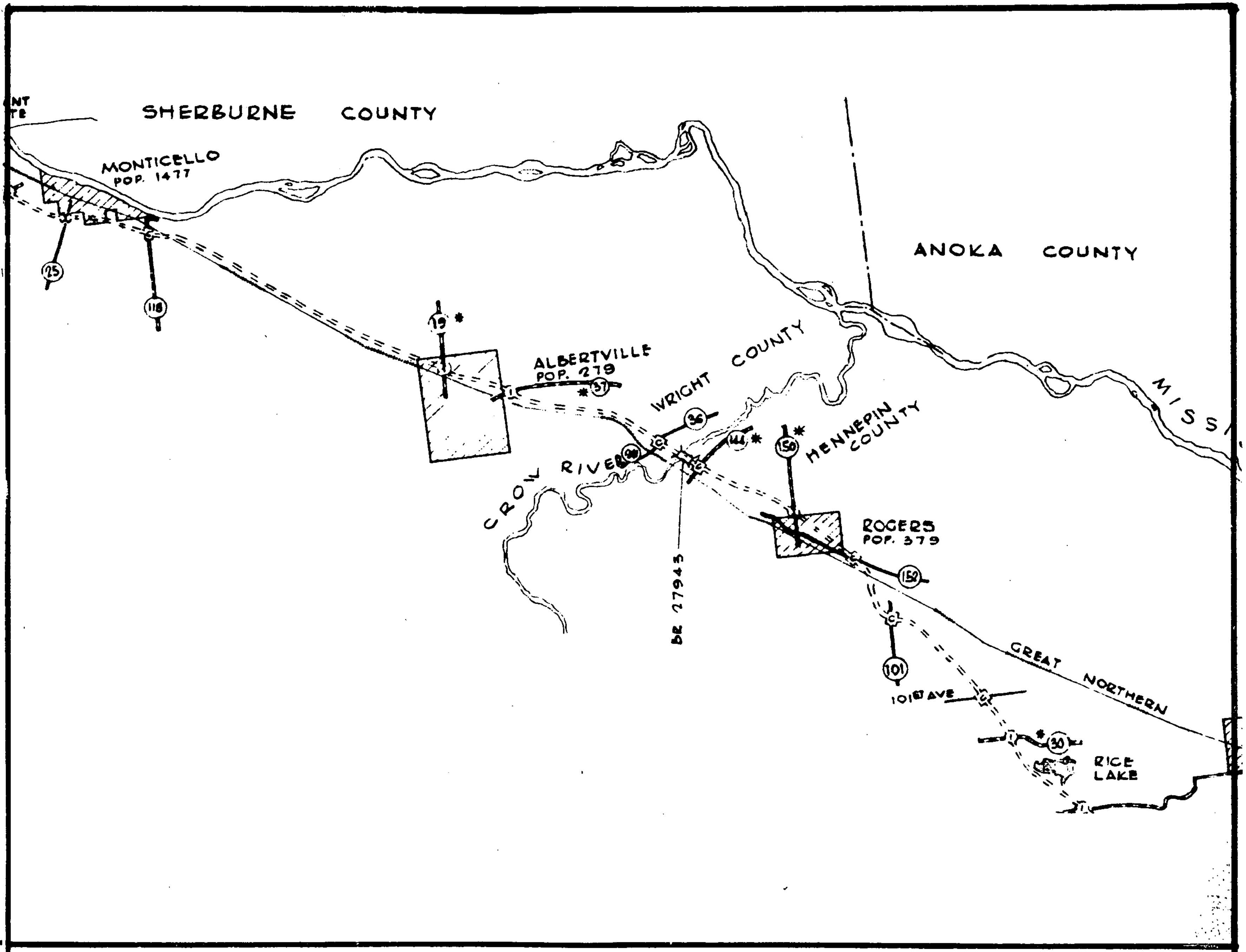
1. Pioneer Service & Engineering Co., Chicago
2. Minnesota State Highway Department
3. Hennepin County Highway Department
4. U. S. Army Engineer District, St. Paul
5. City of Minneapolis Water Department
6. Twin City Barge & Towing Company (Upper Harbor Towing Service)
7. R. J. Potter Dredging, Inc. (Channel Excavation and Dredging)
8. Reconnissance of the area with a trucking company representative to review the proposed route from a trucker's point of view.



MONTICELLO NUCLEAR GENERATING PLANT

Minneapolis - St. Paul

FIGURE B-1



MONTICELLO NUCLEAR GENERATING PLANT

Proposed Route

FIGURE B-2

APPENDIX C

ENGINEERING REQUIREMENTS

The following are the Engineering Requirements which the General Electric Company have placed upon Chicago Bridge & Iron Company (CB&I), the vessel fabricator, for the reactor vessel for the Monticello Nuclear Generating Plant, Unit No. 1, located at Monticello, Minnesota.

I GENERAL DESCRIPTION

1. The reactor vessel will be used as a pressure container supporting the steam generating core in the Monticello Nuclear Generating Plant to be located near Monticello, Minnesota.

2. The equipment to be furnished in accordance with these engineering requirements shall be one reactor pressure vessel assembly with a removable head and nozzles and certain internal support structures, arranged as shown on Figures C-1 through C-1c complete with:

   (a) Attachments for thermal insulation, vessel and core supports, brackets or legs for lifting and handling of the vessel head, and mounts for outside surface thermocouples.

   (b) One set of necessary special tools required to remove and replace the reactor vessel head. The set of tools shall include: four hydraulic stud tensioners, stud elongation measuring device, stud and nut wrenches, one set of stud thread protectors, three head guide caps, one bushing wrench, one stud sling and one reactor vessel head sling. Stud tensioners shall include a lifting device that properly spaces the tensioners over the bolt circle.

   (c) One set of necessary special tools required to install and remove the reactor vessel head seals with manual contact. This set of tools shall include a carrier ring to aid in transporting one set of O-ring seal gaskets about the power plant and a protective cover for the reactor vessel shell flange seal surface.

   (d) Metal boxes for the hand tools. Boxes shall be suitable for handling with a crane and/or fork lift truck.

   (e) One lot of reactor vessel material test plate and material test specimens in accordance with Attachment A, Figures C-11 through C-17.

   (f) Shipping skids for those portions of the Reactor Vessel which are shop fabricated.

II CODES

1. The reactor vessel shall be designed, fabricated, inspected, tested and stamped in accordance with the American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code,

Section III, applicable requirements for Class A Vessels as defined therein, interpretations of the ASME Boiler and Pressure Vessel Code, and all applicable laws, rules and regulations of the State of Minnesota in effect on July 18, 1966.

2. Deviations from the applicable codes or regulations shall be avoided. Where a conflict exists among the codes or regulations, CB&I shall bring this to General Electric's attention. It shall be the responsibility of CB&I to obtain resolution and disposition of deviation with General Electric and other appropriate parties and authorities.

3. The intent of these engineering requirements is to supplement the requirements of the codes specified herein and to encompass the means whereby the design objective is satisfied.

4. All standards and material specifications shall be per latest revision in effect on July 18, 1966.

III DESIGN REQUIREMENTS

1. Operating Conditions

(a) Internal Pressure

Design Pressure: 1250 psig at bottom of the reactor vessel
Normal Operating Pressure: 1000 psig at top of reactor vessel

(b) Temperature

Design Temperature 575° F
Normal Operating Temperature: 546° F

(c) Reactor Core and Internal Weight

The weight of the reactor core and internal structure, centers of gravity and distribution of loadings are shown on Figure C-2.

(d) Water Weight

The weight of water contained in the vessel for various conditions of operation are presented on Figure C-2.

(e) Pipe Reactions

General Electric shall provide CB&I with the pipe reactions which the connecting piping will apply to all nozzles with a nominal size larger than the reactor vessel wall thickness and those nozzles which in addition are subjected to significant thermal cycling. The reactions will be limited by General Electric such that the combined stress as due to pipe reactions and design pressure in the vessel shell at the nozzle attachment will not exceed the design stress allowed by the ASME Code, Section III. These pipe reactions shall be used in the detailed stress analysis required by the Code and performed by CB&I. This analysis shall include the thin section of the nozzle in the vicinity of the weld preparation for connecting piping, any bi-metal weld and shall take into account the nozzle cladding.

(f) Control Rod Drive Weight and Reaction

The momentary reactions which are suddenly applied to each control rod drive housing in the vessel bottom head are presented on Figure C-2.

(g) Steady State Thermal Conditions

Steady state metal temperatures will be computed by CB&I for no more than twelve locations on the reactor vessel. The locations will include the head and shell closure flanges, the shell adjacent to the reactor core, the bottom head and major nozzles including the control rod drive nozzles. Temperature gradients through the shell wall adjacent to the portion of the reactor core peak flux zone will be computed by General Electric and furnished to CB&I.

(h) Cyclic Loading

Reactor coolant temperature, pressure and flow changes, together with the expected number of cycles, are shown on Figure C-3.

(i) Earthquake Loads

Earthquake loads shall be taken into account in accordance with the criteria and load presented on Figure C-4.

2. Design Considerations

(a) Design Objective

The objective shall be to design and fabricate this reactor vessel to have a useful life of forty years under operating conditions specified by General Electric.

(b) Reactor Vessel Supports

Reactor Vessel supports, internal supports, their attachments and adjacent shell shall be designed to take maximum combined loads including control rod drive reactions, earthquake loads, and jet reaction thrusts as defined in Figures C-2 and C-4. There shall be no gross yielding of the reactor vessel supports causing permanent displacement under these conditions.

(c) Stress Concentrations

Care shall be taken in design and fabrication to minimize stress concentrations at changes in sections or penetrations. Fillet radii shall be equal to at least half the thickness of the thinner of the two sections being joined. If reinforcement for openings (except the control rod drive and in-core flux monitor nozzles) requires local vessel shell added thickness, such reinforcement shall extend at least 1-1/2 times the diameter of the opening from the center of the opening. These requirements are not to be construed as a waiver for evaluating the stresses for use in the analysis for cyclic operation.

(d) Corrosion Allowance

Exterior exposed ferritic surfaces of pressure-containing parts including heads, shell, flanges and nozzles shall have a minimum corrosion allowance of 1/16-inch. The interior surface of carbon or low alloy steel parts exposed to the reactor coolant shall also have a minimum corrosion allowance of 1/16-inch.

(e) Main Closure Seal

The reactor pressure vessel main closure seal shall be a double seal designed to have no detectable leakage through the inner or outer member at all operating conditions. These conditions include, but are not limited to: (a) cold hydrostatic pressure test at the design pressure, (b) heating to design pressure and temperature at a rate of 100° F/hr., maximum; (c) operating for extended periods of several months duration at operating conditions, and (d) cooling at a rate of 100° F/Hr., maximum.

(f) Design Stress

Design stress values used in the calculations shall be as contained in ASME Section III and applicable interpretations of ASME Boiler & Pressure Vessel Code for materials covered therein. The design stress values for ASME, Section III calculations for other materials approved by General Electric in accordance with Paragraph VI-1 of these requirements shall be determined per Appendix II, ASME Code, Section III.

(g) Dimensional Control

CB&I shall show the method of controlling, measuring and maintaining alignment and location of control rod drive penetrations with the vessel and core supports.

(h) The vessel shall be designed to minimize retention pockets and crevices.

IV DESIGN ANALYSIS

1. Requirements

CB&I and General Electric shall perform the design calculations and analyses as required by the applicable Standards and Codes indicated in Section II. The requirements of Article 4, ASME Code, Section III, shall be fulfilled. The division of responsibility for the analyses shall be in accordance with paragraph (c) below. The analysis required shall be performed in two divisions as follows:

(a) Stress Analysis

A stress analysis shall be performed in accordance with Section N-430, ASME Code Section III. Calculations shall be performed in accordance with paragraph N-431 to verify that the minimum wall thickness is provided. A detailed stress analysis shall be performed in

accordance with paragraph N-432. This analysis shall take into account all combinations of loads in conjunction with metal temperatures, as indicated in Section III above, and Figure C-3 within the Design Stress Criteria of ASME Code Section III, Article 4.

(b) Analysis for Cyclic Operation

An analysis shall be performed in accordance with Section N-415 of the ASME Code, Section III, to determine that the vessel is suitable for the cyclic loading conditions of paragraph III-1(h) above. This analysis shall also be performed within the design stress criteria of Section III, Article 4, to establish whether the design objective in paragraph III-2(a) is reached. The analysis will be used to determine the adequacy of any required thermal baffling used to control or limit thermal stresses and to place safe operating limits on the cyclic conditions imposed on the vessel where it is reasonable to control them, as in the start-up heating rate and shut-down cooling rate.

(c) Division of Responsibility

CB&I and General Electric shall perform jointly the design analysis required by this specification.

(1) CB&I shall perform calculations to satisfy limits on primary general membrane stress (P_M), primary local membrane stress (P_L), primary bending (P_B), and secondary membrane plus bending stresses (except thermal stresses) (Q) from specified steady state conditions. Also included are calculations necessary to reinforce openings per Paragraph N-450, except the calculations necessary to satisfy the cyclic conditions and Paragraph N-451 (b) which are the responsibility of General Electric.

(2) General Electric shall perform the transient and steady state thermal analysis and the analysis for cyclic operation on all components requiring such analysis. These analyses will provide the stress categories Q and F of Paragraph N-414, ASME Section III. This type of analysis will cover but not necessarily be limited to the following parts of the reactor vessel:

a. Emergency cooling nozzles (safe end and thermal sleeve)

b. Feedwater nozzles (safe end and thermal sleeve)

c. Control rod drive hydraulic system return nozzle (safe end and thermal sleeve)

d. Vessel Support Skirt

e. Refueling bellows support skirt

f. Closure flanges

g. Bolting

h. Control rod drive penetration

(3) The analyses which are the responsibility of General Electric but are made with CB&I's assistance, shall be checked and signed by General Electric.

(4) CB&I shall fulfill the code requirements of Paragraph II above and produce the summary report required by Paragraph 8 below. General Electric shall prepare its portions in suitable form for submission to CB&I.

2. Calculation of Stresses

The detailed structural analysis required to meet the Design Analysis requirements above shall be made for the stresses resulting from internal pressure, external and internal loadings, and the effects of steady and fluctuating temperatures and loads for regions given in Paragraph 3 which involve changes of shape, structural discontinuities, and points of concentrated loadings.

Where dimensions and loading conditions permit, the adequacy of structural elements will be verified by comparison with completely analyzed elements. The calculations shall include a complete analysis of stresses under steady state and transient conditions to determine suitability of the design with respect to the allowable stress given in ASME Code, Section III, and to determine the operational limitations with respect to fatigue of the reactor vessel materials over the life of the reactor vessel (Design Objective) using the loading conditions supplied by G.E.

3. Parts of the Reactor Vessel Assembly to be Analyzed

The parts of the reactor vessel to be analyzed shall include: head closure, bottom head, shell adjacent to reactor core, reactor vessel supports and stabilizers, supports for reactor vessel internals, control rod drive penetration, feedwater nozzle, poison nozzle, emergency core cooling nozzles, drive system return nozzle, and all nozzles 10" or larger in size.

4. Closure Head Seal Calculation

To assure meeting sealing requirements of the main closure seal, the relative rotations of the flanges shall be calculated. These rotations shall be used to demonstrate analytically satisfactory seal performance using the following assumptions:

(a) The mating surfaees of the flanges shall be assumed rigid.

(b) The rotation shall be assumed to cause contact over the minimum area which will sustain the loading between the faces when stressed to the yield strength at the metal temperature.

(c) The flange faces shall be assumed to diverge from the contact area, specified in paragraph (b) above through the angle of calculated relative rotation less any radial taper machined on the face (s) to accommodate the flange rotations.

(d) It may be assumed that the seal will be maintained if, at both O-ring seal locations, the separation between flanges is less than the minimum elastic spring-back of the O-ring.

5. Calculations

The calculations shall be clear and in sufficient detail to permit independent checking. Specific references shall be given for all formulas and methods used or the formulas and methods shall be derived independently. Calculations shall be submitted to General Electric for approval.

6. Descriptions of Computer Programs

If computer programs are used to obtain solutions to design problems, CB&I shall furnish General Electric the description of each different computer program used. These descriptions shall be furnished with the first issue of the design calculations incorporating such programs. The computer program description shall include computer type, program capabilities, assumptions, limitations and statement of availability.

7. Measurement Reports

Measured values of strain, deflections or stresses resulting from tests on models or actual reactor vessels shall be supplied to General Electric by CB&I. These reports shall include all information necessary to duplicate the conditions required to obtain the results reported.

8. Summary Report

After completion of the reactor vessel design, CB&I shall furnish General Electric additional copies of all calculations plus a summary report of results of all computations.

V CONSTRUCTION

The reactor vessel body including all components which contain pressure including the shell, lower and upper heads shall be made of rolled plate and/or forgings welded with full penetration welds throughout except nozzles less than 3" nominal size as discussed below. The shell and head flange and nozzles shall be forged.

1. Shell and Heads

(a) Longitudinal and circumferential weld joints in the reactor vessel shall be oriented so as not to intersect openings or penetrations, wherever practical. Circumferential weld seams should avoid regions of highest neutron flux in the core region, if practical. The region of highest neutron flux occurs between the mid-plane and top of the core.

(b) Bottom Head

The section of the bottom head which encompasses the penetrations for the control rod drives and in-core flux monitors shall be either a single forging or dished plate, if practical. If this is not practical and a weldment is used, the orientation of the weld sections shall as far as practical minimize the number of intersections of weld seams with penetrations.

(c) Top Head

The top head shall be either a single forging or dished plate or shall be fabricated of sections welded together, with the orientation of the weld seams such that no seams intersect openings or penetrations.

(d) Weld Joints

Weld joints shall be designed to facilitate a maximum of radiographic examination per the ASME Boiler and Pressure Vessel Code, Section III, paragraph N-624.

2. Head Closure

(a) Assembly and Disassembly

(1) The head closure shall be designed for removal and reassembly, using 4 or more hydraulic stud tensioners.

(2) It shall be the design objective to replace and remove the head within 16 hours elapsed time. Specifically, the cycle shall include placing the head over the studs, tightening the studs to operating bolt-up loads, unbolting and removal of the head over the studs. It is expected that 120 such cycles will be performed during the life of the reactor vessel.

(b) Seals

(1) The head seal shall be a double seal with a vent between the seals through which leakage of the inner ring can be detected. The seal vent shall be designed for full design pressure of the reactor vessel.

(2) The seal shall be metal O-ring type with pressure equalizing vents on I. D.

(3) The grooves for the O-rings shall be placed in the reactor head flange. Suitable fasteners shall be provided to hold the O-rings in the grooves during head removal and assembly operations.

(4) Provisions shall be made for installation of a low pressure leak detection system outside of the bolt circle. The provisions shall include a vent through the vessel flange with extended 1" nipple and socket weld fitting and either a shallow groove or other suitable backing to retain a soft asbestos braided packing. There shall be no protruding parts of this low pressure seal beyond the O. D. of the head and vessel flange.

(c) Bolting

(1) Studs shall be used to secure the reactor vessel head. Stud, nut and bushing threads shall be in accordance with Figure C-5.

(2) The stud bolt holes in the reactor vessel flange shall be bushed with removable bushings. Keys shall be provided for each bushing to prevent rotation of the bushings when removing studs.

(3) Spherical washers shall be used with the studs to minimize bending of the studs.

(4) It shall be possible to remove and replace the head with the studs installed. To facilitate head removal and replacement, three special guide caps shall be provided to couple onto three studs. The lengths of the guiding surfaces of the guide caps shall be staggered so that the shorter of the three guide caps shall extend above the top of the installed studs for a minimum distance of 4 inches. The length of the three guide caps shall be staggered in 3-inch minimum increments. The internal threads of the guide caps shall be similar to the stud nuts threads. The upper end of the guide caps shall be provided with a conical lead-in taper and a horizontal through-hole bored to accommodate a round bar for wrenching.

(5) Flange hole, bushing, and stud designs shall be such that the studs stand perpendicular to the flange surface when the studs and bushings are bottomed in the holes to facilitate removal and replacement of vessel head over studs as called for in Paragraph (4) above.

(6) The surface of all threads in the studs, nuts and bushings shall be given a phosphate coating to act as a rust inhibitor and to assist in retaining lubricant on the surfaces. An approved lubricant should be applied to the stud threads as soon as possible after coating.

(7) A stud sling for the main closure studs shall be provided. The stud sling shall include a swivel and counter-weight spring to support the weight of the stud during turning of stud into vessel flange. Studs are to be provided with a wrenching surface accessible when suspended on sling.

(8) All main load-carrying threads and spherical washers shall be assembled only after cleaning, gaging, and lubricating. In no case during fabrication or testing shall these parts be assembled without lubricant. Only thread lubricant approved by General Electric shall be used.

(d) Flanges

(1) The top head flange surface shall be machined or the area around each stud hole spot faced. Spot facings shall be complete and extend beyond washer O. D. to accommodate maximum eccentricity of stud in head flange bolt hole.

3. Nozzle Ends

(a) The ends of all nozzles other than flanged nozzles shall be prepared for welding in accordance with Figure C-6. Nozzle safe ends are considered to be part of the vessel, not part of the connecting piping but in no case shall the safe end wall thickness be less than the wall thickness of the connecting pipe.

(b) Where thermal sleeve nozzles are specified to a nominal size, the size of the pipe through the nozzle as well as the nozzle external end shall be the nominal size specified for the nozzle. Thermal sleeves shall be supplied by CB&I.

(c) General Electric will furnish information on the wall thickness, t_p, of all piping connections and will set the inner bore diameter including tolerances and allowances of the connecting piping which will follow ASA Standards. General Electric will use the formulas and allowable stresses of B31.1 for establishing the required piping wall thicknesses. Nozzle safe end wall thickness shall be governed by Figure C-6 and will in general be greater than required by Section III.

(d) Details of the transition weld preparation shall be submitted to General Electric for approval.

(e) Nozzles of 3" nominal size or larger shall be full penetration welded to the vessel. Nozzles less than 3" nominal size may be partial penetration welded if permitted by ASME Code, Section III.

4. Top Head Nozzles

The vessel top head nozzles shall be provided with 1500 pound weld neck flanges with small groove facing. Mating 1500 pound flanges with small tongue facing, gaskets and a complete set of studs and nuts shall also be provided. The loose flanges for the 6 inch instrument nozzles shall be blind, the remainder shall be weld neck. The flanges and gaskets shall be in accordance with ASA Standards B16.5. The threads on studs and nuts shall be 8-pitch series in accordance with ASA Standard B1.1.

5. Reactor Vessel Supports

(a) External and internal supports shall be provided as an integral part of the reactor vessel. The location and design of the supports shall be such that stresses in the reactor vessel and supports will be within ASME Code limits due to reactions at these supports. The design pressure differential across the core shroud support shall be 100 psi (higher pressure under the support) occurring at the vessel design temperature. The design of the core shroud support shall also take into account the restraining effect of the components attached to the support and the weight and earthquake loading as shown on Figure C-4.

(b) The drain nozzle shall extend 12 to 16" below the bottom of the reactor vessel and shall be of the full penetration design.

6. External Attachments

(a) Brackets to support insulation shall be provided on the exterior of the reactor vessel in accordance with Figure C-7.

(b) Provisions shall be made for the attachment of thermocouples in mounts on the reactor vessel exterior as specified on Figure C-8.

VI MATERIALS

1. All materials to be used shall be indicated on the CB&I drawings. CB&I shall submit for General Electric approval, all material selections and material purchasing specifications.

2. Records

CB&I shall maintain complete records showing use of all materials so that it will be possible to relate every component of the finished reactor vessel to the original certification of the material and the fabrication history of the component. CB&I shall prepare a summary of the heat number, chemical composition and mechanical properties for each reactor vessel component.

3. Forgings

Low alloy steel forgings for pressure parts shall be made in accordance with ASTM A508 in accordance with ASME Code Case 1332-3, Paragraph 5. Nozzles which are partial penetration welded may be nickel-chromium-iron forgings made in accordance with ASME SB-166 modified in accordance with Code Case 1336. Forging ingots shall be produced by vacuum degassed pouring.

4. Plate

Plate for pressure parts shall be in accordance with ASTM A533 Class 1, Grade B Firebox Quality in accordance with ASME Code Case 1339-2. Plate ingots shall be produced by vacuum degassed pouring.

5. Castings

The use of castings will be considered by General Electric but specific General Electric approval shall be required. Castings for pressure parts shall be made in accordance with ASME SA-356, Grade 10, Code Case 1333, Paragraph 1.

6. Material for pressure parts shall be selected and worked to produce as fine a grain size as practical. It shall be an objective of the fabrication technique to retain a grain size of 5 or finer in all material. Grain size shall be determined by the method in ASME E112.

7. Heat Treatment

Heat treatment of carbon and low alloy steel pressure parts shall consist of normalizing and then tempering at not less than 1200° F. For section thickness over 3 inches nominal, heat treatment shall consist of accelerated cooling from the austenitizing temperature to below the martensite finish temperature followed by tempering at not less than 1200° F to obtain tensile and impact properties comparable to those developed by normalizing and tempering section thickness of less than 3 in. nominal.

8. Mechanical Properties

The low alloy steel forgings, plate and castings for pressure parts shall be tested in accordance with Paragraph VIII-3, below, and shall have the mechanical properties required therein in addition to those required by the applicable ASME Specification.

9. Studs, Nuts, Bushings, and Washers for Main Vessel Closure

(a) Studs shall conform to ASME SA320, Grade L43 and ASME Code Case 1335, Paragraph 4, Class 3, 4, or 5.

(b) (b) Nuts, bushings and washers shall conform to ASME SA320, Grade L43, and Code Case 1335, paragraph 4, Class 3, 4, or 5 but to suit the stud material used and to have a minimum difference in hardness of 5 Rockwell C points from the stud material.

(c) Hardness and impact properties shall meet the requirements of paragraph VIII-3, below.

10. Cladding Material

All internal carbon and low alloy steel surfaces of the reactor vessel including the closure head, closure head flange mating surface, shell flange and mating surface, shell, bottom head, nozzles for connecting stainless steel piping, and internal attachments shall be clad with weld overlay meeting the following requirements:

(a) Weld overlay cladding shall be a minimum of 0.125 inches total thickness. The finished surface shall have a composition equivalent to ASTM A371, Type ER308 or A240 Type 304 except the carbon content shall not exceed 0.08%.

(b) Cladding in the "as-clad" condition is acceptable, provided the resulting surface finish does not interfere with the ultrasonic and liquid penetrant test requirements.

(c) The sealing surfaces of the reactor vessel head and shell flanges shall be weld overlay clad with austenitic stainless steel which consists of a minimum of two layers and a minimum of 0.25 inch total thickness. The first layer shall be deposited with an analysis equivalent to ASTM A371, Type ER309. The second and subsequent layers shall have a composition equivalent to ASTM A371, Type ER 308, except the carbon content shall not exceed 0.08%. Minimum thickness of 1/4 inch shall apply after all machining, including area under groove.

11. Attachments

(a) Internal attachments other than the weld clad ferritic attachments shall be annealed stainless steel, Type 304 per ASTM A240 or ASTM A276, or Type F304 per ASTM A182. The core support structure shall be stainless steel clad low alloy or carbon steel or solid nickel-chromium-iron alloy per ASME SB166, 167, or 168.

(b) External attachments to the reactor vessel shall be of the same material as the reactor vessel base material, or shall be of a material which has mechanical and impact properties compatible with the base material. Where welds must be made to the attachments in the field, the material selected shall not require pre-heat or post-weld heat treatment.

12. Nozzle Safe Ends and Flanges

(a) Nozzle ends for austenitic pipe shall be ASTM A336, Class F8 or F8m; A240, Type 304, or Type 316; or A376, Type 304 or Type 316 solution heat treated stainless steel, depending upon the mating pipe material selected by the Buyer. Nozzle ends for carbon steel pipe shall be ASTM A105, Grade 11, forgings except phosphorous content shall be 0.035% Max. and sulphur 0.040% Max. Proportions shall be shown on Figure C-6.

(b) Standard flanges for flanged nozzles and separate mating flanges shall be ASTM A182, Grade F304, stainless steel.

(c) Studs for standard flanges shall be SA193, Grade B7. Nuts for standard flanges shall be SA194, Grade 2H.

13. Pipes and tubes shall be ASTM A213, A249, A312, A376, solution heat treated, Grade TP304 or TP316; or A240, Type 304 plate welded and radiographed in accordance with ASME Code, Section III, Paragraph N624.

14. Miscellaneous bolting material shall be subject to General Electric's approval.

15. Weld Electrodes and Rods

(a) Material for weld electrodes and rods shall be selected from ASTM A233, A298, A316, A371 or equivalent for other processes and submitted to General Electric for approval.

(b) All austenitic stainless steel welds and weld cladding shall contain controlled amounts of ferrite, confirmed by quantitative tests. The procedures for control of, and testing for the ferrite content of welds and weld cladding shall be submitted to General Electric for approval. The acceptance standard for quantitative tests shall be either % Cr = 1.9 x % Ni, or 5% ferrite minimum.

16. Alternate Materials

CB&I shall be free to suggest alternate materials during preparation of detailed drawings and shall bring such alternates to the attention of General Electric, but shall not make substitutions without approval of General Electric. Request shall include:

(a) Reason for substitution.

(b) Identification of the component or parts involved.

(c) Either the complete material specification similar to ASTM for each type and form of proposed material, or the information as follows:

(1) Type of Service (Structural, High/Low Pressure, Temperature, Weldable).

(2) Manufactured Form (Pipe, Plate, Tube, Bar, Bolting).

(3) Size, Thickness Limits.

(4) Allow Grades (C-Steel, Alloy Steel, Stainless Steel Designations).

(5) Steel-Making Process (Open Hearth, Basic Electric).

(6) Forming Process (Hot Forged, Hot/Cold Rolled, Drawn, Seamless Welded, Cast).

(7) Heat Treatment, Stress Relief Parameters.

(8) Type, Location and Number of Mechanical Tests (Tensile, Bend Homogeniety, Hydrostatic).

(9) Mechanical Property Acceptance Limits.

(10) Chemical Composition Acceptance Limits.

(11) Inspection Requirements such as: Radiography, Liquid Penetrant, Magnetic particle, Ultrasonic, Including Acceptance Limits.

(12) Surface Finish Acceptance Limits.

(d) Allowable Stresses (If not an ASME Material)

(e) For major pressure parts, additional information will be required regarding details of previous applications of the material, impact strength, NDT temperature, micro-structure

variations, creep, stress rupture, hardness, radiation damage, welding, forming, corrosion and temperature effects as applicable for engineering evaluation of the application and as required for code purposes.

VII FABRICATION

1. Procedures

(a) CB&I shall submit for General Electric's approval, all of the following procedures and procedure specifications:

(1) Heat treatment procedures for all thermal processes exceeding 800° F after the mill rolling or forging or foundry casting operation.

(2) Forming and bending procedures for all forming during fabrication subsequent to mill forging or rolling or foundry forming and cladding.

(3) Welding and weld repair procedures including temporary welds as required in accordance with the ASME Code, Section IX, Paragraphs Q-10 and 11, and QN-10 and 11, Section III, Paragraph N-540.

(4) Method of qualifying welding procedures and performance, if other than ASME Code, Section IX and III.

(5) Repair procedures for major and minor defects as defined in Paragraph 4, below.

(6) Drawings showing location and preparation of test specimens, including specimens required in attached list.

(7) Fabrication schedule including the detailed sequence to be followed in fabrication of the vessel.

(8) All cleaning procedures, preserving procedures and a list of cleaning agents and preservatives together with their chemical content which shall be used during fabrication and in preparation for shipment. In lieu of a complete chemical analysis, General Electric shall accept a report which states the chlorides, fluorides and sulfur content. Other harmful elements should also be reported.

(b) All work by CB&I or its sub-suppliers shall be performed in accordance with General Electric approved drawing, and fabrication and test procedures.

2. Material Cutting

(a) Stainless steel and carbon steel shall be cut to size or shaped by machining, shearing or thermal cutting.

(b) Thermal cutting of stainless steel shall be followed by the removal of approximately 1/32" depth from the cut surface. Thermal cutting of carbon steel shall be followed by the removal of oxides.

3. Welding

(a) The reactor vessel base material pre-heat and interpass temperature shall be as specified in the welding procedures, but in no case less than 300° F, except weld overlay pre-heat which shall be no less than 200° F. Pre-heat temperature shall be maintained after welding until start of post-weld heat treatment. Pre-heating techniques shall be such as to ensure that the full thickness of the weld joint preparation and adjacent base material is at the specified temperature for the distance of "T" or two inches, whichever is greater, where "T" is the material thickness.

(b) When stainless steel or nickel-chromium-iron alloy is welded to itself or to each other, no pre-heat is required, except when the heat-affected zone reaches ferritic base material as in the cases of welding to buttered nozzle ends or cladding. When the buttering or cladding is less than 1/4 inch thick, pre-heat to at least 200° F is required, followed by post-weld heat treatment except that subsequent welding to cladding greater than 1/8 inch thick may be done without preheat if the specific welding procedure is qualified to show that the heat affected zone does not reach the base metal.

(c) All surfaces (to be welded) shall be free of cavities or protrusions which may interfere with the welding procedure.

(d) Pre-heat, welding and post-weld treatment shall be planned and conducted to minimize undue distortion or warping of the parts and preclude cracking.

(e) Machined surfaces and threads shall be protected against weld splatter.

(f) Stainless steel welds shall be cleaned with stainless steel wool or stainless steel brushes before adding the next bead and following the final bead to facilitate inspection. The light oxide discoloration which forms on the weld surface need not be removed.

(g) Welds shall be cleaned of slag and flux between passes and following the final deposit.

(h) Any cracks, blow holes, or other defects which appear on the surface of weld beads shall be removed by machining, chipping, grinding, or arc gouging. Austenitic weld repairs, if arc gouged shall be followed by grinding. Austenitic welds shall not be peened; ferritic welds may be peened under controlled conditions after approval by General Electric.

(i) Wide welds to overcome poor fit are not permissible. Poor fits shall be remedied by suitable means, such as re-grooving, and the remedy approved by General Electric. Except for small cavities, CB&I shall not correct a plate edge deficiency unless approved by General Electric. General Electric may require radiography or other methods of examination of welds used to correct plate edge deficiencies.

(j) Post-weld heat treatment temperature shall be between 1100° and 1175° F. Interstage post-weld heat treatment holding time shall be 15 minutes minimum. Final post-weld heat treatment holding time shall be one hour per inch of thickness, minimum.

4. Repair of Defects

Repair procedures shall be prepared for the repair of all defects. Major defects shall require prior approval by General Electric and may require witnessing by General Electric's representative. Major repair is defined as (1) a repair to material other than weld metal which requires an excavation greater than 3/8" deep or 10% of the wall thickness, whichever is less; (2) the repair of any cracks, other than crater cracks, in any material or weld metal; and (3) the repair of any defect which is indicative of either a fundamental material problem or a process out of control. A minor repair is defined as all other repairs.

5. Cleaning

(a) Interior Surfaces

Interior surfaces of the reactor vessel shall be thoroughly cleaned to be visibly free of lubricant, weld spatter, chips, imbedded iron particles and other foreign materials. It is the general intent that the vessel shall be constructed in such a manner that final cleaning may consist of sweeping, degreasing and flushing with tap water. After the interior is cleaned and dried, the reactor vessel body and top head shall be sealed to prevent entry of dirt or other foreign material. The seals used on the reactor vessel nozzles shall not affect the weld preparation or flange faces of the nozzles.

(b) Exterior Surfaces

Exterior carbon steel surfaces shall be cleaned of oil and grease after which mill scale, rust, rust scale, paint and other foreign matter shall be thoroughly removed by such means as sandblasting. All surfaces shall be brushed or air cleaned to remove all traces of sand or grit and shall then be dried and painted. Sufficient coats of Superior Primer Lead #1746, International

Paint Co., or an equal approved by General Electric, shall be applied to all exterior surfaces to assure complete coverage and sufficient protection from the weather. The temperature shall be at least 50° F when the surfaces are painted.

VIII INSPECTION AND TEST

1. General

CB&I shall submit for General Electric's approval, the following inspection and test procedures:

(a) Ultrasonic Examination Procedure for the following:

(1) Forgings

(2) Plate

(3) Welds

(4) Weld build-up

(5) Cladding

(6) Tubular Products

(b) Magnetic Particle Examination Procedures for the following:

(1) Carbon steel and low alloy steel forgings

(2) Carbon steel and low alloy steel welds

(3) Weld build-ups

(4) Bolting

(5) Carbon steel and low alloy steel tubular products

(6) Carbon steel and low alloy steel castings

(7) Edge preparations of carbon steel and low alloy steel materials.

(c) Liquid Penetrant Examination Procedures for the following:

(1) Austenitic Forgings

(2) Austenitic welds

(3) Austenitic weld buildup

(4) Cladding

(5) Austenitic tubular products

(6) Austenitic castings

(7) Edge preparations of austenitic materials

(d) Radiographic examination procedures for welds and castings for each type of radiographic source.

(e) Hydrostatic Examination Procedures

(f) Leak Check Procedures

(g) Methods, processes and equipment to be used in establishing "as-built" dimensions and alignment checks which are not generally used in a typical industrial shop.

2. Definitions

(a) "As-Fabricated" Specimens

"As-fabricated" specimens are mechanical test specimens taken from carbon and low alloy steel forgings and plates used in the vessel fabrication from each heat and heat treatment lot and from welds between base material made by each welding procedure used and in a thickness equal to or greater than the thickest weld made with each procedure. Coupons for "as-fabricated" specimens shall be taken from the forgings or plates following all hot working or forming and all heat treatment except post-weld heat treatment. These coupons shall then be subjected to a post-weld heat treatment equivalent to the treatments which the parts it represents will receive in the completed vessel. This shall consist of holding the coupon at the post-weld heat treatment temperature for a time equal to or greater than the longest accumulated time any part it represents shall be at the post-weld heat treatment temperature.

(b) "1/4T x T" Location

The "1/4T x T" location of specimens is defined as a location within the material no closer than "1/4T" from one quenched surface, and no closer than "T" from any other quenched edge, where "T" is the nominal thickness of the material.

(c) NIL-Ductility Transition (NDT) Temperature

The nil-ductility transition (NDT) temperature is defined as the temperature at which a specimen is broken in a series of tests in which duplicate no-break performance occurs at a temperature 10° F higher, when tested in accordance with ASTM E208.

(d) Impact-Transition Curve

A curve representing breaking energy vs. temperature from at least twelve Type A Charpy-V specimens, tested in accordance with ASTM A370, except each specimen tested at a different temperature. The temperature range of testing shall establish the upper plateau, the transition region, and the lower plateau. Each plateau shall be determined by at least one, but not more than two points. The remaining specimens shall be used to develop the transition region. The lower plateau need not be developed if it occurs below -80° F.

(e) A "lot of material" consists of all material from one heat (one melt) in a heat treatment furnace.

3. Material Mechanical Tests

(a) Mechanical Properties

(1) Impact properties of all carbon and low alloy steel used in the main closure flanges and the shell and head materials connecting to these flanges shall meet the requirements of the ASME Code, Section III, Paragraph N-330 at a temperature no higher than 10° F. In addition, this material shall have an NDT temperature no higher than 10° F as determined per ASTM E208.

(2) Impact properties of all other "as-fabricated" carbon and low alloy steel pressure containing material and the vessel support skirt material shall meet the requirements of the ASME Code, Section III, N-330 at a temperature no higher than 40° F. In addition, this material shall have an NDT temperature no higher than 40° F as determined per ASTM E208. The actual NDT temperature of all material opposite the center of the active fuel of the core as indicated on Figure C-1 shall be determined.

(3) Tensile test properties of all materials shall be inspected and tested to meet the requirement of the applicable ASME Code or ASTM specification.

(4) Test data shall be reported to General Electric.

(b) Required Number and Specimen Location

The number and location of tensile and impact test specimens required shall be per ASME Code, Section III, N-313.2 and the following depending on the form of the material. The following tests may be integrated with the tests required by the ASME Code and ASTM Specification wherever possible.

(1) Vessel Flange and Head Flange Forgings

Tangential specimens, as-fabricated, shall be taken from locations per ASME Code, Section III, N-313.2 (d) (2). A total of at least 2 tensile, 6 Charpy-V impact and 4 drop weight specimens shall be tested for each flange from which 1 tensile, 3 Charpy-V impact and 4 drop weight specimens shall be located approximately 180° from the other specimens. The material shall meet the requirements of paragraph VIII-3(a), above.

(2) Low-Alloy Steel Nozzle Forgings

Specimens, as fabricated, shall be taken from locations per ASME Code, Section III, N-313.2 (d) for forged nozzles. At least 2 tensile, 3 Charpy-V and 2 drop weight specimens shall be tested for each heat and heat treatment charge, except that nozzles with wall thickness of less than 4 inches and outside diameter less than 12 inches shall not require drop weight testing. The material shall meet the requirements of Paragraph VIII-3(a), above.

(3) In addition to the tests required by the ASME Boiler and Pressure Vessel Code, longitudinal specimens (parallel to the primary rolling direction), as-fabricated, shall be taken from the 1/4T x T location. At least 2 drop weight specimens shall be tested from the top end (top as determined by ingot pouring) or each mill rolled plate and each heat treatment charge. The material shall meet the requirements of Paragraph VIII-3(a), above. Additional drop weight specimens shall be required for NDT temperature determination per Paragraph VIII-3(a)(2), above, for plates located opposite the center of the core.

(4) Castings

Tangential specimens, as-fabricated, shall be taken from locations per ASME Code, Section III, N-313.2(d). Castings 1000 lb. weight and under shall have a total of 1 tensile specimen, 1 metallographic specimen, and 3 Charpy-V and 2 drop weight specimens, tested for each heat and heat treatment charge. Castings over 1000 lb. weight shall have a total of 2 tensile specimens, 2 metallographic specimens, 6 Charpy-V and 4 drop weight specimens tested from which 1 tensile specimen, 1 metallographic specimen, 3 Charpy-V and 2 drop weight specimens shall be taken 180° apart and/or diagonally opposite. The metallographic specimens shall be for reference only. Additional drop weight specimens shall be required for NDT temperature determination in accordance with paragraph VIII -3(a)(2), above, if the casting is located in the core area. The material shall meet the requirements of paragraph VIII-3(2), above.

(5) Studs, Nuts, Bushings and Washers for Main Vessel Closure

Hardness tests shall be made on all main vessel closure bolting to demonstrate that heat treatment has been performed. Studs, nuts and bushings shall be hardness tested individually. One sample from each lot of washers shall be hardness tested. Impact tests required by ASME Code, Section III, paragraph N-330 shall meet the Code requirements at a temperature no higher than 10° F. In addition to the magnetic particle or liquid penetrant acceptance standards specified in ASME Code, Section III, paragraph N-325, axial defects of less than thread depth shall be investigated to determine their nature. Any cracks or sharply defined linear indications are unacceptable.

4. Welded Base Material - Mechanical Tests

(a) ASME Code Weld Test Plates

CB&I shall prepare and test weld coupons of Category A and B joints in accordance with ASME Code, Section III, N-713. The impact test temperatures shall be determined in accordance with paragraph VIII-3(a), above. In addition to the tests required by the Code, 6 drop weight specimens shall be taken from the 1/4T x T location from these plates and, if different welding procedures are used, from plates for base material to base material welds of Category D joints as defined in ASME Code, Section III, N-461. Two each of the drop weight specimens shall represent the base metal, heat affected zone and weld metal. The specimens shall meet the requirements of paragraph VIII-3(a), above. Additional drop weight specimens shall be required in accordance with paragraph VIII-3(a)(2), above, if the welding procedure is to be applied in the area opposite the core.

(b) One of the test plates of Category A or B required in (a) above shall be selected by General Electric for the fabrication tests required in Attachment A, Paragraph 2. CB&I shall perform all required tests and reports. These tests are for information only, but time is of the essence and the tests should be performed and results reported as early as practical.

(c) CB&I shall prepare and ship, but not test, Surveillance Test Program material and specimens in accordance with Attachment A, Paragraph 3.

(d) Flange Forging Weld Test Plate

In the event the vessel and head flanges are made by welding two or more forged segments, CB&I shall prepare a weld test plate from the forging material. Impact and tensile specimens shall be prepared and tested. The specimens shall be prepared from material in the weld-heat-affected zone and from the weld metal. Test results shall meet the requirements of paragraph VIII-3(a), above.

5. Ultrasonic Inspection

(a) Ultrasonic inspection of plate and forged material shall be performed in accordance with ASME Code, Section III, except that ASME Case Interpretation 1338-2, Alternate 2 shall not be acceptable, and the plate material testing shall be a 100 percent volumetric inspection and shall be performed after forming and heat treatment. The following acceptance criteria shall apply in addition to code requirements. A defect which causes any echo indication that exceeds 50 per cent of the indication from the calibration standard and that is continuous during movement of the transducer more than 3 inches in any direction shall be unacceptable. A chart shall be maintained of defects with 50 per cent or greater loss of back reflection.

(b) Prior to connecting any attachment, support or bracket, except insulation and thermocouple brackets, to the interior or exterior of plate portions of the vessel by means other than groove welds below the plate, the plate shall be ultrasonically inspected. The plate shall be inspected to a depth at least equal to the thickness of the part being joined, and over the entire area of the subsequent connection plus a band all around this area of width equal to half the thickness of the part being joined. The inspection shall be in accordance with ASME Code, Section III, Paragraph N-321, using longitudinal wave technique. The surface shall be 100 per cent inspeced with the transverse interval being no greater than 90 per cent of the crystal diameter.

(1) Reference Standard

CB&I shall prepare a reference standard which consists of a flat bottom hole having a diameter equal to one-quarter of the thickness of the part being joined or 1/4 inch diameter whichever is greater. The bottom of the hole shall be one thickness of the part being joined below the plate surface. This reference standard shall be used for calibration purposes.

(2) Acceptance Standards

Any defect which produces a trace line pattern equal to or in excess of the appropriate reference standard shall be unacceptable.

(c) The main closure stud, nut, bushing and washer material shall be ultrasonically tested following heat treatment and rough machining to 125 rms or better finish using both longitudial and shear wave techniques. Longitudinal wave examination shall be performed on 100% of the cylindrical surface, and in addition on stud material from both ends of each stud. The longitudinal wave transducer shall have a maximum diameter of 1/2 inch. Shear wave examination shall be performed on 100% of the outer cylindrical surface in both axial and circumferential directions.

(1) Reference Standards

CB&I shall prepare a reference standard of the same material, thickness and curvature as the part being examined. The reference standard shall contain calibration features as follows:

a. Longitudinal Wave-Radial Scan: 1/2 inch diameter flat-bottom hole having a depth equal to 10% of the material thickness.

b. Longitudinal Wave-End Scan: Flat-bottom hole with area equal to 1% of stud cross-section or 1/4 inch diameter, whichever is smaller, having a depth of 1/2 inch.

c. Shear Wave: Square bottomed notches 1 inch long and 3% of the part thickness in depth, both axial and circumferential.

(2) Acceptance Standards

Any defect which produces a trace line pattern (echo indication) greater than the indication from the applicable calibration feature shall be unacceptable. A distance-amplitude curve may be used for the longitudinal wave examination. The curve may be a line established by plugging the hole and examining it from both sides of the material. For end examination of studs the curve may be established for half the stud length and applied to an examination from each end to the center

6. Cladding

(a) Ultrasonic Inspection - Cladding General

(1) The cladding bond shall be tested with the transducer on the clad side using a suitable couplant. The entire clad surface shall be inspected at intervals 1.4 times the base material thickness, but not greater than 12 inches, transverse to the direction of welding.

(2) Reference Standard

CB&I shall prepare a reference standard which consists of a flat bottom groove in typical clad plate. The groove shall be 0.35 inch maximum width by at least one crystal diameter long, parallel to the direction of welding. The groove shall be formed by machining the base metal within 1/32" of the cladding interface and etched with nitric acid to remove excess ferritic material from the interface. This reference standard shall be used for calibration purposes.

(3) Acceptance Standards

Cladding which produces a trace line pattern equal to or in excess of the appropriate Reference Standard shall be unacceptable if a continuous pattern occurs during movement of the transducer more than three inches in any direction or if one or more patterns occur during movement of the transducer less than one inch in any direction from the boundary of any one pattern.

(b) Liquid Penetrant Inspection - Cladding General

All clad areas and clad repairs shall be liquid penetrant inspected per ASME Code, Section III, N-627. The following indications shall constitute unacceptable defects and shall be repaired.

(1) Any crack-like indications or incomplete fusion.

(2) Linearly-disposed spot indications of 4 or more spots spaced 1/4 inch or less from edge to edge of the indication.

(3) Spot indications which are indicative of defects greater than 1/32 inch deep as revealed by bleed-out.

(c) Ultrasonic Inspection - Cladding Special Areas

(1) The flange seal surfaces shall be inspected for bond to the flanges as per paragraph VIII -6(a), above, except that the inspection shall be over 100 per cent of the area. Prior to final machining the volume 1/8 inch above and below the surfaces on which the double seals will seat shall be 100 percent inspected for defect using longitudinal wave technique. The acceptance criteria shall be that any defect which produces a trace line pattern equal to or in excess of a 1/16 inch flat bottom hole may be unacceptable.

(2) The final machined surfaces on which the double seals seat shall be inspected by surface wave technique. Any defect producing a signal greater than the signal produced by the 0.002 inch deep by 1/8 inch long spark machined groove in a reference standard which the CB&I shall furnish may be cause for rejection depending on location.

(d) Liquid Penetrant Inspection - Cladding Special Areas

The area of the flange seal surfaces on which the double seals seat shall be liquid penetrant inspected per ASME Code, Section III, N-627, except that any indication of any type shall be unacceptable.

(e) Magnetic Particle Inspection - Plate Material

Both internal and external surfaces of all low alloy steel plate material shall be magnetic particle inspected per ASME Code, Section III, Paragraph N-626 following forming and heat treatment. The acceptance standard of ASME Code, Section III, Paragraph N-625.5 shall apply.

(f) Openings in Pressure Parts

(1) The entire surface of all openings for partial penetration nozzles, regardless of size, except for the seal leak detection connection, shall be examined in accordance with ASME Code, Section III, N-513.

(2) The entire surface of the finished stud holes in the head flange and the holes in the vessel flange prior to tapping shall be examined by the methods of ASME Code, Section III, N-513. Any indication of cracks or linear indications shall be reported to General Electric for information. Any crack or linear indication may be subject to removal and repair if required.

7. Welds

(a) Radiographs

(1) Use of gamma rays shall be subject to approval by General Electric.

(2) Films shall be suitably marked to identify the weld. Film identification markings shall coincide with the detail drawing markings for each weld.

8. Hydrostatic Tests

(a) Code Test

After completion of fabrication the reactor vessel shall be pressure-tested in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Paragraph N-714. Reactor vessel material temperature shall be at least 100° F. In no case, however, shall the water temperature be higher than 200° F. Suitable gasket material instead of metal "0"-rings may be used for this test.

(b) Second Hydrostatic Test

Following the Code test, the vessel shall be hydrostatically tested at design pressure with new metal "0"-rings. This test shall demonstrate that the head seal meets the sealing requirements. Relative displacement and rotation of the head closure flanges during this test shall be measured in at least twelve places and reported to General Electric. The measurements shall be made prior to stud tightening and at 250 psi intervals from zero psi to the design pressure.

(c) During the course of the second test, the translation and rotation from the reactor vessel vertical centerline of the control rod penetrations in the bottom head shall be measured for at least four of the outermost holes at 250 psi intervals from zero psi to the design pressure and reported to General Electric.

9. Bolt-up and Unbolting Times

The placing of the head, tightening the studs to operating bolt-up loads, unbolting and removal of the head over the studs shall be demonstrated. The elapsed times for each step shall be recorded.

10. Final Inspection

Final inspection after hydrostatic test per ASME Code, Section III, N-618 shall include seal surfaces and the nozzle weld preparations.

IX SHIPMENT

1. Small Parts

Small, loose pieces, including bolting, tools, gaskets, etc., shall be adequately crated or boxed for protection during shipment. Parts subject to rusting shall be suitably protected. All pieces shall be marked with the equipment piece number or mark specified by General Electric.

2. Shipping Weights and Dimensions

Estimated shipping weights and overall clearance dimensions of all major pieces to be shipped to the erection site shall be shown on the drawings when submitted to General Electric for approval.

3. Shipping Skids

Shipping skids for components shall be designed to support the components adequately and securely during shipment to the erection site and to account for the means of movement lifting, and positioning to be provided by CB&I at the erection site.

X SUBMITTALS

1. Tabulation

Fabrication, qualification and inspection procedures, reports, processes, and calculations to be submitted to General Electric are tabulated below. This tabulation shall in no way be construed as being complete or limiting the documents necessary to meet the requirements of this specification.

Heat treatment procedure.

Forming and bending procedure.

Welding and weld repair procedure specification.

Repair procedures.

Cleaning and preserving procedures.
Ferrite content or Ni/Cr ratio control procedure.
Ultrasonic examination procedure.
Magnetic particle examination procedure.
Liquid penetrant examination procedure.
Radiographic examination procedure.
Hydrostatic examination procedure.
Leak Check Procedure.
Measurement reports.
Summary reports.
"As-built" dimensions and alignment checks procedures.
Design analysis calculations.
Material purchase specifications.
Material selections.

2. The following shall be submitted.

(a) Drawings

(1) Outline Drawings - A drawing depicting the outline of the reactor vessel indicating over-all dimensions, location and size of nozzles, location of supports, shipping and operating weights.

(2) Assembly Drawings - A section drawing depicting the arrangement of the functional parts, parts list and material designation.

(3) Detail Drawings - Drawings for details of construction such as weld preparations, surface finishes, finished dimensions, nozzles lifting attachments, insulation attachments, thermocouple pads, flanges and supports.

(4) Drawings for Approval - Outline, assembly and detail drawings shall be submitted for approval. The detail drawings submitted shall be for design details enumerated in (3), above, which are required for coordination with piping and structure and design details which are at variance with the code or these General Electric "Engineering Requirements".

(5) Controlling Location Arrangement Drawings

One or more drawings shall be devoted exclusively to outline dimensions such that mating components designed and supplied by others such as piping, anchor bolts, instruments, etc., may be procured for an exact fit with the reactor vessel assembly. These drawings shall show reference to the controlling detail drawings and show over-all dimensions and locations on reactor vessel.

(6) Drawings to be Ceritified - Outline, Assembly and Detail drawings for design coordination shall, upon completion of the design, be certified to be correct with no further changes required. No alterations may be made to the design after certification without the approval of General Electric.

(7) As-Built Drawings - CB&I shall provide an outline drawing with the previously designated actual measured significant dimensions. The accuracy of as-built measurements shall be at least 25% of the tolerance of the dimension measured. If the final construction differs from the previously submitted assembly and detail drawings, corrected drawings shall be provided by CB&I.

(b) Instruction Manuals

(1) Instruction manuals shall present the following basic categories of information in a practical, complete and comprehensive manner, prepared for use by operating and/or maintenance personnel:

a. Instructions for making up the head closure seal for: 1) Normal Operation and 2) Hydrostatic Tests.

b. Instructions for opening up the head closure.

c. Instructions for operating, maintenance and repair of all tools provided.

d. Recommended maximum heating and cooling rates with maximum allowable temperature differences between the various thermocouple locations.

e. Recommended inspection points and period inspection.

f. Ordering instructions for all replaceable parts, gaskets, etc.

(2) The information shall be organized in a logical and orderly sequence. A general description of the equipment including significant technical characteristics shall be included to familiarize operating and maintenance personnel with the equipment.

(3) Necessary drawings and/or other illustrations shall be included or copies of appropriate certified drawings may be bound into the manual. Test, adjustment and calibration information, as appropriate, shall be specified and identified to the specific equipment. Safety and other warning notices and installation, maintenance and operating cautions shall be emphasized.

(4) A parts list shall be included showing part nomenclature, manufacturer's part number and/or other information necessary for accurate identification and ordering of replacement parts. Common hardware items or other parts to be locally procured shall be adequately identified by technical description.

(5) Instructions and parts list shall be clearly legible and prepared on good quality paper; carbon copies and tissue copies or other flimsy material are not acceptable. Multiple page instructions shall be securely bound.

(6) If a standard manual is furnished covering more than the specific equipment purchased, the applicable model (or other identification) parts and other information for the specific equipment purchased shall be clearly identified.

(c) Photographs

CB&I shall provide General Electric with sets of progress photographs of the vessel at each significant stage of fabrication. One set shall consist of one negative and three glossy 8" x 10" prints.

(d) Engineering Schedule

(e) Fabrication Schedule

3. Records

CB&I shall maintain records of all material qualifications, all weld and welder qualifications and all process qualifications required by this specification and the material specifications. In addition, CB&I shall maintain records of all tests and inspections (e.g. - ultrasonic, radiography and hydrostatic). A list of the records shall be submitted to General Electric on completion of the job. General Electric shall be able to obtain certified copies of such records for a five-year period. Where CB&I considers the actual test records to be proprietary, it shall submit certified reports containing all pertinent test data excerpted from the actual test reports. These certified test reports shall also be available for a five year period.

ATTACHMENT A - MATERIAL TESTS AND TEST SPECIMENS

I SCOPE

CB&I shall retain selected portions of the material used to fabricate the reactor vessel of this contract. CB&I shall process some of this material into finished mechanical specimens which shall be in metallurgical conditions representative of the following as-fabricated reactor vessel material: Base-Plate, Welds and Heat-Affected Zone. CB&I shall test some of these specimens for "Fabrication Tests" to determine the effect of thickness on the mechanical properties of the material. The remainder of the specimens and the remainder of the selected test material shall be prepared for shipment. These latter specimens will be used for "Surveillance Tests" to monitor the effect of neutron irradiation on the mechanical properties of the reactor vessel steel.

II FABRICATION TEST PROGRAM

1. Material

(a) The fabrication test material shall be representative of the formed, heat-treated, and full-fabricated reactor vessel, and shall be removed from one of the heats of plate material used in the reactor vessel construction, but need not necessarily be from a plate which becomes a part of the reactor vessel.

(b) The fabrication test material shall be documented as to chemistry, thermal history, degree of hot and/or cold work, and welding.

2. Description

(a) CB&I shall perform fabrication tests of base metal and welded joint. The results of the fabrication tests shall be reported during the early stages of reactor vessel construction. All of the fabrication test specimens shall be removed from the same plate.

(b) CB&I shall make and test .505 inch diameter tensile specimens with the gage length in the tangential direction of the shell plate material. Tensile specimens shall be prepared from the O.D., 1/4T, 1/2T, and 3/4T thickness levels of the plate material. Each thickness level shall be tested at room temperature, 550° F, and 650° F per most recent ASTM Specifications E8 and E21. These specimens shall be tested at each temperature for each thickness level. The tensile strength, yield strength, elongation, and reduction of area shall be reported.

(c) CB&I shall make and test, per most recent ASTM Specification E8, six tensile specimens whose gage diameter is at least 80% of the reactor vessel wall thickness.

(1) The gage length to gage diameter ratio of the specimens shall be no less than 3 to 1. Tests shall be conducted at room temperature. Stress-strain curves, tensile strength, yield strength, elongation, reduction of area and macrophotographs of the breaks shall be reported for each specimen tested.

(2) Where the reactor vessel wall courses are made from rolled plate with a longitudinal weld, three specimens shall be made from a base metal test plate with their gage lengths oriented to a vessel wall tangential direction and three specimens shall be made from a test plate simulating a vessel longitudinal weld with their gage lengths across the weld.

(3) Where the reactor vessel wall courses are made of forged rings, three specimens shall be made from a base metal test plate with their gage lengths oriented to a vessel wall longitudinal direction and three specimens shall be made from a test plate simulating a vessel girth weld with their gage lengths across the weld.

(d) CB&I shall make and test Charpy V-Notch impact specimens (ASTM E23, Type A) entirely from base material to establish curves for determining the 30 ft.-lb. transition temperature at the O.D., 1/4T, 1/2T, and 3/4T thickness levels of the plate material. The energy data, fracture appearance data and lateral expansion data for each individual specimen shall be reported. The data from each individual specimen shall be reported. There shall be at least six points reported within the 20 to 40 ft.-lb. range, and at least three testing temperatures represented within the range. In addition to the above the Impact Transition curves shall conform to Paragraph VIII-2 (d) of "Engineering Requirements."

III SURVEILLANCE TEST PROGRAM

1. <u>Base Metal - Figure C-11</u>

(a) CB&I shall furnish two plates, as shown in Figure C-11, from the plate used to make the reactor vessel in the reactor core region, or from a similar plate from the same heat.

(b) CB&I shall heat treat these plates with the reactor vessel, or in similar fashion, to insure that they represent the metallurgical condition of the vessel steel, in the core region of the completed reactor vessel including all post-weld heat treat cycles seen by that region.

(c) CB&I shall furnish documents to General Electric showing the location of the test plates and detailing all metallurgical data concerning the test plates.

(d) CB&I shall make mechanical test specimens, as outlined below. from one of these plates and send the other to General Electric.

2. Welded Plate - Figure C-12

(a) CB&I shall furnish a welded plate representative of a reactor vessel longitudinal weld, if the reactor vessel is formed from plate or representative of a reactor vessel girth weld if the reactor vessel is formed from forged rings. See Figure C-12. The sample shall be from the plate used to make the reactor vessel in the reactor core region, or from a similar plate from the same heat.

(b) CB&I shall heat treat the plate with the reactor vessel, or in similar fashion, to insure that it and the weld represent the metallurgical condition of a vessel weld, in the core region of the completed reactor vessel including all post weld heat treatment cycles seen by that weld.

(c) CB&I shall furnish documents to General Electeic showing the location of the test plates, detailing all metallurgical data and demonstrating that the weld was made in a manner similar to a reactor vessel weld. X-rays of the weld shall be furnished.

(d) CB&I shall make mechanical test specimens, as outlined below, from half of the plate and shall supply the other half to General Electric.

3. Surveillance Specimen Fabrication

(a) CB&I shall provide a detailed plan of specimen preparation for General Electric's approval prior to the start of any work required by this attachment. General Electric can furnish a plan which CB&I may use as a guide. CB&I shall be specific in indicating how the notch location of the Heat-Affected Zone Charpy specimens will be determined.

(b) All specimen cutting shall be done by machining.

(c) Specimen marking and mark orientation are of upmost importance. Each specimen shall be marked serially with the FAB Code series provided.

(d) CB&I shall apply rust preventative to all specimens, shall arrange them in serial groups of like materials, and shall wrap them to prevent mechanical damage.

(e) CB&I shall provide drawings showing all specimen locations with respect to the plate.

4. Preparation of Base Metal Charpy Test Specimens

(Refer to Figure C-13 and Figure C-9)

CB&I shall prepare 53 standard Charpy V-Notch impact specimens (ASTM E23, Type A, Figure C-9) from the base plate material described in previous paragraphs. The specimens shall be taken from

1/4 thickness positions in the plate and at least 1T from any as quenched edge. The long axes of the specimens shall be parallel to the plate rolling direction, or principal forging direction. The specimen notches shall be perpendicular to the original plate surface and shall be controlled by the orientation of the end marking on the specimen blanks.

5. Preparation of Base Metal Tensile Specimens

(Refer to Figure C-13 and Figure C-10).

CB&I shall prepare 14-1/4 inch gage diameter tensile specimens as per Figure C-10, from the base plate material previously described. The specimens shall be taken from 1/4 thickness positions in the plate and at least 1T from any as-quenched edge. The long axes of the specimens shall be parallel to the plate rolling direction or principal forging direction.

6. Preparation of Weld Charpy Specimens

(Refer to Figure C-14 and Figure C-9).

CB&I shall prepare 53 Charpy impact specimens, per Figure C-9 and Figure C-14, from the weld deposit material of the furnished plate. The long axes of the specimens shall be perpendicular to the weld direction and parallel to the plate surface, with the middle of the specimen at the mid-plane of the weld, as shown in Figure C-14. The specimen location in the stock material shall be recorded, approximately, by the numbering system. The notch shall be parallel to the plate surface and its orientation shall be controlled by the orientation of the marking symbols.

7. Preparation of Weld Tensile Specimens

(Refer to Figure C-15 and Figure C-10).

CB&I shall prepare 13 tensile specimens, per Fig. C-10 from the weld deposit material of the furnished plate. The long axes of the specimens shall be parallel to the length of the weld and parallel to the top surface of the plate (See Figure C-15). The gage length of the specimens shall be of weld-deposit metal only. The threaded ends of the specimens may include Heat-Affected Zone or base metal. The approximate location of the specimens in the stock material shall be recorded by the marking system.

8. Preparation of Heat-Affected Zone Tensile Specimens

(Refer to Figure C-16 and Figure C-10).

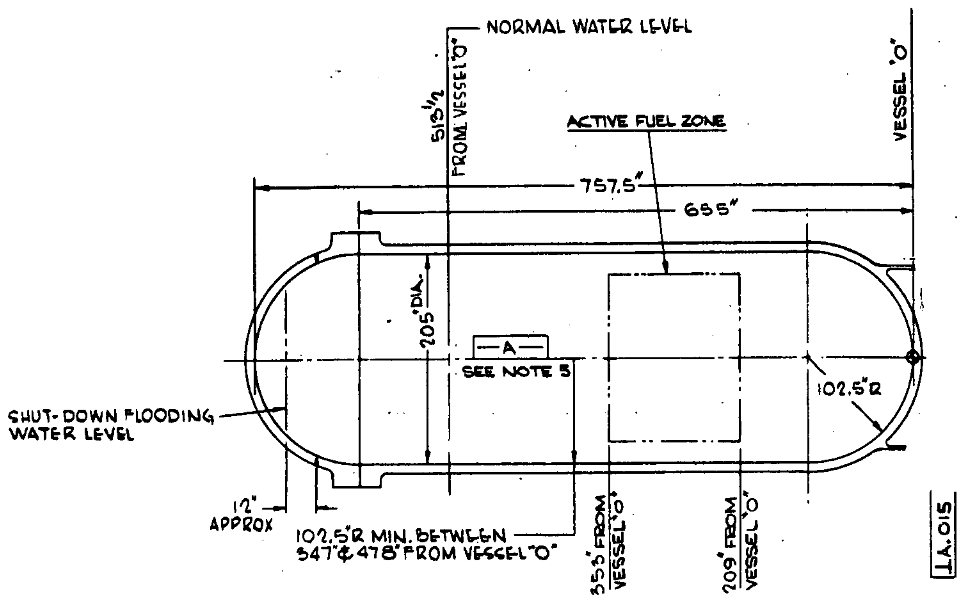
CB&I shall prepare 13 tensile specimens, per Figure C-10, from the welded material of the furnished plate. The long axes of the specimens shall be perpendicular to the length of the weld and parallel to the top surface of the plate (See Figure C-16). The center of the specimen shall be in

the Heat-Affected Zone adjacent to the edge of the weld metal. The approximate location of the specimens in the stock material shall be recorded by the marking system.

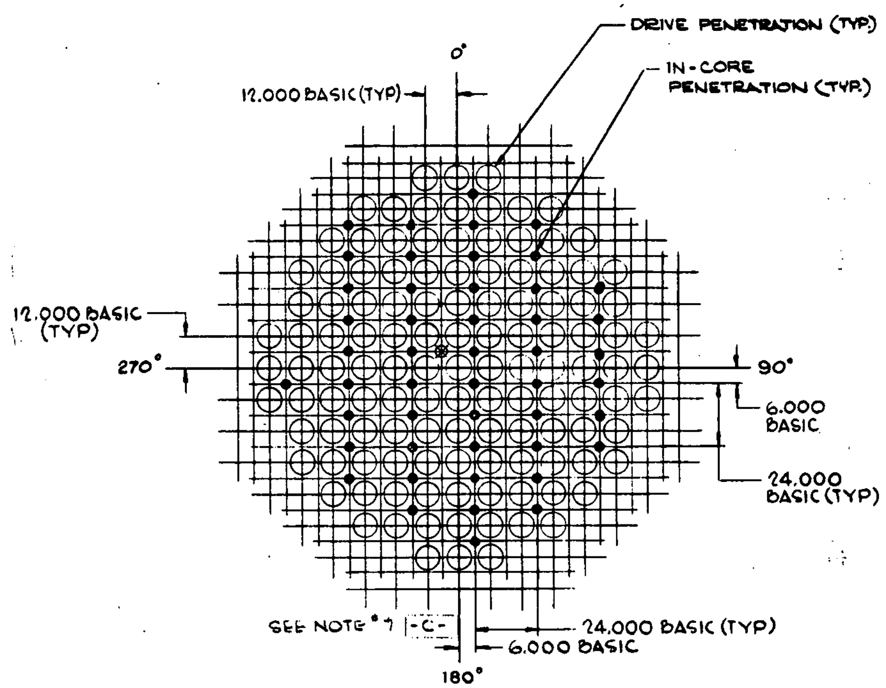
9. Preparation of Heat-Affected Zone Charpy Specimens

(Refer to Figure C-17 and Figure C-9).

CB&I shall prepare 53 Charpy specimens, per Figure C-9 from the welded material of the furnished plate. The long axes of the specimens shall be perpendicular to the length of the weld and parallel to the top surface of the plate (See Figure C-17). The radius of the notch of the specimen shall be at one outer edge of the weld. The axis of the notch shall be parallel to the original surface. The notch orientation shall be controlled by the marking orientation. The location of the specimen in the stock material shall be recorded, approximately, by the marking system.



LONGITUDINAL SECTION



BOTTOM HEAD PLAN VIEW

REFERENCE DRAWINGS	
VESSEL FLANGE BOLTING	FIG. C-5
NOZZLE THERMAL CYCLES	FIG. C-3
NOZZLE END PREPARATION	FIG. C-6

NOZZLE SCHEDULE

NOZZLE NO.	QUAN.	SIZE	FUNCTION	AZIMUTH ± 0°-8'	DISTANCE FROM VESSEL O ± 1/4	END PREP.	MATING PIPE O.D.	MATING PIPE SCH. OR WALL	MATING PIPE MATERIAL	REMARKS
N1A, N1B	2	36"x28"	RECIRCULATION OUTLET	A-0°, B-180°	150" [1]	107C5305	28.000	1.549	SA240-TP304	SEE SH. 3 & SH. 2 FOR ALTERNATE ELEVATION
N2A THRU N2K	10	12"	RECIRCULATION INLET	A-30°, B-60°, C-90°, D-120°, E-150°	186"		12.750	SCH. 80	SA312-TP304	SEE SH. 3 DESIGN PRESSURE 1565 PSIG.
				F-210°, G-240°, H-270°, J-300°, K-330°						
N3A, N3B, N3C, N3D	4	18"	STEAM OUTLET	A-72°, B-108°, C-252, D-288°	595"		18.000	SCH. 80	SA212-GRB	———
N4A, N4B, N4C, N4D	4	10"	FEEDWATER	A-45°, B-135°, C-225°, D-315°	466"		10.750	SCH. 120	SA106-GRB	SEE SH. 3 DESIGN PRESSURE 1475 PSIG.
N5A, N5B	2	8"	CORE SPRAY & FLOODING	A-90°, B-270°	461"		8.625	SCH 80	SA312-TP304	SEE SH. 3
N6A, N6B	2	8"	INSTRUMENTATION	A-0°, B-180° ON TOP HEAD AT 30"	———		———	———	———	6"-1500LB FLG. SMALL GROOVE FACING.
N7	1	4"	VENT	TOP DEAD CENTER.	———		———	———	———	4"-1500LB FLG. SMALL GROOVE FACING.
N8A, N8B	2	4"	JET PUMP INSTRUMENTATION	A-60°, B-240°	134" [1]		4.500	SCH. 80	SA312-TP304	———
N9	1	3"	CONTROL ROD DRIVE HYD. SYS. RETURN	65°	439"		3.500	SCH. 80	SA312-TP304	SEE SH. 3.
N10	1	2"	CORE DIFF. PRESS & LIQUID CONTROL	350°	79 1/2"		2.375	SCH. 80	SA312-TP304	SEE SH. 3.
N11A, N11B	2	2"	INSTRUMENTATION	A-40°, B-220°	542"		2.375	SCH. 80	SA312-TP304	———
N12A, N12B	2	2"	INSTRUMENTATION	A-40°, B-220°	422"	107C5305	2.375	SCH. 80	SA312-TP304	———
N13	1	1"	HIGH PRESSURE SEAL LEAK DET.	BETWEEN HEAD BOLTS 0° APPROX.	———	———	———	———	———	SEE SH. 2 1"-3000LB SOC. WELD FITTING
N14	1	1"	LOW PRESSURE SEAL LEAK DET.	BETWEEN HEAD BOLTS 5° APPROX.	———	———	———	———		SEE SH 2 1"-3000LB SOC. WELD FITTING
N15	1	2"	DRAIN	SEE BOTTOM HEAD PLAN VIEW	———	———	2.375	SCH 160	SA106-GRB	⊠
	121	6"	CONTROL ROD DRIVE	SEE BOTTOM HEAD PLAN VIEW	———	———	———	———	———	SEE SH. 2.
	40	2"	FLUX MONITOR	SEE BOTTOM HEAD PLAN VIEW	———	———	———	———	———	SEE SH. 2.

(1)

NOTES:

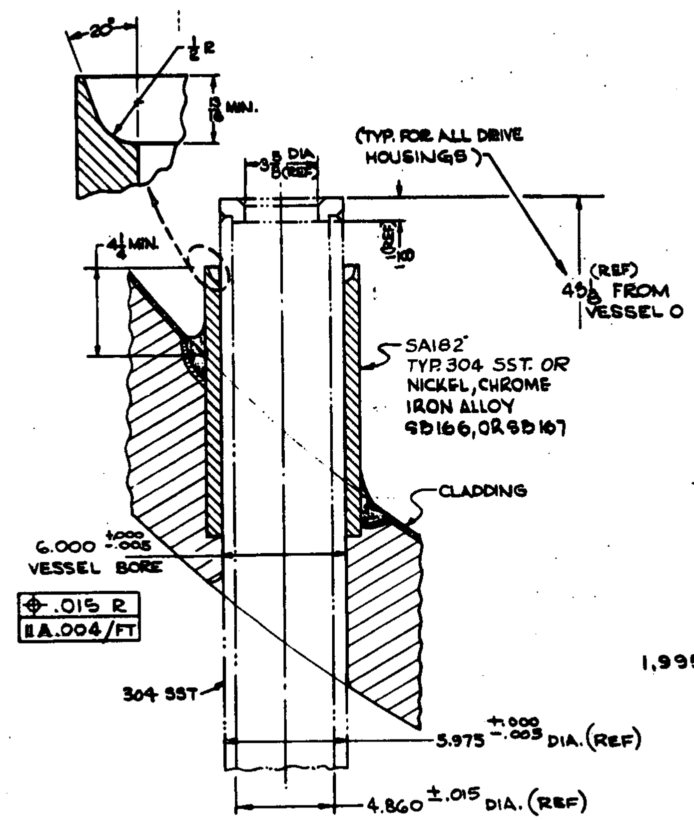
1. DESIGN PRESS.-1250 PSIG AT VESSEL "O"
2. DESIGN TEMP.-575°F
3. NORMAL OPERATING PRESS.-1000 PSIG AT 655 FROM VESSEL "O" ELEVATION.
4. NORMAL OPERATING TEMP.-SATURATION TEMP. AT 1000 PSIG.
5. VESSEL CENTERLINE SHALL BE DETERMINED BY CENTER CONTROL ROD DRIVE PENETRATION BORE AND CENTER OF VESSEL AT 100' FROM VESSEL O.

7. VESSEL AZIMUTH AXIAL PLANES DETERMINED BY CENTER LINE DATUM -A- & 0° OUTER CONTROL ROD DRIVE BORE AT TOP OF PENETRATION.

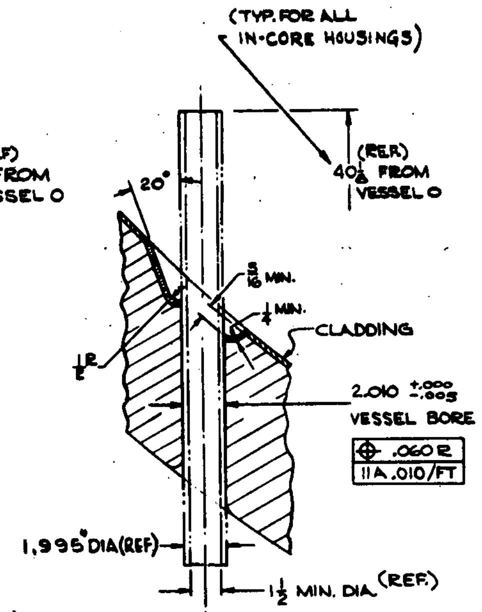
MONTICELLO NUCLEAR GENERATING PLANT

Reactor Vessel

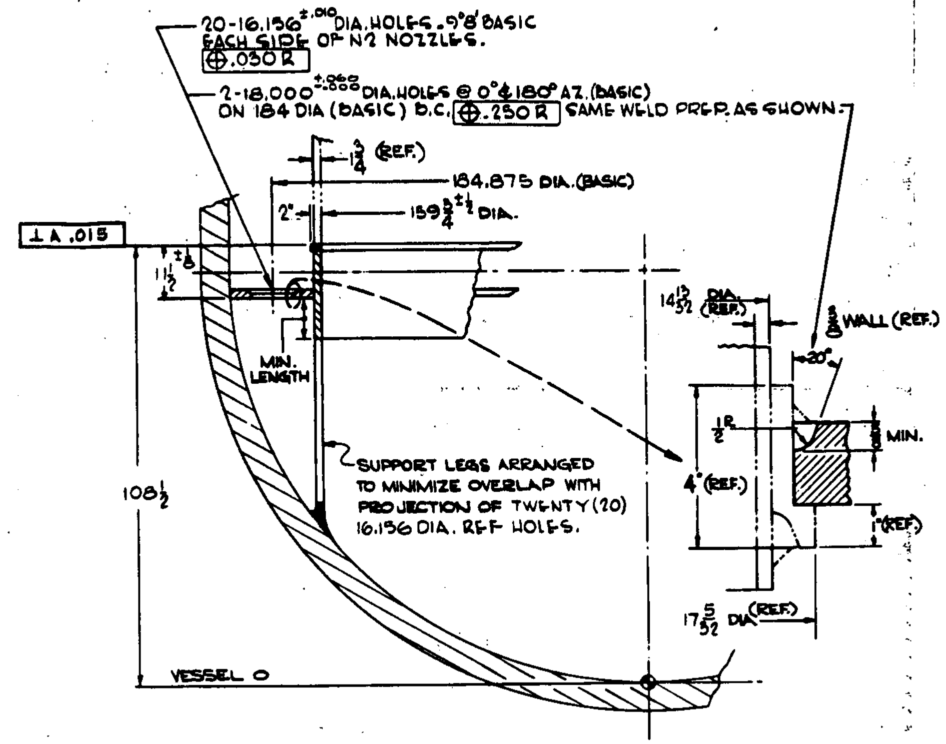
FIGURE C-1



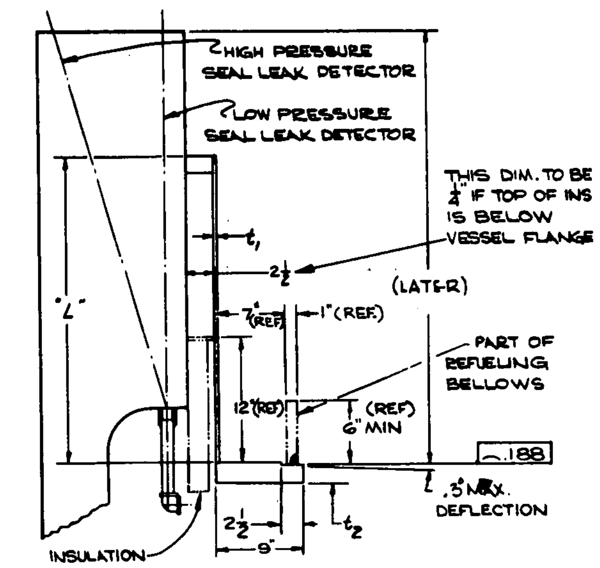
CONTROL ROD DRIVE PENETRATION



IN-CORE PENETRATION

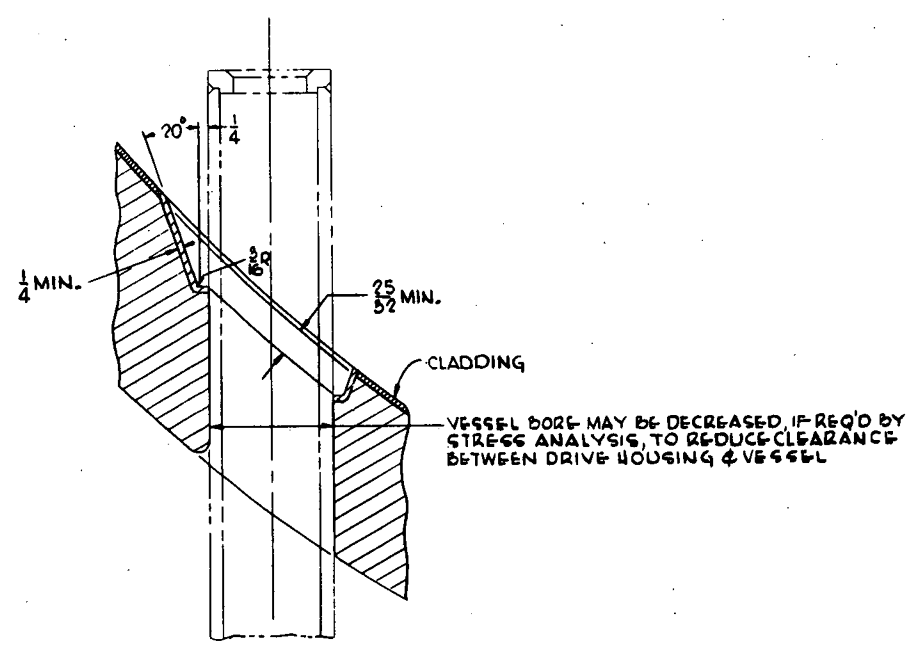


SHROUD SUPPORT

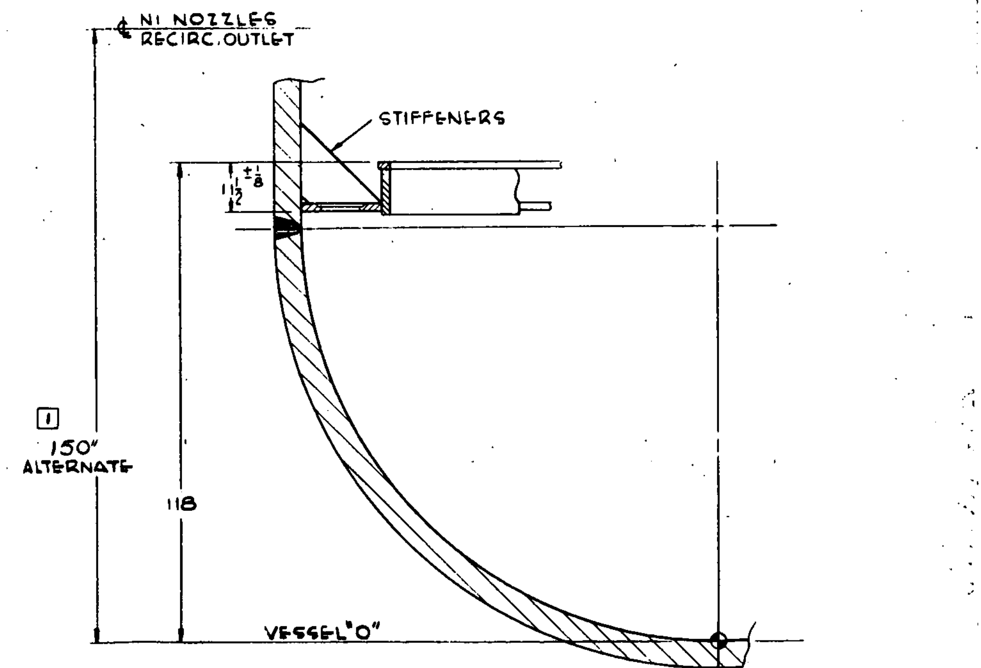


THICKNESSES "t1 & t2" AND "L" TO BE DETERMINED BY VESSEL VENDOR ANALYSIS

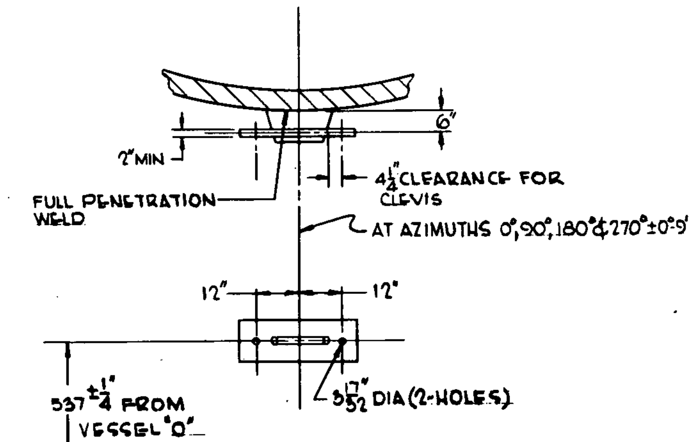
VESSEL SHELL FLANGE



CONTROL ROD DRIVE PENETRATION-ALTERNATE
(SAME AS ABOVE EXCEPT AS SHOWN)
THIS ALTERNATE ACCEPTABLE ONLY IF SELLER INSTALLS THE CONTROL ROD DRIVE HOUSING.

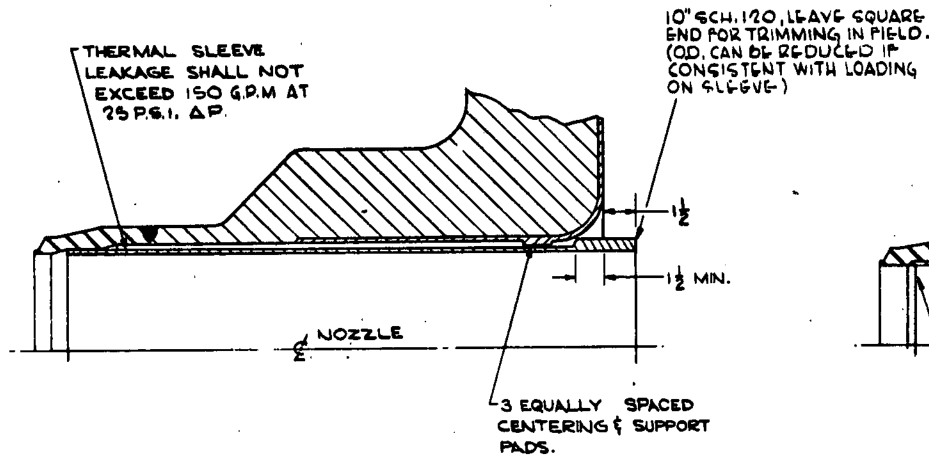


SHROUD SUPPORT-ALTERNATE
(SAME AS ABOVE EXCEPT AS SHOWN)

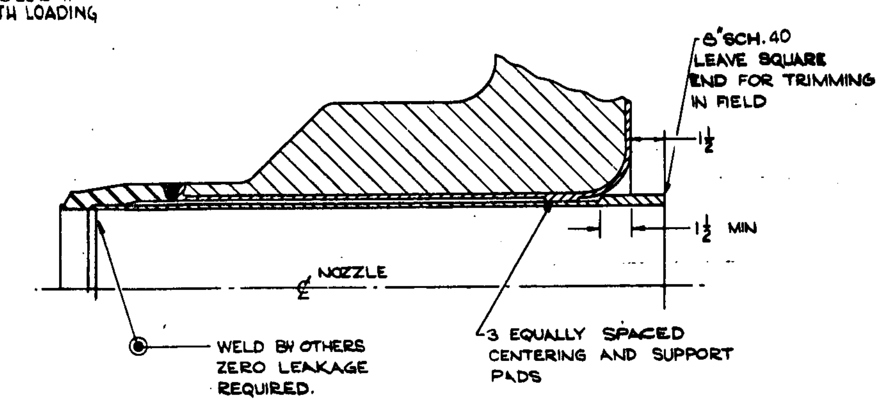


STABILIZER BRACKET

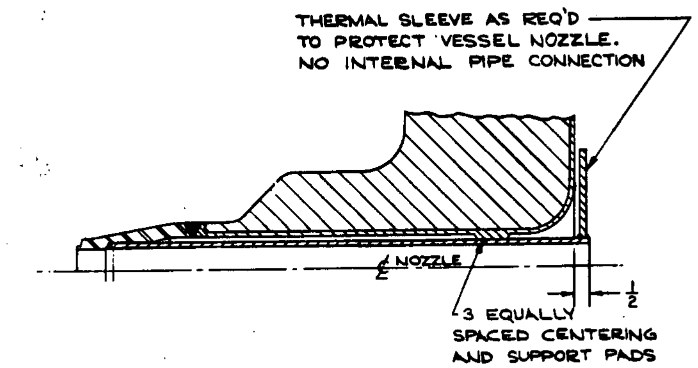
MONTICELLO NUCLEAR GENERATING PLANT
Reactor Vessel Details Sheet 1
FIGURE C-1a



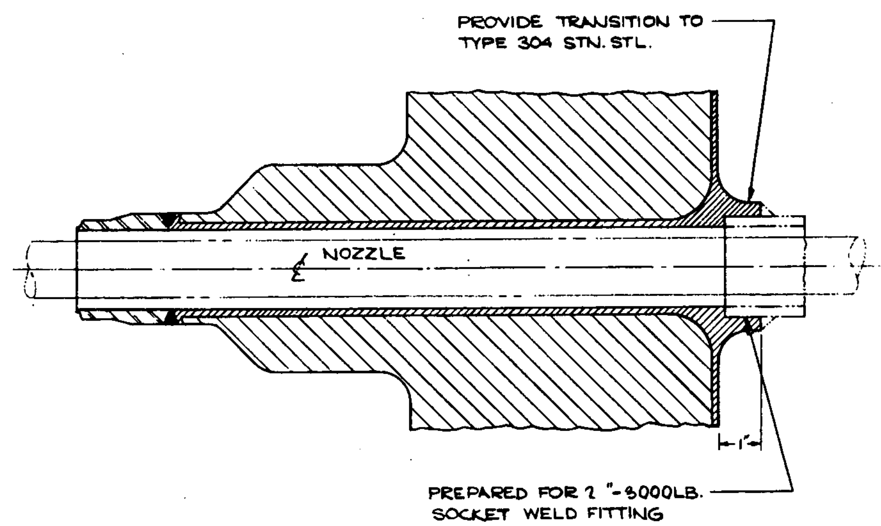
FEEDWATER NOZZLE



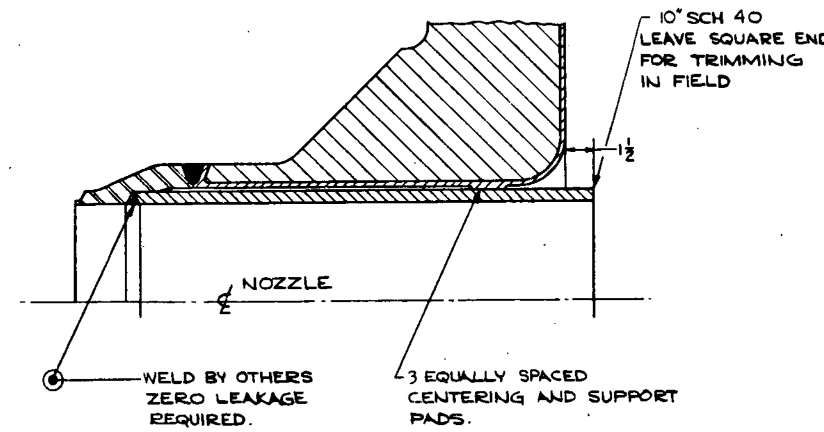
CORE SPRAY NOZZLE



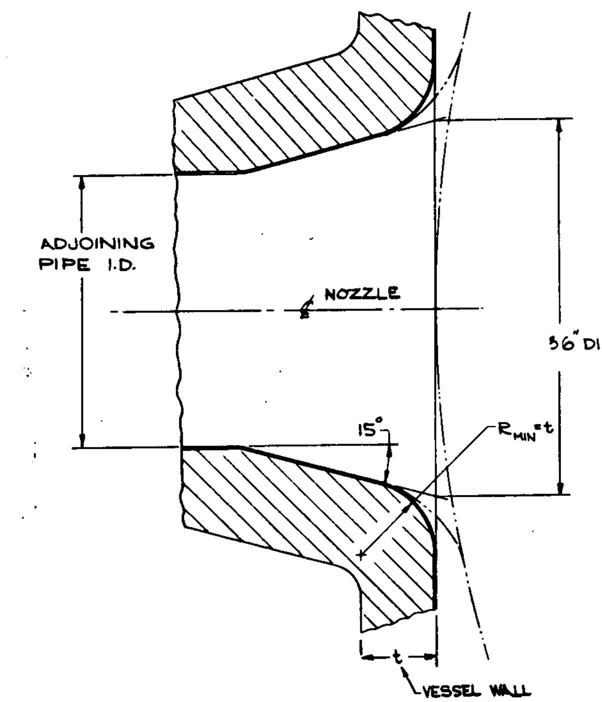
CONTROL ROD DRIVE HYDRAULIC SYSTEM RETURN NOZZLE



CORE DIFFERENTIAL PRESSURE & LIQUID CONTROL NOZZLE



RECIRCULATION INLET NOZZLE

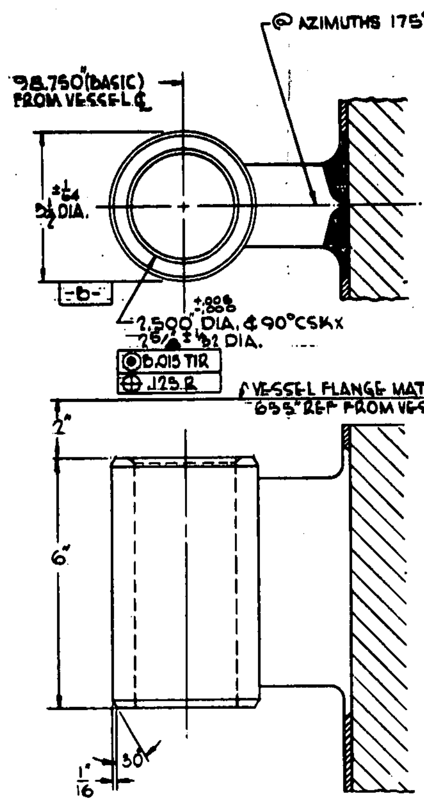


RECIRCULATION OUTLET NOZZLE

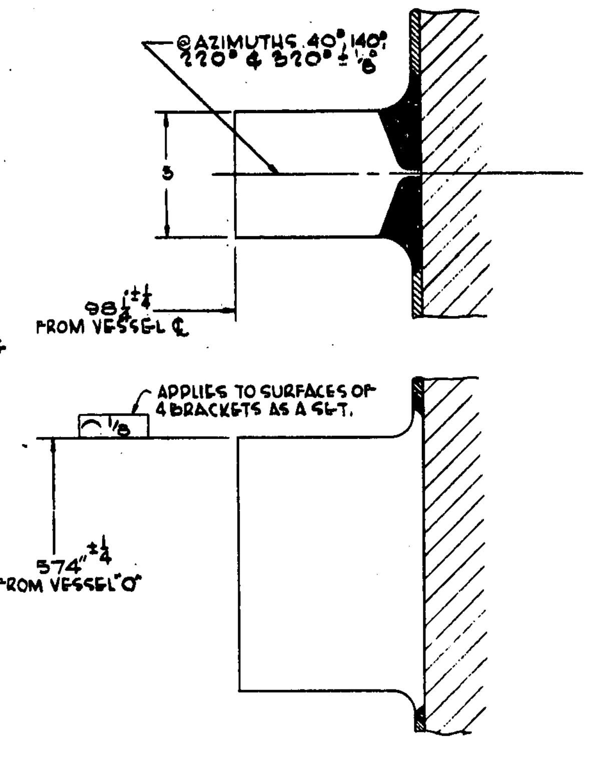
MONTICELLO NUCLEAR GENERATING PLANT

Reactor Vessel Details
Sheet 2

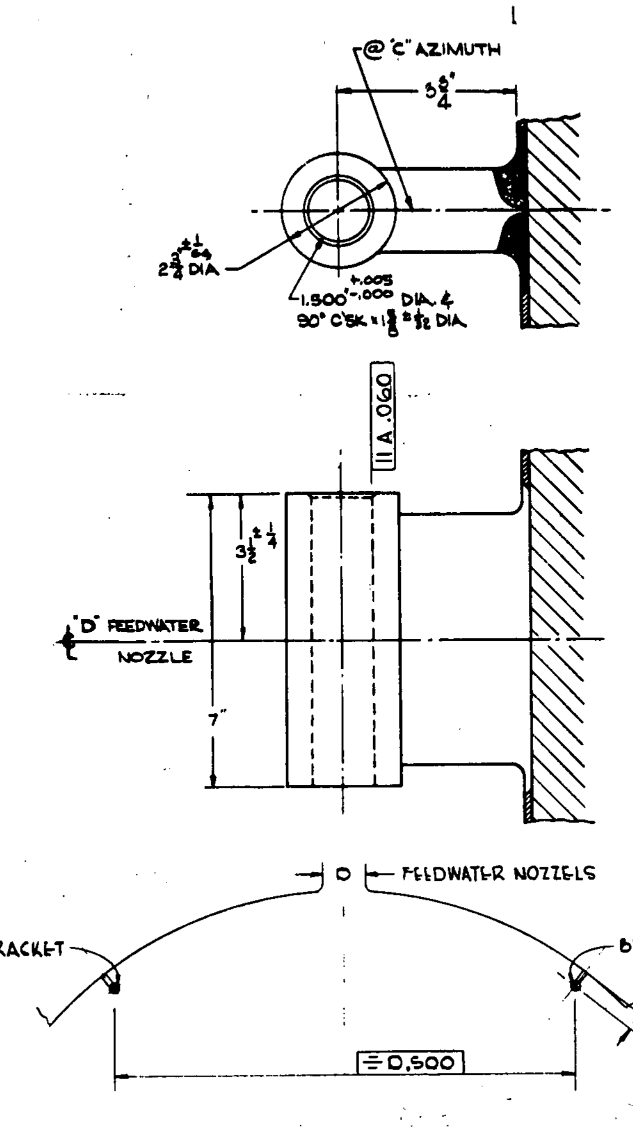
FIGURE C-1b



GUIDE ROD BRACKET

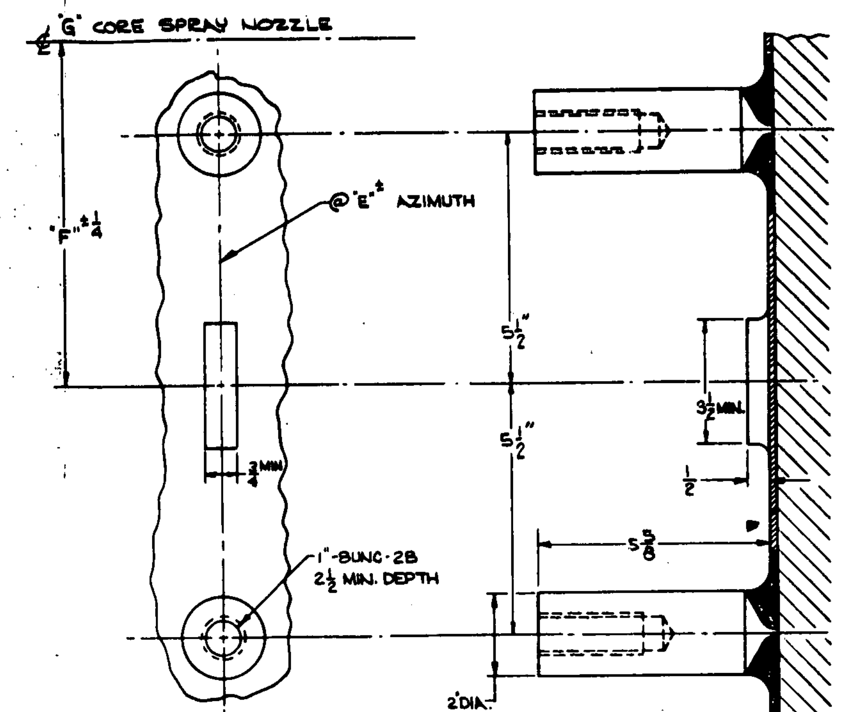


STEAM DRYER SUPPORT BRACKET



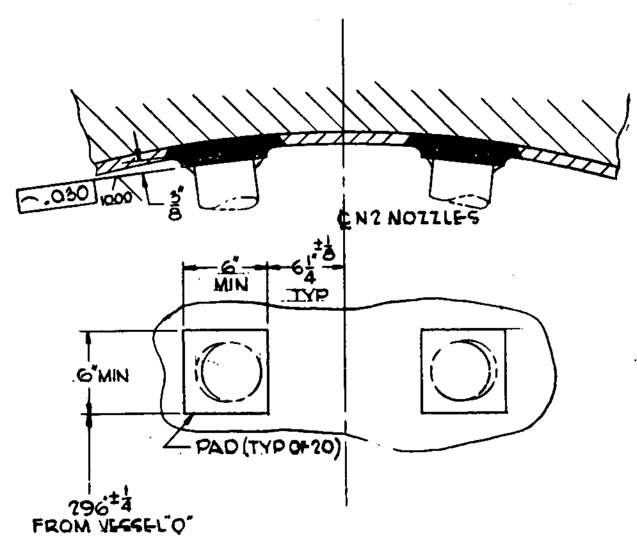
FEEDWATER SPARGER BRACKET

QUAN	C	D
2	7°, 83°	N4A
2	97°, 168°	N4B
2	187°, 265°	N4C
2	277°, 348°	N4D

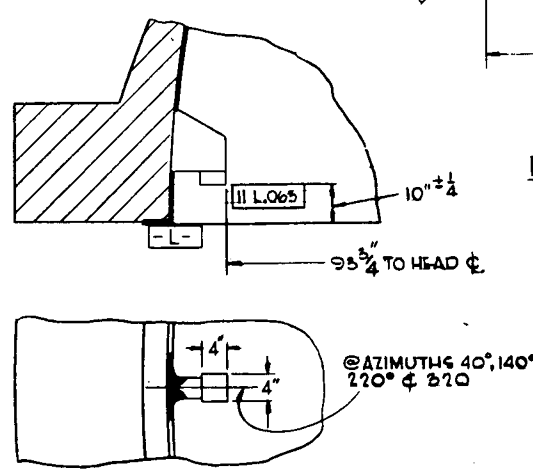


CORE SPRAY BRACKET

QUAN	E	F	G
2	30°-150°	0	N5A
2	210°-330°	0	N5B



JET PUMP RISER SUPPORT PAD



DRYER HOLD DOWN BRACKET
(IN VESSEL TOP HEAD)
(TYP FOR 4)

MONTICELLO NUCLEAR GENERATING PLANT

Reactor Vessel Details
Sheet 3

FIGURE C-1c

TABLE 1 - WATER LOADS (TABLE 9 LOADS NOT INCLUDED)

OPERATING CONDITION	PRESS PSIG	RECIRC. FLOW	WATER LEVEL ABOVE VESSEL 0	WATER WT. KIPS	WATER CG ABOVE VESSEL 0	REMARKS
NORMAL FULL POWER	1000	ON	513 1/2"	353.1	274	
HOT, STAND-BY	1000	ON	513 1/2"	381.4	274	
COLD, VESSEL FULL	ATM	OFF	757 1/2"	729.2		
REFUELING	ATM	OFF	927"	1080		
REFUELING	ATM	OFF	655"	651	340	WATER IN VESSEL ONLY

TABLE 2 - VESSEL INTERNAL COMPONENT LOADS

COMPONENTS		WEIGHT KIPS	CG ABOVE VESSEL 0	REMARKS
SUPPORTED AT EACH CONTROL ROD PENETRATION IN BOTTOM HEAD	FUEL	2.80	281"	
	DRIVE	.4	-40" EXTENDED -67" RETRACTED	
	CONTROL ROD	.26	261" EXTENDED 125" RETRACTED	
	GUIDE TUBES	.500	121"	
	THERMAL SLEEVES & DRIVE HSG	.56	-45"	
SUPPORTED AT EACH INCORE FLUX MONITOR PENETRATION IN BOTTOM HEAD		.19	121"	
SUPPORTED BY INTERNAL SHROUD SUPPORT	INTERNAL STRUCTURE & PERIPHERY FUEL	189	355"	
	GUIDED LOADS (ALL FUEL, DRIVES, CONTROL RODS, GUIDE TUBES) FOR HORIZONTAL EARTHQUAKE LOADS ONLY	397	277"	
	JET PUMPS	1.0		

TABLE 3 - NOZZLE REACTIONS (SEE FIG. 1)

NOZZLE	LBS Fx	LBS Fy	LBS Fz	FT. LBS Mx	FT. LBS My	FT. LBS Mz	REMARKS
RECIRC. OUTLET	3200	3400	1040	33×10^3	33×10^3	116×10^3	ALL VALUES TO BE APPLIED AT DESIGN PRESSURE & TEMP. USE DIRECTION SIGNS TO PRODUCE THE LARGEST MOMENTS & HIGHEST STRESSES (applies to all nozzles)
RECIRC. INLET	4000	3600	3600	13.5×10^3	13.5×10^3	16.7×10^3	
STEAM OUTLET	7200	2000	12.8×10^3	33×10^3	18.4×10^3	26.2×10^3	
FEED-WATER	930	3900	1300	31×10^3	13×10^3	23×10^3	
CORE SPRAY	400	2000	600	14.7×10^3	2690	6850	

TABLE 4 - NOZZLE THERMAL SLEEVE REACTIONS (SEE FIG 2)

NOZZLE	LBS. Fx	LBS. Fy	LBS. Fz	FT. LBS. Mx	FT. LBS. My	FT. LBS. Mz	REMARKS
RECIRC. INLET	0	20×10^3	20×10^3	16.7×10^3	0	0	AT THE ORIGIN FIGURE 2
CORE SPRAY	0	3470	-3000	-1075	0	0	NORMAL OPERATION AT DESIGN TEMP. & PRESS.
	0	540	713	256	0	0	SPRAY INITIATION, VESSEL 545°F, SLEEVE 40°F, PRESS. 0
	0	1261	5625	2020	0	0	SPRAY OPERATION, VESSEL 545°F, SLEEVE 135°F, PRESS. 0

TABLE 5 - CONTROL ROD DRIVE MOMENTARY REACTIONS

ROD SCRAM REACTION ON EACH DRIVE	LOAD KIPS	REMARKS
NORMAL START	8.2	DOWNWARD THROUGH HOUSING TO HEAD & VESSEL SUPPORT SKIRT
STUCK ROD	13.0	TO HOUSING ONLY
END OF STROKE	7.0	UPWARD ON HOUSING, HEAD, & VESSEL SUPPORT SKIRT

TABLE 6 - VESSEL INSULATION LOADS

LOCATION	WEIGHT KIPS	REMARKS
AT EACH BRACKET AT UPPER ELEVATION	1.2	LOADS GIVEN ARE MAX. LOADS THAT WILL APPEAR DURING ERECTION OR SERVICING, THE TOTAL WEIGHT OF THE INSULATION SUPPORTED BY THE VESSEL IS 13 KIPS, DIVIDED AS FOLLOWES- TOP HEAD, 2.8 KIPS: BOTTOM HEAD & SUPPORT SKIRT, 1 KIP: CYLINDER 9.2 KIPS.
AT EACH BRACKET AT LOWER ELEVATION	1.2	
ON HEAD	2.4	

TABLE 7 - EARTHQUAKE COEFFICIENTS

DIRECTION	FORCE		REMARKS
HORIZONTAL	0.40G MIN.	OR PER APPLICABLE CODE	ACTING ON DEAD LOADS PLUS CONTINUOUS LIVE LOADS
VERTICAL	±0.08G MIN.		

TABLE 8 - HORIZONTAL JET REACTION LOADS

NOZZLE	LOAD KIPS	REMARKS
STEAM OUTLET	330	INDEPENDENT OF EARTHQUAKE LOADS AND INDEPENDENT OF EACH OTHER
RECIRC. OUTLET	658	

TABLE 9 - REFUELING BELLOWS SUPPORT LOADS (SEE FIG. 3)

OPERATING CONDITION	WATER LOAD KIPS	BELLOWS LOAD KIPS	REMARKS
NORMAL FULL POWER	0	60#/IN CIRCUMFERENCE	
REFUELING	LATER	18#/IN CIRCUMFERENCE	

TABLE 10 - BRACKET LOADS

EACH BRACKET FOR	DIRECTION	LOAD KIPS	TEMP. °F	REMARKS
GUIDE ROD	VERTICAL-UP	60	120°	HORIZONTAL & VERTICAL FORCES ARE NOT APPLIED CONCURRENTLY
	VERTICAL-DOWN	60	120°	
	HORIZONTAL	10	120°	
DRYER HOLD DOWN	VERTICAL-UP	33	545°	
	VERTICAL-DOWN	0	↑	
	HORIZONTAL	0		
STEAM DRYER SUPPORT	RADIAL	5		
	VERTICAL-DOWN	13		
	TANGENTIAL	5		
FEEDWATER SPARGER	VERTICAL-UP	±0.9		ALL FORCES ACT SIMULTANEOUSLY
	VERTICAL-DOWN	0.5		
	RADIAL	0.4		
CORE SPRAY	VERTICAL-UP	2.5		APPLIED AT EACH PAIR OF STUDS
	VERTICAL-DOWN	2.5		
	RADIAL	3.5		
JET PUMP	VERTICAL-UP	LATER		LATER
	VERTICAL-DOWN	LATER	↓	LATER
	HORIZONTAL	LATER	545°	LATER

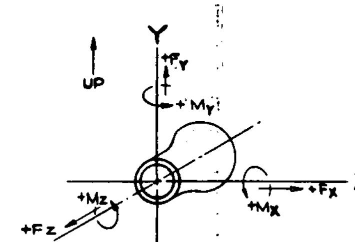


FIGURE 1

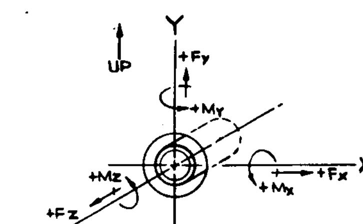


FIGURE 2

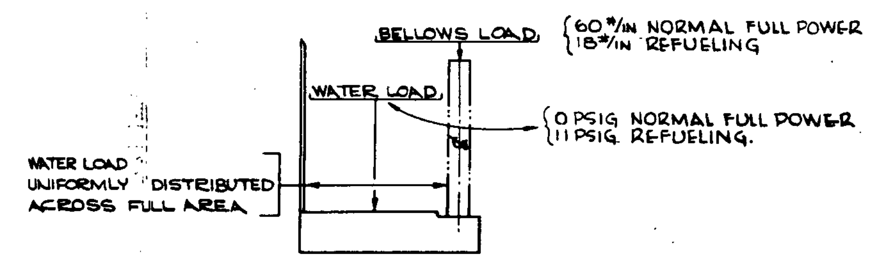
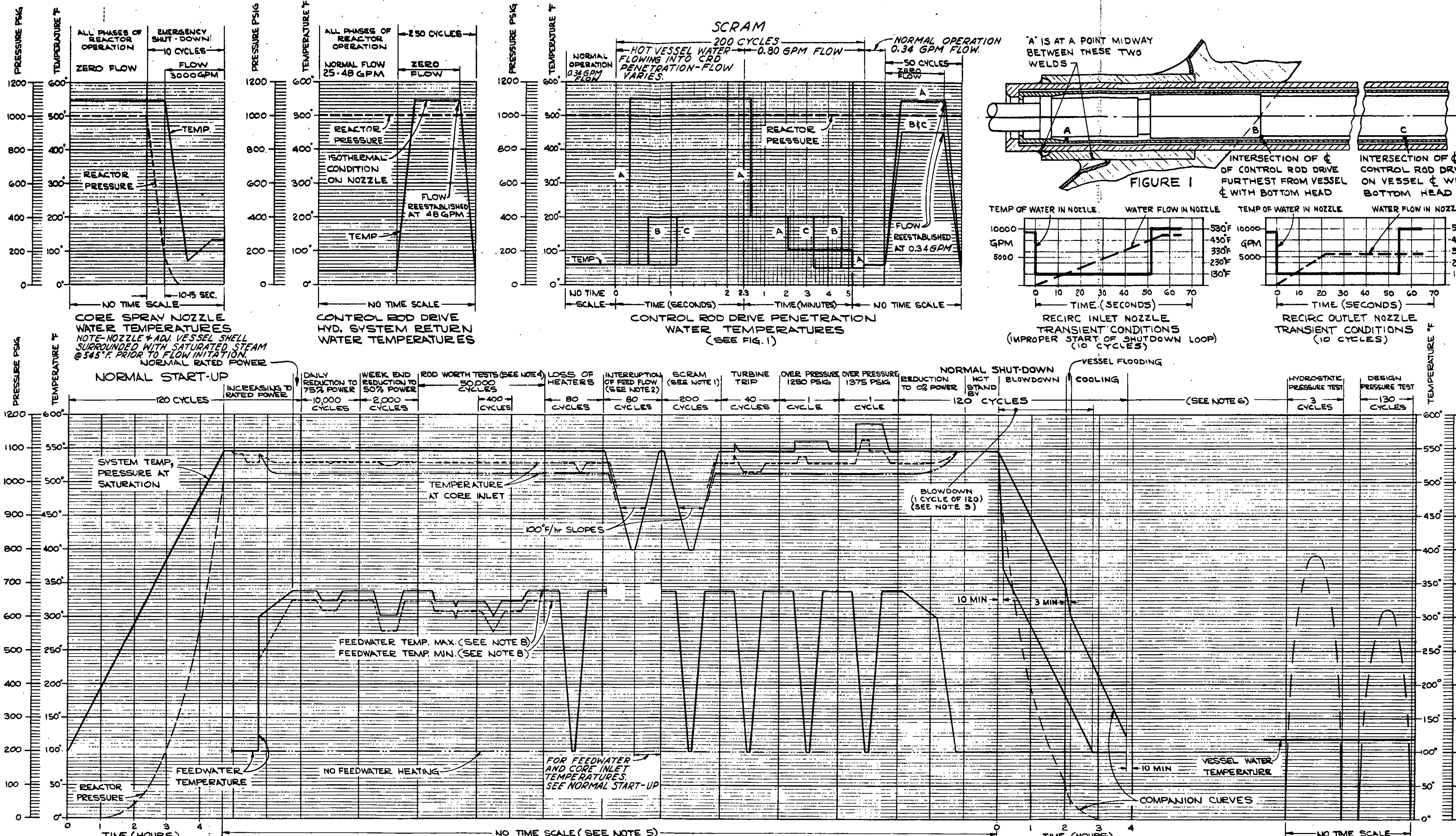


FIGURE 3

MONTICELLO NUCLEAR GENERATING PLANT

Loads and Nozzle Reactions

FIGURE C-2



CORE EXIT, CORE INLET AND FEEDWATER TEMPERATURES
(SEE NOTE 7)

FCF 104R861 (DRESDEN 2) 201-102
104R921 (QUAD CITIES #1) 201-102
104R896 (MILLSTONE) 201-102
104R892 (NUCLENOR) 201-102
(MONTICELLO)
(BROWN'S FERRY)

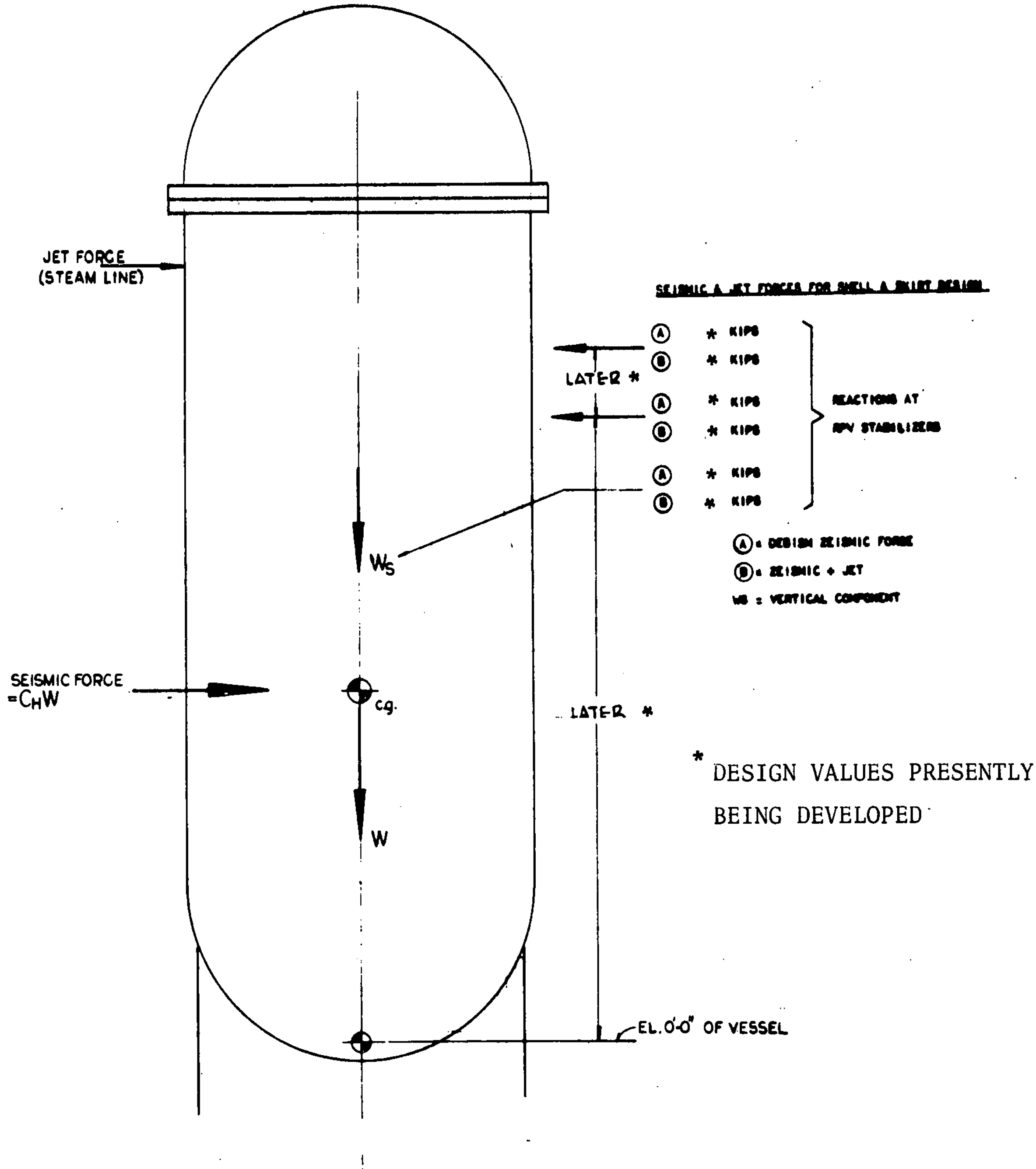
NOTES:

1. FOR SCRAM CONDITIONS, SYSTEM COOLDOWN OCCURS AS INDICATED FOR NORMAL SHUTDOWN. TEMPERATURE REDUCTION SHOWN BEFORE RECOVERY IS TYPICAL.
2. SCRAM OCCURS. SEE NOTE 1
3. SINGLE RELIEF OR BYPASS VALVE FAILS OPEN WITH ZERO REACTOR HEAT GENERATION. RAPID COOLDOWN IS TERMINATED BY ISOLATION VALVE CLOSURE.
4. THESE TESTS OCCUR WHEN POWER IS CUT TO 75%.
5. THE OCCURENCES SHOWN IN THIS RANGE, WITH THE EXCEPTION OF DAILY AND WEEKLY LOAD VARIATIONS, HAPPEN IN SECONDS OR AT THE MOST A FEW MINUTES, EXCEPT WHERE NOTED.
6. THE NUMBER OF CYCLES IS BASED ON A 40 YEAR PLANT LIFE.
7. DOES NOT INCLUDE TRANSIENTS RESULTING FROM PUMP TRIPS.
8. INCLUDES RATED AND STRETCH RATED VARIATIONS.
9. ALL PHASES OF OPERATION HAVE NORMAL WATER LEVEL EXCEPT WHEN VESSEL IS FLOODED FOR SHUT-DOWN. SEE REACTOR VESSEL DWG FOR WATER LEVEL ELEVATIONS, EXCEPT AS OTHERWISE NOTED.

MONTICELLO NUCLEAR GENERATING PLANT

Nozzle Thermal Cycles

FIGURE C-3



SEISMIC DESIGN COEFFICIENTS

C_H = * = HORIZONTAL

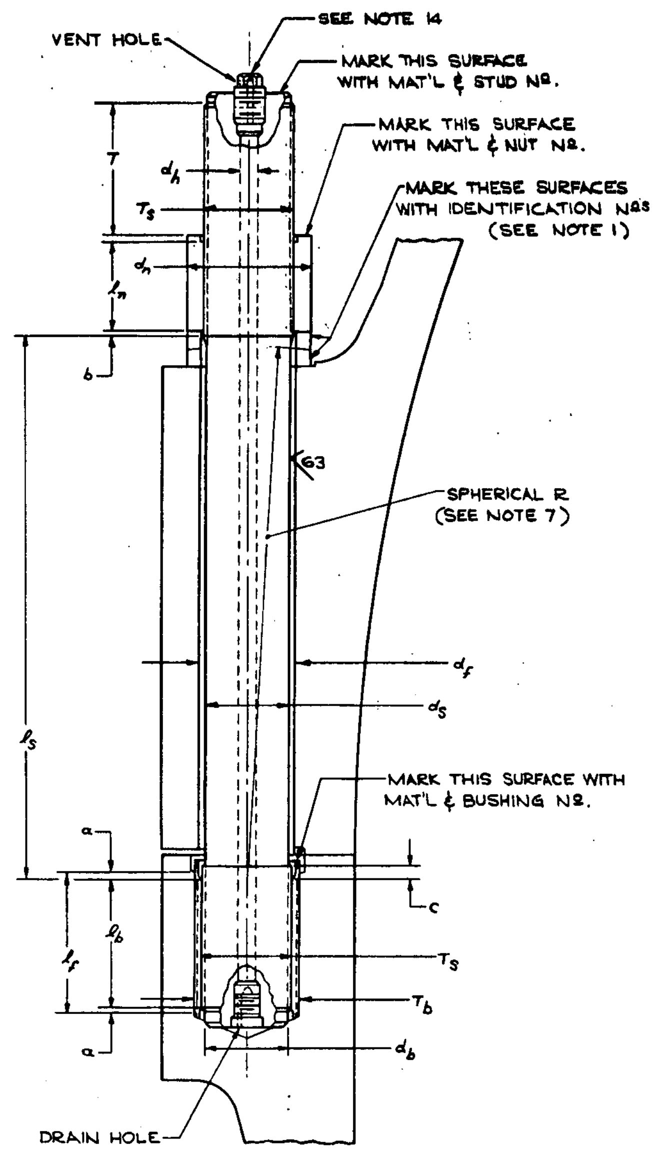
C_V = * = VERTICAL (APPLIED TO W ONLY)

THE PRIMARY STRESSES RESULTING FROM THE COMBINATION OF DEAD LOAD + LIVE LOAD + HORIZONTAL & VERTICAL SEISMIC LOADS SHALL NOT EXCEED CODE ALLOWABLE WHEN STRESSES RESULTING FROM JET FORCES ARE ADDED TO THE STRESS DUE TO DEAD, LIVE AND SEISMIC LOADS. THE RESULTING PRIMARY STRESSES SHALL NOT EXCEED 0.9 X Y.P. OF THE MATERIAL.

MONTICELLO NUCLEAR GENERATING PLANT

Seismic and Jet Forces

FIGURE C-4



TOP HEAD AND VESSEL FLANGE BOLTING

SEE NOTES 2,3 & 4

NOTES:

[2] 1. SPHERICAL SURFACES TO BE LAPPED IN SETS. 75% CONTACT AREA REQUIRED.
2. ALL PARTS TO BE SERIALLY NUMBERED TO AVOID DUPLICATION.
3. ALL THREADS TO BE BLUNT START THREADS.
4. BUSHING TO VESSEL FLANGE THREADS SHALL USE A THREAD FORM DEVELOPED BY THE RULES IN ASA B1.1-1960 WITH AN ALLOWANCE AND A TOLERANCE TO DEVELOP FULL STRENGTH OF JOINT WITH MINIMUM METAL.
5. FEATHER EDGES AND BURRS ARE TO BE REMOVED FROM OUTSIDE EDGES BY A METHOD NOT TO EXCEED MINIMUM METAL CONDITION OF RADII SHOWN.
6. THREAD ROOTS SHALL BE FORMED TO RADII WITHIN METAL LIMITS SHOWN.
7. TOOL WEAR SHALL BE CLOSELY MONITORED TO PRODUCE REQUIRED TOLERANCES.
8. "GO" AND "NOT GO" THREAD GAGES SHALL BE USED ON COMPLETED THREAD WHEN INSPECTING IN CONJUNCTION WITH I.D. & O.D. AND THREAD FORM MEASUREMENTS.
9. LEAD AND ANGLE OF THREADS ARE TO BE CHECKED THROUGHOUT ENTIRE LENGTH OF THREAD.
10. THREADS SHOWN IN ENGAGED MAXIMUM METAL CONDITION.
11. BALANCED THREAD FORM USED FOR REASONS OF THREAD STRENGTH AND TO MINIMIZE POSSIBLE MECHANICAL DAMAGE.
12. THE STUD THREAD SHALL BE DESIGNED TO PERMIT FREE TURNING OF THE NUT WHEN THE STUD IS UNDER MAXIMUM TENSION. THIS MAY BE PROVIDED BY ALLOWANCE IN PITCH DIAMETER OR THREAD LEAD.
13. INTERNAL THREAD TO BE 63√ FINISH OR BETTER, AND EXTERNAL THREAD TO BE 32√ FINISH OR BETTER
14. A THREADED PLUG SHALL ALSO BE PROVIDED FOR THE TOP OF THE STUD HOLE. WHEN THIS PLUG IS REMOVED, THE STUD THREADS SHOULD ACCOMODATE AN EYEBOLT FOR LIFTING WITH THE STUD SLING.
[1] 15. THE FLANGE AND EXTERNAL BUSHING THREADS MAY BE STANDARD 8-PITCH, CLASS 2 THREALS.

LEGEND

d_s = STUD DIAMETER - INCHES

d_h = HOLE DIAMETER FOR EXTENSIOMETER - INCHES

$A_s = \frac{\pi}{4}\left[d_s^2 - d_h^2\right]$ = STUD AREA - INCHES^2

$T_s = d_s + .250$ - INCHES

d_f (MINIMUM) $= T_s + .250$ - INCHES

d_n (MINIMUM) $= \sqrt{\frac{4A_s}{\pi} + d_f^2}$ - INCHES

$d_b = d_s$

$T_b = T_s + .750$ - INCHES

$\ell_n \cdot \ell_b = 1.02\,T_s$ - INCHES

$\ell_f = 1.08\,T_s$ - INCHES

a (MINIMUM) $= \frac{1}{8}$ INCHES.

b (MINIMUM) $= \frac{3}{16}$ INCHES

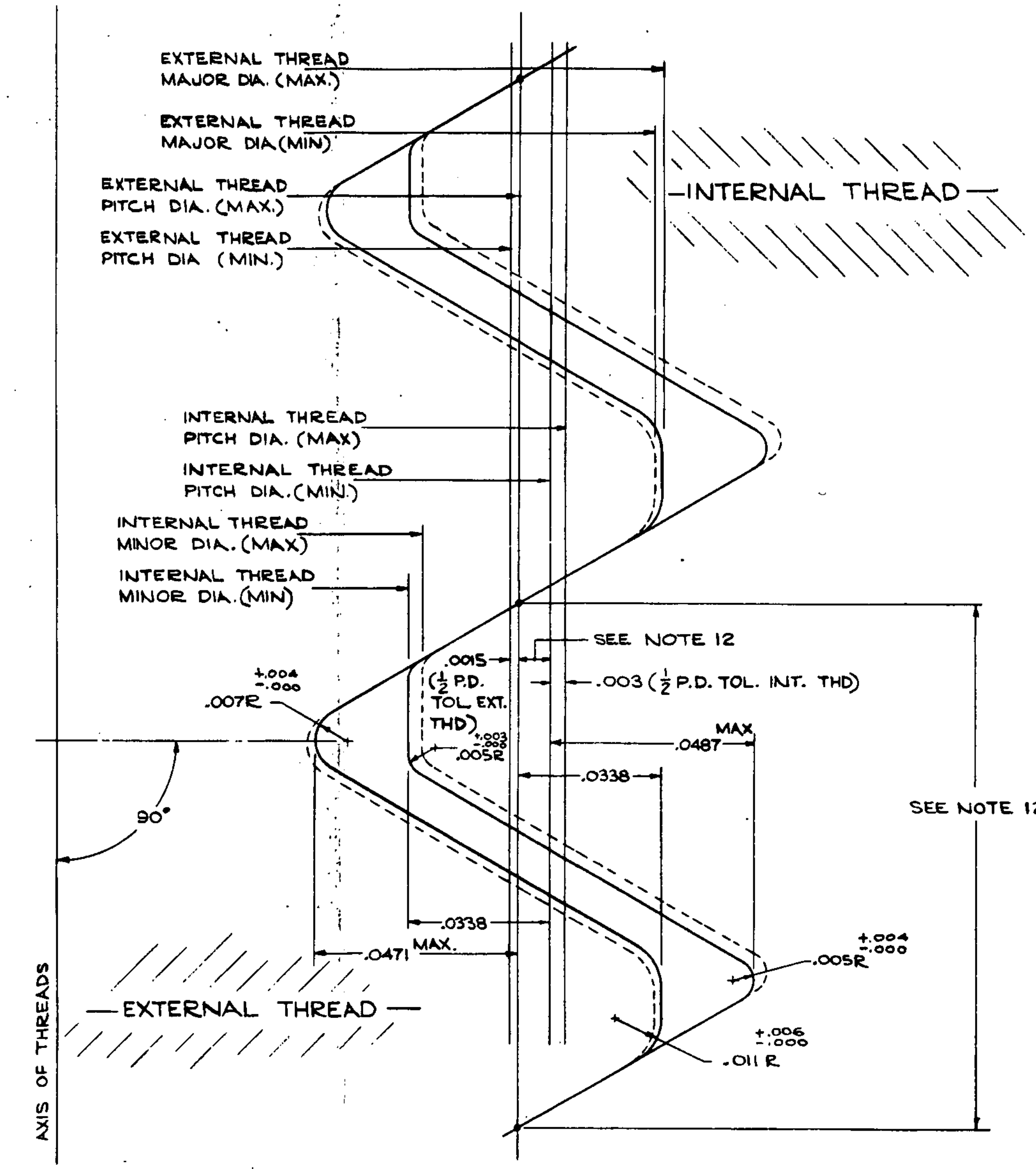
c (MINIMUM) $= \frac{1}{4}$ INCHES

$T = \ell_n + 1.500$ MIN. - INCHES

$R = \ell_s$ - INCHES (SPHERICAL RADIUS)

EFFECTIVE LENGTH OF STUD = EL - INCHES

$EL = \ell_s + b + \frac{1}{2}(\ell_b + \ell_n)$ - INCHES



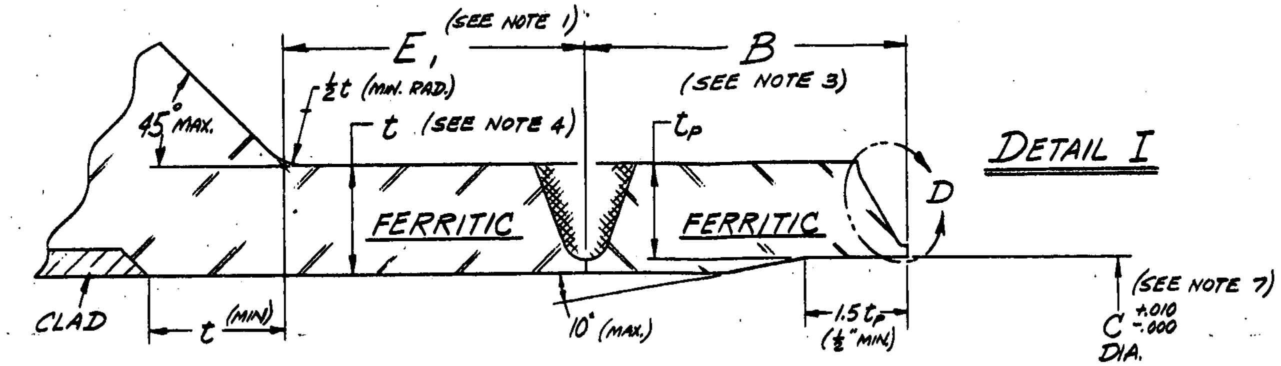
SPECIAL 8 PITCH THREAD

ALL THREADS ARE 60° STRAIGHT THREADS.
SEE NOTES 5 THRU 13

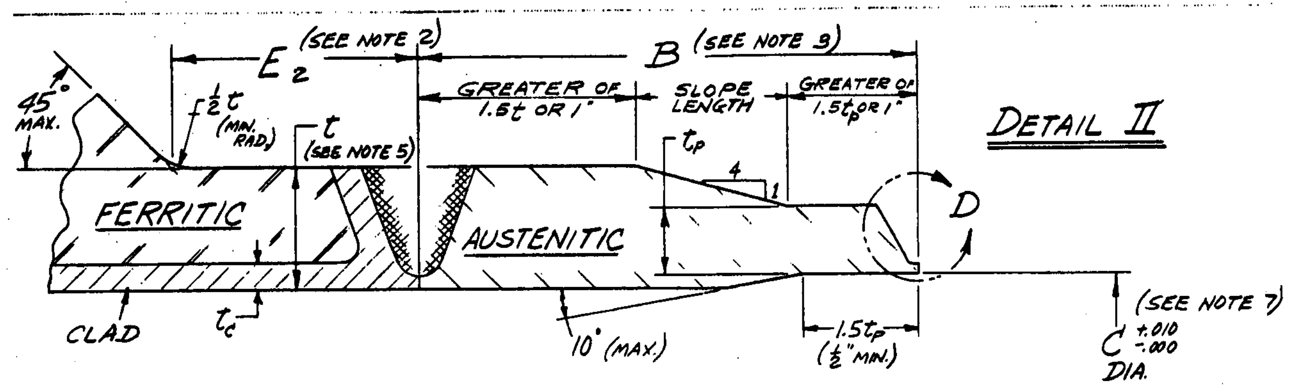
MONTICELLO NUCLEAR GENERATING PLANT

Vessel Flange Bolting

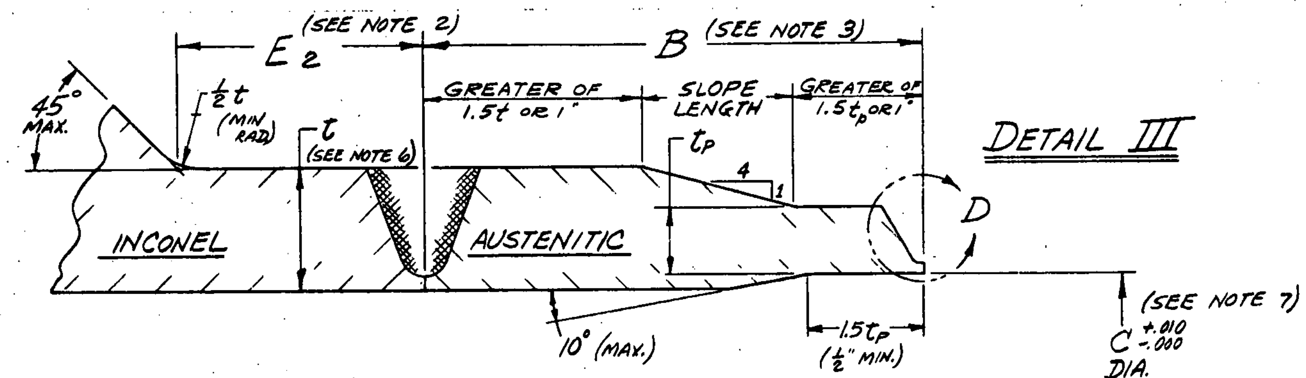
FIGURE C-5



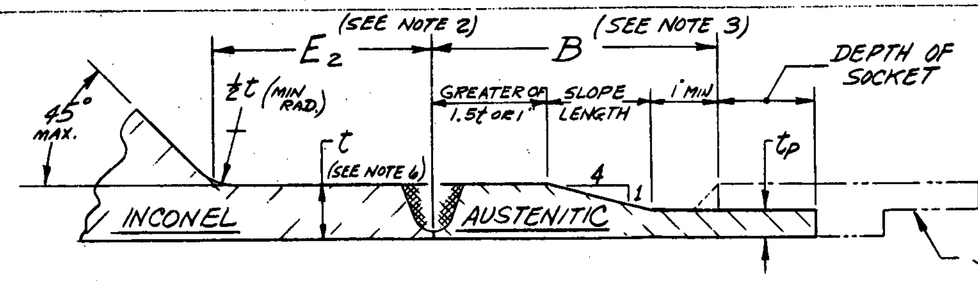
DETAIL I



DETAIL II



DETAIL III



DETAIL IV

(FOR STD. ASA SCHEDULE PIPE SIZES ONLY)

NOTES;

1.- $E_1 = 0.75\sqrt{Rt + 0.5t^2}$

2.- $E_2 = 1.5\sqrt{Rt + 0.5t^2}$ OR 2t + 2.00' WHICHEVER IS GREATER

3.- $B = 1.5\sqrt{Rt_p + 0.5t_p^2}$
OR
$B = 1.5t$ + SLOPE LENGTH $+ 1.5t_p$
OR
$B = 2.00"$
} WHICHEVER IS LONGEST

4.- $t_{(MIN)} = t_p$

5.- $t_{(MIN)} = 1.25t_p + t_c$

6.- $t_{(MIN)} = 1.25t_p$

7.- WHEN MATING PIPE IS A STD ASA SCHEDULE PER ASA B36.10 OR WALL THICKNESS IS GIVEN SEPARATELY, COMPUTE "C" DIM. FROM FOLLOWING FORMULA; (FROM ASA B16.25)

$$C = A - 0.031 - 1.75t_{p(NOM)} - 0.010$$

8.- IN ABOVE FORMULAS;

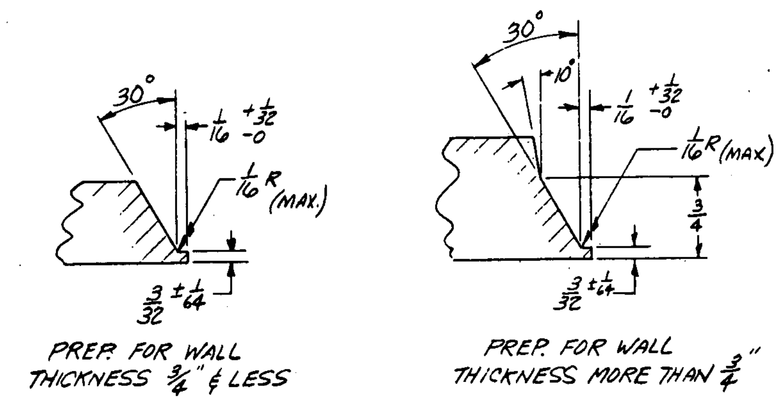
$t_{p(NOM)}$ = NOM. PIPE WALL THICKNESS IN INCHES

t_p = MIN. PIPEWALL THICKNESS IN INCHES

A = NOM. PIPE O.D. IN INCHES

R = INSIDE RAD. OF PART UNDER CONSIDERATION

9.- BLEND 10° & 4:1 SLOPES INTO ADJACENT SURFACES WITH 1/8" MIN. RADIUS

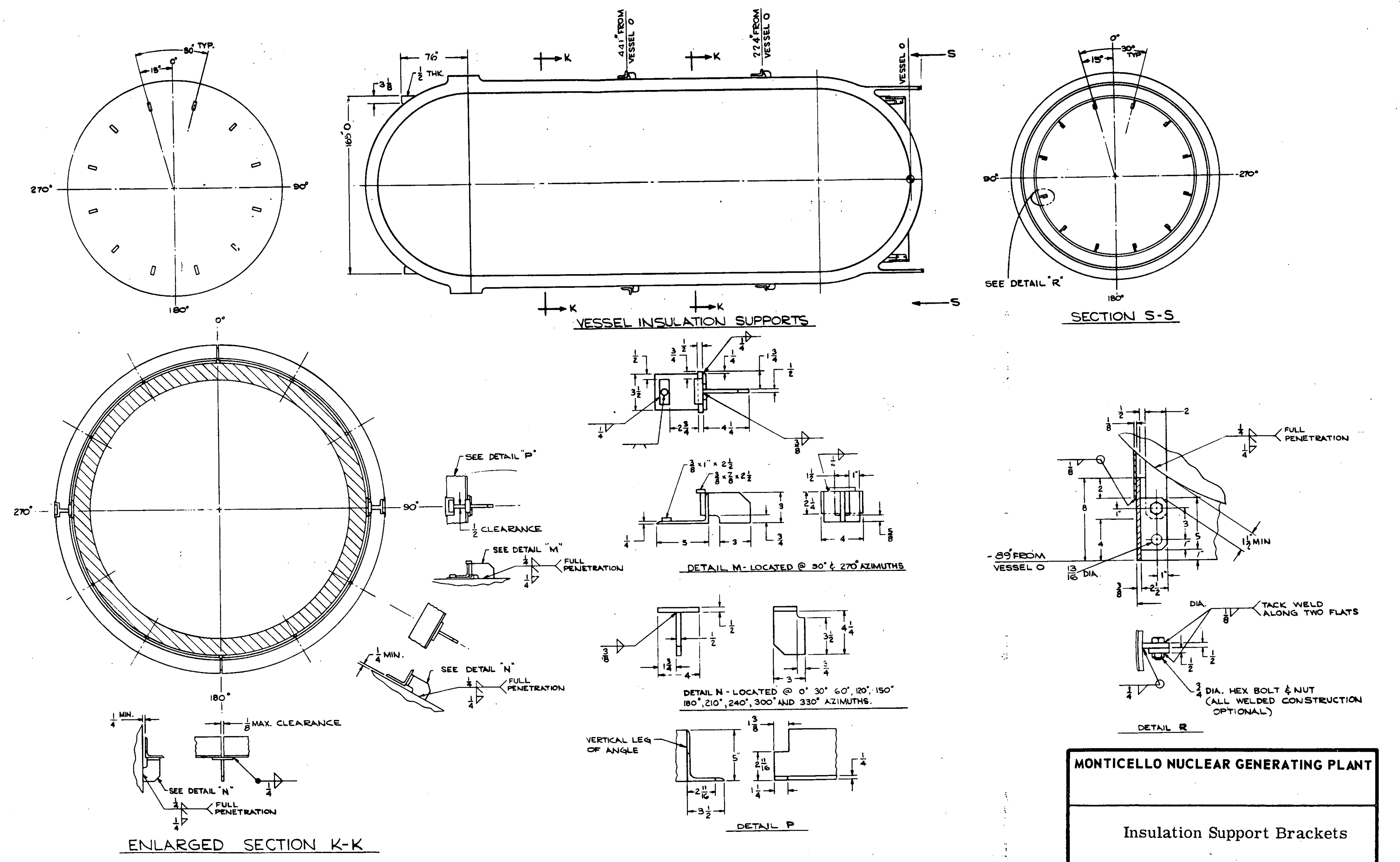


VIEW AT "D"

MONTICELLO NUCLEAR GENERATING PLANT

Nozzle End Preparations

FIGURE C-6

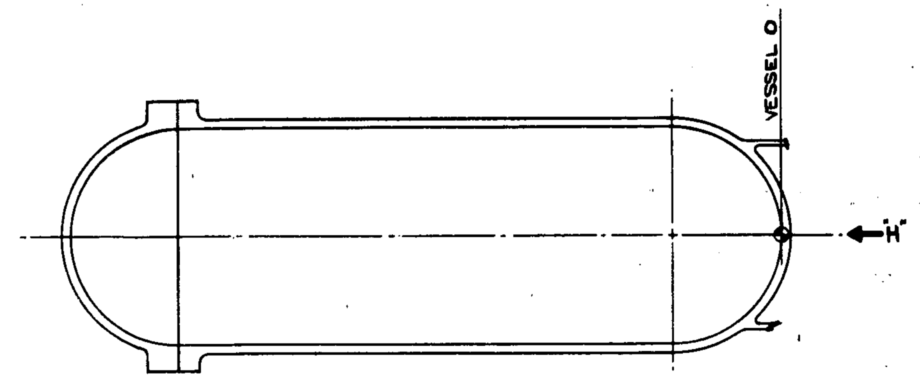


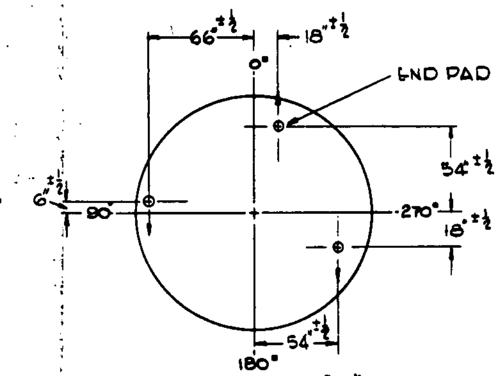
MONTICELLO NUCLEAR GENERATING PLANT

Insulation Support Brackets

FIGURE C-7

THERMOCOUPLE PADS			
LOCATION	END PAD: AZIMUTH ±1/2°	END PAD: DISTANCE FROM VESSEL 0 ±1/4	DIRECTION OF CLAMP PAD IN RELATION TO END PAD.
VESSEL FLANGE	15°	643	TOWARD 0°
↓ ↓	130°	643	270°
↓ ↓	270°	643	0°
STEAM	15°	613	0°
↓	130°	613	270°
↓	270°	613	0°
BELOW WATER LEVEL	15°	475	0°
↓	130°	475	270°
↓ ↓	270°	475	↓ 0°
FEEDWATER NOZZLE 4B	SEE FIG I		
FEEDWATER NOZZLE 4C	SEE FIG I		
VESSEL - CORE	15°	281	TOWARD 0°
↓ ↓	130°	281	270°
↓ ↓	270°	281	0°
DOWNCOMER	15°	165	0°
↓	130°	165	270°
↓	270	165	0°
BOT. ABOVE SKIRT JCT.	15°	74	0°
↓	130°	74	270°
↓	270°	74	0°
BOT. BELOW SKIRT JCT.	15°	46	0°
↓	130°	46	270°
↓ ↓	270	46	0°
SKIRT	15°	46	0°
↓	130°	46	270°
↓	270°	46	↓ 0°
VESSEL BOTTOM	SEE VIEW AT H		
↓ ↓	SEE VIEW AT H		
↓ ↓	SEE VIEW AT H		
SKIRT ABOVE MTG. FLG.	15°	-4	TOWARD 0°
↓ ↓	130°	-4	270°
↓ ↓	270°	-4	↓ 0°





VIEW AT "H"

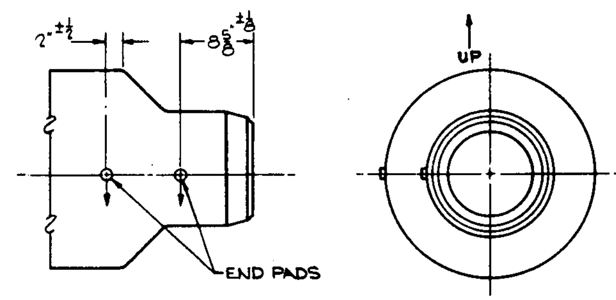
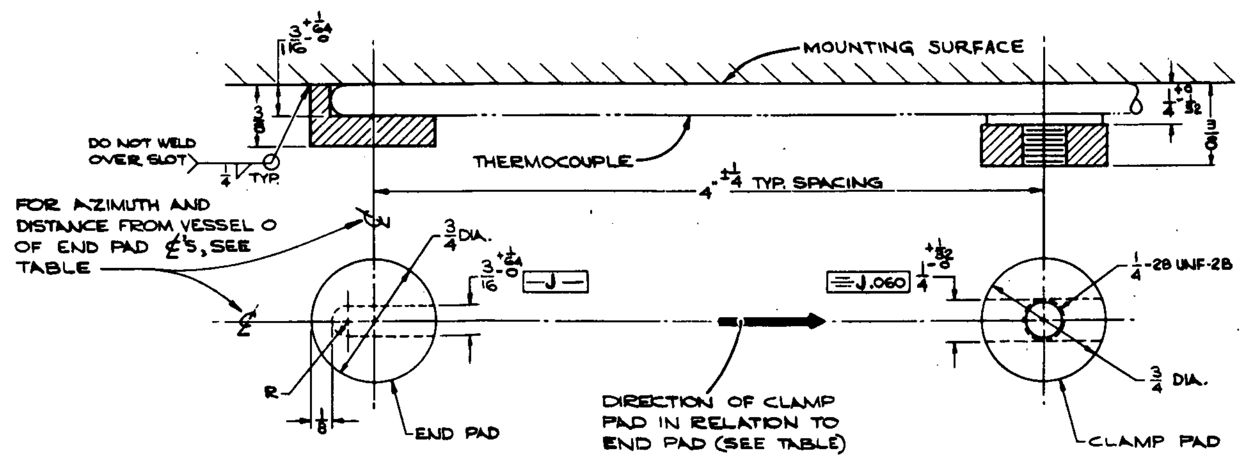
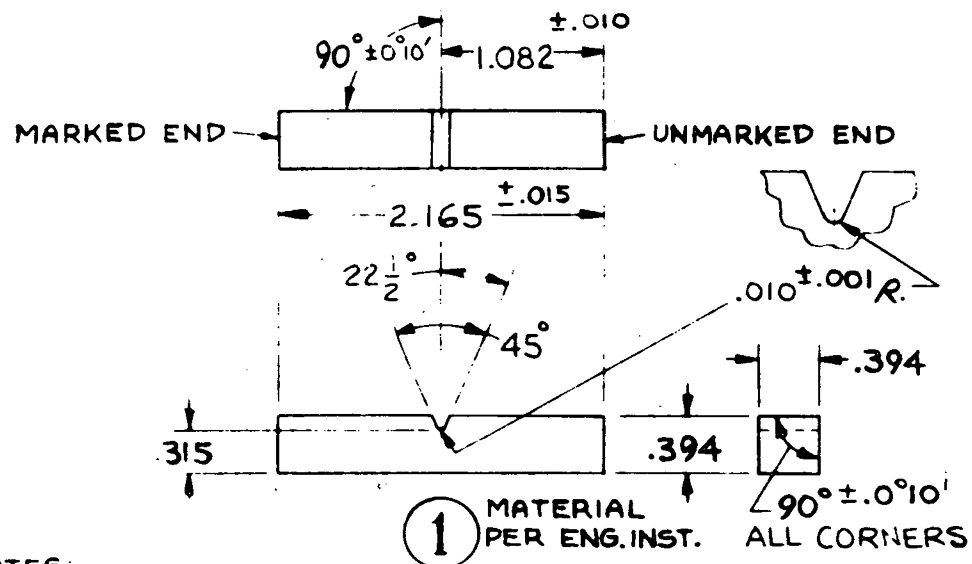


FIGURE 1



THERMOCOUPLE PADS

MONTICELLO NUCLEAR GENERATING PLANT
Thermal Mounting
FIGURE C-8



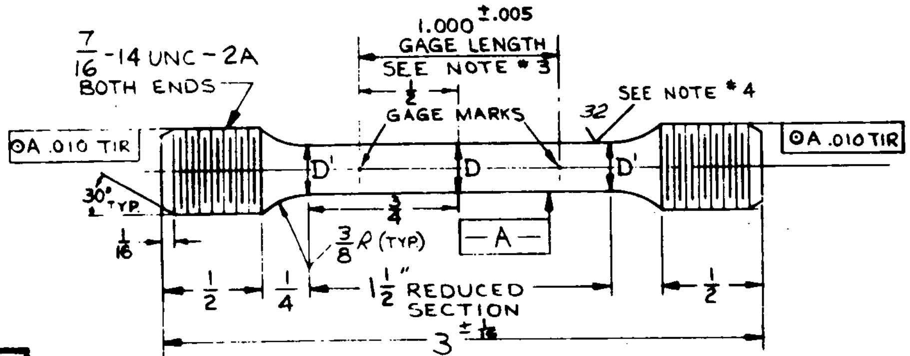
NOTES:

1. FINISH GRIND ALL SURFACES, EXCEPT ENDS, TO 63 MICROINCHES MAINTAINING CONTINUOUS FLOW OF COOLANT.
2. MACHINE UNMARKED END TO MAKE IT SQUARE NO SPECIAL FINISH REQUIRED.
3. MARKED END OF BLANK DOES NOT REQUIRE MACHINING. PRESERVE ORIGINAL IDENTITY MARKS ON END OF BLANK IF POSSIBLE. REMARKING IS REQUIRED MARK ONE END ONLY. RACTERS AND THEIR ORIENTATION ARE TO BE IDENTICAL TO TNAT OF BLANK.
4. LL OR BROACH "V" NOTCH ON SIDE ADJACENT TO TOP OF IDENTIFICATION MARKS. BOTTOM OF "V" NOTCH SHALL BE MACHINED SMOOTHLY WITH NO CHATTER OR TOOL MARKS. MEASURE NOTCH LOCATION WITH RESPECT TO UNMARKED END.
5. REMOVE ALL BURRS.
6. 100% DIMENSIONAL INSPECTION REQUIRED.

MONTICELLO NUCLEAR GENERATING PLANT

Charpy Impact Specimen

FIGURE C-9



(1) MATERIAL PER ENG. INST.

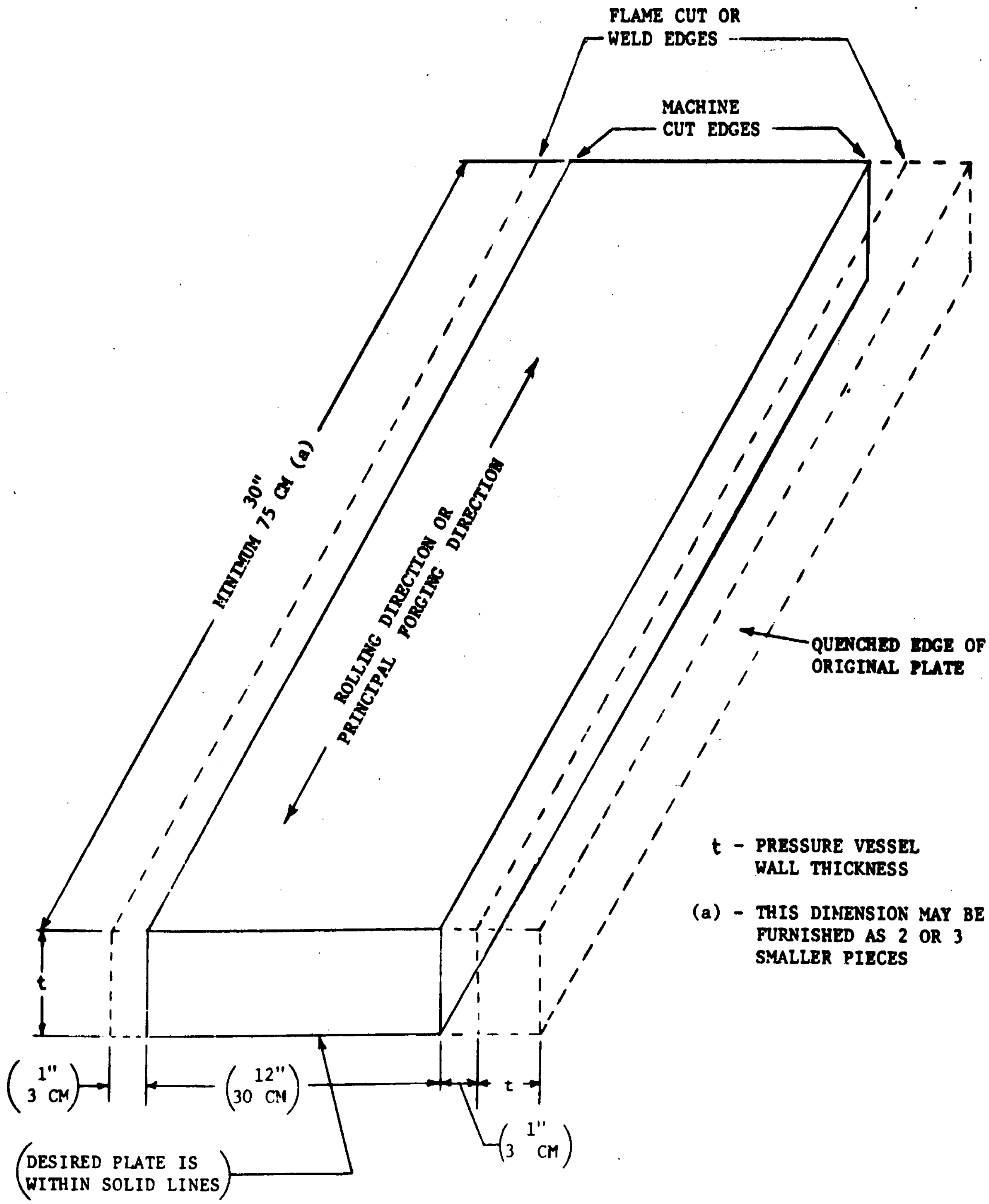
NOTES:

1. D = .250 ±.001 DIA. AT CENTER OF REDUCED SECTION.
2. D' = ACTUAL "D" DIA. + .002 TO .005 AT ENDS OF REDUCED SECTION, TAPERING TO "D" AT CENTER.
3. USE PRESET EXTENSOMETER. GAGE MARKER FOR PRICK PUNCHING GAGE MARKS.
4. POLISH REDUCED SECTION AND RADIUS TO 32 rms, REMAINDER AS TURNED.
5. EACH PIECE IS TO BE MARKED AS PER SPECIMEN BLANK FROM WHICH IT WAS MADE.
6. 100% DIMENSIONAL INSPECTION REQUIRED.

MONTICELLO NUCLEAR GENERATING PLANT

1/4-Inch Tensile Test Specimen

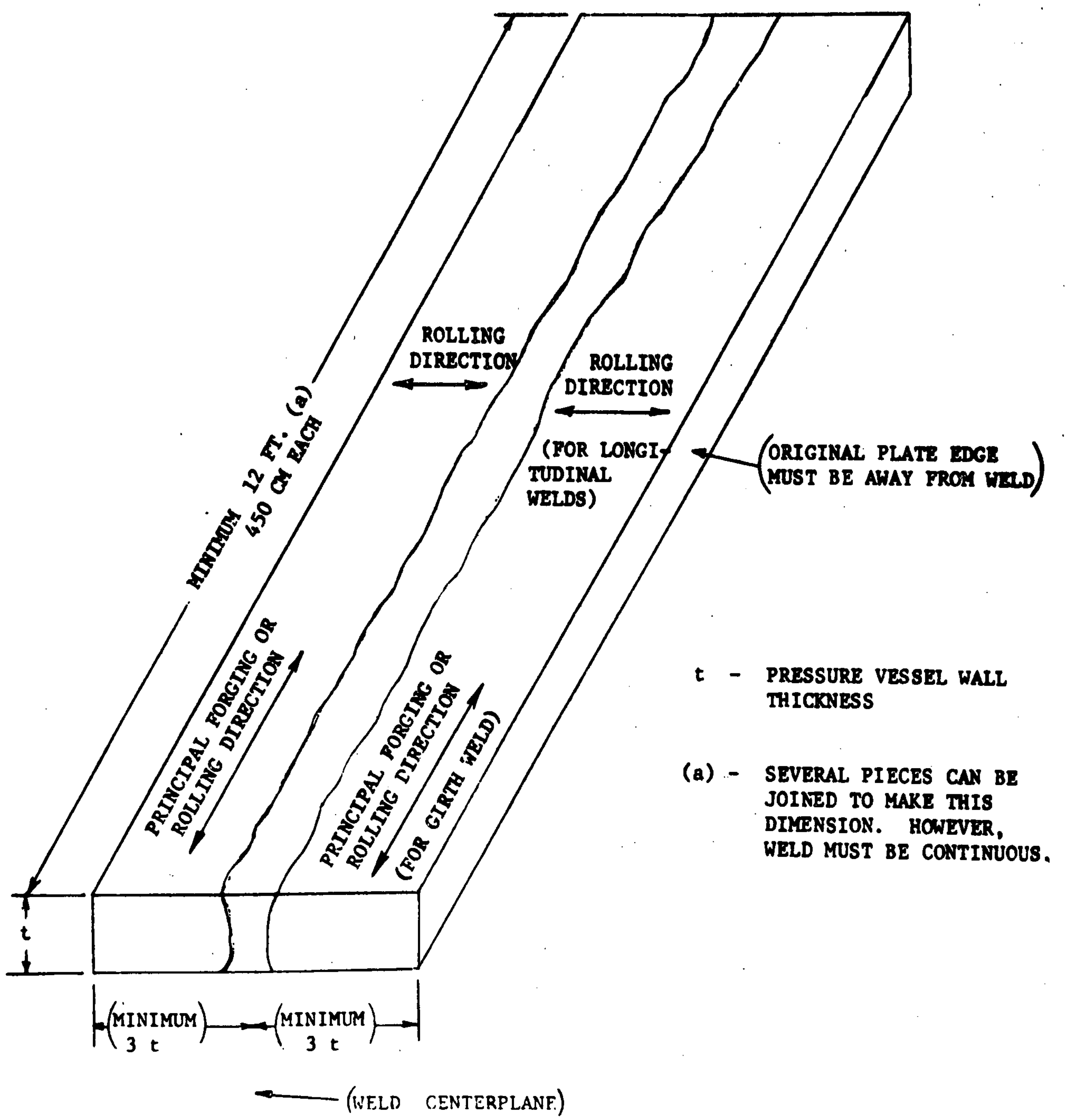
FIGURE C-10



MONTICELLO NUCLEAR GENERATING PLANT

Test Plate - Base Metal Specimens

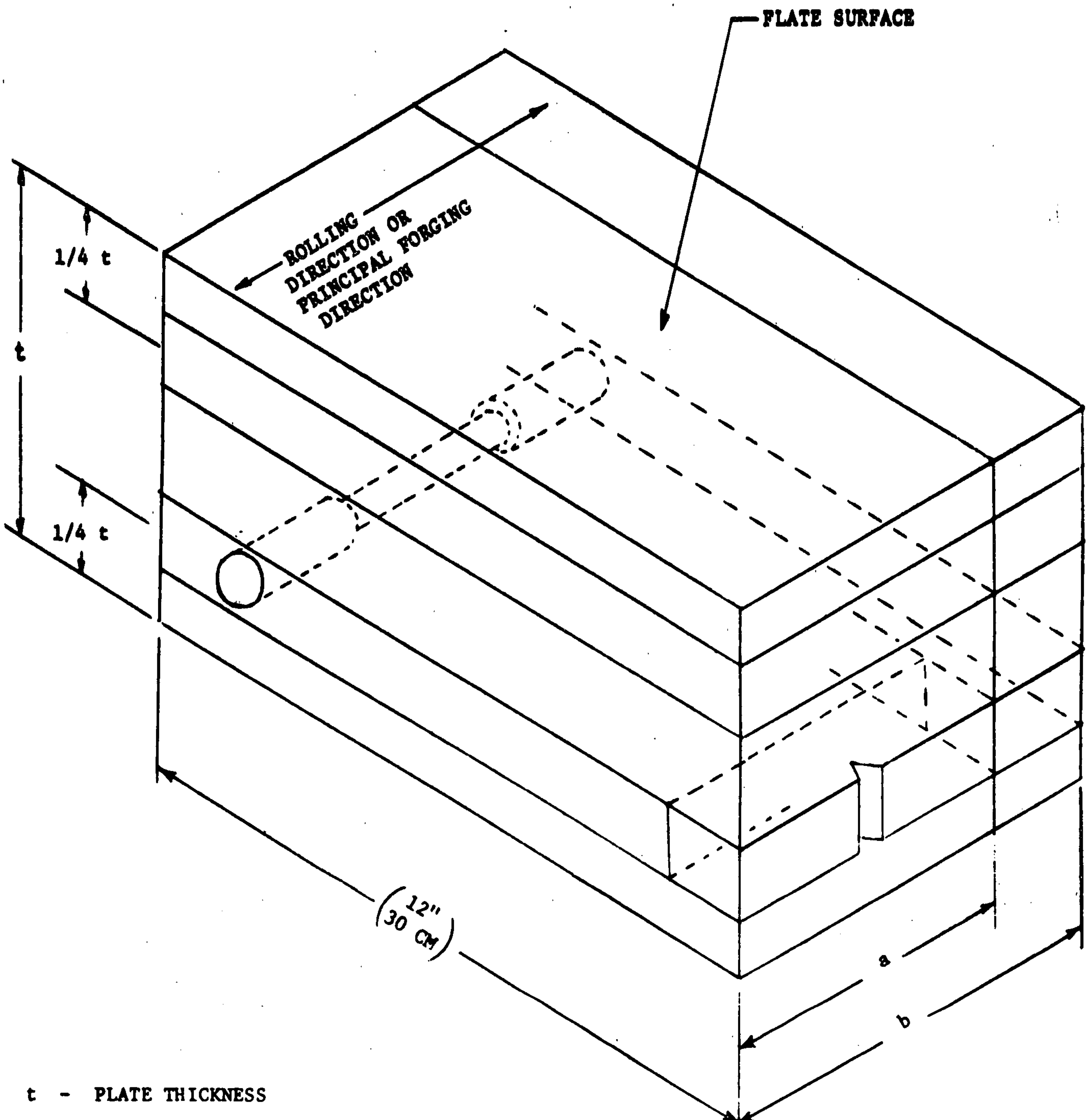
FIGURE C-11



MONTICELLO NUCLEAR GENERATING PLANT

Test Weld for Weld and Heat Affected Zone Specimen

FIGURE C-12



t - PLATE THICKNESS

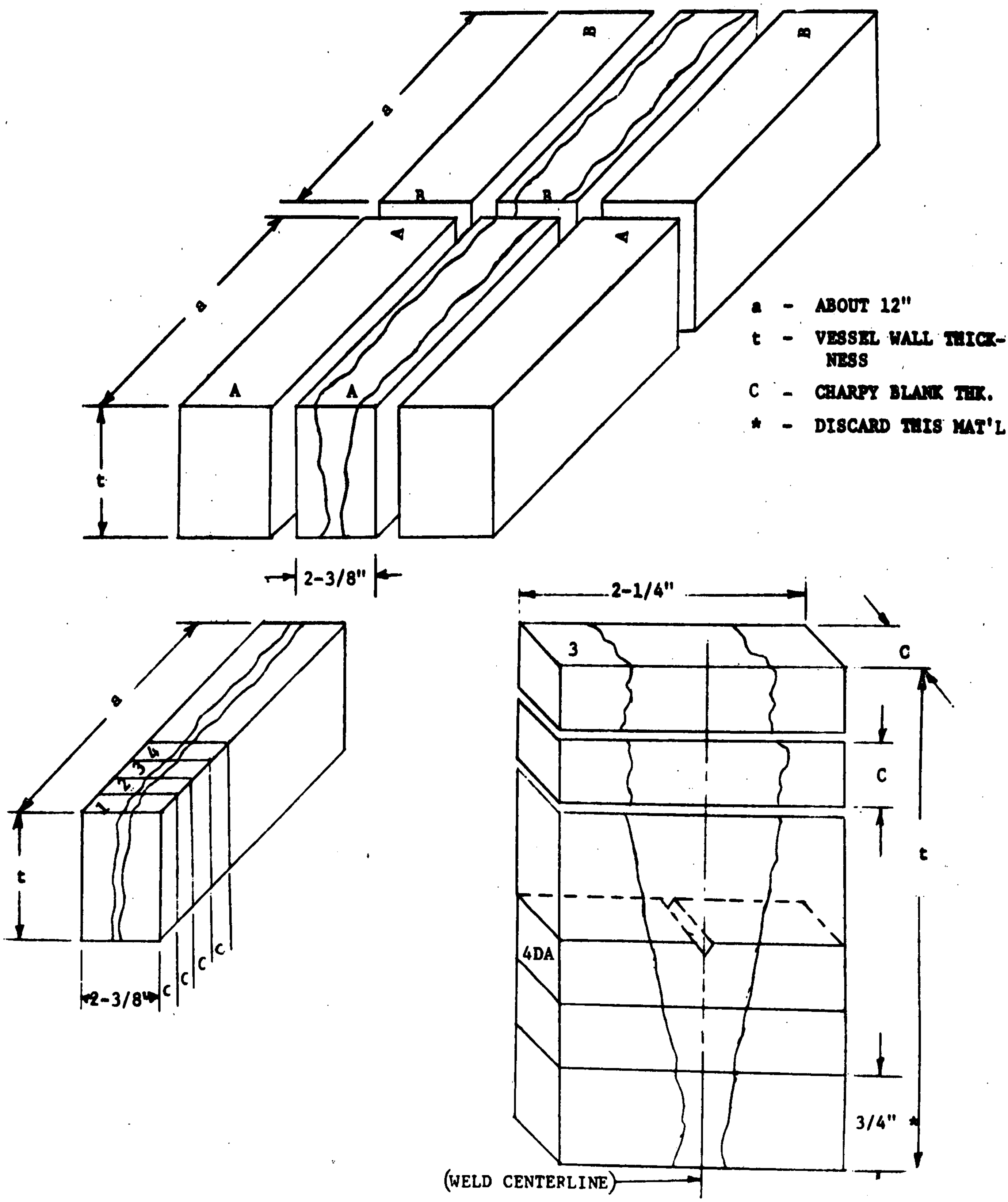
a - CHARPY BLANK LENGTH

b - TENSILE BLANK LENGTH

MONTICELLO NUCLEAR GENERATING PLANT

Base Metal Charpy and Tensile Specimen Location

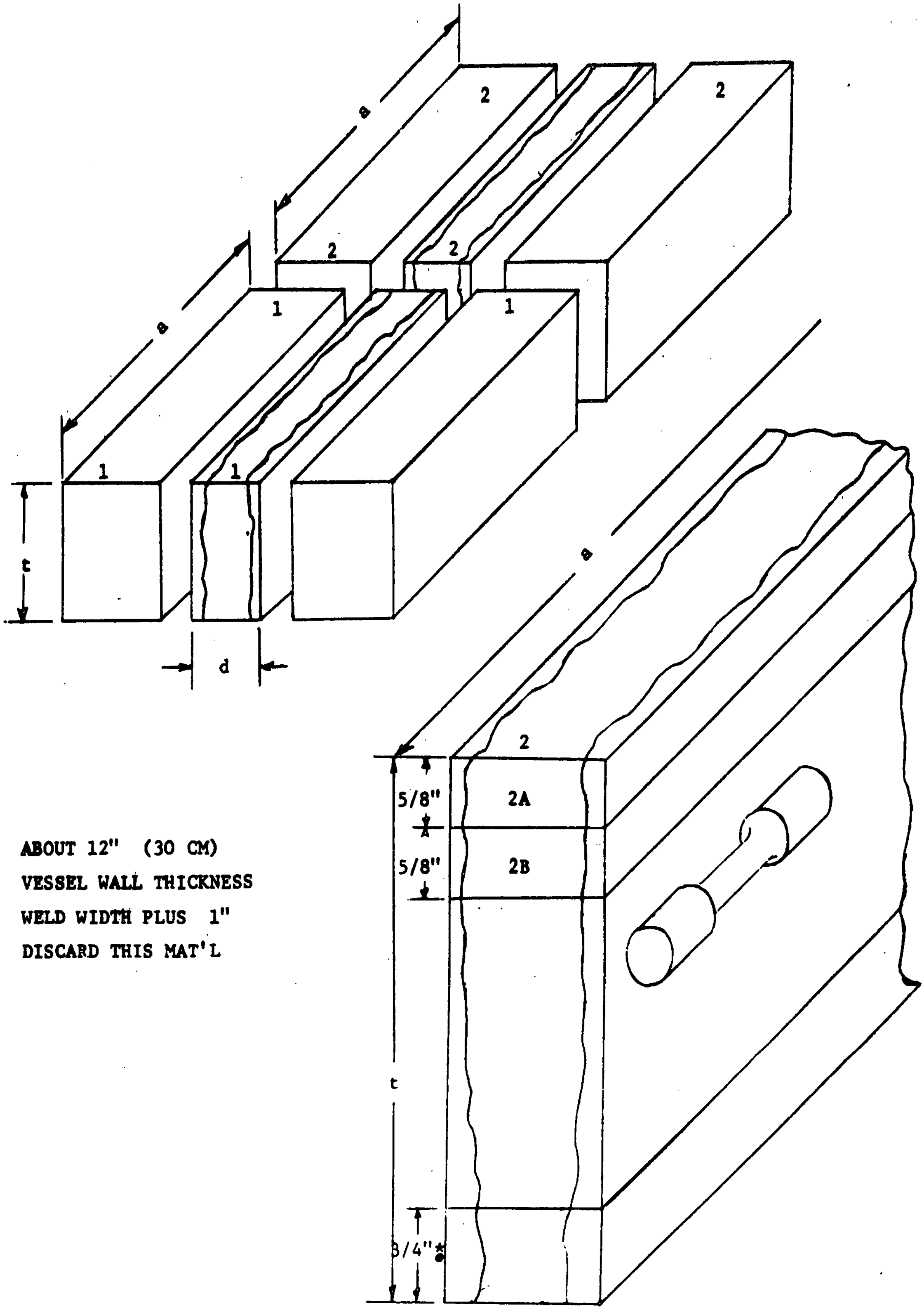
FIGURE C-13



MONTICELLO NUCLEAR GENERATING PLANT

Weld Charpy

FIGURE C-14

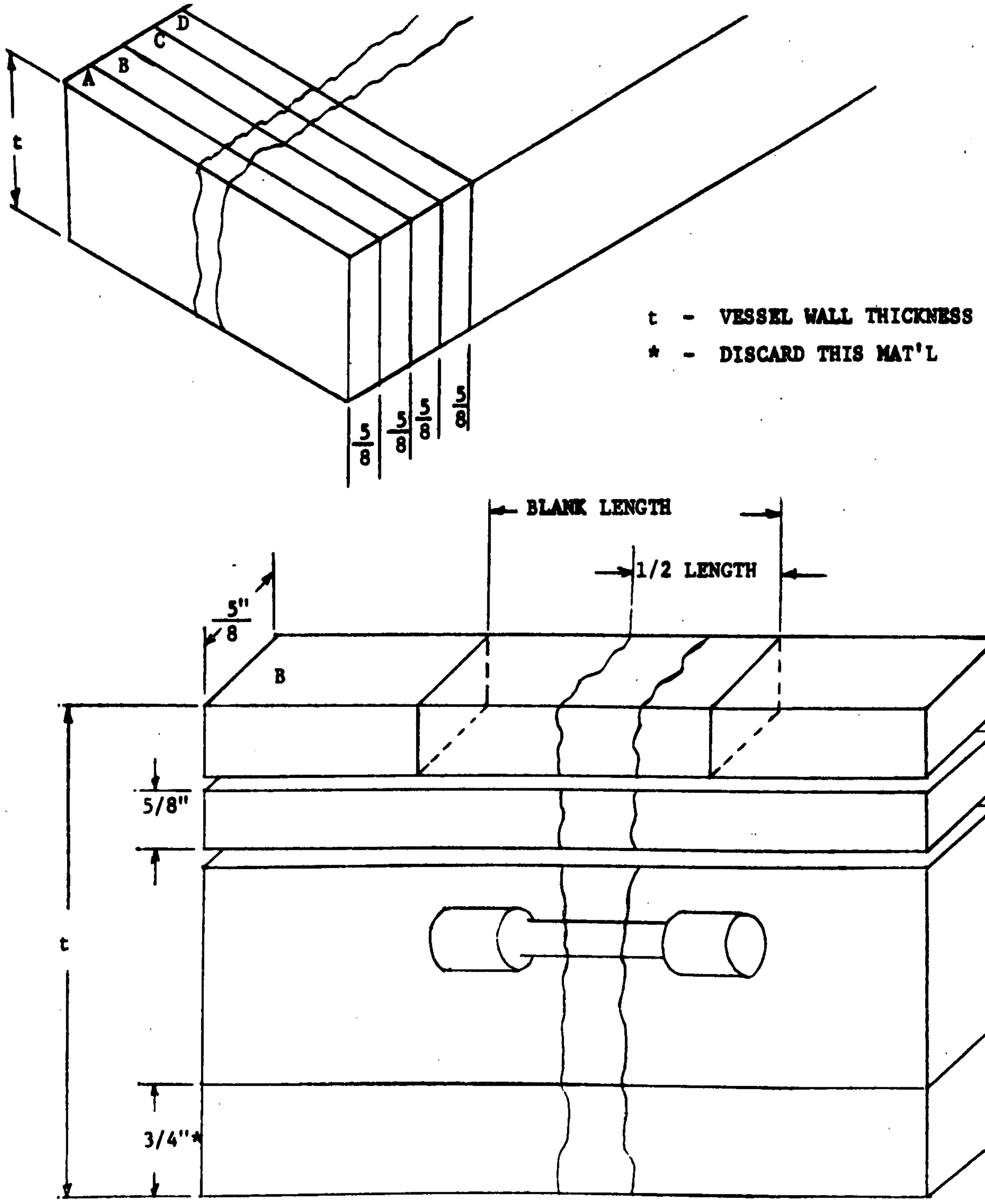


a - ABOUT 12" (30 CM)
t - VESSEL WALL THICKNESS
d - WELD WIDTH PLUS 1"
* - DISCARD THIS MAT'L

MONTICELLO NUCLEAR GENERATING PLANT

Weld Tensile

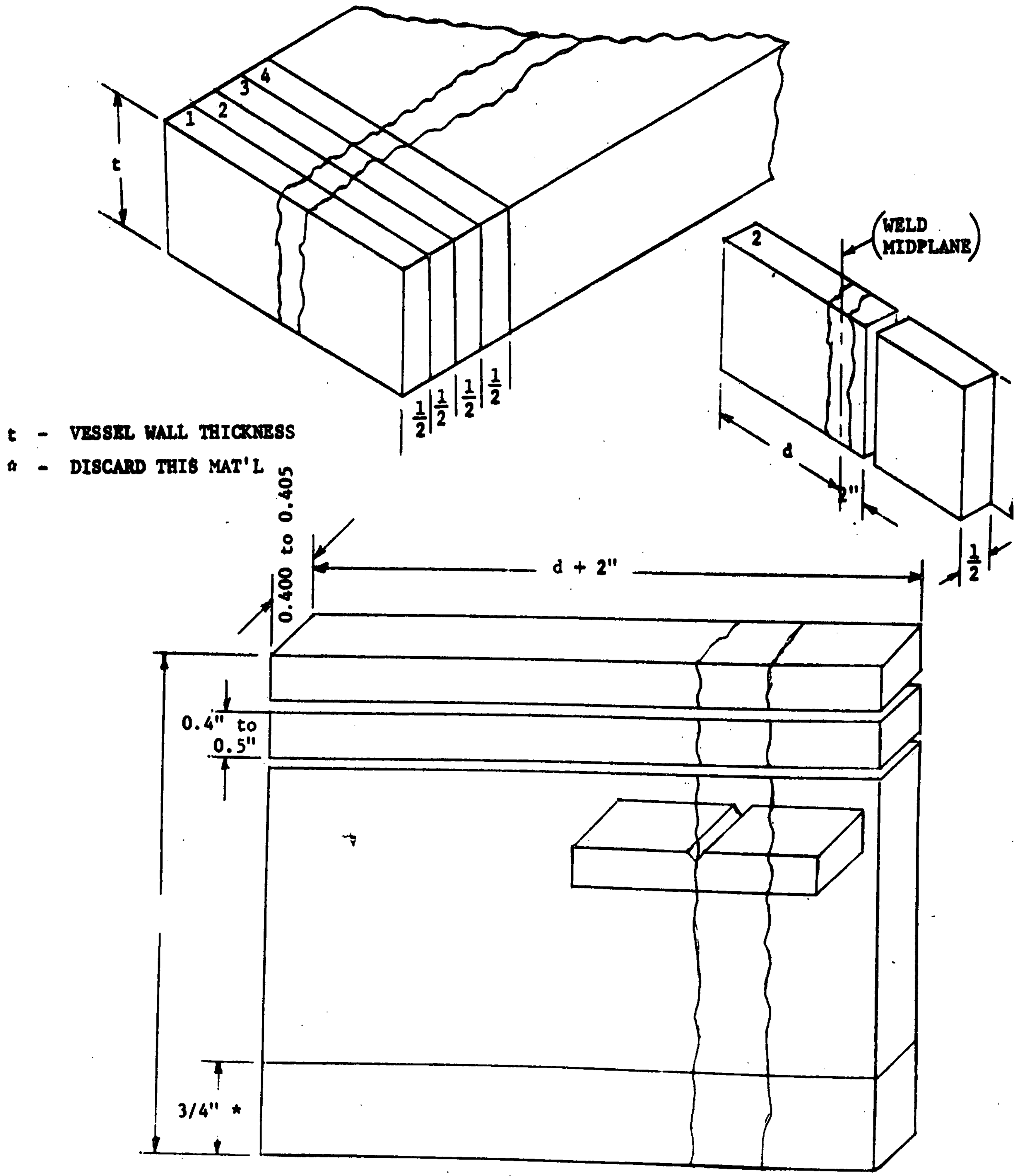
FIGURE C-15



MONTICELLO NUCLEAR GENERATING PLANT

Heat Affected Zone Tensile

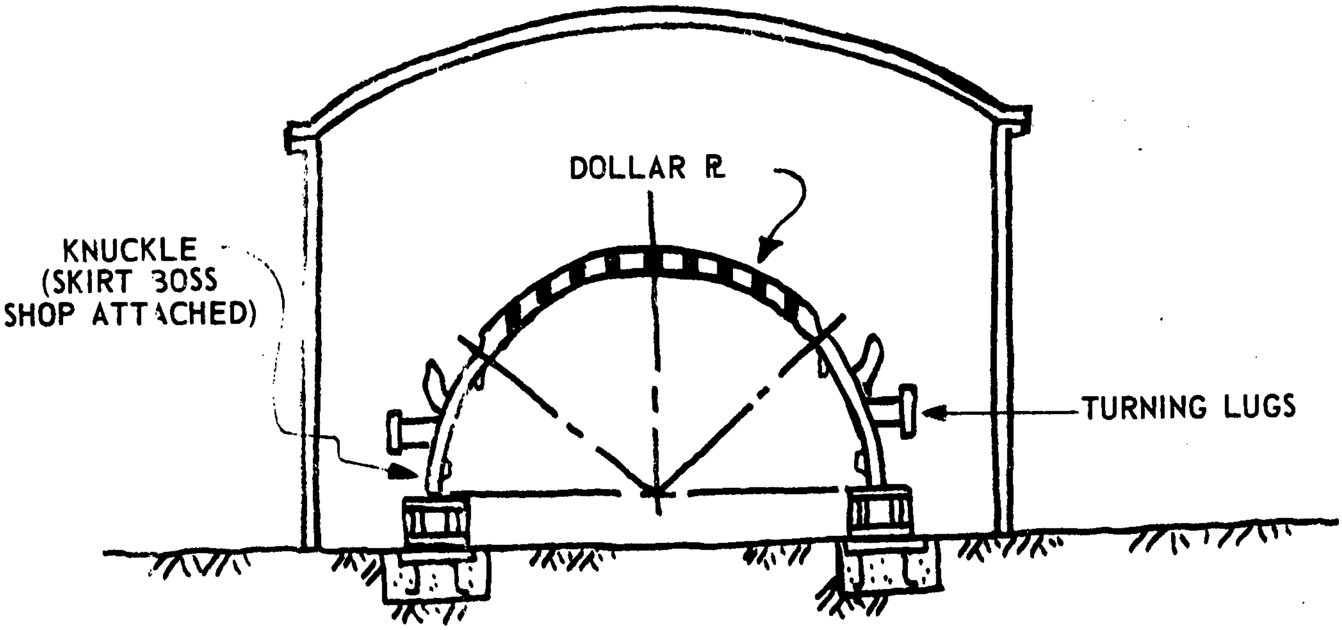
FIGURE C-16



MONTICELLO NUCLEAR GENERATING PLANT

Heat Affected Zone Charpy

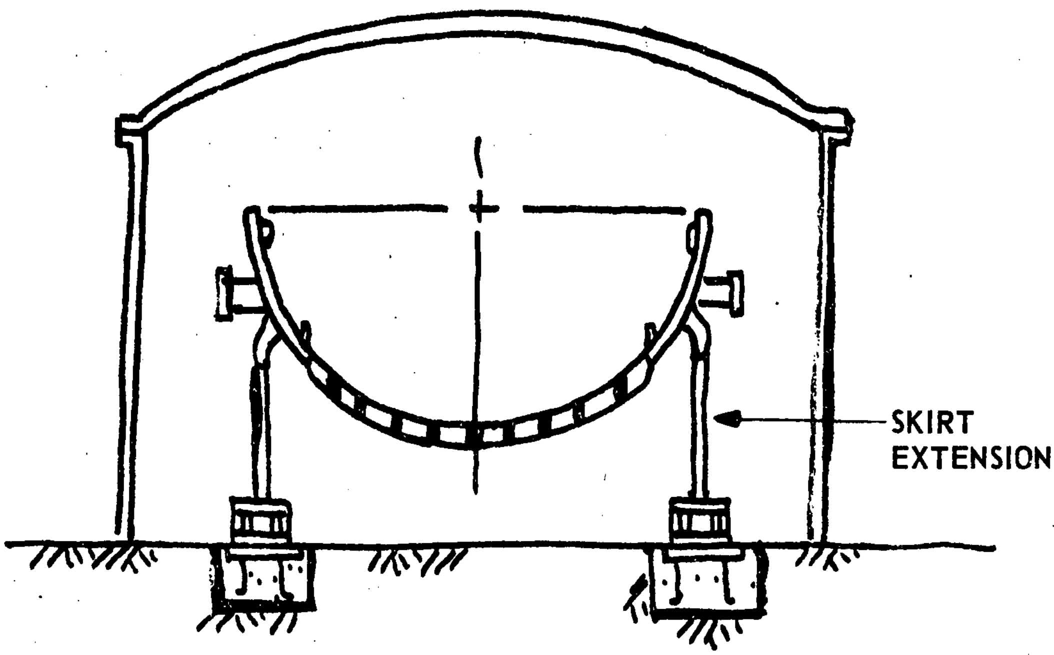
FIGURE C-17



BOTTOM HEAD TOGETHER

1. DOLLAR R TO KNUCKLE FIT AND PRE-HEAT
2. DOLLAR R TO KNUCKLE - WELD BACKING MATERIAL
3. PWHT
4. ULTRASONIC AND RADIOGRAPH
5. PRE-HEAT AND OVERLAY
6. ULTRASONIC AND DYE PENETRANT SEAM OVERLAY

MONTICELLO NUCLEAR GENERATING PLANT
Bottom Head Together FIGURE D-1



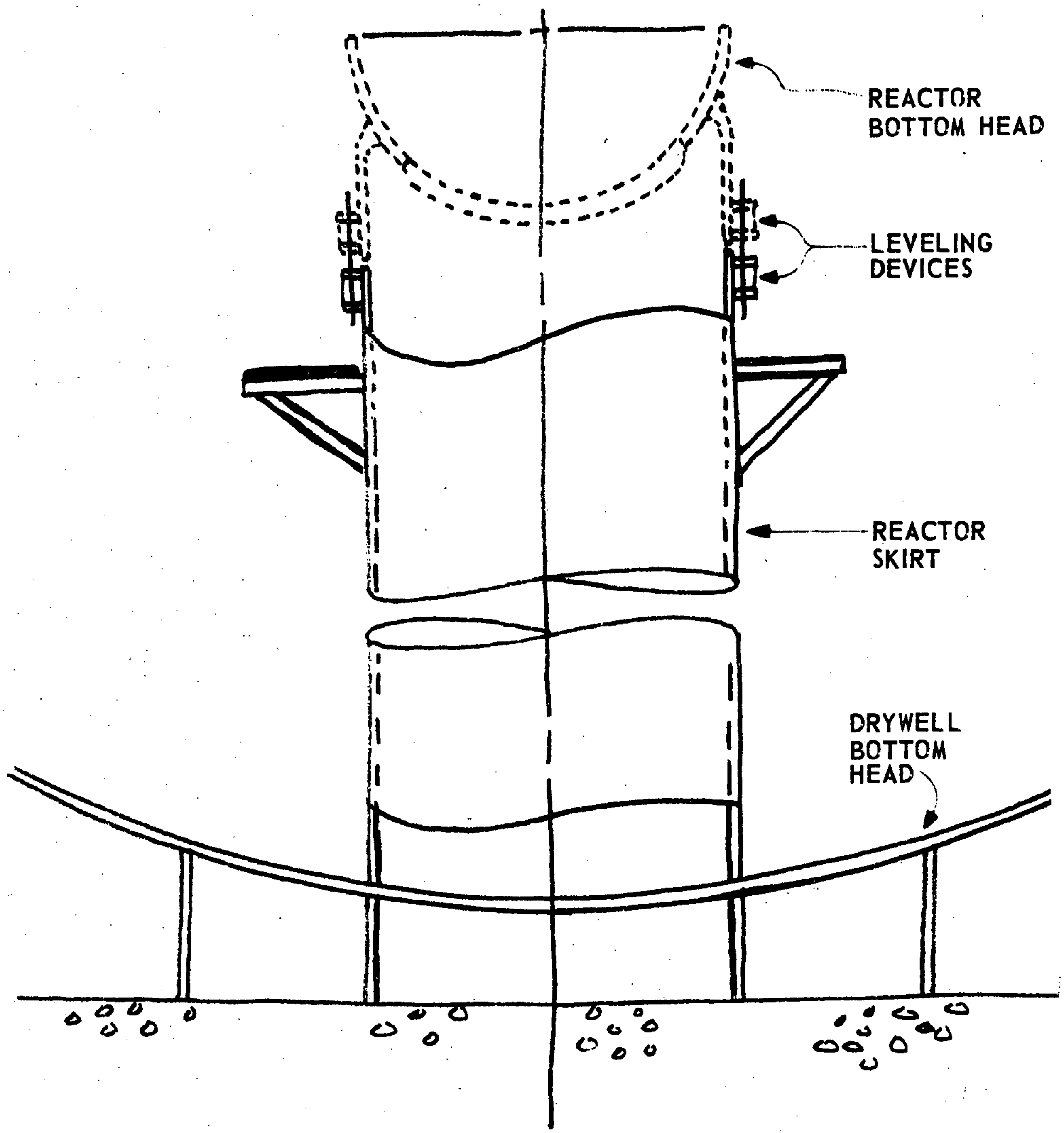
BOTTOM HEAD TO SKIRT EXTENSION

1. FIT AND PRE-HEAT
2. WELD
3. PWHT
4. ULTRASONIC AND RADIOGRAPH

MONTICELLO NUCLEAR GENERATING PLANT

Bottom Head to Skirt Extension

FIGURE D-2

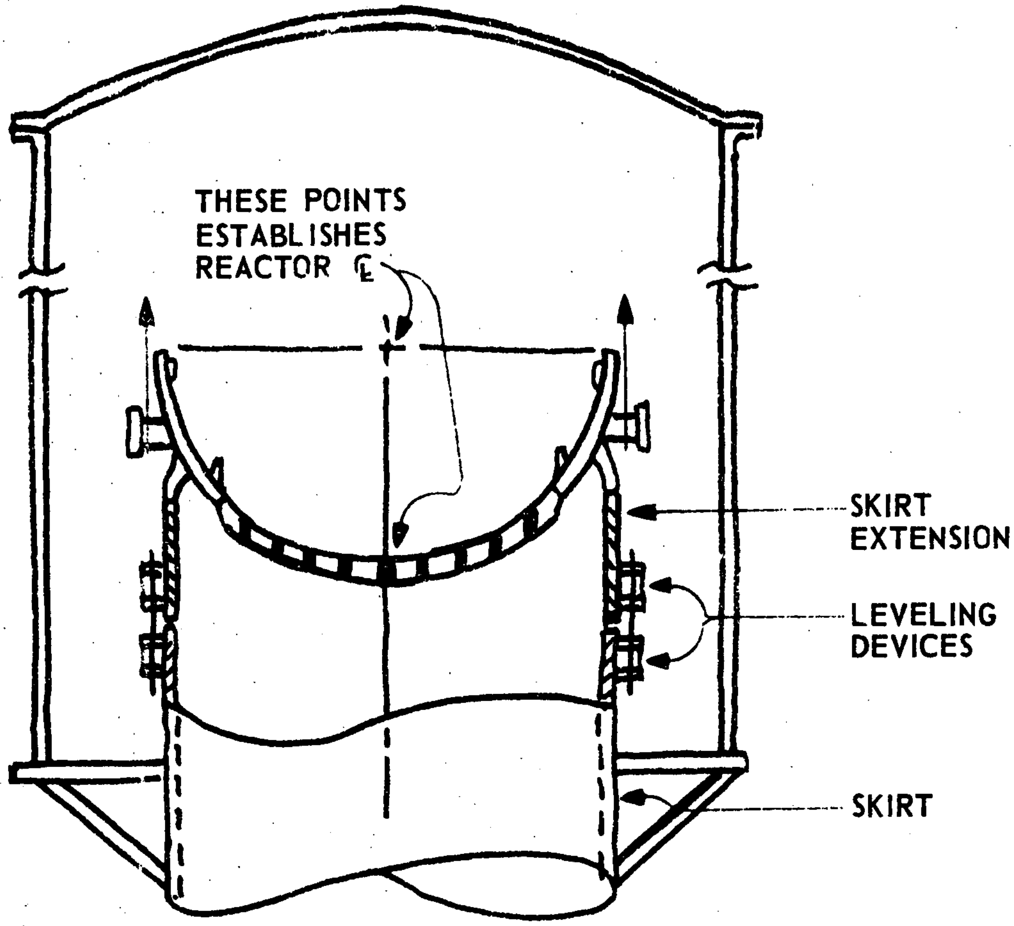


REACTOR SKIRT

MONTICELLO NUCLEAR GENERATING PLANT

Reactor Skirt

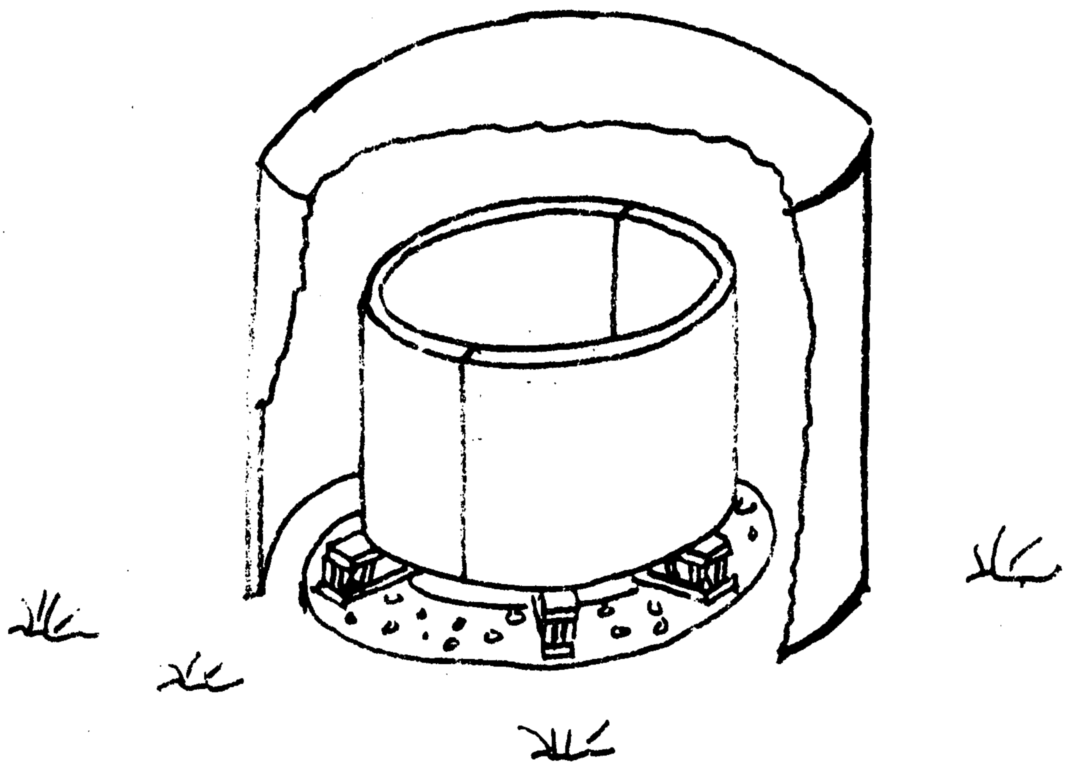
FIGURE D-3



SKIRT EXTENSION TO SKIRT

1. ERECT BOTTOM HEAD ASSEMBLY
2. WITH LEVELING DEVICES, POSITION BOTTOM HEAD ASSEMBLY
3. WELD

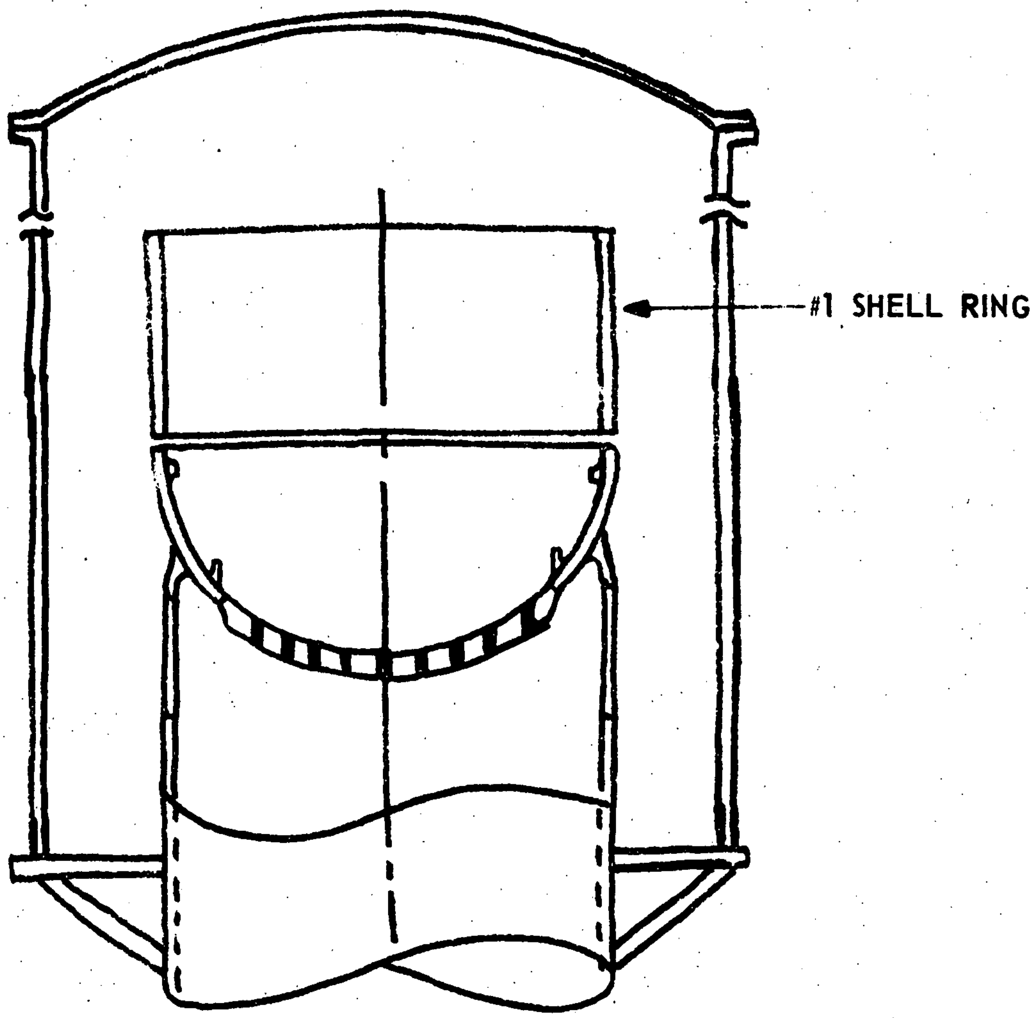
MONTICELLO NUCLEAR GENERATING PLANT
Skirt Extension to Skirt
FIGURE D-4



SHELL SECTIONS TOGETHER

1. FIT AND PRE-HEAT
2. WELD BACKING MATERIAL
3. PWHT
4. ULTRASONIC AND RADIOGRAPH
5. PRE-HEAT AND OVERLAY VERTS
6. PWHT
7. ULTRASONIC AND DYE PENETRANT

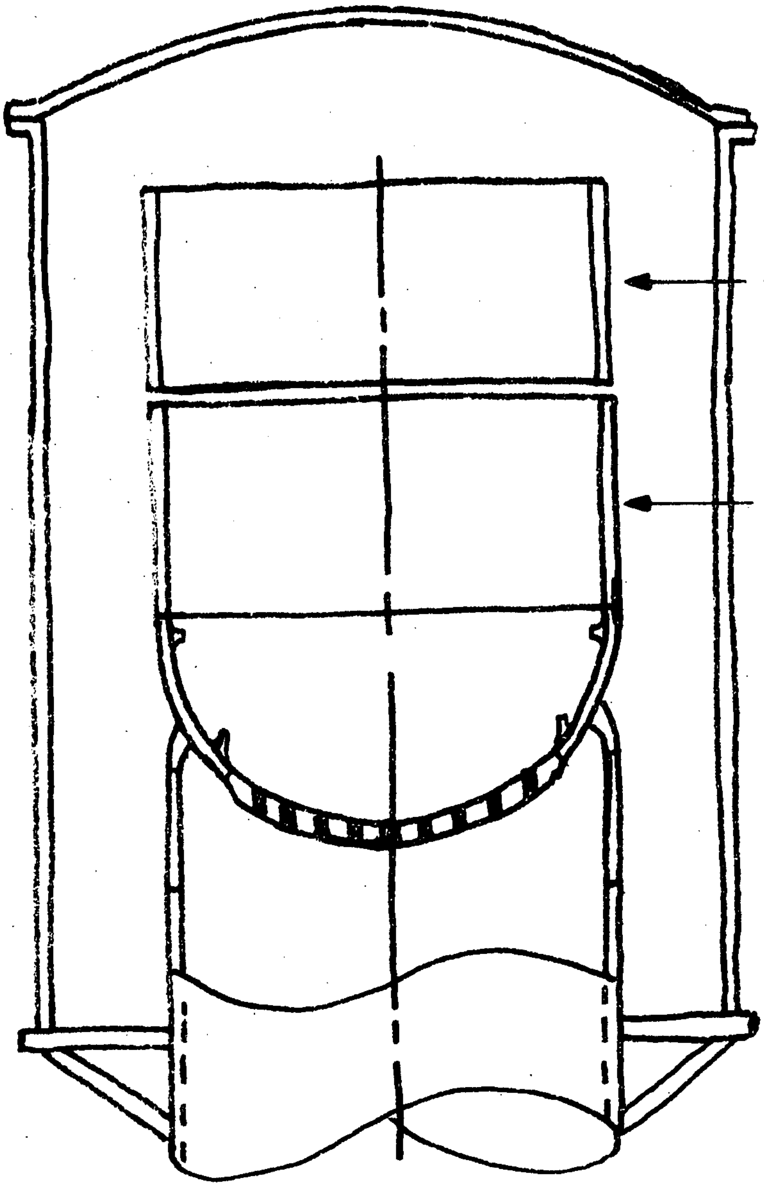
MONTICELLO NUCLEAR GENERATING PLANT
Shell Sections Together FIGURE D-5



#1 SHELL RING TO BOTTOM HEAD

1. FIT AND PRE-HEAT
2. WELD BACKING MATERIAL
3. PWHT (BOTTOM HD AND #1 SHELL RING)
4. ULTRASONIC AND RADIOGRAPH
5. PRE-HEAT AND OVERLAY
6. PWHT
7. ULTRASONIC AND DYE PENETRANT

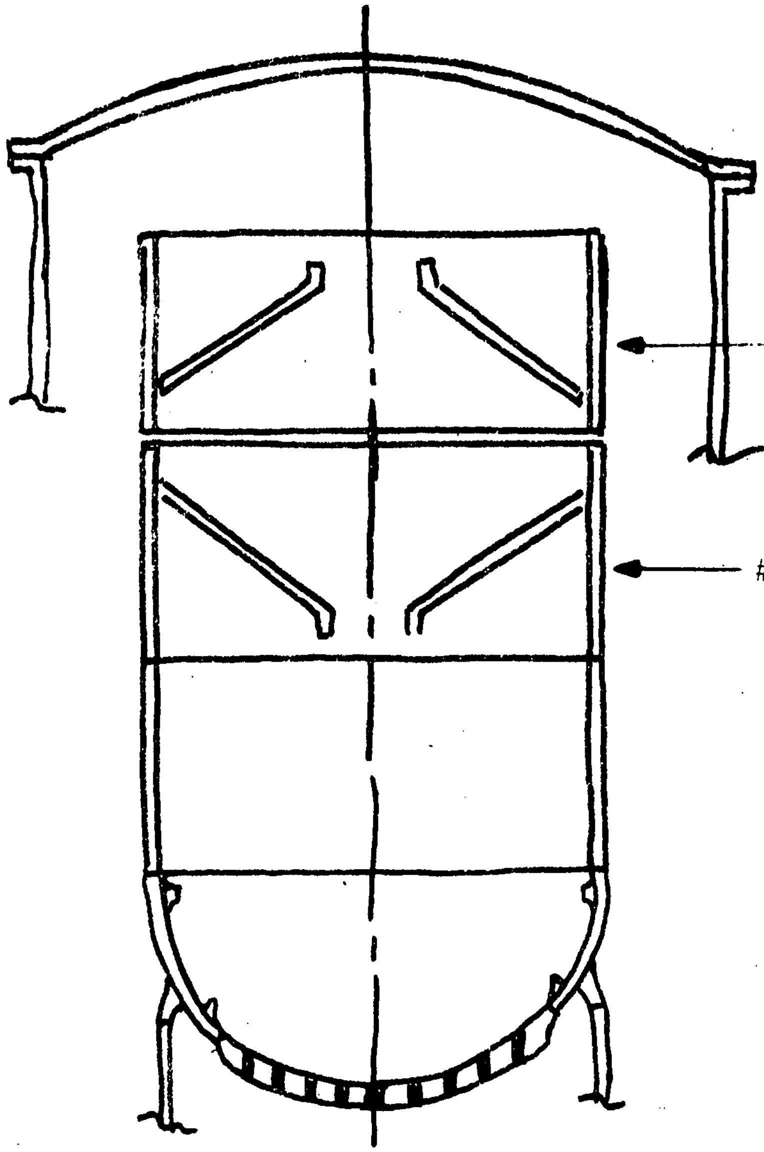
MONTICELLO NUCLEAR GENERATING PLANT
#1 Shell Ring to Bottom Head FIGURE D-6



2 SHELL RING TO # 1 SHELL RING

1. FIT & PRE-HEAT
2. WELD BACKING MATERIAL
3. PWHT (BOTT HD & SHELL RINGS)
4. ULTRASONIC & RADIOGRAPH
5. PRE-HEAT & OVERLAY
6. PWHT
7. ULTRASONIC & DYE PENETRANT

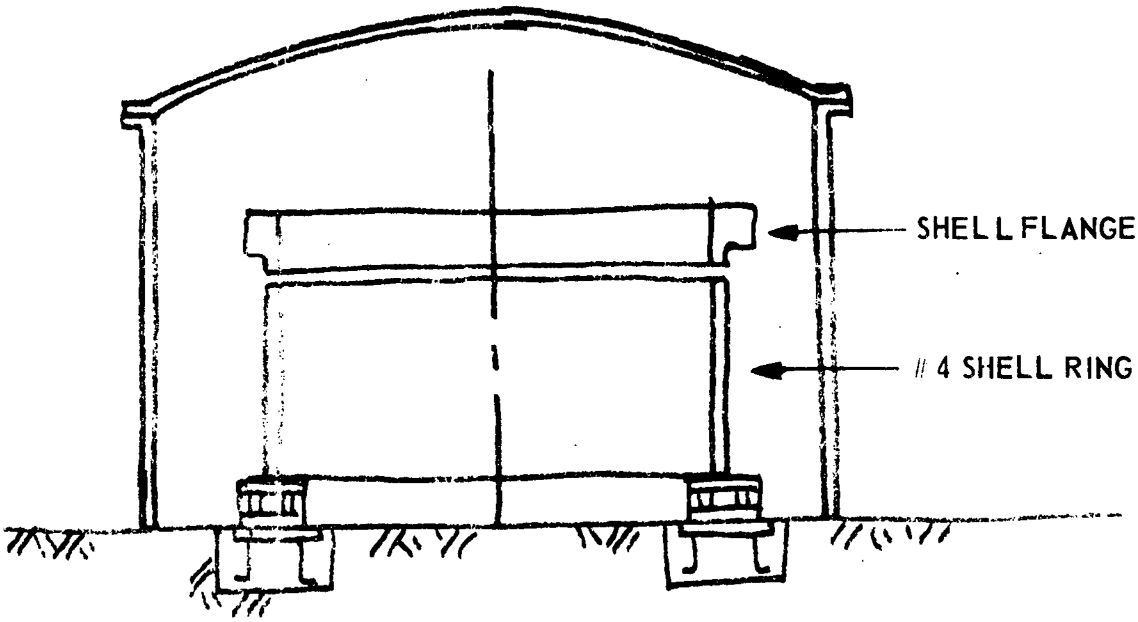
MONTICELLO NUCLEAR GENERATING PLANT
#2 Shell Ring to #1 Shell Ring FIGURE D-7



3 SHELL RING TO # 2 SHELL RING

1. FIT & PRE-HEAT
2. WELD BACKING MATERIAL
3. PWHT (LOCAL)
4. ULTRASONIC & RADIOGRAPH
5. PRE-HEAT & OVERLAY
6. PWHT
7. ULTRASONIC & DYE PENETRANT

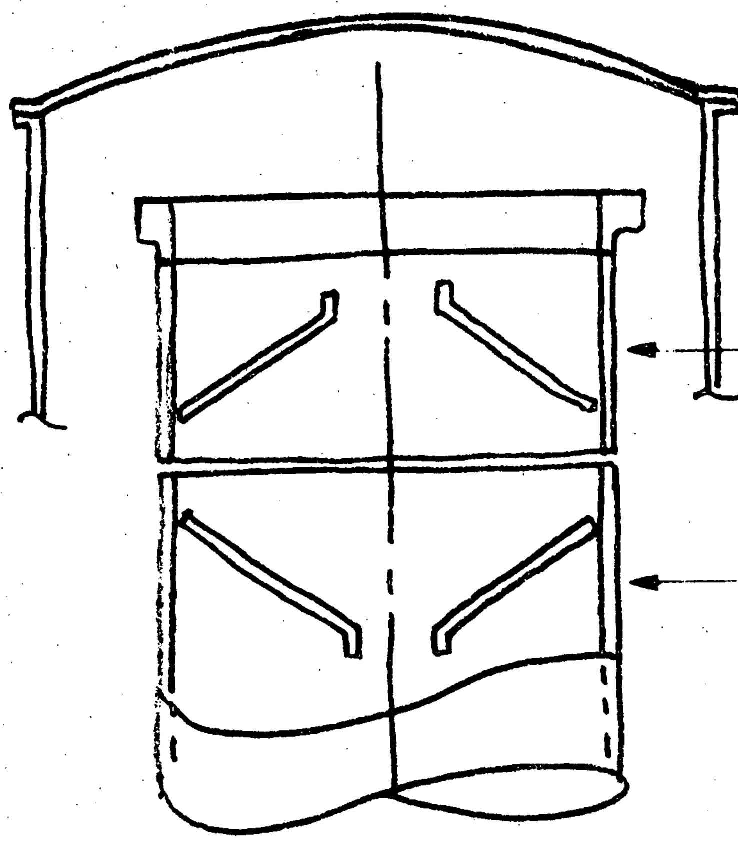
MONTICELLO NUCLEAR GENERATING PLANT
#3 Shell Ring to #2 Shell Ring FIGURE D-8



SHELL FLANGE TO # 4 SHELL RING

1. PRE-HEAT & OVERLAY FLANGE
2. PWHT FLANGE
3. ULTRASONIC & DYE PENETRANT FLANGE OVERLAY
4. FIT & PRE-HEAT FLANGE TO SHELL
5. WELD FLANGE TO SHELL
6. PWHT FLANGE TO SHELL
7. ULT & RAD FLANGE TO SHELL
8. PRE-HT & OVERLAY FLANGE TO SHELL
9. PWHT FLANGE TO SHELL
10. ULTR & DYE PEN FLANGE TO SHELL

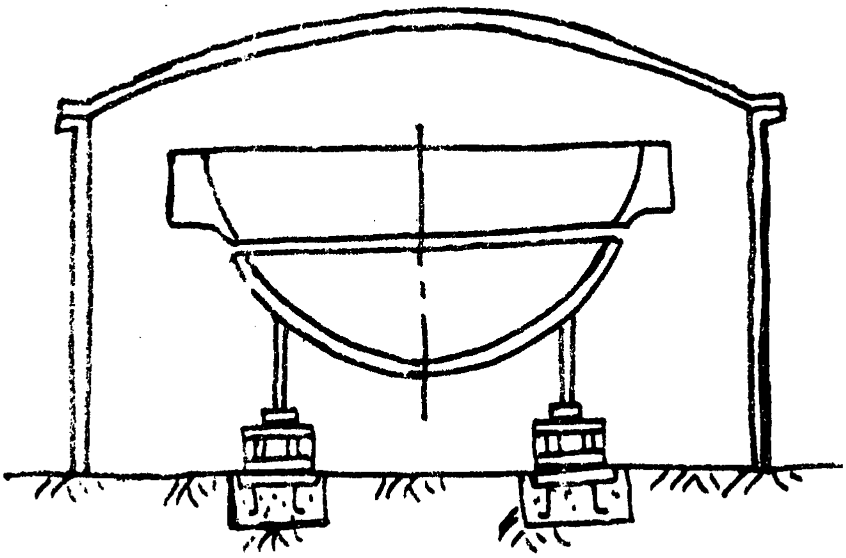
MONTICELLO NUCLEAR GENERATING PLANT
Shell Flange to #4 Shell Ring FIGURE D-9



4 RING TO # 3 RING

1. FIT & PRE-HEAT
2. WELD BACKING MATERIAL
3. PWHT (LOCAL)
4. ULTRASONIC & RADIOGRAPH
5. PRE-HEAT & OVERLAY
6. PWHT
7. ULTRASONIC & DYE PENETRANT

MONTICELLO NUCLEAR GENERATING PLANT
#4 Ring to #3 Ring FIGURE D-10



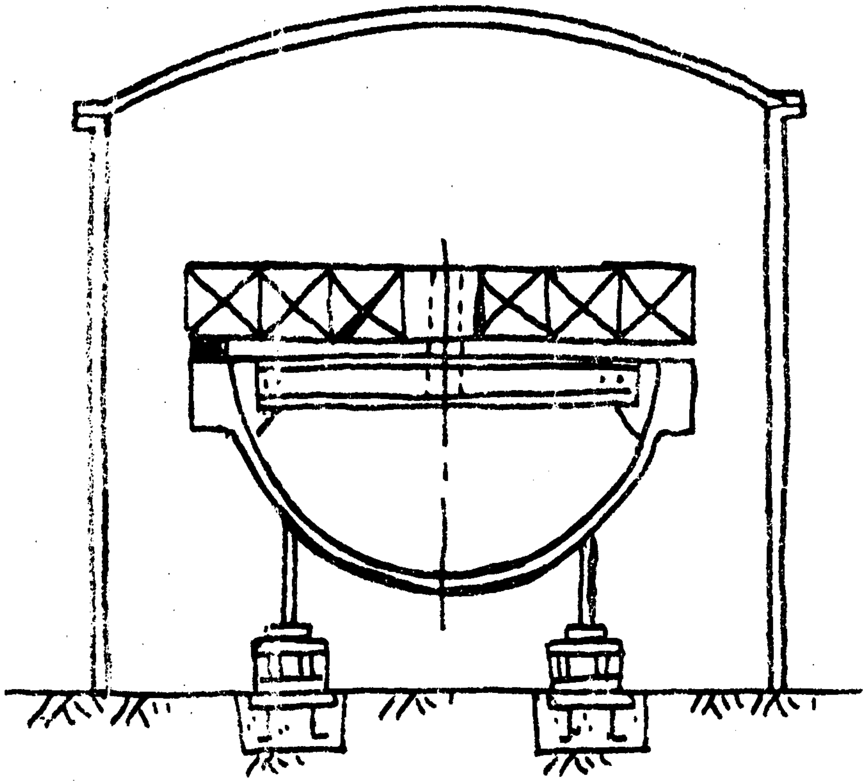
HEAD FLANGE TO TOP HEAD

1. PRE-HEAT & OVERLAY FLANGE
2. PWHT FLANGE
3. ULTRASONIC & DYE PENETRANT FLANGE OVERLAY
4. FIT & PRE-HEAT
5. WELD
6. PWHT
7. ULT & RAD
8. PRE-HT & OVERLAY
9. PWHT
10. ULTR & DYE PEN

MONTICELLO NUCLEAR GENERATING PLANT

Head Flange to Tap Head

FIGURE D-11



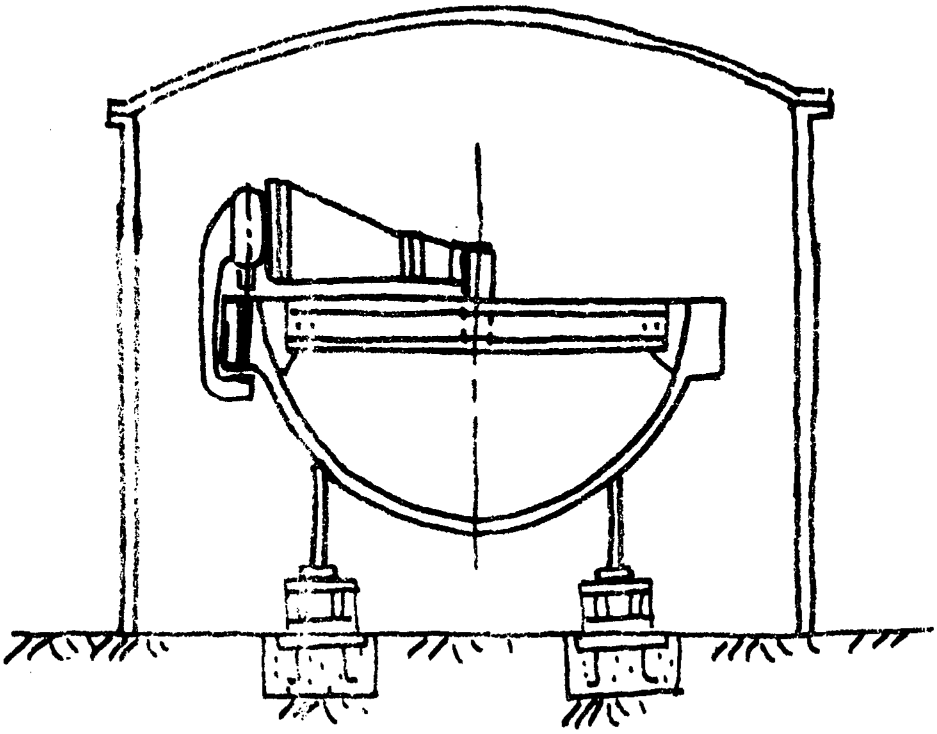
MACHINING TOP HEAD FLANGE

1. LEVEL TOP HEAD ASSEMBLY
2. SETUP MACHINING EQUIPMENT
3. MACHINE FLANGE
4. MACHINE GROOVES FOR GASKETS

MONTICELLO NUCLEAR GENERATING PLANT

Machining Top Head Flange

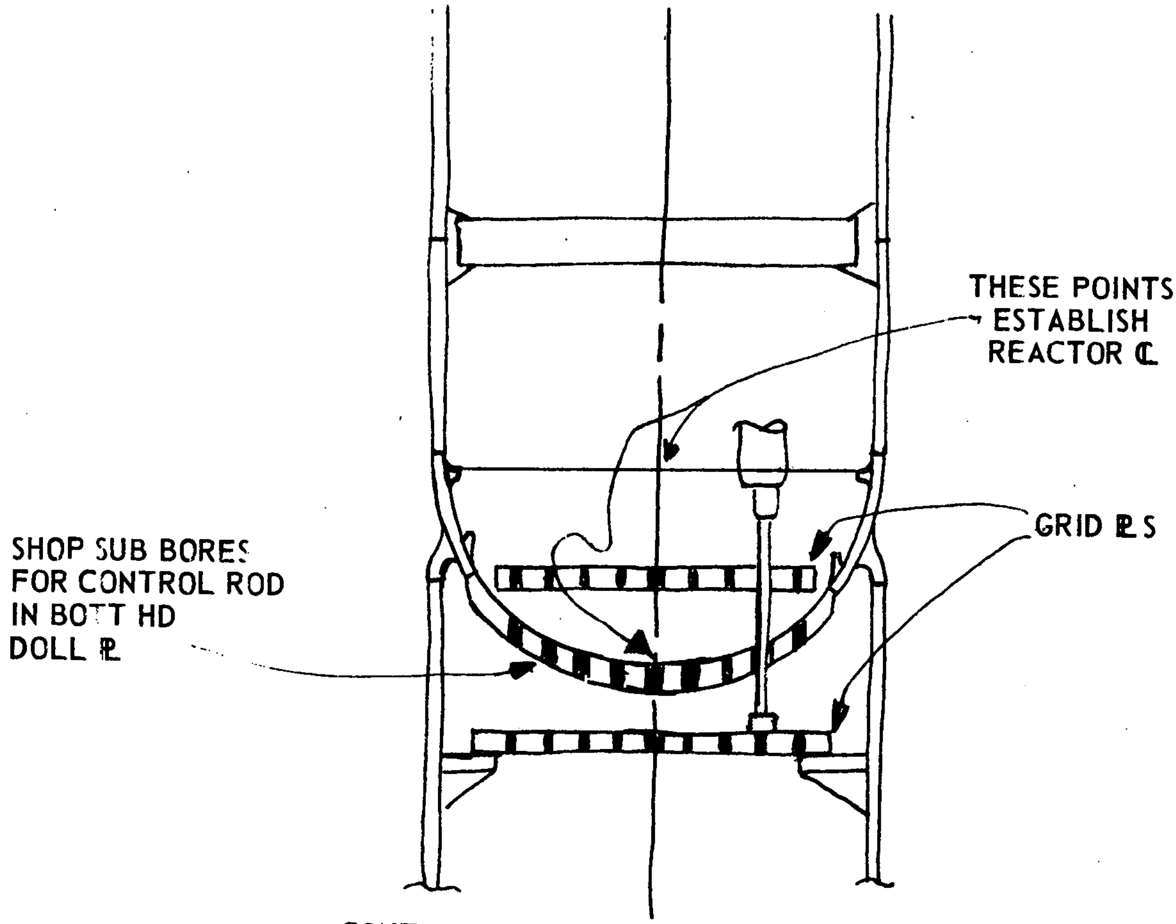
FIGURE D-12



DRILLING HOLES IN TOP HEAD FLANGE

1. AFTER FLANGE IS MACHINED SET UP DRILL EQUIPMENT
2. DRILL HOLES
3. TURN SECTION OVER AND INSTALL STUD TENSIONERS

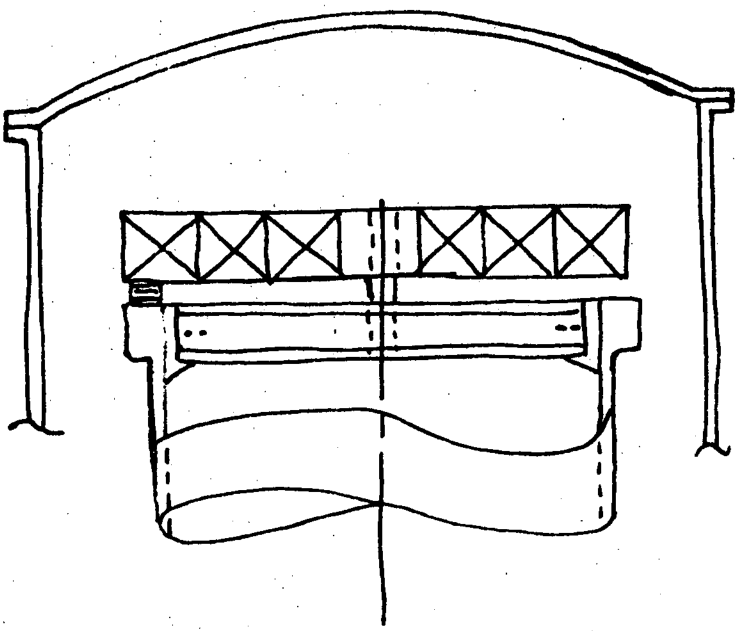
MONTICELLO NUCLEAR GENERATING PLANT
Drilling Holes in Tap Head Flange
FIGURE D-13



CONTROL ROD & IN CORE PENETRATIONS

1. INSTALL GRID ℗S & POSITION ON REACTOR ℄.
2. INSTALL BORING EQUIPMENT.
3. BORE FOR CONTROL ROD SLEEVES.
4. INSTALL & WELD CONTROL ROD SLEEVES.
5. FINAL BORE CONTROL ROD SLEEVES.
6. DRILL FOR IN CORE PENETRATIONS.

MONTICELLO NUCLEAR GENERATING PLANT
Control Rod and In-Core Penetrations FIGURE D-14



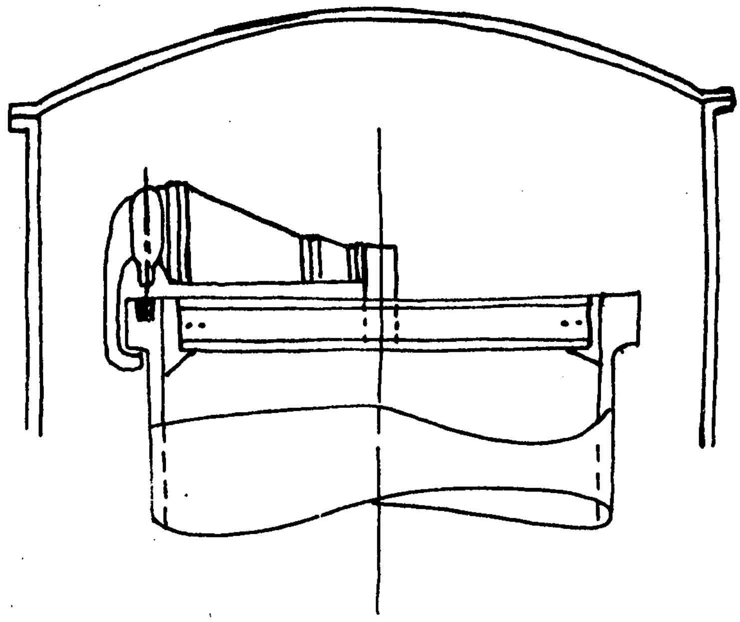
MACHINING SHELL FLANGE

1. SET UP MACHINING EQUIPMENT
2. MACHINE FLANGE

MONTICELLO NUCLEAR GENERATING PLANT

Machining Shell Flange

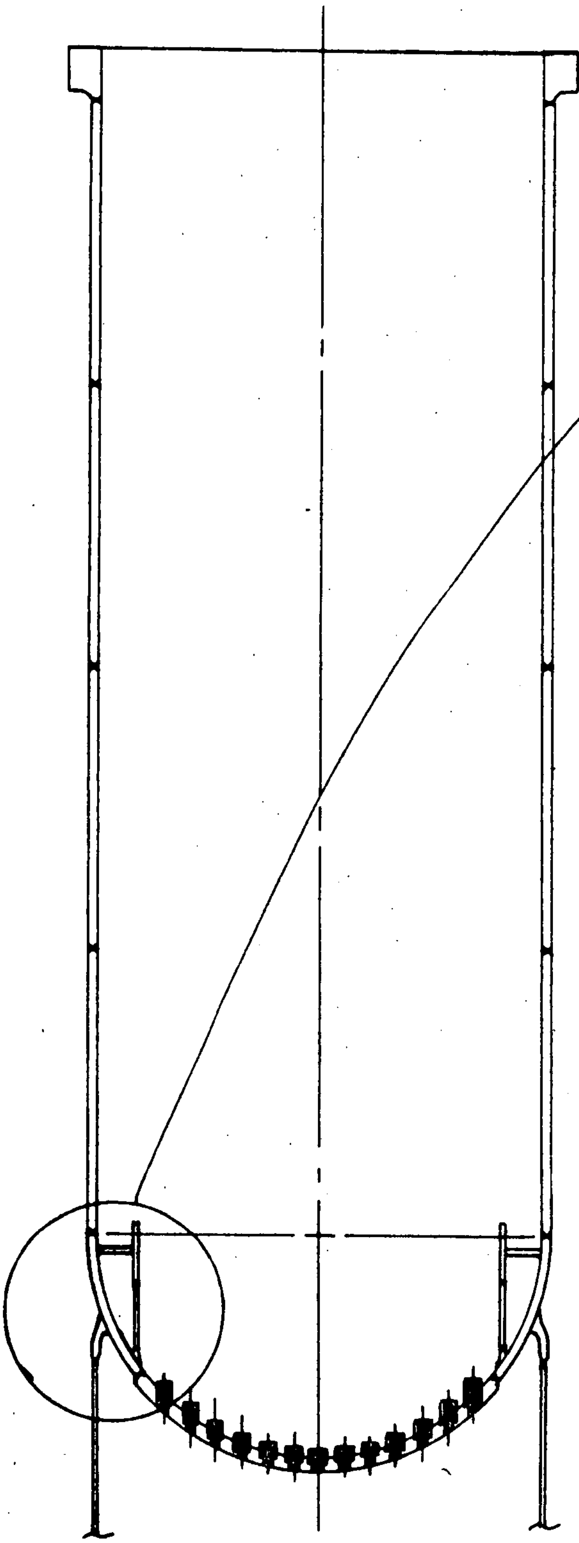
FIGURE D-15

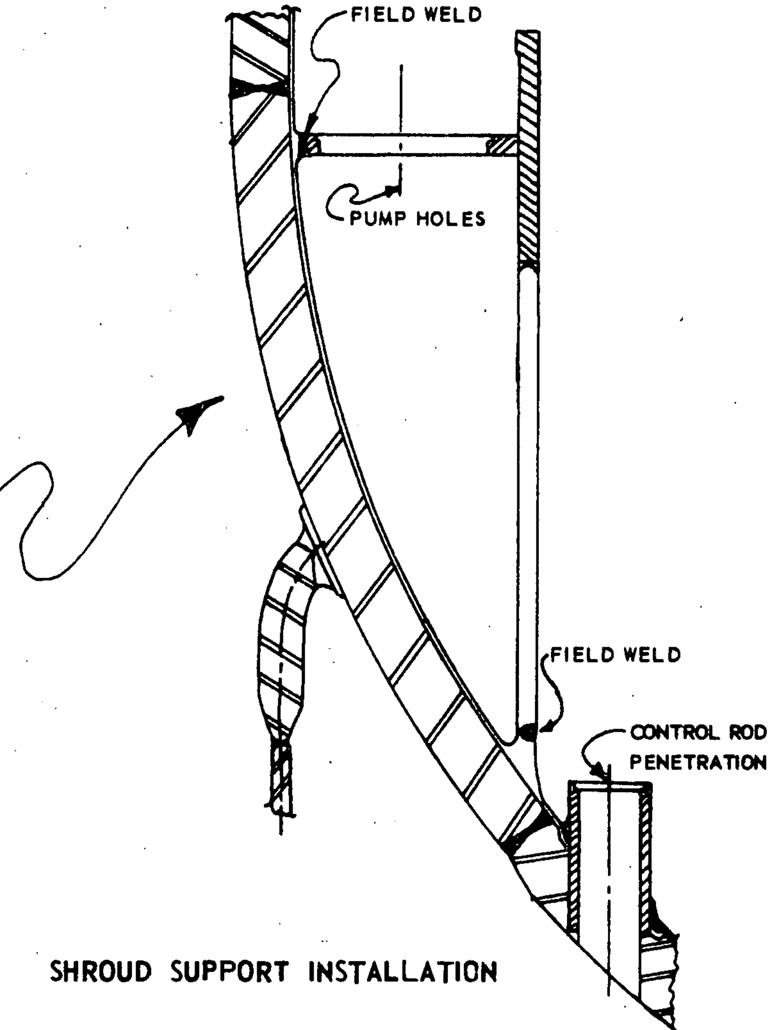


DRILL & TAP SHELL FLANGE

1. AFTER FLANGE IS MACHINED SET UP DRILL EQUIPMENT.
2. DRILL & TAP
3. INSTALL THREADED SLEEVES
4. INSTALL STUDS.

MONTICELLO NUCLEAR GENERATING PLANT
Drill and Tap Shell Flange FIGURE D-16





SHROUD SUPPORT INSTALLATION

1. THE SHROUD SUPPORT IS SHIPPED FROM THE SHOP IN ONE ASSEMBLY.
2. THE SHROUD SUPPORT IS INSTALLED AFTER THE CONTROL ROD PENETRATIONS HAVE BEEN FIELD INSTALLED AND FINAL BORED.
3. THE PUMP HOLES ARE LOCATED AND BORED.
4. THE SHROUD SUPPORT IS DIMENSIONALLY CHECKED.

MONTICELLO NUCLEAR GENERATING PLANT

Shroud Support Installation

FIGURE D-17

APPENDIX E

TRAINING OF WELDING SUPERVISORS

The attached article "Training of Welding Supervisors", written by P. C. Arnold, Vice President, and Manager, Welding Research, CB&I was prepared at the request of the American Welding Society and presented at one of its annual meetings.

The text of the article is presented in the same style as the verbal presentation, rather than in a formally edited style.

APPENDIX E

TRAINING OF WELDING SUPERVISORS

P.C. Arnold

GENERAL

Some 20 years ago the Chicago Bridge & Iron Co. asked me to set up a welding and inspection department for the primary purpose of training welding inspectors. It soon became apparent that we needed men who could do more than merely inspect and see that work was done right. We needed men who could not only perform these functions, but also teach, train and supervise. We therefore found it necessary to change our program of training inspectors to training supervisors. The American Welding Society has asked me to pass on to you our experience in this endeavor.

First of all, what services do we expect our welding supervisors to perform? By outlining specific duties, a training program can be organized to fulfill the requirements. Table E-1 shows a brief outline of some of the duties of a welding supervisor engaged in the fabrication and construction of ferrous and non-ferrous tanks and pressure vessels using the gas metal-arc, the gas tungsten-arc, the shielded metal-arc and the submerged arc welding processes.

TABLE E-1

DUTIES OF A WELDING SUPERVISOR

1. Recruit, teach and train welders and operators.
2. Administer performance tests to welders and operators.
3. Aid new men in starting actual welding operations.
4. Check fit-up of joints to be welded.
5. Examine back gouging or chipping on joints being welded.
6. See that the correct electrodes or wires are being used.
7. Verify that the proper code and specification requirements are being fulfilled.
8. Make certain that the proper welding procedure is being followed for each joint.
9. Witness and evaluate the various nondestructive or destructive quality control tests:

   radiography: magnetic particle; liquid penetrant; ultrasonic; air, oil and vacuum; trepanned specimens; any further special quality control tests.
10. Supervise the making of special production or impact tests plates.
11. Visually inspect all completed weldments.
12. Check all areas where temporary gadgets have been welded to see that the material has not been damaged and has been restored to its original condition.
13. See that the product has been built in accordance with plans and drawings.
14. Check preheat and postweld heat treatment practices.
15. Witness final proof tests.
16. Send in regular reports of work covered each week.

It is evident from this list that a welding supervisor must be trained not only to inspect the work but also to teach, train and supervise. If he is successful in getting the work done correctly the first time, then there is no need for a large amount of inspection to follow. The codes recognize that not all welding operations can be completely supervised; however, a certain amount of inspection must be performed in order to ensure a predetermined quality level. Therefore, if the supervisor has adequately taught, trained and supervised the welders, operators and welding operations, this quality level will naturally result.

Since we have outlined in detail the duties of a supervisor for a specific welding industry, we can rapidly develop a training program to fulfill these needs. From our experience, we have found it necessary to spend a minimum of two weeks with the prospective supervisors. About half the time is spent in the classroom and the rest in the laboratory doing actual welding and inspection work. This preparation should be followed with additional training and supervision on the job after the supervisors have completed their formal training course. As additional welding methods and processes are developed and new codes and specifications are adopted, the course must be enlarged and extended. This can be done by holding night sessions or by extending the program into a third week. In the past 20 years, 28 classes with between 15 and 20 candidates in each class have been held.

Table E-2 illustrates some of the subjects covered in our training program for our industry.

TABLE E-2

SUBJECTS COVERED IN THE TRAINING PROGRAM
CLASSROOM SUBJECTS PROGRAM

1. Study and learn the various code requirements concerning fabrication, welding, inspection and testing items:

   AWS API-650, API-620; ASME Section VIII, Section IX and Section III (Reactor and Containment Vessels)

2. Detail requirements of ASME Section IX for qualification procedures for welders and operators.
3. Properties of materials to be welded and fabricated.
4. Technique for performing and evaluating the requirements for various testing methods

   radiography; magnetic particle; liquid penetrant; trepanning; ultrasonic; and vacuum, oil, air, and water tests.

5. The occurrence of brittle fracture, notches, stress concentrators and catastrophic failures.
6. Basic practices in the use of electrode, wires, weld equipment and processes.
7. Standard and special welding procedures.
8. Preheating and postheating practices and requirements.
9. Brief course in drawing, reading and interpretation.
10. Hydrostatic and pneumatic testing procedures and requirements.
11. Brief introduction to welding metallurgy.
12. The preparation of weekly or contract reports.
13. Quality control methods.

TABLE E-2 (Continued)

10. Hydrostatic and pneumatic testing procedures and requirements.
11. Brief introduction to welding metallurgy.
12. The preparation of weekly or contract reports.
13. Quality Control methods.

LABORATORY WORK

1. Demonstrate and make test plates using cellulose and low hydrogen electrodes.
2. Learn to use and make weldments using the various welding materials and processes such as:

   (a) Manual covered electrode welding of low and high alloys such as: 2-1/4 Cr., 5 Cr. - 12 Cr., stainless steel Cupro-nickel, T-1, 9% nickel
   (b) Gas tungsten-arc welding of aluminum and stainless materials
   (c) Gas metal-arc welding of aluminum, stainless and high nickel alloys
   (d) Submerged arc welding in the flatdown and horizontal positions
   (e) CO_2 flux cored wire and inner shield welding
   (f) Automatic vertical welding

With the information contained in the first two tables, any company should be able to set up a training program.

A considerable amount of equipment is required to adequately carry on a training program. One of the first prerequisites is a classroom containing desks or tables, a blackboard and a screen for viewing films and slides (Figure E-1). In the classroom the students are given the theory and introduction to welding supervision; then they are taken to the laboratory where they can practice what they have learned in the classroom.

The laboratory should contain suitable welding equipment for the demonstration and teaching of the various welding processes: automatic submerged arc, manual electric arc, TIG, MIG, CO_2 and any others that might be used in joining metals together. Enough different types of material should be available so that everything taught in the class can be demonstrated and reinforced in the laboratory.

The laboratory must also be equipped with all of the nondestructive and destructive testing equipment: radiography, liquid penetrant, magnetic particle, ultrasonic and air, oil and vacuum testing. In addition, equipment should be provided to demonstrate the mechanical tests that must be performed on material and weldments: a tensile machine, bending machine, (see Figure E-2), drop weight testing machine, impact machine, furnaces and low temperature equipment, so that the supervisor can be adequately taught all of the testing requirements. A demonstration on a particular piece of equipment is worth a thousand words in the classroom.

CLASSROOM WORK

To be most effective, copies of all the material to be covered in the lectures must be given to the student. This can be in textbook form, pamphlets, letters of instruction, or standards and codes that cover the particular field of training. The students are expected to read this material and study it at night to be prepared for the lectures the next day. The lectures are most effective when accompanied with slides, films and demonstrations. Examinations should be given periodically to keep the students on their toes.

The following figures, tables and discussions illustrate some of the material covered in the training class. Since this particular industry designs, fabricates and erects pressure vessels, storage tanks, elevated tanks, basic osygen furnaces, low temperature vessels, cryogenic vessels and many other welded products, our students are given excerpts from all of the codes and standards that apply to this work. Table E-3 illustrates some subjects that are covered in acquainting the students with the various code requirements. All the sections in the codes dealing with fabrication, erection and testing are gone over in detail so that the student has a good knowledge of the requirements of the position.

Table E-4 provides test specimen information with which the supervisor must be familiar. Table E-5 is an illustration of material and welding data presented to supervisors for future reference.

The AWS-ASTM classifications of electrodes must be discussed so that the supervisor will completely understand why a certain electrode is chosen for a particular material. Table E-6 is an example of information given to the supervisor so that the classifications become clear and familiar.

The chemical analysis of the various types and classifications of welding electrodes is shown in Table E-7. Time should be taken to discuss the various types of electrodes and what elements are added for additional strength and notch toughness. The merits of the cellulose electrode versus the low hydrogen electrode should be discussed, along with illustrations and examples of the difficulties encountered in welding heavy and high strength material. The role of hydrogen in welding may be effectively illustrated in the various electrodes by placing a sample weldment in a beaker of glycerin. The bubbles coming from the weldment will indicate the different amounts of hydrogen in the cellulose and the low hydrogen electrodes.

Since the supervisor is going to be working with both ferrous and non-ferrous vessels, he must also be given knowledge and instructions on materials such as aluminum, nickel, inconel, copper and so forth. Table E-8 illustrates the information that is given to the supervisors about aluminum materials.

Filler wire information for the various aluminum materials appears in Table E-9. Each alloy with its respective welding process and filler material should be discussed and understood. The importance of using the proper filler material with each alloy cannot be overemphasized. This can further be demonstrated in the laboratory by showing cracking or other difficulties that may be encountered when the wrong filler material is used.

One of the most important tools that has been invented in the past 20 years to assist in making a good weldment is the carbon-arc air gouge. Information concerning its use should be familiar to the supervisor along with what can be done and what cannot be done with this equipment. (Table E-10) Those who have not learned to use this tool prior to attending the class should be given demonstrations of its use in the laboratory and taught how to effectively use it on various materials. It should be emphasized that the tool must be used in the proper manner and never without a full blast of air; residual carbon should never be allowed to remain in the joint.

A session must also be held on the postweld heat treatments of the various materials. Table E-11 illustrates some of the thermal treatment information given to the welding supervisors. In addition to the written information, many slides illustrating both the shop and field methods of postweld heat treatment can be shown. Since the supervisor must check to see that the postweld heat treatments are performed satisfactorily, he should be familiar with the requirements.

There is almost no end to the amount of discussion and instruction that can be given in welding procedure. The necessity for preheat, drying of electrodes, continuous welding, peening and postweld heat treatments should be discussed with the students. In addition, many examples can be shown of the difficulties encountered if the situation is not properly evaluated. Table E-12 shows reasons for cracking and appropriate remedies when welding the various materials. The effect of notches, stress concentrations, improper procedure and lack of adequate testing can be shown very well with catastrophic failure slides.

One of the present day useful tools in nondestructive testing of weldments is the radiograph. The supervisor should be taught the theory of radiography, the use of equipment and the development and interpretation of films. A portion of this work can be done in the classroom, while the actual use of the equipment and the development of the films must be done in the laboratory. Table E-13 illustrates defects that are encountered in weldments; the acceptable limits of these defects must be clearly defined.

Figure E-3 shows some common defects described in Table E-13. After the student has learned the acceptable limits for the various welding defects, he must be trained to read film and understand grading. (Figure E-4) Following training in the reading of radiographs, the students receive a grading quiz. This is accomplished by giving each student a dozen or so radiographs with various size defects in them and asking them to grade them as acceptable or unacceptable. Following this quiz on acceptance standards, the student's grading mistakes are discussed and evaluated. Following the classroom work the student must be taught to actually take, develope and evaluate radiographs (Figure E-5 and E-6).

In discussing radiographs, the individual's safety should be emphasized. The supervisor must also be acquainted with the use of the radioactive materials and also the safety requirements that go with the use of this procedure. State, municipal and federal codes and regulations must be covered, both from the point of acceptance standards and of safety. Perhaps radiography training is overemphasized, but in many instances the welding supervisor can subsequently be used to help train radiographic technicians in both the shop and field. Therefore, complete radiography as well as spot radiography must be covered in the instructions.

Along with such areas as welding procedure, tensile strength, shrinkage, and residual stresses, the subject of brittle fracture should be covered. Every person involved with welding is aware of the many catastrophic failures that have occurred in ships, truck tanks, storage tanks and pressure vessels. It is difficult to understand why one vessel will fail and another will perform satisfactorily. It is also hard to explain that all materials have certain mechanical properties, including tensile strength, ductility and, most importantly, notch touchness.

One of the most effective means we have found of explaining notch toughness is to show pictures and details of catastrophic failures and analyze the causes. Once the supervisor understands that it usually takes three factors to cause such a failure, he can see where he possibly could prevent failures in the future by his inspection. It can be pointed out that there must be a certain level of stress in the material, a temperature below its transition temperature and some sort of a notch present to trigger off the initiation of the brittle fracture. The elimination of this notch is one vital job for the welding supervisor.

An example of this method of teaching brittle fracture is shown in the accompanying figures. Figure E-7 shows a re-erected welded tank that catastrophically failed. This tank was made from a cut-down riveted tank. When the rivet holes were cut from the plate edges, they were not cut back far enough from the edge of the hole to remove cracks that had occurred during the punching of the holes. When the first ring plates were subsequently welded to the bottom stretch plates, the welders noticed some cracks opening up in the first ring plate just ahead of the fillet wel d being applied to this joint. Properly trained supervisors would have called this to the attention of their superiors and steps would have been taken to remove these notches.

Figure E-8 shows a portion of the first ring and the bottom of the tank; the arrows point to cracks starting at the rivet holes which had subsequently been welded over in putting the tank together. The first ring of the tank has failed by cleavage square cut fracture and without any signs of ductility. Without adequate inspection, some cracks were unobserved and remained in the structure. During a particularly cold night when the tank was half full of crude oil, one of these notches, perpendicular to the fillet weld joining the first ring to the bottom, propagated and ran vertically up the shell allowing the tank to open. This is a good illustration of a notch that, after several years of operation, finally triggered off the catastrophic failure. Undoubtedly, the change in temperature and perhaps the freezing and heaving of the soil foundation put additional stresses at the root of the notch.

Figure E-9 illustrates failure of a pressure vessel during the hydrostatic test. Figure E-10 shows the notch that triggered off the catastrophic failure. At the time this particular pressure vessel was built, the bottom plates were laid directly on the grade and backing-up strips were used under the welded joints. The backing-up strip intersection which was never welded together created a notch. During welding high residual stresses from shrinkage of the weld metal caused a transverse crack. This particular joint was a circumferential joint in the bottom of the pressure vessel and, as can be seen from the picture, the residual stresses caused the crack to come almost to the surface. This crack was not discovered when magnetic particle tested, probably because of its right angle orientation to the weld.

Figure E-11 illustrates a notch, such as an unwelded backing-up strip intersection, which can cause transverse cracks to occur, in turn leading to initiation and propagation of a brittle fracture. On the overload test of this vessel to 1-1/2 times the working pressure with the water at approximately 32° F, the notch propagated and the vessel failed.

Figure E-12 shows another illustration of stress concentration and notches that can cause failures. In this particular instance, two fittings have been placed in the shell close together so that the toes of the adjoining fillet welds are almost touching. The residual stress from the shrinkage of the welds, plus the concentration of stress caused by the one thickness of material between the reinforcing plates causes a crack to occur, usually during the static test.

Individual companies undoubtedly having had problems and failures can pass on a tremendous amount of experience to their welding supervisors. The welding supervisors in turn could do a great deal to keep these problems and difficulties from occurring in the future. Since the very nature of brittle failure

prevents knowledge of when a vessel has been saved by removing notches and stress concentrations, a welding supervisor may feel that his work in this field may never be too well appreciated. But on the other hand, it is always evident with brittle fracture and failure, that something important has been neglected.

LABORATORY WORK

The preceding discussion, tables and figures examine a few of the areas covered in the classroom work during the intensive two weeks of welding supervisory training. The remainder of this paper will discuss and illustrate few of the items covered in the laboratory in actual welding demonstrations and testing procedures.

To be a good welding supervisor, it is necessary that the student already be a good welder and welding operator. If a supervisor is going to be able to teach and train people to do the job properly, he must naturally be able to demonstrate and show the proper procedure and technique. In order to evaluate the ability of a supervisor, he should be asked to manually weld test plates in all positions using various types of electrodes. If he is weak in any of these accomplishments, he should be taught how to do it properly and also taught how to teach others the proper procedure and techniques. Figure E-13 shows an instructor checking the ability of a prospective supervisor to manually weld in the overhead position. After the student has made his test plates, he takes bend specimens, makes his own guided bend test, thus evaluating his own performance. If he fails to pass any of the tests, he should receive additional training and instruction.

Not only must he be instructed and tested in welding of ferrous materials, but also on his ability to use the other welding processes. Most of the prospective supervisors can handle the ferrous materials and the standard type of manual electrodes. Usually a fewer number have had experience with the welding of stainless steel, aluminum and the nickel alloys. Few have had experience in the use of the MIG and TIG processes.

At the same time that the students are making their test plates, they are also checked out on the carbon-arc air gonger and trained in its proper use. Figure E-14 shows a student demonstrating his ability to use the carbon-arc gouger for back grooving his test plate. The students are also instructed in the use of submerged arc welding methods. First, the theory is explained and then they are given a machine to operate in the laboratory. The student must be fully acquainted with the equipment, since he must be able to instruct others in its use. He also might be called upon to help maintain the equipment while it is in operation. Figure E-15 shows the students receiving instructions on the flat down submerged arc welding equipment. Figure E-16 shows the students receiving instructions on the automatic girth submerged arc welding equipment. Two welding heads are being used and both sides of the joints are being welded simultaneously. Since most of the oil storage tanks today have their circumferential joints welded automatically, the supervisor must be well acquainted with this machine.

Figure E-17 illustrates a student welding two pieces of stainless stell pipe together with the TIG method. He should be instructed on the use of TIG welding of aluminum material as well. A great many of the cryogenic vessels are built of aluminum and stainless steel, and consequently the same material in pipe

form must be connected to these vessels. The student must know the fundamentals of the TIG welding system and, if possible, become an expert with this torch. Many of them cannot in the short training period become proficient, but with the elementary knowledge they have learned they can practice and become more expert after they return to productive work. With MIG torch welding the supervisor must know the fundamentals of the equipment and the welding system and have enough practice so that he understands the problems (Figure E-18). It is important to explain the importance of rod feed speed, amperage and voltage. He must become acquainted with the method of long arc-welding versus short arc welding and become familiar with the different operating characteristics of the constant potential type welding machine and the variable voltage type. This takes much classroom instruction along with laboratory work. Most of our classwork on the fundamentals of welding equipment was covered in evening sessions enabling the students to obtain additional information.

One of the most recent developments in the welding industry is the introduction of the CO_2 welding process and the flux cored wires (Figure E-19). Classroom work must be devoted to the fundamentals of this system together with equipment operation practice for best results.

Another new development in the welding field is the automation of vertical welding. Figure E-20 shows such equipment with an instructor preparing the machine for a demonstration. We have found that the students are easily taught to manipulate this equipment since most already operate a girth automatic machine.

One of the important duties of a welding supervisor is to be able to check the weld and see that it has been properly made. Although this can be checked by different methods, it is also important that visual examination as the work is performed also takes place. While they are attending the class, the supervisors should be instructed in the theory of nondestructive testing including laboratory demonstrations of equipment. The students should then be allowed to perform the test work themselves.

Figure E-21 shows the magnetic particle testing method with the instructor explaining the proper procedure. Representative plates have to be made to illustrate various defects. In addition, the instructor must illustrate the proper current to be used, correct orientation of the prods in relation to the expected defect, and the difference between the prod method of magnetic particle testing and the coil method. Both the AC and DC method of magnetic particle testing should be demonstrated.

With nonmagnetic material the magnetic particle method of testing can be replaced by the dye penetrant test method. Again, representative test plates must be made that show defects not visible to the eye (Figure E-22). An easy method of making one of the sample plates is to weld on ferrous material with a high nickel electrode. This involves a considerable amount of current and penetration with subsequent pick-up of carbon and fine cracking. The instructor must emphasize the care that must be exercised in making the dye penetrant test. First, a suitable penetrant should be applied to the joint and left for sufficient time for it to get into all of the discontinuities. Second, the excess penetrant must be completely removed from the joint to avoid false indications. Third, the developer must be applied evenly and the joint inspected carefully soon after this application to recognize the first indications and evaluate the defects.

Another widely used nondestructive test is the ultrasonic testing procedure. There is not enough time in this program to train a welding supervisor to become an ultrasonic testing operator. However, he can become acquainted with the fundamentals. By making suitable test plates and radiographing them to illustrate the weld defects, the ultrasonic testing operator. However, he can become acquainted with the fundamentals. By making suitable test plates and radiographing them to illustrate the weld defects, the ultrasonic testing method can be graphically presented (Figure E-23). It is practical to teach the supervisor enough about this testing method so that he can, with practice, learn to be proficient. But even if he himself does not conduct the test, he can check that others performing this test are doing it properly.

In order for the supervisor to appreciate the mechanical testing that is required on materials and weldments, it is well to demonstrate various mechanical tests in the laboratory. Figure E-24 illustrates the tensile testing of the material, the mode of fracture and the associated ductility. In addition, the use of an extensometer can be shown and the value of a stress strain curve discussed, particularly when comparing various types of materials. Brittle fracture and notch toughness is a very important subject to supervisors. Many good points can be made in the laboratory while illustrating the tests that measure the notch toughness of the various materials.

The breaking of a Charpy-vee notch specimen shows how the energy is measured (Figure E-25). This becomes extremely important when showing that one material will perform so much differently from another. This can suggest to the supervisors why weldments sometimes fail and other times do not. It also makes them realize that designers usually choose the proper material and that the chances of failure are small.

Figure E-26 shows the drop weight machine and the cold box that is used to bring specimens to proper temperature. This is a test that is relatively new, but is being increasingly used by fabricators and material manufacturers. It demonstrates to the supervisor that most ferrous materials will become brittle when the temperature is sufficiently lowered.

Figure E-27 shows a group of drop weight specimens that were tested in the presence of a class of supervisors. In addition to using the regular ASTM E208 procedure for making the drop weight tests, a number of crack starters were made on these drop weight specimens by arc strikes. The arc strikes method of making crack starters is very effective and impressively demonstrates to the supervisors how a seemingly harmless arc strike can initiate a crack and propagate if a material is brittle enough.

The introduction to metallurgy, listed in Item 11 of Table E-2, has to be very brief. It should, however, cover the steelmaking procedure and the effects of inclusions, laminations, heat treating and rolling practices in steel. Metallurgical terms should be introduced so that these men will have some idea of what a welding engineer is talking about when he uses such words as "ferrite," "Austenite," "martensite" and "pearlite." In addition, a short time can be spent in the metallurgical lab seeing hardness tests being made. Also, various structures of different materials can be identified through the microscope. Figure E-28 shows a group of supervisors using the screen of a microscope to identify basic metallic structures.

A brief description of each structure should be given by the instructor, along with identification of the grains and grain boundaries and inclusions present. The instructor also should identify the change in the structure following heat treatments. This can illustrate the various tensile strengths and notch toughness formed by different heat treatments.

Most of the other subjects covered in the training program, as listed in Table E-2 are self-explanatory. The inspection work that a supervisor is to perform on a particular contract should be gone over in detail; a report form can be studied so that he knows how to send in the desired information. Some companies will include welding supervisors in their safety program, while others have separate handling of the safety portion.

From this discussion, you can see that the program is intensive. The supervisor should receive documented material for future reference. Otherwise, he cannot hope to assimilate all of the information that is given him in a two weeks period. Also, it must be recognized that this formal training program is only the first step towards making an efficient welding supervisor. Many of the prospects are trained before they come to the class, and all of them must be given additional training, direction and supervision on the job. This should be carried on by another staff of people, those who direct the activities of the welding supervisors both in the plants and in the field. These head welding supervisors should be kept up-to-date with new developments and solutions to welding problems, and pass this on to their supervisors.

The final examinations at the end of the two weeks period covers all of the classroom work plus many items of practical nature learned in the laboratory. Since the supervisors are advised at the beginning of the program that they will be given a written final examination, this should serve as a stimulant for them to do more reading and more studying during this period. (Figure E-29).

Nothing as yet has been said concerning the real importance of having a group of welding supervisors to help with the welding activities. Properly trained welding supervisors with head supervisors to direct their activities assures an organization where a new method of welding or a new procedure can quickly be passed down to the man on the job. When a new process is developed or new equipment is acquired, a refresher course can be held and certain supervisors trained immediately to do the job. He, in turn, can return to the actual operation and train other workmen to make the weld properly and ensure that the proper quality is obtained and maintained.

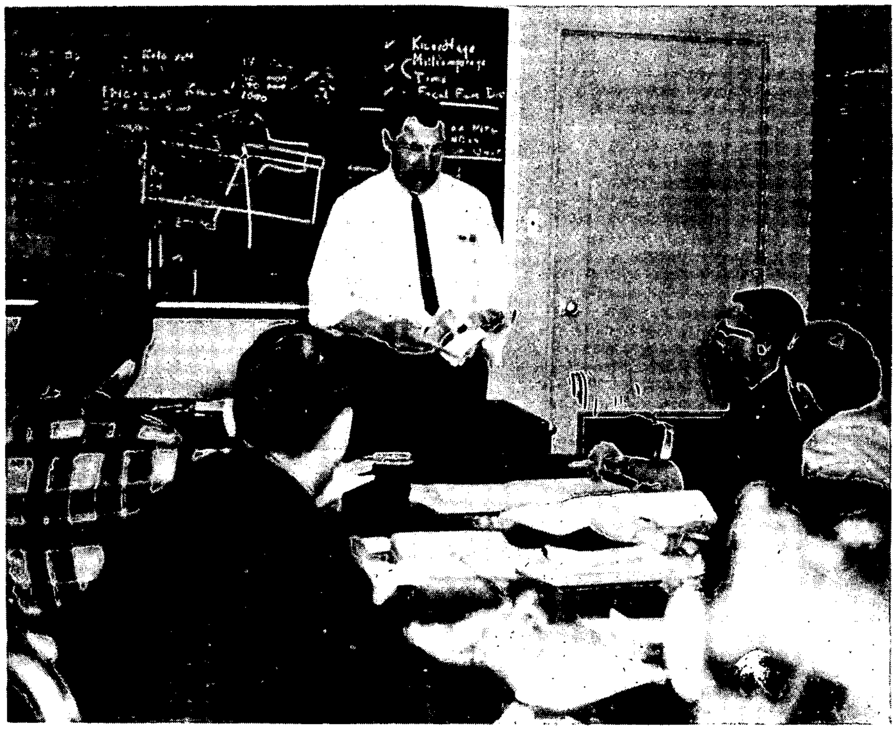


FIGURE E-1. CLASSROOM

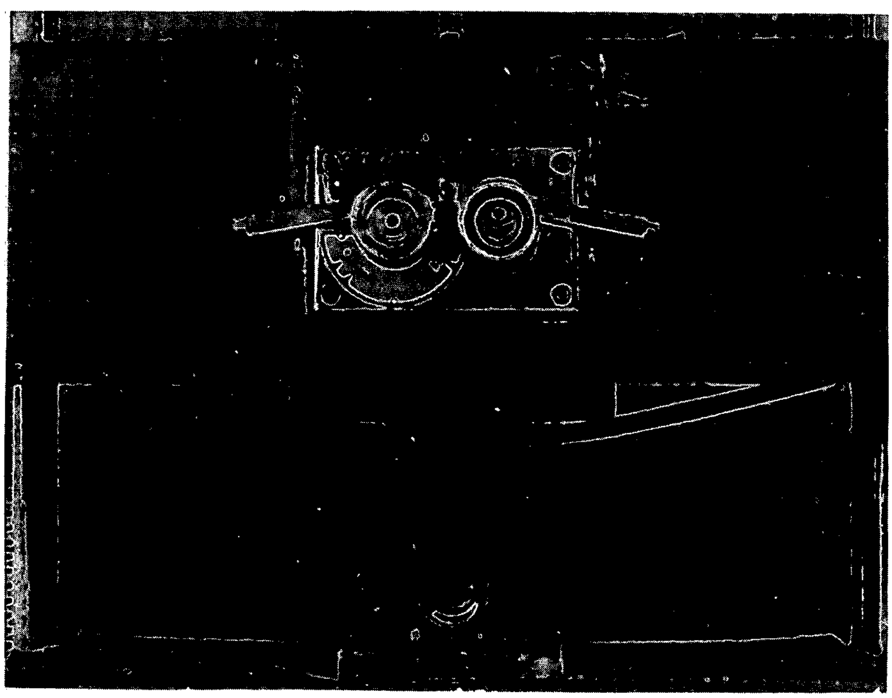


FIGURE E-2. SPECIMEN BENDER

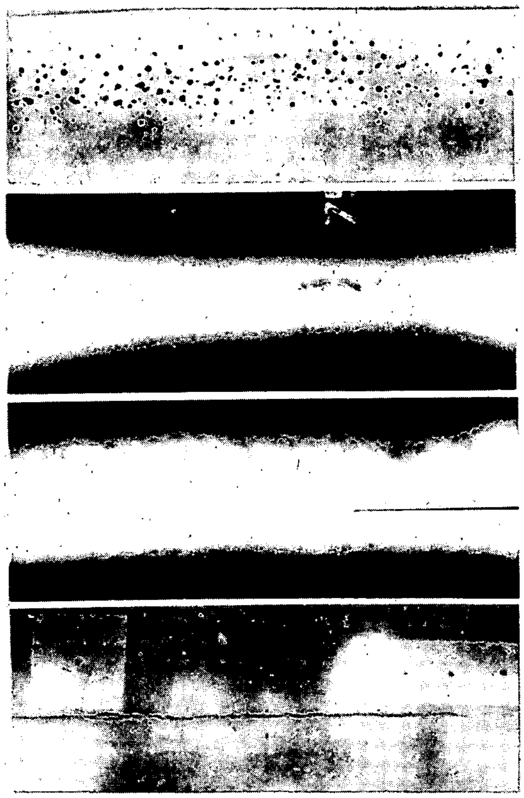


FIGURE E-3. WELDING REJECTS

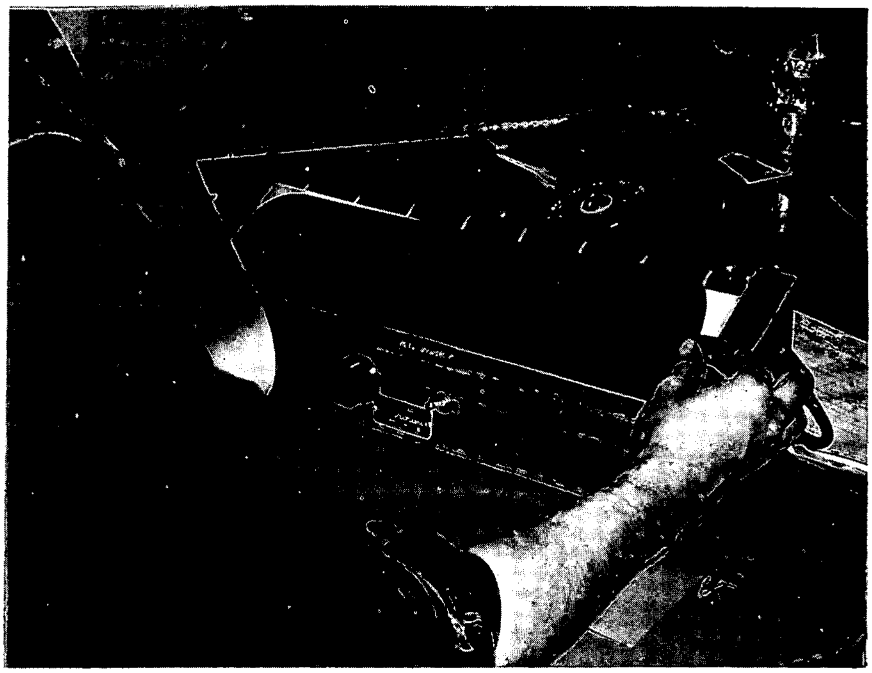


FIGURE E-4. RADIOGRAPH READING

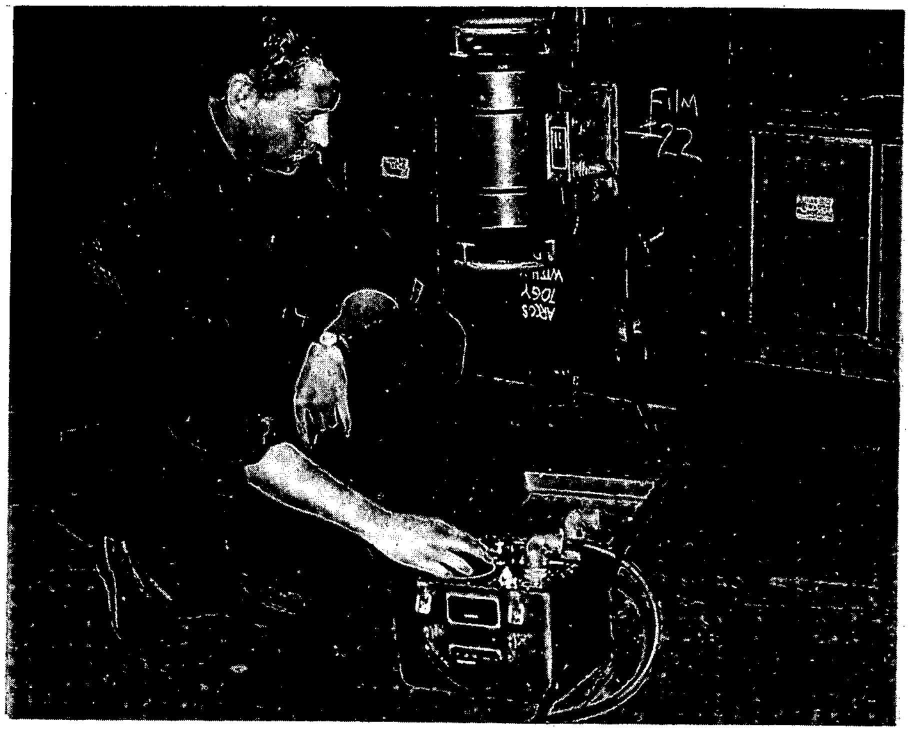


FIGURE E-5. RADIOGRAPHING

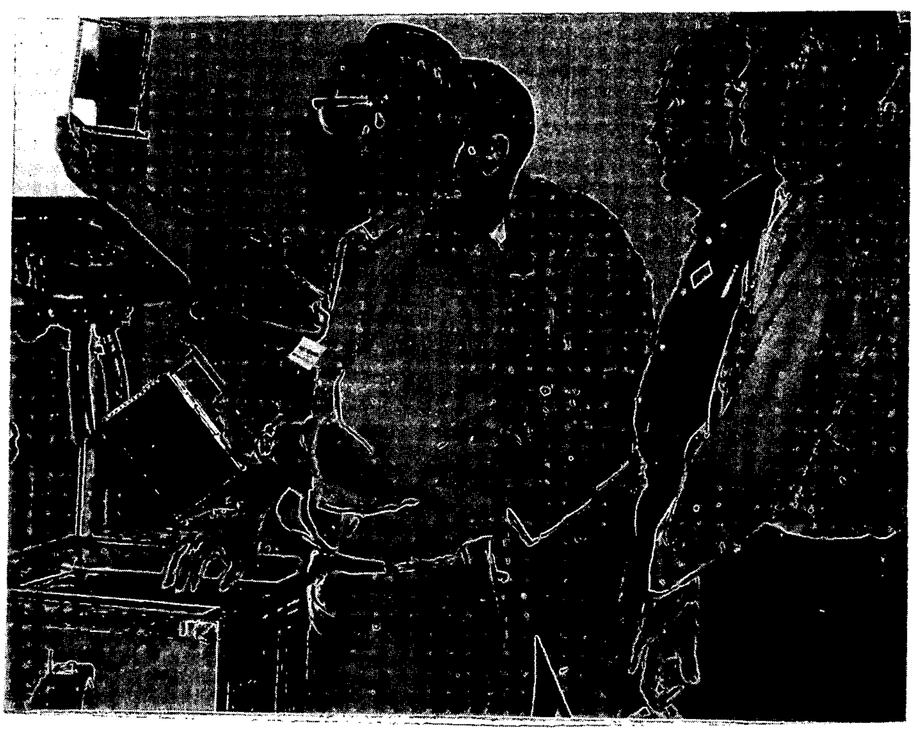


FIGURE E-6. FILM DEVELOPING AND READING

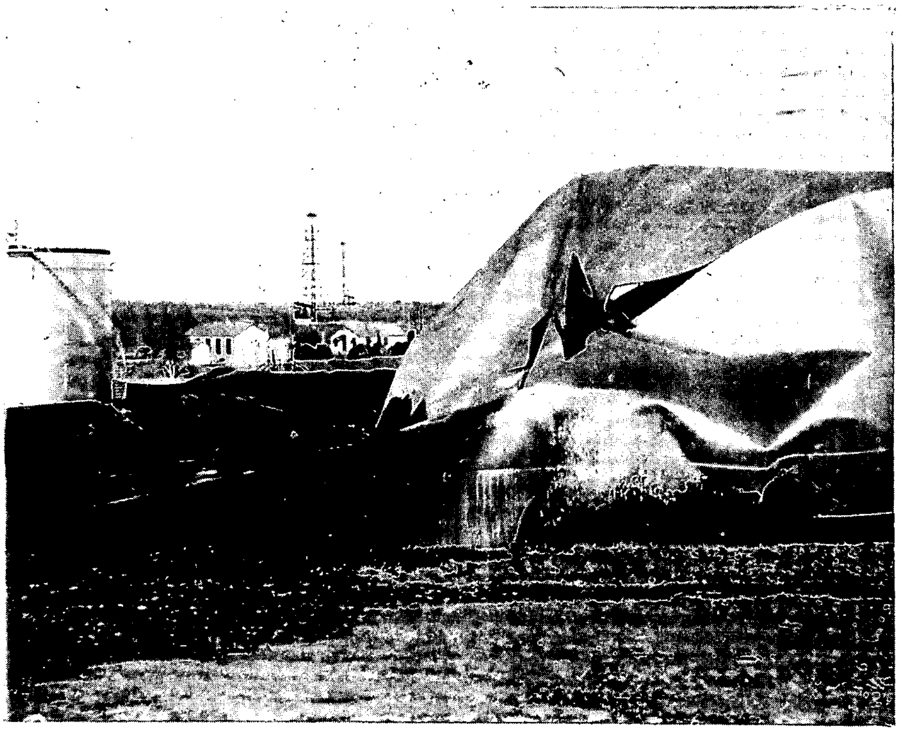


FIGURE E-7. CATASTROPHIC FAILURE OF OIL STORAGE TANK

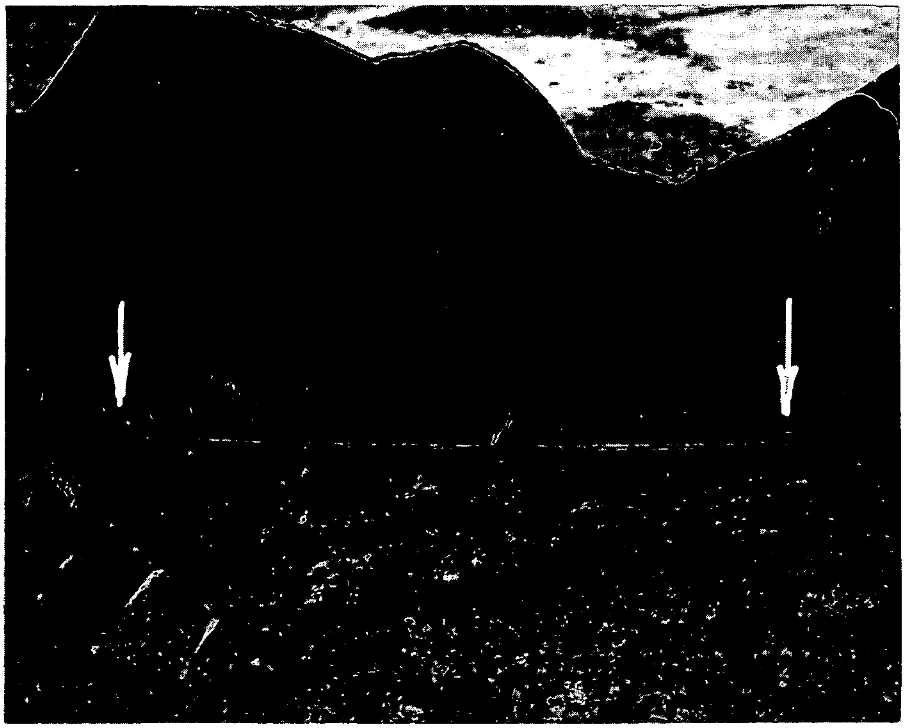


FIGURE E-8. FIRST RING FAILURE BY CLEAVAGE SQUARE CUT FAILURE

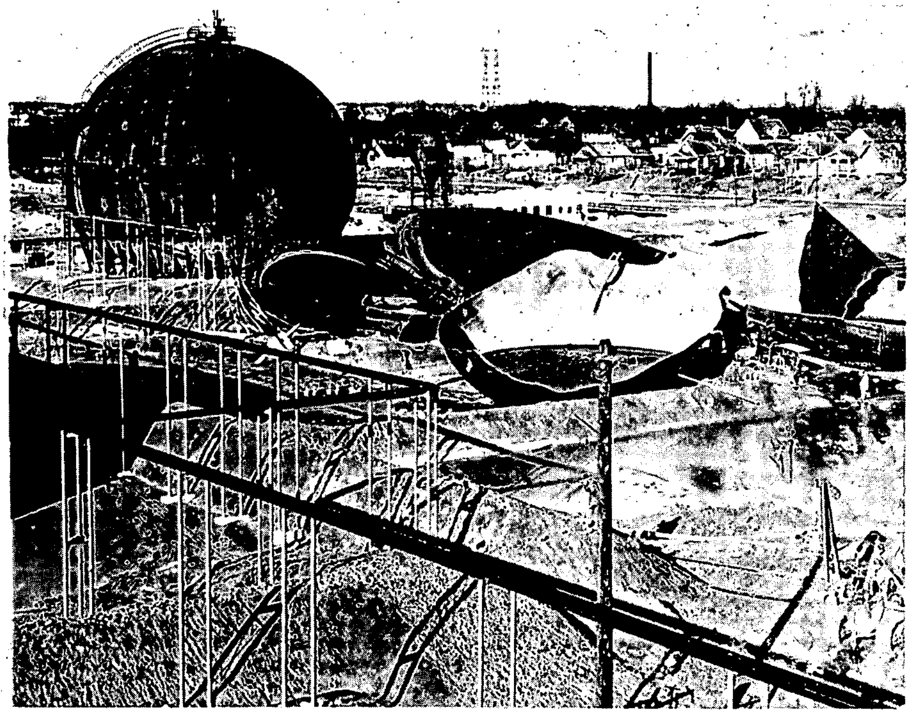


FIGURE E-9. CATASTROPHIC FAILURE DURING HYDROSTATIC TEST

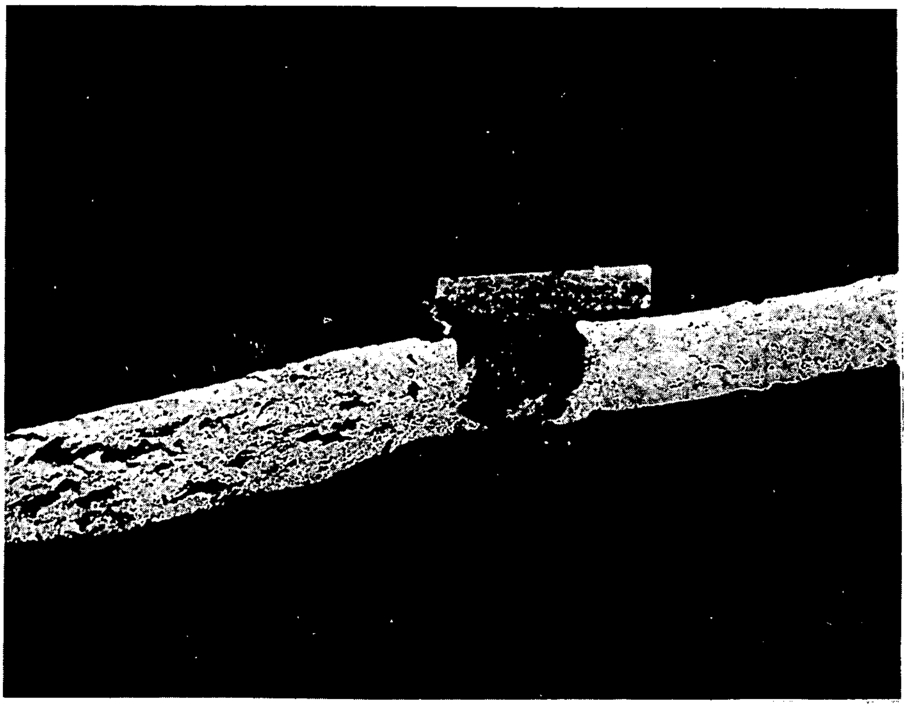


FIGURE E-10. NOTCH THAT TRIGGERED FAILURE

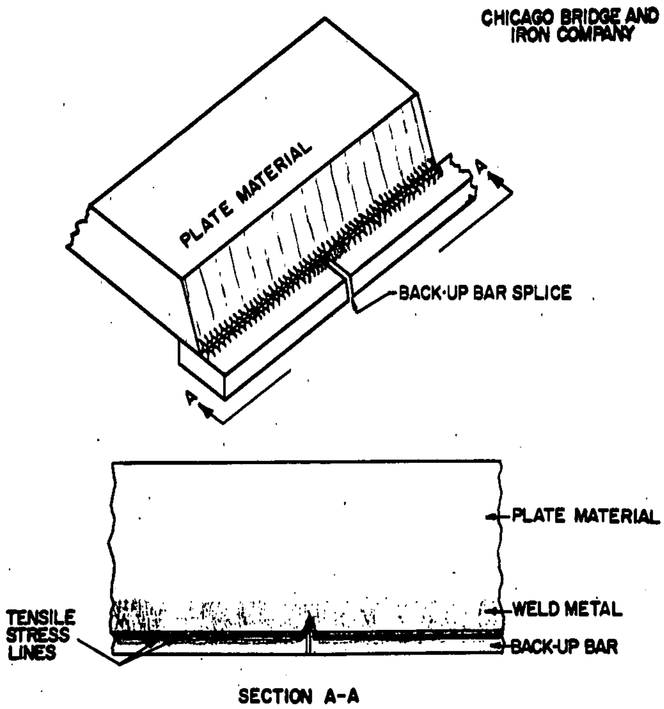


FIGURE E-11. NOTCH FAILURE DEMONSTRATION SKETCH

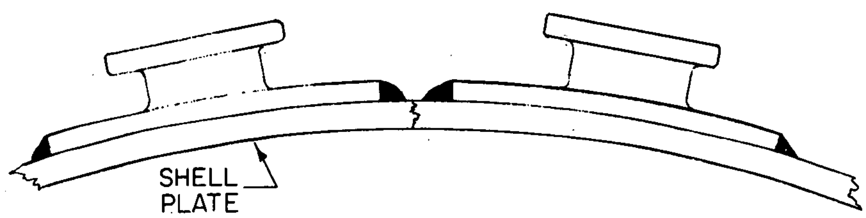


FIGURE E-12. STRESS CONCENTRATION DESIGN

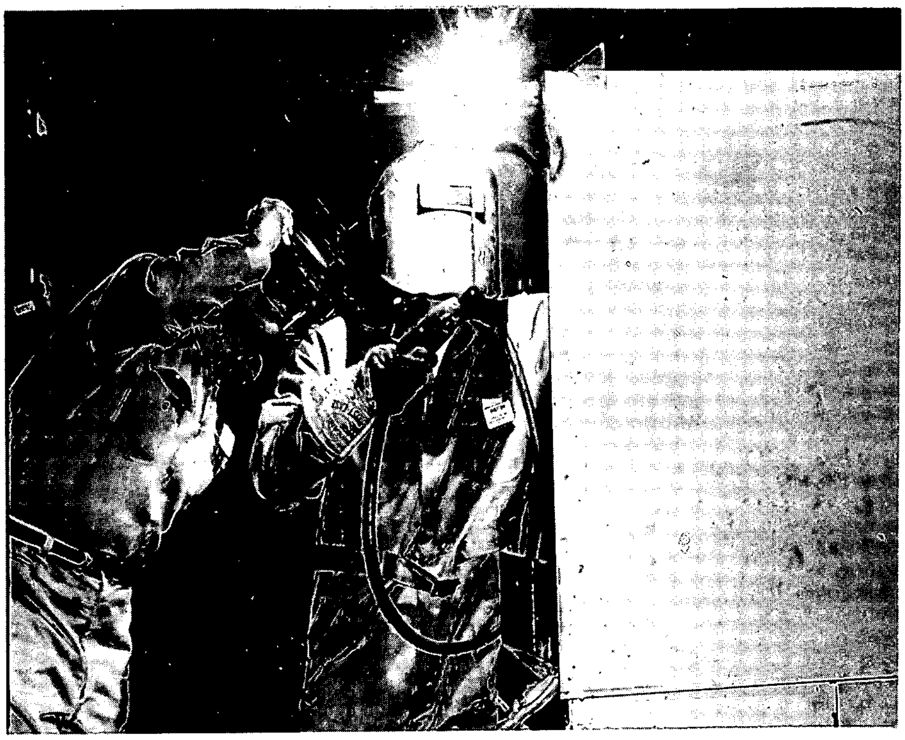


FIGURE E-13. INSTRUCTOR CHECKING PROSPECTIVE SUPERVISOR

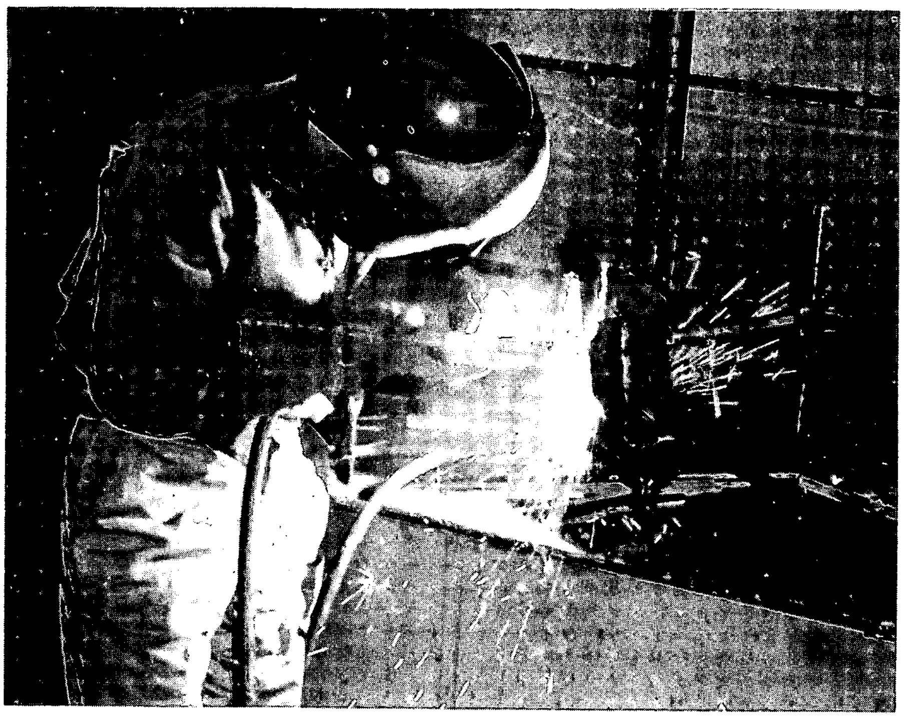


FIGURE E-14. USING THE CARBON ARC GAUGER

FIGURE E-15. SUBMERGED ARC WELDING INSTRUCTION

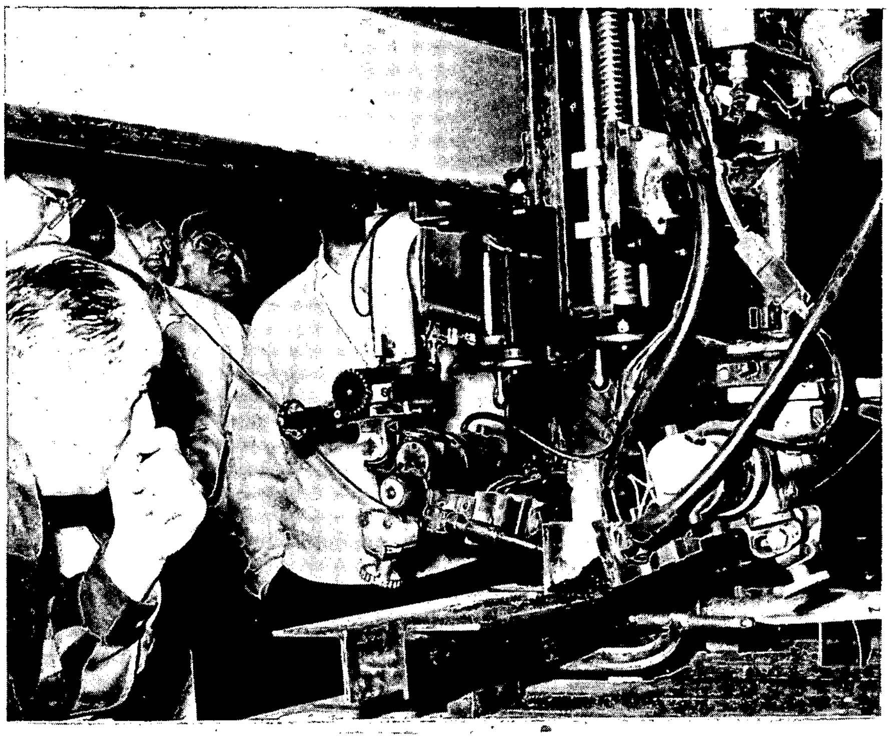


FIGURE E-16. AUTOMATIC GIRTH WELDING INSTRUCTION

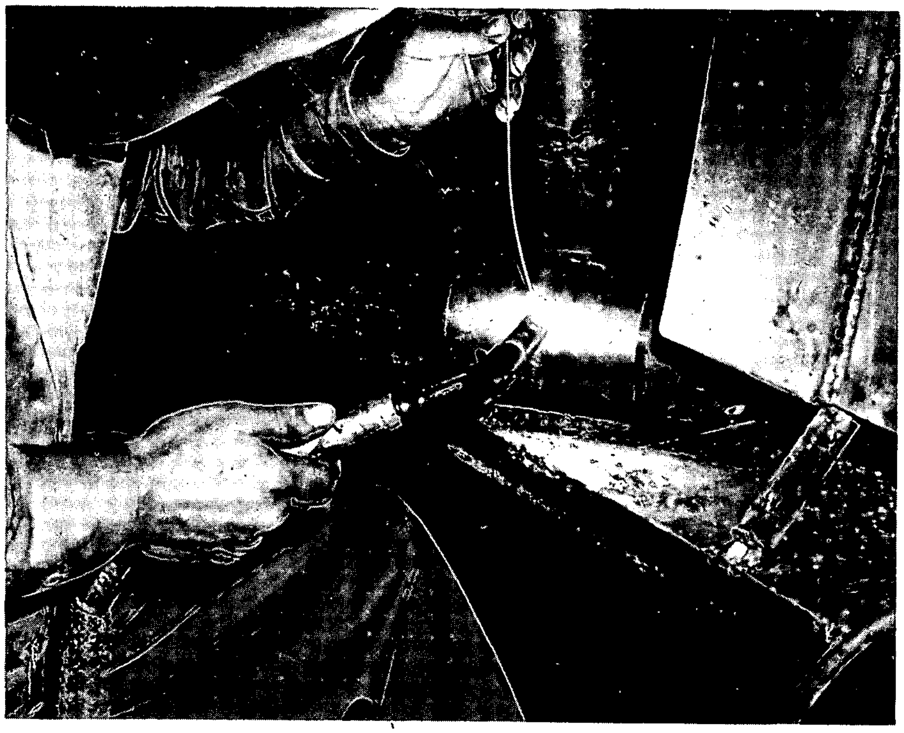


FIGURE E-17. TIG WELDING

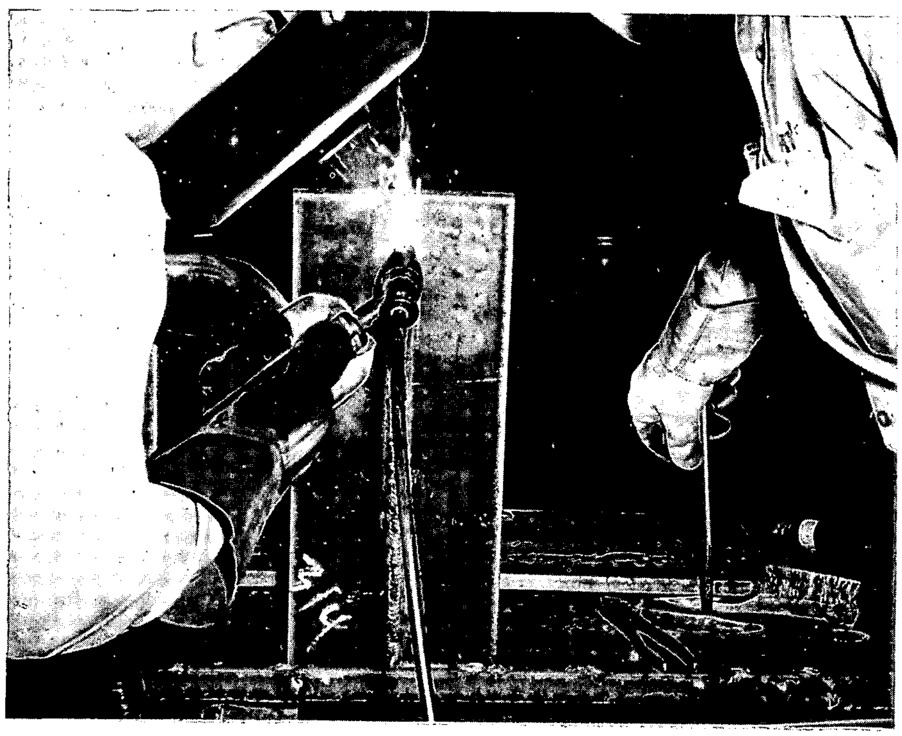


FIGURE E-18. MIG TORCH WELDING

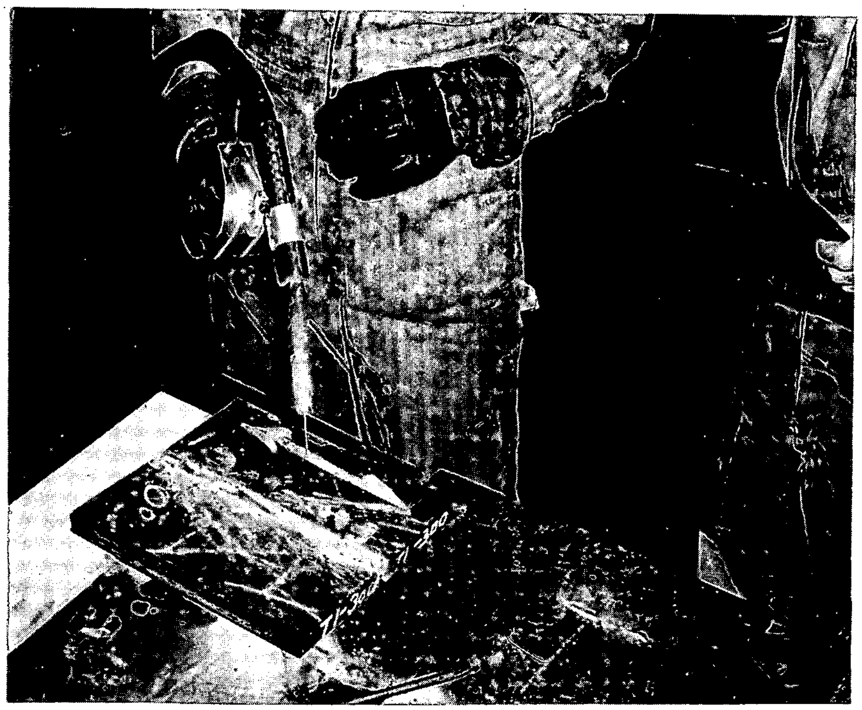


FIGURE E-19. CO_2 OR INNERSHIELD WELDING

FIGURE E-20. AUTOMATIC VERTICAL WELDING

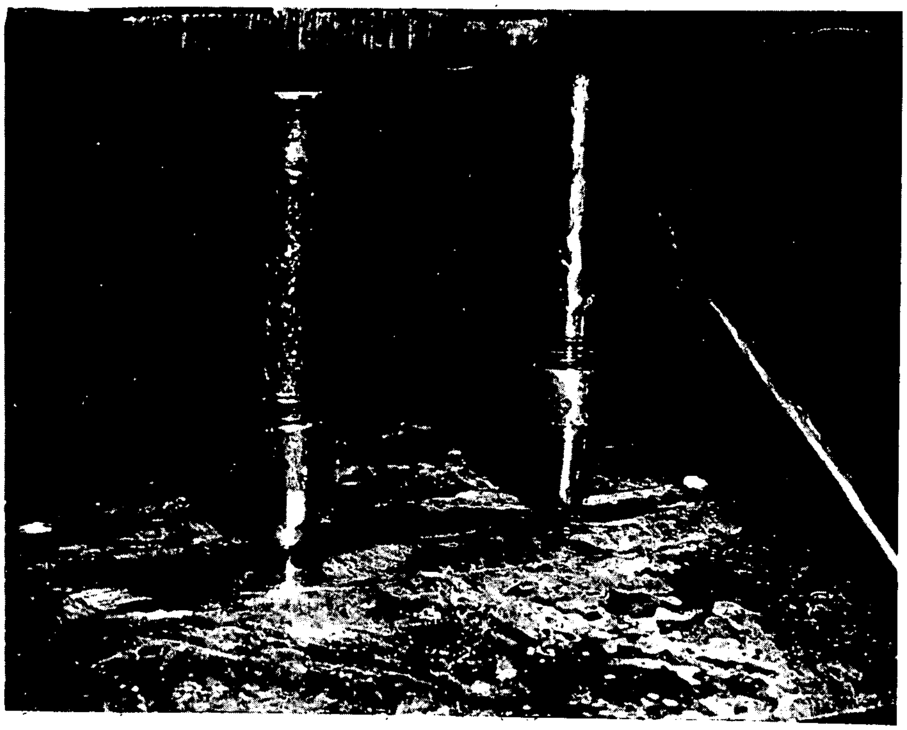


FIGURE E-21. MAGNETIC PARTICLE TESTING

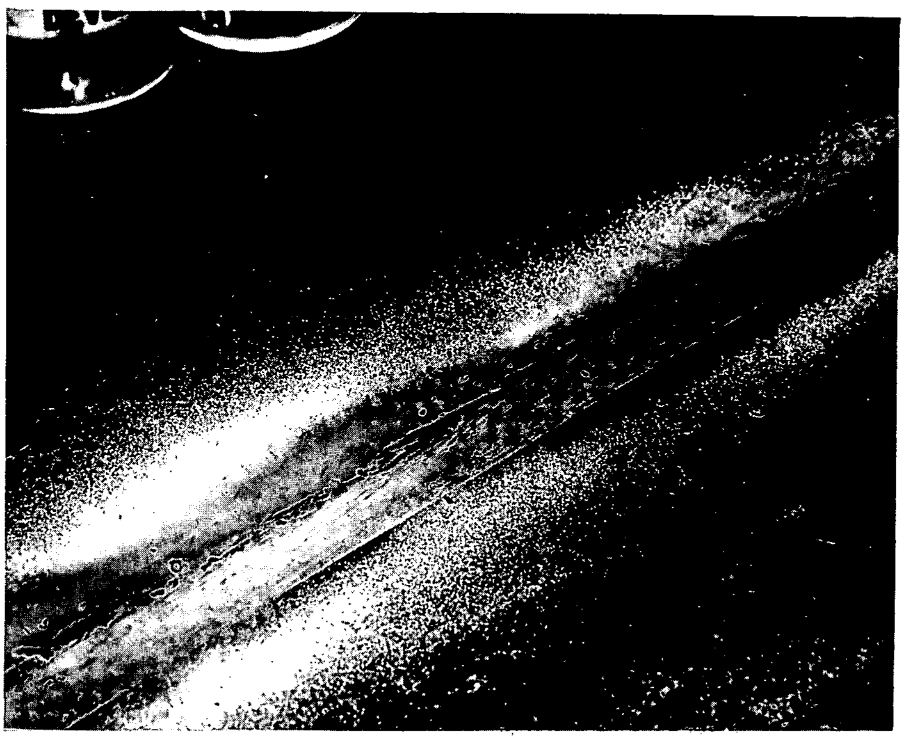


FIGURE E-22. DYE PENETRANT TESTING

FIGURE E-23. ULTRASONIC TESTING

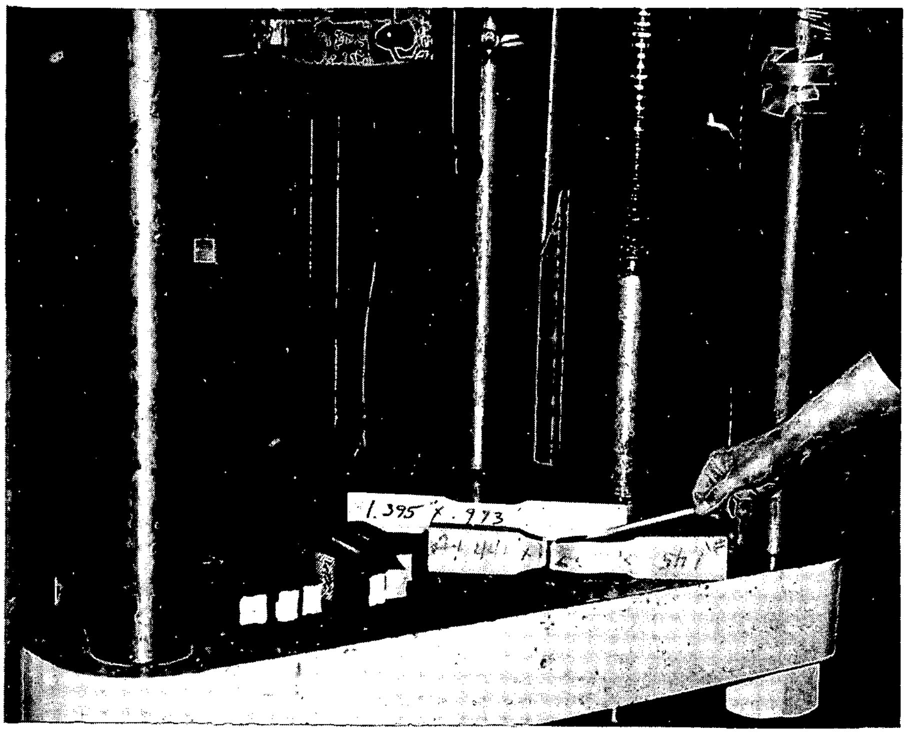


FIGURE E-24. TENSILE TESTING

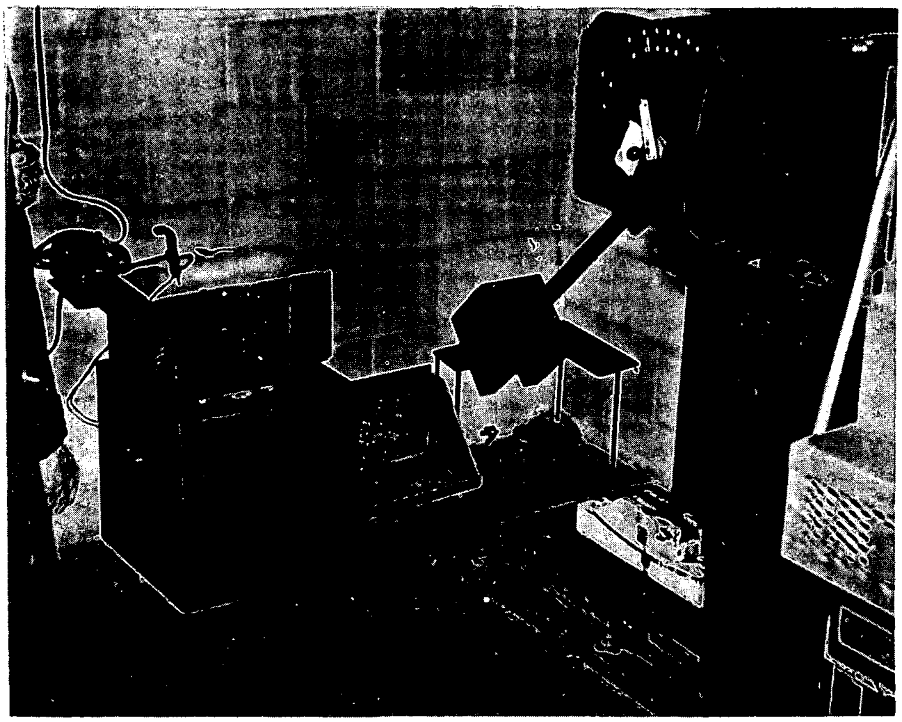


FIGURE E-25. CHARPY VEE NOTCH SPECIMEN TESTING

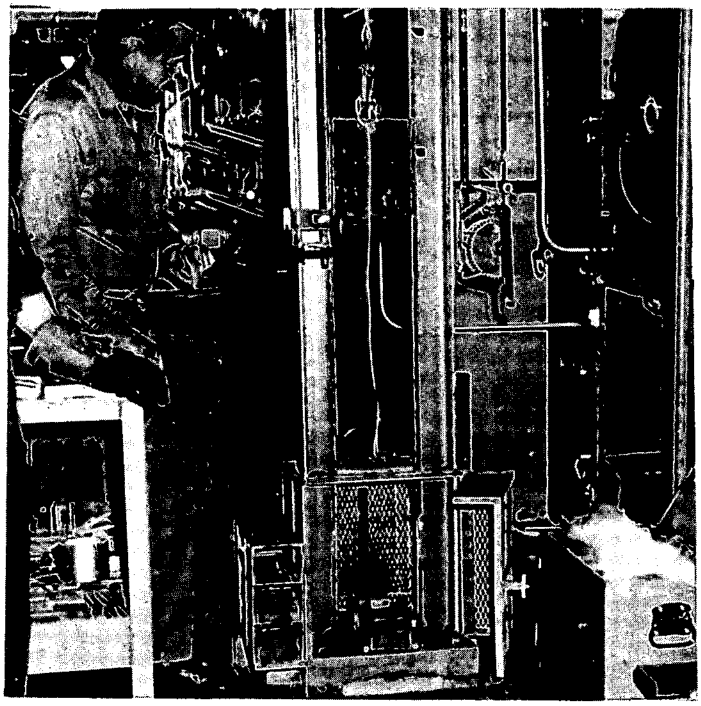


FIGURE E-26. DROP WEIGHT TESTING

FIGURE E-27. DROP WEIGHT TEST SPECIMENS

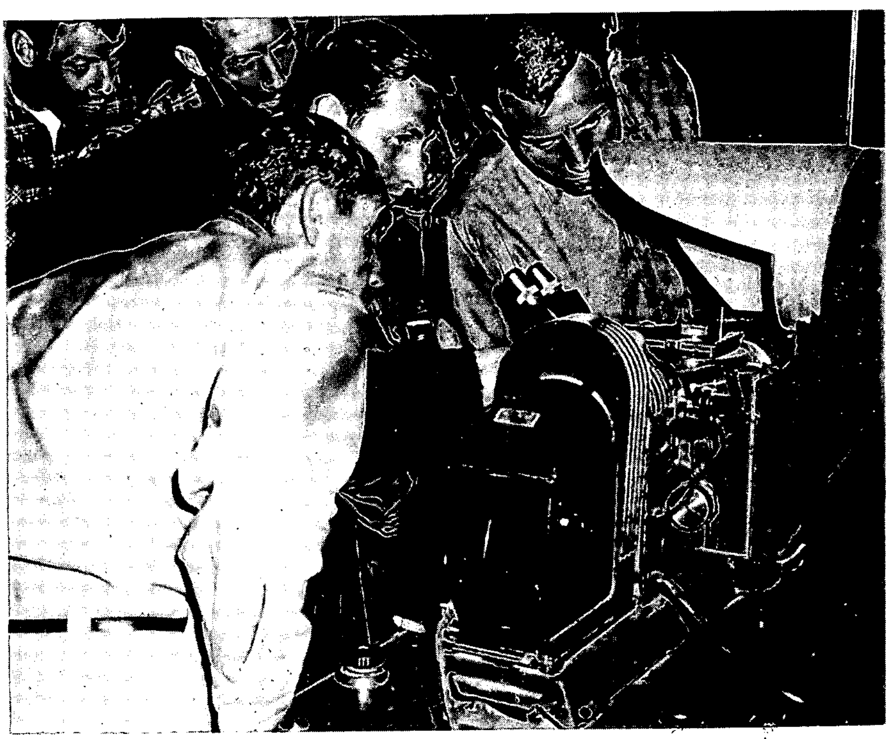


FIGURE E-28. BASIC STRUCTURE STUDY

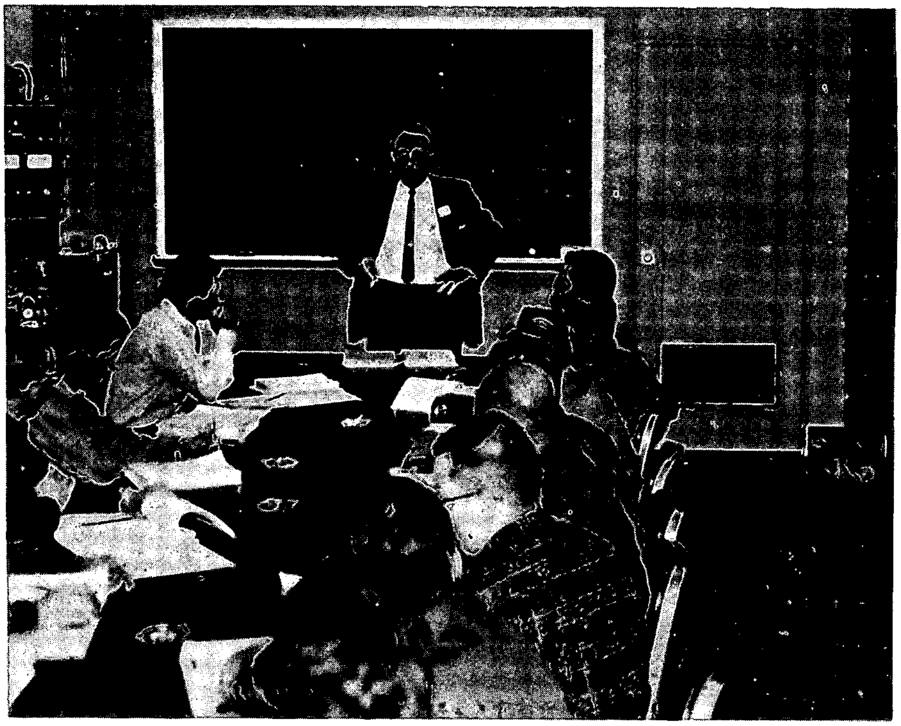


FIGURE E-29. FINAL EXAM

CODE REQUIREMENTS

ITEMS	API-650 CODE AND APPENDIX D-ADB	API-620	1962 ASME CODE	AWWA CODE
JOINT EFFICIENCES	API-650 ...... MAX. 85% ADB ...... MAX. 100%	85% to 100%	70% to 100%	MAX. 85%
FUSION IN VERT JOINTS FUSION IN GIRTH JOINTS	API-650= 100% 3/8" & UNDER-100% PENETRATION & FUSION. OVER 3/8"- 2/3rds FUSION. ALL GIRTH INTERSECTIONS-100% PENETRATION & FUSION FOR 3" EACH SIDE. ADB= ALL VERTICAL & HORIZONTAL SHELL JOINTS EXCEPT SHELL TO BOTTOM SKETCH PLATES-100% FUSION	100% 100%	100% 100%	100% 3/8" & UNDER-100% OVER 3/8"- 2/3rds. FUSION. ALL GIRTH INTERSECTIONS-100% PENETRATION & FUSION 3" EACH SIDE
QUALIFICATION OF WELDING PROCEDURES AND OPERATORS	ASME SECTION IX EXCEPT THAT HORIZONTAL BUTT JOINTS NOT REQUIRING 100% PENETRATION & FUSION WILL HAVE PROCEDURES QUALIFIED BY REDUCED SECTION TENSION TEST ONLY (NOT LESS THAN 63% OF MINIMUM TENSILE STRENGTH OF PARENT METAL.)	SECTION IX OF ASME CODE	SECTION IX OF ASME CODE	AWS RULES SAME AS CBI
ALIGNMENT OF PLATES VERTICAL JOINT	10% OF PLATE THICKNESS OR 1/16" WHICHEVER IS LARGER	1/4" & LESS-1/16" OVER 1/4"-25% MAX. 1/8"	25% OF PLATE THICKNESS WITH 1/8" MAX. EXCEPT 1/4" OR LESS 1/16" OK	10% MAX. OF THINNER PLATE OR 1/16" WHICHEVER IS LARGER
HORIZONTAL JOINT	20% OF THINNER PLATE WITH 1/8" MAX. 1/16" PERMISSABLE IF THINNER PLATE IS 5/16" OR LESS	SAME AS ABOVE	25% OF PLATE THICKNESS UP TO 3/4" 3/4" TO 1-1/2" – 3/16" OVER 1-1/2"–12-1/2% WITH MAX. 1/4"	20% OF THINNER PLATE OR 1/8" WHICHEVER IS SMALLER
OUT OF ROUNDNESS OF VESSEL	NO REQUIREMENT	1% WITH MAX. OF 12"	MAX. OF 1% OF NOMINAL DIAMETER	NO REQUIREMENT
STAGGER REQUIREMENT OF LONGITUDINAL JOINTS	5-T, T= THICKNESS OF THICKER PLATE COURSE. NO VERTS IN ALIGNMENT IN THREE CONSECUTIVE COURSES.	NONE UNLESS SPECIFIED BY CUSTOMER IN WHICH CASE AT LEAST 5T OF THICKER COURSE	5T, T= THICKNESS OF THICKER COURSE EXCEPT WHEN X-RAYED 4" EACH SIDE OF INTERSECTION	NONE
WELDING TEMPERATURE LIMITATIONS	API-650 - PREHEAT IF OVER 1-1/4" OR BELOW 32°F. NO WELDING BELOW 0°F. ADB - PREHEAT PREDICATED UPON MATERIAL USED IN VESSEL DESIGN. IN GENERAL ABOVE RULES WILL APPLY	PREHEAT IF OVER 1-1/4" OR BELOW 32°F. NO WELDING BELOW 0°F.	PREHEAT BELOW 32°F. NO WELDING BELOW 0°F.	PREHEAT ON 1-1/2" OR OVER & BELOW 32°F. NO WELDING BELOW 0°F.
INSPECTION OF WELDING	API-650 - SPOT RADIOGRAPHIC INSPECTION FOR JOINTS REQUIRING 100% PENETRATION AND FUSION. (SECTIONING BY AGREEMENT WITH CUSTOMER) VERTS- ONE SPOT FROM FIRST TEN FT. FOR EACH WELDER, ONE SPOT EVERY 100' THEREAFTER GIRTH: ONE SPOT FIRST 10' REGARDLESS OF NUMBER OF WELDERS. 1 SPOT EVERY 200' THEREAFTER. 25% OF TOTAL X-RAYS TO BE AT INTERSECTIONS. MINIMUM OF 2 INTERSECTIONS PER TANK. INSPECTION BY SECTIONING WHEN 100% PENETRATION & FUSION ARE NOT REQUIRED.	COMPLETE RADIOGRAPH OR SPOT EXAMINATION WITH 1 SPOT FROM 1st 10' THEN 1 SPOT FOR EACH 50'. EXCEPT ON CIRCUMFERENTIAL JOINTS IN CYLINDERS WHICH REQUIRE ONE SPOT FOR EACH 100'	COMPLETE RADIOGRAPH OR SPOT EXAMINATION EACH 50' AND ONE SPOT FOR EACH OPERATOR AND EACH DIFFERENT PROCEDURE.	VISUAL AND SECTIONING = 1 PLUG FROM FIRST 10', 1 PLUG FROM EVERY 100' OF PRIMARY SEAM, 1 PLUG FROM EVERY 200' OF SECONDARY SEAM.

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TABLE E-3 CODE REQUIREMENTS

TYPE AND NUMBER OF TEST SPECIMENS AND RANGE OF THICKNESS QUALIFIED
(PERFORMANCE QUALIFICATION)

TYPE OF JOINT	THICKNESS, t, OF TEST PLATE OR PIPE AS WELDED, INCHES	RANGE OF THICKNESS OF MATERIALS QUALIFIED BY TEST PLATE, INCHES		TYPE & NUMBER OF TESTS REQUIRED[1] (GUIDED-BEND TESTS)			
		MIN.	MAX.[2,3]	SIDE BEND	FACE BEND	ROOT BEND	TEE JOINT
GROOVE	1/16" TO 3/8" INCL.	1/16"	2t		1	1	
GROOVE[4]	OVER 3/8" BUT LESS THAN 3/4"	3/16"	2t		1	1	
GROOVE[4]	OVER 3/8" BUT LESS THAN 3/4"	3/16"	2t	2			
GROOVE	3/4" AND OVER	3/16"	MAX. TO BE WELDED	2			
FILLET	SEE Fig. Q-9	ALL THICKNESSES					1

1 - A TOTAL OF FOUR SPECIMENS REQUIRED FOR POSITION 5-G AS PRESCRIBED IN Par. Q-24(c)

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2 THE MAXIMUM THICKNESS QUALIFIED IN GAS WELDING IS THE THICKNESS OF THE PLATE OR PIPE

3 SEE Par. Q-23(b)

4 EITHER THE FACE-AND ROOT-BEND TESTS OR SIDE-BEND TESTS MAY BE USED FOR THICKNESSES FROM 3/8" TO 3/4"

TABLE E-4 PERFORMANCE QUALIFICATION

EXAMPLE OF MATERIAL AND WELDING DATA PRESENTED TO WELDING SUPERVISORS

ASME P-No	SA-No AND GRADE	SIMILAR SPEC. NUMBER PIPE	SIMILAR SPEC. NUMBER FLANGE	TENSILE STRENGTH (KIPS)	CHEMICAL ANALYSES OF PLATE MATERIAL C.	Mn.	Si	S.	P.	Cr.	OTHERS	ELECTRODE DEPOSIT CLASS. REFERENCE	ELECTRODE DES. (F-No) SA233 316-298	PREHEAT DATA	P.W.H.T. DATA	CODE X-RAY DATA
P-1	201B	A-106	A-105	60/72	0.24	0.80	0.15 0.30	0.05	0.04			A-1	F-1,2,3,4	OVER 1-1/4" OR BELOW 32°F WARM TO HAND. 2" AND OVER, P.H. 200°F.	OVER 1-1/2" T. 1100°F. 1 HR/In. T.	OVER 1-1/4"
P-1	212B	A-106A	A-181-1	70/85	0.31	0.90	0.15 0.30	0.04	0.035			A-1	F-1,3,4	OVER 1" OR BELOW 60°F. WARM TO HAND.	do do do	OVER 1-1/4"
P-3	204C	A335P1	A182F1	75/90	0.23	0.90	0.15 0.30	0.04	0.035		Mo. 0.45 0.60	A-2	F-4	OVER 1" - 200° - 300°F.	OVER 5/8" - 1100°F 1 HR/In. T.	OVER 3/4"
P-3	302B			80/100	0.20	1.10 1.50	0.15 0.30	0.04	0.035		Mo. 0.45 0.60	A-3	F-4	OVER 1" - 200° - 300°F.	ALL THICKNESSES 1100°F. 1 HR/In. T.	OVER 3/4"
P-3	387A	A335 P-12	A182 F-12	65/82	0.21	0.40 0.80	0.15 0.30	0.04	0.035	0.50 0.80	Mo. 0.45 0.85	A-3	F-4	OVER 1" - 200° - 300°F.	OVER 5/8" T. 1100°F. 1 HR/In. T.	OVER 3/4"
P-4	387B	A335 P12	A182 F12	60/82	0.17	0.40 0.65	0.15 0.30	0.04	0.035	0.60 1.15	Mo. 0.45 0.65	A-3	F-4	UP TO 1-1/4" - 200°F. (MIN.)	ALL THICKNESSES 1100°F. (Min.) 1 HR./In. T.	OVER 5/8"
P-5	357	A335 P-5	A182 F5	60/80	0.15	0.30 0.60	0.50	0.03	0.04	4.00 6.00	Mo. 0.45 0.65		F-4,5	UP TO 1" - 300°F. (MIN.), OVER 1" - 400°F. (MIN.) } F-4; USE 200° - 300°F. - F-4, F-45	ALL THICKNESSES 1250°F. (Min.) 1 HR./In. T.	ALL THICK.
P-5	387D	A335 P22	A182 F22	60/85	0.15	0.30 0.60	0.50 MAX.	0.035	0.035	2.00 2.50	Mo. 0.90 1.10		F-4	UP TO 1-1/2" - 300°F. (MIN.)	do do do	ALL THICK.
P-5	T-1			115/135	0.10 0.20	0.60 1.00	0.15 0.35	0.04	0.035	0.40 0.80	Mo. .4 - .6 Cu. .15 - .50 V. .03 - .10, B*		F-4	ALL THICKNESS - 200° - 300°F.	OVER .58" 1000°F. (Min.) TO 1100°F. (Max.) 3 HR/In. T.	ALL THICK.
P-7	240 (TYPE 405)	A268 TP405		60	0.08	1.00	1.00	0.030	0.040	11.50 14.50	AL - 0.10 - .30 Ni. - 0.60	A-8	F-4,5	F-4 - 200° - 300°F. NONE REQUIRED FOR F-5 OR F-45 EXCEPT AS NOTED IN PWHT REQ.	OVER 1-1/2" T. - 1350°F. 1 HR/In. T. UNDER 3/8 IF F5, F45 NOT REQ. NONE UP TO 1-1/2" IF P.H. 450°	F-4 ALL T. F5, F45 } OVER 1/2"
P-8	240 (TYPE 304)	A213 TP304	A182 F304	75	0.08 MAX.	2.00	1.00	0.030	0.045	18.00 20.00	Ni. - 8.00 12.00	A-7	F-5	NONE REQUIRED	NONE REQUIRED	OVER 1-1/2"
P-9	203D	A233 GR3		65/77	0.17	0.70	0.15 0.30	0.040	0.035		Ni 3.25 3.75	A-4	F-4,5	200° - 300°F.	OVER 5/8" - 1150°F. (Min.) 1250°F. (Max.) 1 HR./In. T.	EXCEEDS 5/8" THICK.
P-10	353B			100/120	0.13	0.80	0.15 0.30	0.040	0.035		Ni 8.50 9.50		F-45	100° - 200°F.	NONE REQUIRED	ALL THICK.

* B = .002 - .006

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TABLE E-5. WELDING DATA PRESENTED TO SUPERVISORS

METALLIC ARC	TENSILE STRENGTH (KIPS)	POSITION	COATING, POLARITY, QUALITY
E	6 0	1	0
E	7 0	1	8
E	8 0	1	6
E	9 0	1	6
E	1 0 0	1	6
E	1 1 0	1	6

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TABLE E-6. CLASSIFICATION CLARIFICATION INFORMATION

CHICAGO BRIDGE & IRON COMPANY

ELECTRODE CHART FOR MANUAL WELDING

ELECTRODE	CHEMICAL ANALYSIS					
	C	Mn.	Si.	Cr.	Ni	Mo.
E6010	.10	.40	.30			
E7018	.06	.70	.65			
E8016-C1	.12	.80	.35		2.50	
E8016-B2	.12	.75	.50	1.10		.65
E9016-B3	.12	.90	.60	2.25		1.10
502	.10	.75	.75	5.0	.40	.65
309-16	.08			25.00	12.00	
E10018-D2	.06	1.77	.70			.46
E11018-G	.12	1.96	.27	.30	1.75	.46

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TABLE E-7. ELECTRODE CHART FOR MANUAL WELDING

ALUMINUM PRESSURE VESSEL MATERIALS

ASME SPEC. Nº	ASA TYPE	MAJOR ALLOYING ELEMENTS										TENSILE STRENGTH (KIPS)*
		Al.	Cu.	Fe	Si.	Mn.	Mg.	Zr.	Cr.	Ti.	Be.	
SB209	1100	99.0 min.	.20	(1.00 max. Fe.+Si.)		.05 max.	—	.10 max.	—	—	—	11-16
	1060	99.6 min.	.05 max.	.35	.25	.03	.03	.05	—	.03	—	9.5-12
	5050	REMAINDER	.20 max.	.7 max.	.4 max.	.10 max.	1.0-1.8	.25 max.	.10	—	—	18-25
	5052	REMAINDER	.10 max.	(4.5 Fe.+Si.)		.10 max.	2.2-2.8	.20 max.	.15-.35	—	—	25-34
	5154	REMAINDER	.10 max.	(4.5 Fe.+Si.)		.10 max.	3.1-3.9	.20 max.	.15-.35	.20 max.	—	30-39
	6061	REMAINDER	.15-.40	.7 max.	.4-.8	.15 max.	.8-1.2	.25 max.	.15-.35	.15 max.	—	24-30
	3003	REMAINDER	.20 max.	.7 max.	.6 max.	1.0-1.5	—	.10 max.	—	—	—	14-20
	3004	REMAINDER	.25 max.	.7 max.	.30 max.	1.0-1.5	.8-1.3	.25 max.	—	—	—	22-32
	5083	REMAINDER	.10 max.	.4 max.	.4 max.	.3-1.0	4.0-4.9	.25 max.	.05-.20	.15	—	40-51
	5086	REMAINDER	.10	.5	.4	.2-.7	3.5-4.5	.25	.05-.25	.15	—	35-54
	5456	REMAINDER	.20	(.4 Fe.+Si.)		.5-1.0	4.7-5.5	.25	.05-.20	.20	.005	42-56

FROM A.W.S. HANDBOOK

*DEPENDING ON TEMPER

TABLE E-8. ALUMINUM PRESSURE VESSEL MATERIALS

ALUMINUM WIRE DATA

(RECOMMENDED FILLER WIRE-PLATE COMBINATION)

PARENT MATERIAL	WELDED TO	WITH FILLER WIRE
3003	3003	1100
	6061	4043
5052	5052	5554 OR 5254
	6061	4043
5652	5652	5652
	6061	4043
5154	5154	5554
	6061	4043
5083	5083	5183
	6061	4043
	5086	5183
5086	5086	5183
	6061	4043
5454	5454	5554
	6061	4043
	3003	4043
5456	5456	5556
	6061	4043
6061	6061	4043
3003	5083	4043
	5086	4043

CHICAGO BRIDGE & IRON CO.

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TABLE E-9. ALUMINUM WIRE DATA

ELECTRODE TYPE, CURRENT, AND POLARITY FOR AIR CARBON-ARC CUTTING OF VARIOUS METALS

MATERIAL	ELECTRODE	CURRENT	POLARITY
STEEL	D-C A-C	D-C A-C	REVERSE
STAINLESS STEEL	D-C A-C	D-C A-C	REVERSE
IRON (CAST, DUCTILE AND MALLEABLE)	A-C D-C	A-C OR D-C D-C	STRAIGHT REVERSE
COPPER ALLOYS	A-C D-C	A-C OR D-C D-C	STRAIGHT REVERSE
NICKEL ALLOYS	A-C	A-C OR D-C	STRAIGHT

RECOMMENDED CURRENT RANGES FOR VARIOUS AIR CARBON-ARC CUTTING ELECTRODES

ELECTRODE SIZE In. →	5/32	3/16	1/4	5/16	3/8	1/2	5/8	3/4
MINIMUM AMP.	80	110	150	200	300	400	600	800
MAXIMUM AMP.	150	200	350	450	550	800	1000	1600

FROM A.W.S HANDBOOK

TABLE E-10. CARBON ARC CUTTING

TYPICAL THERMAL TREATMENTS FOr WELDMENTS

MATERIAL	SOAKING TEMP. °F.
CARBON STEEL	1100 — 1250
CARBON - 1/2 % Mo. STEEL	1100 — 1325
1/2 % Cr. - 1/2 % Mo. STEEL	1100 — 1325
1 % Cr. - 1/2 % Mo. STEEL	1150 — 1350
1-1/4 % Cr. - 1/2 % Mo. STEEL	1150 — 1375
2 % Cr. - 1/2 % Mo. STEEL	1150 — 1375
2-1/4 % Cr. - 1 % Mo. STEEL	1200 — 1375
5 % Cr. - 1/2 % Mo. STEEL (TYPE 502)	1200 — 1375
7 % Cr. - 1/2 % Mo. STEEL	1300 — 1400
9 % Cr. - 1 % Mo. STEEL	1300 — 1400
12 % Cr. STEEL (TYPE 410)	1350 — 1400
16 % Cr. STEEL (TYPE 430)	1400 — 1500
1-1/4 % Mn. - 1/2 % Mo. STEEL	1125 — 1250
LOW-ALLOY Cr. - Ni. - Mo. STEEL	1100 — 1250
2 TO 5 % Ni. STEELS	1050 — 1150
9 % Ni. STEELS	1025 — 1085

FROM: AWS HANDBOOK

TABLE E-11. TYPICAL THERMAL TREATMENTS FOR WELDMENTS

TYPICAL WELDING PROBLEMS
CRACKING—WELD METAL

CAUSES	REMEDIES
HIGH RIGIDITY OF JOINT	LOWER COOLING RATE (PREHEAT). MECHANICALLY RELIEVE RESIDUAL STRESSES (PEENING). MINIMIZE SHRINKAGE STRESS (BACKSTEPPING). INCREASE STRENGTH, GREATER WELD SECTION
EXCESSIVE ALLOY PICKUP FROM BASE METAL	CHANGE CURRENT LEVEL AND RATE OF TRAVEL, WELD WITH STRAIGHT POLARITY IF POSSIBLE. OVERLAY BASE METAL AT LOW AMPERAGE PRIOR TO JOINT WELDING
DEFECTIVE ELECTRODES. (MOISTURE, ECCENTRICITY, POOR STRIKING ENDS, POOR CORE WIRE)	CHANGE ELECTRODES; GRIND STRIKING ENDS TO PROPER DIMENSIONS; BAKE ELECTRODES (LOW HYDROGEN)
POOR FIT UP	REDUCE ROOT GAP; CLAD EDGES; WELD WITH POOR FIT UP TECHNIQUE
SMALL BEAD	INCREASE CROSS SECTIONAL ARE OF WELD, USE LARGER ELECTRODE
HIGH SULFUR IN BASE METAL (CARBON AND LOW-ALLOY STEELS)	USE PROCESS WITH SULFUR-FIXING ELEMENTS (BASIC SLAG FROM EXX15, 16, 18
ANGULAR DISTORTION (WELD ROOT IN TENSION)	CHANGE TO BALANCED WELDING ON BOTH SIDES; CONSIDER PEENING; PREHEAT.
CRATER CRACKS	FILL IN CRATER PRIOR TO WITHDRAWING ELECTRODE; USE TAPERING DEVICE FOR GAS TUNGSTEN-ARC

FROM WELDING HANDBOOK

TABLE E-12. TYPICAL WELDING PROBLEMS

COMMON DEFECTS ENCOUNTERED IN RADIOGRAPHY

DEFECT	DESCRIPTION	REFERENCE
POROSITY	GAS POCKETS–VOIDS IN METAL	Fig. 3
SLAG INCLUSIONS	NON-METALLIC SOLID ENTRAPPED IN WELD OR BETWEEN WELD AND PLATE	Fig. 3
INCOMPLETE FUSION	FAILURE OF WELD DEPOSIT TO FUSE WITH PLATE OR PRECEDING BEADS	Fig. 3
CRACKS	DISCONTINUITY RESULTING FROM NARROW SEPARATION OF METAL	Fig. 3

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rev. 8-31-65

TABLE E-13. COMMON DEFECTS ENCOUNTERED IN RADIOGRAPHY

CBI	Cold Forming Effect on A533 Material
CUSTOMER General Electric Company	PROCEDURE NUMBER CFP-1
PRODUCT Boiling Water Nuclear Reactor	PAGE NO. 1 OF 4
ASSEMBLY Test Plate	DATE 9-19-66
DESCRIPTION	REVISION NO. 1 (10-18-66)

0.1 Scope:

To determine the effect of the cold forming operation upon ASTM A533 Grade B, Class I material with respect to the tensile and impact properties. This procedure may be conducted using either a separate plate or the first bottom head plate received for the contract.

0.2 Specification and Code Reference:

ASTM E23 (Type A longitudinal), ASTM A370 and Paragraph N515, Section III, ASME Code, Nuclear Vessels, Class A Vessels. Cold Forming Procedure CFP-1, Ultrasonic Examination Procedure UTP-1, Magnetic Particle Examination Procedure MTP-1, Liquid Penetrant Procedure PTP-1.

1.0 Apparatus:

1.1 3000 Ton Press
1.2 Various Machining Equipment
1.3 Calibrated Testing Machines
 1.3.1 Tensile Testing Machine
 1.3.2 Charpy Impact Testing Machine

2.0 Procedure:

2.1 Inspect the plate prior to forming in order to determine (and accurately record) all defects present in the plate as received from the mill. Perform 100% volumetric UT examination (Procedure UTP-1), 100% Magnetic particle examination of all surfaces (Procedure MTP-1), and 100% liquid penetrant examination on all surfaces (Procedure PTP-1). Designate plate surface to be brought into tension.

2.2 Pieces D, E, & F shall be removed prior to the forming operation using burning methods for rough cutting.

2.3 Piece D shall be post heat treated for 50 hours at 1150°F (-50°F/+25°F).

2.3.1 Remove 32 full size longitudinal Charpy Vee notch impact specimens from Piece D after post heat treating. Sixteen specimens shall be removed from the 1/4T location and sixteen from 1/8 inch below the surface.

CUSTOMER APPROVAL	REVIEWALS				
	FEM	LPZ	AJL	PREPARED OGS	10-18-66
	WAD	AGS	CSS	CHECKED EEV/DLM	10-19-66
	PCA	WHS		APPROVED EEV	

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MONTICELLO NUCLEAR GENERATING PLANT

Cold Forming Effect on A533 Material (Page 1)

FIGURE F-1

2.3.2 Remove four (4) .505"Ø Tensile specimens. Two (2) are to be removed from the 1/4T location and two (2) from 1/8 inch below the surface.

(1) 2.4 Pieces E & F shall be set aside for "back-up" purposes if required.

2.5 The remaining test plate is to be cold formed * with the aid of a 3000 ton press to cause a permanent strain = 3.9%

$$\% = \frac{65t}{R}$$

t = Plate thickness ($6\frac{1}{4}$ inches)
R = Final Spherical radius (103 inches)

The cold forming shall be performed in two steps. The initial forming operation shall be to a radius approximately two times the final radius, (206 inches). Post heat treat (1) the test plate at 1150°F (-50°F; +25°F), for $1\frac{1}{2}$ hours. Final form the test plate to a 103 inch radius before again post (1) heat treating at 1150°F (-50°F; +25°F) for $1\frac{1}{2}$ hours. (The amount of strain on the test plate will be approximately the same amount of strain as the dollar portion of the bottom head in the Reactor at the Monticello location).
(1) *<u>If bottom head plate is used, forming radii are to be as shown on the contract drawings.</u>

(1) 2.6 Inspect the plate after final forming and second post heat treatment to determine (and accurately record) all defects present in the plate after forming. Duplicate the UT, MT, and PT requirements of Paragraph 2.1.

(1) 2.7 Remove Pieces A and B. Piece C is to remain attached for back-up purposes in case heat treatment for development of properties is required. Final heat treat Piece B only for 47 hours at 1150°F (-50°F/+25°F). Piece A does not receive heat treatment specified for Piece B.

2.8 Remove 24 full size longitudinal Charpy Vee notch impact specimens from Piece A (cold formed material before final post heat treatment). Twelve specimens shall be removed from the 1/4T location and twelve from 1/8 inch below the surface.

(1) 2.9 Remove 32 full size longitudinal Charpy Vee notch impact specimens from Piece B (cold formed material after final post heat treating). Sixteen specimens shall be removed from the 1/4T location and sixteen from 1/8 inch below the surface.

MONTICELLO NUCLEAR GENERATING PLANT

Cold Forming Effect on A533 Material (Page 2)

FIGURE F-1

2.9.1 Remove four (4) .505"Ø tensile specimens from Piece B. Two specimens to be removed from the 1/4T location and two from 1/8 inch below the surface.

2.10 All specimen cutting shall be done by machining methods. Removal shall be made by the same methods, except burning methods may be used for rough cutting.

2.11 All depth locations are to be measured from the tensile surface.

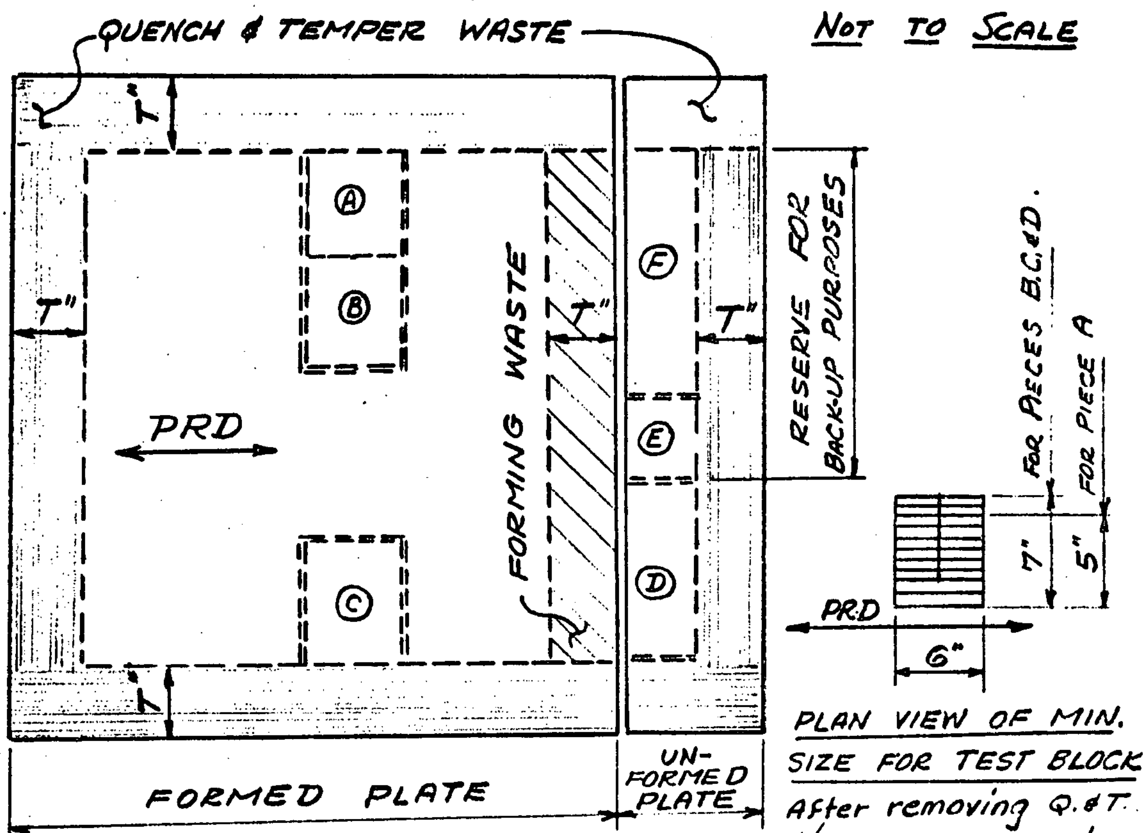
3.0 Testing:

3.1 Six impact-transition curves, 2 each from Pieces A,B and D representing breaking energy (energy absorbed) in ft. lbs. vs. temperature shall be made. The temperature range of testing shall establish an upper plateau. Each plateau shall be determined by at least one but not more than two points. The values at 10°F and 40°F for Pieces B and D shall be developed using six specimens. The remaining specimens in each group of sixteen or twelve shall be used to develop the transition region. The lower plateau need not be developed if it occurs below -80°F. (The two curves developed from Piece A are for information only).

3.2 Tensile strength of the unformed post heat treated material shall be determined from Piece D by tests at the 1/4T location and the 1/8 inch below the surface location. The effects of cold forming upon the tensile strength shall be determined by comparing the sets of test results from Pieces B and D. (ASTM A533 Grade B, Class I tensile requirements shall be met).

3.3 The results for Piece D and Piece B shall be compared to determine if they meet the requirements of Section III of ASME Code.

CB&I	Cold Forming Effect on A533 Material
CUSTOMER: General Electric Company	PROCEDURE NUMBER: CFE-1
PRODUCT: Boiling Water Nuclear Reactor	PAGE NO. 4 OF 4
ASSEMBLY: Test Plate	DATE: 9-19-66
DESCRIPTION:	REVISION NO. 1 (10-18-66)



PLAN VIEW OF MIN. SIZE FOR TEST BLOCK After removing Q.&T. &/or forming waste.

TYPICAL PLATE for TESTING

1) Layout shown is for 48"x60" test plate. Other plate sizes may be used to fit available material.
2) Size and locate test blocks to provide sufficient material so that required tensile and impact specimens can be cut.
3) No test specimen shall be taken from material closer than T" to either a formed edge or a quenched & tempered edge.
4) Orient test blocks & specimens with respect to PRD.
5) Maintain identity of tensile surface, both on formed & on un-formed test blocks.

MONTICELLO NUCLEAR GENERATING PLANT
Cold Forming Effect on A533 Material (Page 4)
FIGURE F-1

CB&I	CONTRACT 9-5624 MONTICELLO, MINN. 17'-1" DIA. X 63'-1½" INS. OA REACTOR VESSEL NORTHERN STATES POWER COMPANY GE/APED P. O. 205-55582-1	Cold Forming Procedure

CUSTOMER	General Electric Company	PROCEDURE NUMBER	CFP-1
PRODUCT	Boiling Water Nuclear Reactor	PAGE NO.	1 OF 3
ASSEMBLY		DATE	9-20-66
DESCRIPTION		REVISION NO.	0

0.1 Scope

Covers cold forming of shell and head plates for Boiling Water Nuclear Reactor plates made of ASTM A533 Grade B, Class I material.

0.2 Specification and Code Reference

ASME Boiler and Pressure Vessel Code, Section III.

1.0 Apparatus

1.1 1500,3000, or 6000 ton press.

2.0 Procedure

2.1 Before forming, the plate thickness shall be measured at the four corners (as determined by the finished dimensions) and at the midpoint of the four edges, by micrometer and recorded. On double curved plates, the thickness at the center shall be measured by micrometer, calipers, or by ultrasonic means and recorded.

2.2 All plate edges and corners shall be smoothed by grinding where necessary before forming. The plate shall be visually inspected for any sharp notches or laps on the surface which shall be smoothed by grinding if found.

2.3 Plates shall be preheated in the furnace to a minimum of 400°F to minimize the possibility of a brittle fracture during forming. No forming is to be done if the plate temperature drops below 100°F. Temperature measurements shall be made using heat sensitive crayons or indicators.

2.4 The plates shall be cleaned by blowing compressed air over the surface to remove all dirt, loose mill scale and abrasive material present. This procedure shall be used to remove any scale loosened by bending.

2.5 Plates shall be press formed progressively on a sequential die.

2.6 Shell plates shall be visually squared with the press girder to assure that after forming, a cylindrical segment of parallel and co-planar edges will result.

CUSTOMER APPROVAL	REVIEWALS				
Approved by P. Herbert 9-26-66 VPF#1811-6-1 EP#2-1 Orig. GE approved copy on file at Q.C. Oak Brook Office.	PCA - LPZ	CSS-AGS	PREPARED	OWK	9-16-66
	FEM - AJL	WF-HLW	CHECKED	RFC	9-20-66
	OBJ		APPROVED	EEV	9-20-66

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MONTICELLO NUCLEAR GENERATING PLANT

Cold Forming Procedure
(Page 1)

FIGURE F-2

CBI	CONTRACT 9-5624 MONTICELLO, MINN. 1 17'-1" DIA. X 63'-1½" INS. OA REACTOR VESSEL NORTHERN STATES POWER COMPANY GE/APED P.O. 205-55582 I	Cold Forming Procedure

CUSTOMER	General Electric Company	PROCEDURE NUMBER	CFP-1
PRODUCT	Boiling Water Nuclear Reactor	PAGE NO.	2 OF 3
ASSEMBLY		DATE	9-20-66
DESCRIPTION		REVISION NO.	0

2.7 Head plates shall be carefully positioned in the press, visually, to assure that after forming, a spherical segment of uniform radius will result.

2.8 If total elongation of the outer fiber of the plate material will exceed 3% during forming, an intermediate stress relieving operation shall be required each time the 3% maximum increment is reached. Stress relieving shall be at 1150°F plus 25°F/minus 50°F for a minimum time of 1/4 hour per inch of thickness. The elongation of the outer fibre (in percent) is calculated using the following formulas:

(a) For elongation resulting from cylindrical forming

$$e = 50\ t/R$$

(b) For elongation resulting from double curvature forming

$$e = 65\ t/R$$

where: t = nominal plate thickness in inches
R = nominal centerline radius in inches
e = % elongation

2.9 The thinning allowance for all plates will be based upon previous experience.

2.10 After final forming, the plates shall be stress relieved at 1150°F plus 25°F/minus 50°F for a minimum time of 1/4 hour per inch of thickness. Cold sizing within 1% will not require further stress relieving.

2.11 After final forming, the plate thicknesses shall be measured at the same locations noted in paragraph 2.1 and recorded. The chords and diagonals shall be taped to assure that proper configuration has been achieved.

2.12 Test coupons shall be removed from plates after final forming and stress relieving, and shall be tested in accordance with the applicable portions of the customer's specifications and the requirements of the ASME Code, Section III.

MONTICELLO NUCLEAR GENERATING PLANT

Cold Forming Procedure
(Page 2)

FIGURE F-2

2.13 A qualification test shall be performed prior to any forming. Material of identical chemistry and heat treatment shall be formed and tested in accordance with approved procedure.

2.14 When all requirements have been met, (See Paragraph 3.0) the remaining portion of stock shall be removed from the plate for the necessary welding test plates and/or fabrication test specimens.

3.0 Acceptance Criteria

3.1 The finish radius inside shall be determined using a segmental 6' circular template of the "sweep" type. The maximum deviation from the true radius at either the center or ends shall not exceed ½".

3.2 If the requirements of paragraphs 2.11 and 2.12 are not met, the plate shall be heat treated for properties, and reworked if necessary. New test coupons shall be taken from both ends of the plate and all required tests shall be performed in accordance with the applicable portions of the customer's specifications and the applicable portions of the ASME Code Section III.

4.0 Documentation Required

4.1 As mentioned in paragraphs 2.1 and 2.11, the thickness at various points on each plate, before and after forming, shall be recorded on a sketch showing the locations where measurements were taken.

5.0 Distribution of Documented Reports

5. Copies of the thickness report shall be sent to the Fabrication Quality Control Coordinator. The original shall be filed in the inspection office.

POST FORMING/WELDING
HEAT TREATING PROCEDURE

CUSTOMER General Electric Company	PROCEDURE NUMBER HTP-1
PRODUCT Boiling Water Nuclear Reactor	PAGE NO. 1 OF 3
ASSEMBLY	DATE October 12, 1966
DESCRIPTION	REVISION NO. 1

0.1 Scope:

This procedure applies to post weld heat treatment and post forming heat treatment performed in enclosed stationary furnaces of the car bottom type, and fired with natural gas.

0.2 Reference:

ASME Boiler & Pressure Vessel Code, Section III.

1.0 Apparatus:

1.1 Furnace Description: Enclosed, natural gas fired, car bottom type. Design such as to prevent direct impingement of the flame on the part being heat treated.

1.2 Furnace Controls: Furnace temperature controlled and monitored using instruments of the recording type connected to thermocouples attached to the furnace walls. The actual temperature of the part being heat treated to be monitored using a recording/indicating instrument connected to thermocouples located on or near to the part. (All instruments are under surveillance by the furnace operator and any discrepancies are reported to the maintenance department for correction).

1.3 Thermocouples:

Chromel-Alumel, type "K"
Iron-Constantan, type "J"

1.4 Calibration:

1.4.1 Instruments: All instruments are calibrated to assure that the accuracy at any temperature is within plus or minus 0.5%. (The maintenance department calibrates all instruments on a 6 week basis using a portable potentiometer certified traceable to the National Bureau of Standards).

MONTICELLO-NSP
GENERAL ELECTRIC CO.
APED – SAN JOSE
VPF # 1811-9-2
EP # 2-1

APPROVED AS CHECKED BELOW
[ ] Not Approved. Revise and resubmit for approval.
[X] No further action required. Proceed with fabrication.
[ ] As noted. Proceed with fabrication and resubmit corrected transparency and prints.
[ ] Refer to comments
[ ] Without comments. Proceed with fabrication and submit corrected transparency and prints.
10/28/66

CUSTOMER APPROVAL	REVIEWALS				
	FEM	PCA	LPZ	PREPARED QEK	9-26-66
	WAD	CSS	AJS	CHECKED AJL	9-26-66
	AJL	REC	HLk	TAE APPROVED	-26-66

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MONTICELLO NUCLEAR GENERATING PLANT

Post Forming/Welding Heat Treating Procedure (Page 1)

FIGURE F-3

1.4.2 Thermocouples: A master thermocouple of the Platinum-10% rhodium platinum type is used as the standard. (Accuracy plus or minus 0.25% as certified traceable to the National Bureau of Standards). Thermocouples are heated with the master thermocouple to assure that the accuracy is within plus or minus 0.75%.

2.0 Procedure:

2.1 All parts shall be inspected for cleanliness prior to heat treatment. Dirt and foreign materials shall be removed by blowing compressed air over the part. Excessive oil and grease shall be removed.

2.2 Parts shall be supported on saddles no less than 12 inches above the top of the furnace car. The spacing of the saddles and any necessary bracing shall be such that the parts do not undergo any distortion during heat treatment which will cause a permanent change in configuration after cooling.

2.3 The location and number of thermocouples attached to the part during heat treatment may vary depending upon the size of the part. A sketch showing the number and location of thermocouples shall be prepared for every heat.

2.4 The temperature of the furnace shall not exceed 600°F at the time the part is placed in the furnace.

2.5 Above 600°F, the rate of heating shall not be more than 400°F per hour divided by the maximum plate thickness in inches (but need not be less than 100°F per hour), or 400°F per hour maximum.

2.6 During the heating period there shall not be a greater variation in temperature throughout the portion of the part being heated than 250°F within any 15 feet interval of length.

2.7 The part shall be held at 1150°F plus 25°F/minus 50°F for no less than the holding time indicated below.

HOLDING TIME

Post forming heat treatment: 1/4 hour per inch of thickness (Intermediate or final)

Intermediate PWHT: 1/4 hour per inch of thickness for fabrication of base metal.

Intermediate PWHT: 2 hours total for stainless overlay.

MONTICELLO NUCLEAR GENERATING PLANT

Post Forming/Welding Heat Treating Procedure (Page 2)

FIGURE F-3

Final PWHT: 1 hour per inch of thickness

During the holding period, there shall not be a greater difference than 75°F between the highest and lowest temperature of the part being heated. (see para. 2.7)

2.8 Above 600°F, cooling shall be accomplished in a closed furnace at a rate not greater than 500°F per hour divided by the maximum plate thickness in inches (but need not be less than 100°F per hour), or 500°F per hour maximum. Below 600°F, the part may be cooled in still air.

3.0 Acceptance Criteria:

3.1 A machine stamped chart of time vs. temperature is plotted automatically by a recording/indicating instrument for every heat. This chart shall be reviewed by the heat treating supervisor to assure that the operation conforms to all requirements of the ASME Code and to the customer's specifications.

4.0 Documentation:

4.1 Detailed instructions are given to the furnace operator on a "Furnace Cycle Report". The furnace operator uses this report as his instructions and signs off when he has completed the heat treating operation. The "Furnace Cycle Report" is returned to the supervisor along with the machine stamped chart mentioned in para. 3.1 above.

4.2 A hand drawn chart shall be prepared from the stamped chart and kept as a permanent record of every heat.

4.3 A complete thermal history, starting from the finished forged shape or the rolled plate, prior to heat treating for development of mechanical properties, shall be prepared and maintained for all parts until they are shipped.

CBI

ULTRASONIC EXAMINATION PROCEDURE FOR PLATES

CUSTOMER General Electric Company
PRODUCT Boiling Water Nuclear Reactor
ASSEMBLY
DESCRIPTION

PROCEDURE NUMBER UTP-1
PAGE NO. 1 OF 4
DATE October 12, 1966
REVISION NO. 1

1.0 Scope

1.1 This examination procedure is to be used for low alloy plates manufactured for a nuclear boiling water reactor. This procedure will make use of longitudinal (normal) beam method for detecting discontinuities parallel to the rolled surface. Pulse echo type ultrasonic equipment is acceptable for this examination procedure.

1.2 This examination shall be performed two times. The first examination is to be made at the mill prior to shipment of the plates to Chicago Bridge & Iron Company.

1.3 The second performance of this procedure shall be made after plates have been formed and heat treated in Chicago Bridge & Iron Company's Plant.

2.0 Reference

2.1 This procedure is in accordance with ASME Boiler and Pressure Vessel Code Section III Nuclear Vessels.

3.0 Apparatus

3.1 This procedure shall be performed using ultrasonic equipment of the pulse echo longitudinal beam type capable of providing linear presentation within ± 5% up to at least 75% of full screen height.

3.2 The transducer used shall be 1" or 1-1/8"Ø or 1" square of a frequency adequate to provide penetration and resolution with a minimum noise level.

3.3 Other transducers may be used for evaluation at operator's discretion.

MONTICELLO-NSP
GENERAL ELECTRIC CO.
APED – SAN JOSE
VPF # 1811-10-1
EP # 2-1

CUSTOMER APPROVAL	REVIEWALS			
	FEM	AGS - PCA	PREPARED	FCB
	LPZ - BME	CSS - WHS	CHECKED	GSS/EEV
	AJL - WAD	OBJ	APPROVED	EEV

GB 186

MONTICELLO NUCLEAR GENERATING PLANT

Ultrasonic Examination Procedure for Plates (Page 1)

FIGURE F-4

4.0 Procedure

4.1 In accordance with this procedure, ultrasonic inspection may be performed on one major surface of the plate after surface preparation.

4.2 The plate surface used as contact shall be sufficiently clean and smooth to maintain a good couplant between the transducer and the plate surface during scanning.

Method of preparation of plate surface to maintain back reflection requirements and smooth scanning is at plate manufacturer's option. If necessary after overall plate preparation is complete, localized rough surfaces may be removed by grinding.

4.3 This procedure is to be performed using direct contact method and adequate couplant to allow good transmission of ultrasound. Typical couplants are water soluble oil, glycerine, or cellulose gum solution. Upon completion of the examination, the surface of the plate shall be wiped to remove excess couplant.

4.4 In performance of this procedure, 2.25 MC frequency shall be used except where thickness, grain size or other micro-structure of the material makes it necessary to use a different frequency. Transducer shall be operated at the rated frequency and present an easily interpretable trace pattern regardless of the frequency of transducer used during examination procedure.

4.5 Examination shall be performed continuously over 100% of the selected contact surface of the plate, thereby giving 100% volumetric inspection.

4.6 After completion of the examination, the flat plate is to be stamped indicating ultrasonic examination in accordance with this procedure. This stamp shall be located near the identification stamping of the plate in such a position that it might be retained on the finished shell segment of the vessel. All ultrasonic chartings should be referenced to this marking.

5.0 Ultrasonic Examination Using Flat Bottom Hole As Reference Calibration

MONTICELLO NUCLEAR GENERATING PLANT
Ultrasonic Examination Procedure for Plates (Page 2)
FIGURE F-4

5.1 This examination shall be performed two times, once at the mill prior to shipment of plates, and after plates have been formed and heat treated in Chicago Bridge & Iron Company's Plant.

5.2 All equipment used to perform this examination shall meet the specifications described in paragraph 3.0 of this procedure.

5.3 A reference specimen shall be used to calibrate the equipment and establish acceptance criteria. The reference specimen shall be of the same nominal thickness, metallurgical structure and the same or acoustically similar P number grouping as the material being tested, and it shall have a flat bottom hole with a depth of 10% of the thickness of the material being inspected. For material less than 4", the hole shall be 1/2"Ø flat bottom drilled 1/10 of thickness of the material. For material above 4", the flat bottom hole shall be 3/4"Ø and drilled 1/10 of thickness of the material.

5.4 The instrument shall be calibrated by setting the equipment to produce back reflection signal equal to 75% of full screen at any location on the reference specimen representing its full thickness. The noise level shall not exceed 20% of full scale.

5.5 With this setting, the search unit should be placed over the calibration hole and the amplitude of the back reflection and the amplitude of the signal from the flat bottom hole recorded.

5.6 Set the search unit on the ultrasonically sound area of the plate to be examined and adjust the back reflection to 75%.

5.7 During the scan, minor adjustments may be made to restore the back reflection to 75% of full scale to compensate for effects of surface condition. Such adjustments shall be made over an ultrasonically sound area of the plate showing comparable surface condition.

5.8 With the instrument so adjusted, 100% volumetric examination of the plate is to be made from either of the major surfaces.

CB&I		ULTRASONIC EXAMINATION PROCEDURE FOR PLATES
CUSTOMER	General Electric Company	PROCEDURE NUMBER UTP-1
PRODUCT	Boiling Water Nuclear Reactor	PAGE NO. 4 OF 4
ASSEMBLY		DATE October 12, 1966
DESCRIPTION		REVISION NO. 1

6.0 Acceptance Criteria

6.1 Any area where one or more continuous ultrasonic indications on the same plane cause a loss of back reflection greater than produced by the calibration hole in the reference specimen, and that is continuous during movement of transducer 3" in any direction shall be unacceptable.

6.2 Any area where continuous ultrasonic echo indications occur that exceed 50% of the reflection from the calibrated hole in the reference specimen, and that is continuous during movement of the transducer more than 3" in any direction, shall be unacceptable.

6.3 No repair of plate rejected under ultrasonic examination shall be done without approved repair procedure for specific repair.

7.0 Recording

7.1 Charted results based on a grid pattern for 100% scan shall be provided with each plate. The grid shall be referenced to the ultrasonic plate marking. A chart using this grid pattern shall be maintained of all defects with 50% or greater loss of back reflection regardless of size. These charts shall be furnished in triplicate to purchaser thru Fabrication Quality Control Coordinator.

7.2 Adequate notice shall be provided for purchaser to furnish personnel to witness ultrasonic examination performed by manufacturer.

MONTICELLO NUCLEAR GENERATING PLANT

Ultrasonic Examination Procedure for Plates (Page 4)

FIGURE F-4

CB&I	Liquid Penetrant Testing Procedure
CUSTOMER: General Electric Company	PROCEDURE NUMBER: PTP-1
PRODUCT: Boiling Water Nuclear Reactor	PAGE NO. 1 OF 2
ASSEMBLY:	DATE: 11-9-66
DESCRIPTION:	REVISION NO. PRELIMINARY

0.1 SCOPE:

This examination procedure is to be used when liquid penetrant examination to be performed by CB&I Company is required for the following:

0.1. Austenitic forgings

0.1.2 Austenitic welds

0.1.3 Austenitic weld build-up

0.1.4 Cladding

0.1.5 Austenitic Tubular Products

0.1.6 Austenitic castings

0.1.7 Edge preparations of Austenitic materials

0.2 REFERENCE:

ASME Boiler and Pressure Vessel Code, Section III, Para. N-627 with mandatory inclusion of proposed addenda as published in the "Mechanical Engineering" magazine dated July, 1966

1.0 APPARATUS:

1.1 Water soluble visible dye penetrant or water soluble fluorescent dye penetrant.

1.2 Liquid developer

1.3 Black light (use with fluorescent dye penetrant)

2.0 PROCEDURE:

2.1 The procedure shall be as described in the ASME Code, Section III, Para. N-627 with proposed addenda as referenced in 0.2 above, and in accordance with the

CUSTOMER APPROVAL	REVIEWALS	PREPARED / CHECKED / APPROVED
	~~FEM~~ WHS JEH CSS	PREPARED FCB
	PCA LPZ WEG AGS	CHECKED DLM 11-9-66
	~~GSS~~ ~~WAD~~ ~~AJL~~	APPROVED DLM EV 11-9-66

MONTICELLO NUCLEAR GENERATING PLANT

Liquid Penetrant Testing Procedure
(Page 1)

FIGURE F-5

following qualifications and requirements.

2.1.2 Water soluble visible dye penetrant or water soluble fluorescent dye penetrant shall be used.

2.1.2 A water spray from a source with less than 50 psi pressure and less than 110°F temperature shall be employed for excess penetrant removal as recommended in Para. N-627.4 (d) (1).

2.1.3 A liquid developer shall be employed.

3.0 ACCEPTANCE CRITERIA:

3.1 Acceptance standards as set forth in the ASME Code, Section III, Para. N-627 with proposed addenda as referenced in 0.2 above, shall apply except as follows:

3.1.1 Additional unacceptable defect indications for clad areas and clad repairs are as follows:

3.1.1.1 Linearly - disposed spot indications of 4 or more spots spaced 1/4" or less from edge to edge of the indication.

3.1.1.2 Spot indications which are indicative of defects greater than 1/32" deep as revealed by bleed-out.

3.1.2 For the examination of the clad area of the closure flange seal surfaces on which the double seals seat, any indication of any type shall be unacceptable.

4.0 DOCUMENTATION REQUIRED:

4.1 A signed written report will be made of all customer required liquid penetrant examinations.

MONTICELLO NUCLEAR GENERATING PLANT

Liquid Penetrant Testing Procedure
(Page 2)

FIGURE F-5

CBI	Magnetic Particle Testing Procedure
CUSTOMER: General Electric Company	PROCEDURE NUMBER: MTP-1
PRODUCT: Boiling Water Nuclear Reactor	PAGE NO. 1 OF 2
ASSEMBLY:	DATE 11-8-66
DESCRIPTION:	REVISION NO. PRELIMINARY

0.1 SCOPE:

This examination procedure is to be used when magnetic particle examination to be performed by C. B. & I. Co. is required for the following.

0.1.1 Carbon steel and low alloy steel forgings

0.1.2 Carbon steel and low alloy steel welds

0.1.3 Weld build-ups

0.1.4 Carbon steel and low alloy steel tubular products

0.1.5 Carbon steel and low alloy steel castings

0.1.6 Edge preparations of carbon steel and low alloy steel materials

0.1.7 Surfaces of low alloy steel plate material.

0.2 REFERENCE:

ASME Boiler and Pressure Vessel Code, Section III, Para. N-626 with mandatory inclusion of proposed addenda as published in the "Mechanical Engineering" magazine dated July, 1966.

1.0 APPARATUS:

1.1 Magnetic particle testing machine, welding machine, or equiv. (Current source for prod method)

1.2 Dry particles (Contrasting color desirable)

1.3 Prods or Yoke

2.0 PROCEDURE:

2.1 The procedure shall be as described in the ASME Code, Section III, Para. N-626 with proposed addenda as referenced in 0.2 above, using either the prod method performed in

CUSTOMER APPROVAL	REVIEWALS	
	~~FEM~~ WHS PCA LPZ	PREPARED FCB
	~~GSS~~ ~~WAD~~ JEH CSS	CHECKED DLM 11-8-66
	~~WEG~~ ~~AGS~~ AJL	APPROVED DLM/EEV 11-8-66

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MONTICELLO NUCLEAR GENERATING PLANT

Magnetic Particle Testing Procedure (Page 1)

FIGURE F-6

accordance with Para. N-626.3 (a) using dry particles, or the yoke method performed in accordance with Para. N-626.3 (c) using dry particles. The following shall apply to the prod method only.

2.1.1 Magnetic particle testing machines, welding machines, or equiv. may be used as the source of electrical current.

3.0 ACCEPTANCE CRITERIA:

3.1 Acceptance standards as set forth in the ASME Code, Section III, Para. N-626 with proposed addenda as referenced in 0.2 above, shall apply.

4.0 DOCUMENTATION REQUIRED:

4.1 A signed written report will be made of all customer required magnetic particle examinations.

MONTICELLO NUCLEAR GENERATING PLANT

Magnetic Particle Testing Procedure

(Page 2)

FIGURE F-6

CONTRACT 9-5624 MONTICELLO, MINN.
1-17'-1" DIA. X 63'-1½" INS. OA REACTOR VESSEL
NORTHERN STATES POWER COMPANY
GE/APED P. O. 205-55582-1 - REACTOR

CB&I	TITLE	Plate Material Specification
CUSTOMER	General Electric Company	PROCEDURE NUMBER MS-1
PRODUCT	Boiling Water Nuclear Reactor	PAGE NO. 1 OF 3
ASSEMBLY		DATE 8/25/66
DESCRIPTION		REVISION NO. 0

1.0 Scope:

1.1 This specification covers Low Alloy Plates heat treated by Plate Manufacturer for a Nuclear Boiling Water Reactor.

2.0 Reference:

2.1 ASME Boiler and Pressure Vessel Code Section III, Nuclear Vessels.

3.0 Specification:

3.1 Plates shall conform to ASTM Specification A-533 Class I Grade B Firebox Quality.

3.2 Plates shall be produced to fine grain practice. Grain size shall be 5 or finer as determined on a fully heat treated coupon cut from the test plate described in paragraph 3.6 below and measured by the method given in ASTM Specification E-112.

3.3 Plate ingots shall be produced by vacuum degassed pouring.

3.4 Heat treatment shall consist of accelerated cooling from the austenitizing temperature to below the martensite finish temperature followed by tempering at not less than 1200°F. Manufacturer's proposed heat treatment procedure shall be submitted to CB & I for approval at least 60 days prior to heat treatment.

3.5 The mill shall clearly identify with steel stencil the top or bottom of each plate in relation to the top and bottom of the pouring of the ingot from which the plate is rolled. Test plates shall be taken from a location no closer than "1/4T" from one quenched and tempered surface, and no closer than "T" from any quenched and tempered edge where "T" is the nominal thickness of the material.

3.6 Test plates shall be heat treated to simulate a series of post weld heat treatments by heating uniformly to 1150°F plus 25°F/minus 50°F and holding for 50 hours. The rate of heating and cooling shall conform to the ASME Code Section III, paragraph N-532.3. The mill may remove the test specimens from the test plates prior to simulated post weld heat treatment if desired.

CUSTOMER APPROVAL	REVIEWALS				
B Herbert 8/25/66	REC,	EEV,	LPZ,	[illegible]	8/25/66
	GSS, WRM			PFP	8/25/66
				[illegible]	[illegible]/66

MONTICELLO NUCLEAR GENERATING PLANT

Plate Material Specification
(Page 1)

FIGURE F-7

CONTRACT 9-5624 MONTICELLO, MINN.
1-17'-1" DIA. X 63'-1½" INS. OA REACTOR VESSEL
NORTHERN STATES POWER COMPANY
GE/AFCO P. O. 205-55582 1 - REACTOR

CBI

TITLE	Plate Material Specification
CUSTOMER General Electric Company	PROCEDURE NUMBER MS-1
PRODUCT Boiling Water Nuclear Reactor	PAGE NO. 2 OF 3
ASSEMBLY	DATE 8/25/66
DESCRIPTION	REVISION NO. 0

3.7 At least two of the shell plates and all of the top head plates shall meet the requirements of the ASME Code, Section III, paragraph N-330 at a temperature no higher than 10°F. In addition, this material shall have an NDT temperature no higher than 10°F as determined by ASTM E-208. All other plates shall meet the requirements of the ASME Code, Section III, Paragraph N-330 at a temperature no higher than 40°F. In addition, this material shall have an NDT temperature no higher than 40°F as determined by ASTM E-208.

3.8 At least two drop weight speciments shall be tested from the top end (top as determined by ingot pouring) of each mill rolled plate. Results shall be reported on the certified test report. The NDT temperature shall not exceed 10°F for the 10°F NDT plates of paragraph 3.7.

3.9 Plates shall be blast cleaned on both sides to remove scale prior to ultrasonic testing. Specified thickness is thickness after blasting.

3.10 Plates shall be ultrasonically tested in accordance with ASME Code Section III as modified by Code Case 1338-2, Alternate 2 except 100% volumetric scan shall be used. Chicago Bridge & Iron Company reserves the right to witness and chart results of ultrasonic testing at the mill. The plate manufacturer shall give Chicago Bridge & Iron Company five (5) days notice before the ultrasonic test is performed.

3.11 The plate manufacturer shall furnish an ultrasonic grid chart for each plate which shall show the location of all acceptable defects. These grid charts shall be submitted to Chicago Bridge & Iron Company for approval before shipping the plates. All repair welding shall be done by Chicago Bridge & Iron Company. The cost of such repairs shall be for the plate manufacturer's account.

3.12 Based on Chicago Bridge & Iron Company contract requirements, an additional ultrasonic test is to be performed in accordance with ASME Code Case 1338-2 with the following acceptance requirements. A defect which causes an echo indication that exceeds 50% of the indication from the calibrated standard and that is continuous during movement of the transducer more than 3" in any direction, shall be unacceptable. A chart shall be maintained of defects with 50% or greater loss of back reflection.

Since Lukens has rejected orders to this specification, the above is required for Chicago Bridge & Iron Company informational purposes only. Mill rejection will be based on ASME Code 1338-2, Alternate 2.

MONTICELLO NUCLEAR GENERATING PLANT

Plate Material Specification
(Page 2)

FIGURE F-7

CB&I

[illegible] INS. OA REACTOR VESSEL
NORTHERN STATES POWER COMPANY
[illegible] P. O. 205 [illegible] 1 REACTOR

TITLE	Plate Material Specification
CUSTOMER General Electric Company	PROCEDURE NUMBER MS-1
PRODUCT Boiling Water Nuclear Reactor	PAGE NO. 3 OF 3
ASSEMBLY	DATE 8/25/66
DESCRIPTION	REVISION NO. 0

3.13 Certified test reports shall show the complete heat treatment of plates before removing test plates and of test plates after removal. Certified test reports and grid sketches shall be submitted at the same time the plates are shipped. It is important that these be received and the plates identified before starting fabrication.

3.14 Care shall be used in rolling plates to avoid imbedded scale, cold laps or "snakes" and other surface defects. Approval shall be obtained in writing for the acceptance of such defects subject to repair by CB&I Company.

3.15 All steel stamping shall be in accordance with the requirements of paragraph N-512 of ASME Code Section III.

MONTICELLO NUCLEAR GENERATING PLANT

Plate Material Specification
(Page 3)

FIGURE F-7

ULTRASONIC TEST PROCEDURE
UT-R2

I. SCOPE

This procedure is written for the express purpose of examining welds contained in heavy wall reactors. The following ultrasonic test procedure will be performed by Chicago Bridge & Iron Company using qualified personnel.

II. EQUIPMENT

1. Branson Model 50C or equivalent will be used. Instrument used will be certified to the same calibration level as described in Section III, ASME Code, under N-625.2 (b).

2. Transducers with frequency adequate to permit penetration of the type and thickness material being examined with minimum noise level are to be used.

3. Adequate couplant, 30 weight motor oil or equivalent is to be used, except in cases of rough surfaces or vertical seam examination, in which case, light qrease or heavy oil may be used.

4. Standard block of similar material (shown in reference block sketch included in this procedure) or where possible, the material in the vessel being examined may be used for reference.

III. CLEANING

1. Cleaning for shear wave examination. All welds to be ultrasonically tested using shear wave shall have a smooth surface. The welds shall be ground with a smooth contour from the plate up and over the weld reinforcement and down to the plate on the opposite side to insure good contact of transducer at all times. In addition to the smooth contour of the weld, an area on either side of the weld adequate to insure complete coverage of the weld by the ultrasonic beam shall be cleaned for good contact and free movement of the transducer.

2. Cleaning for longitudinal wave examination. The surface along which the transducer is to be passed shall be cleaned free of all weld splatter, loose mill scale, and the contour shall be such that the transducer shall make good contact and allow free movement with normal couplant and pressure. The width of the path cleaned for longitudinal wave examination shall be determined by the size of the weld to be examined.

IV. METHODS

1. Shear wave examination of butt welded shell seams: During examination, the movement of the transducer shall be such that the entire area of the weld is inspected. The direction of the transducer shall be 90° from the centerline of the weld, except that it shall be rotated continuously to a few degrees alternately to each side of 90°. While moving the transducer in this manner, it shall be advanced a distance adequate to cover the entire weld surface. In addition to the above two movements and simultaneously with these movements, the transducer will be advanced parallel to the centerline of the weld at a speed which will permit the operator to define defects. The transducer shall also be passed down the centerline of the weld over areas that have been examined as above described as an additional examination for possible transverse defects. The direction of the transducer shall be parallel to the centerline of the weld and the direction of travel shall be parallel and along the centerline of the weld with a slight movement of the transducer alternately to each side of the centerline. A pattern of the above described transducer movement during shear wave examination of welds is shown on the included sketch entitled "Shear Wave Search Pattern."

When using shear wave examination for nozzle welds, the examination shall be conducted in the same manner as above described except where such welds are inaccessible from both sides of the weld, an additional pass down the center of the weld using longitudinal wave examination shall be substituted for the shear wave from the inaccessible side of the weld. For nozzles having full penetration corner welds, the examination shall be made using longitudinal wave only.

Longitudinal wave inspection of nozzles will be in accordance with the attached sketch, which is an indication of the scan path of nozzles, determining thickness in nozzles and the "T" which is to be used to establish the attenuation curve. The "T", as indicated for the appropriate type nozzle installation will be used in connection with the reference block for longitudinal wave inspection.

V. INSTRUMENT SENSITIVITY

1. When using the shear wave examination method, the sensitivity of the instrument will be set using a 45° wedge and the standards block shown in the included sketch entitled "Reference Block for Shear Wave Evaluation." The position of the transducer

MONTICELLO NUCLEAR GENERATING PLANT

Ultrasonic Test Procedure
(Page 2)

FIGURE F-8

in this position, the reflection from the notch shall be set at 100% screen height. All evaluation of defects found by shear wave examination shall be made at the sensitivity level required by the 1% notch in the position shown on the reference block sketch and in accordance with the included defect chart.

2. When using longitudinal wave method of weld examination, the instrument shall be set to resolve the following size holes depending on the thickness of material being examined.

Thickness Range	Hole ϕ Inches	Hole Depth Inches
1" - 3"	1/8	1/2
3" - 4"	1/4	1/2
4" - 5"	3/8	1/2
5" - 6"	1/2	1/2
6" - 7"	5/8	1/2
7" - 8"	3/4	1/2

Using the hole size matching the corresponding material thickness, the sensitivity of the instrument shall be set with the transducer over the base material such that it will produce a back reflection, then it shall be moved over the appropriate hole and the first back reflection from the hole shall be set at 100% full screen height. The reference from the second back reflection is to insure adequate penetration through the weld and beyond to any reinforcement which may contain defects.

During the examination using the longitudinal wave method, the sensitivity of the instrument should always be set with the defect as its maximum distance from the applied search unit. Scanning may be conducted at a higher sensitivity level to allow the operator to move faster while still adequately interpreting screen signals. For evaluation purposes, the appropriate sensitivity level and attenuation curve shall be used.

VI. BASIS OF REJECTION

1. The basis of rejection for defects found using shear wave examination is determined from the attached defect chart. This chart is based on an instrument sensitivity set as described under instrument sensitivity for shear wave inspection. This chart is also based on material of 4" and greater. The evaluation of all defects found using the shear wave examination method shall be made in accordance with the attached defect chart.

The basis of rejection for defects found using the longitudinal wave examination shall be determined from an attenuation curve drawn to fit the thickness material being examined, and the sensitivity of the instrument set in accordance with the appropriate paragraph of this procedure. Using this sensitivity and the attenuation curve, any defect which exceeds 80% of the signal height on any point of the attenuation curve, and has a linear dimension or travel of 2 inches and greater shall be considered rejectable.

VII. REFERENCE BLOCK DESCRIPTION

1. Shear wave reference block: This reference block is made based on a sensitivity of 1% of material thickness. This is accomplished by cutting a notch in the material or in the reference block to a depth of 1% of the material thickness, the notch having an included angle of 90°. Since this reference block is designed for use with a 45° wedge, the 1% notch containing an angle of 90° shall be cut in the reference block using a chipping tool with shoulders ground at a depth to 1% of the plate thickness to prevent the tool from going deeper. The length of this notch shall be greater than the width of the transducer being used. The chisel shall also be checked to insure that it has a 90° included angle. The block also may have a step cut in it which is 1/2 "T" and the same 1% notch cut in this depth to demonstrate the effect of attenuation due to material. The surface of this block shall be equal to the surface of the material being tested. This reference block is designed to have the transducer placed such that the first half node of the ultrasonic beam will strike the notch on the opposite side of the plate as shown.

2. The reference block for the longitudinal wave examination is made in accordance with the appropriate hole sizes as shown in the chart on Page 3. The attached sketch shows the depth to which these holes may be drilled in order to establish attenuation curve for longitudinal wave inspection.

VIII. ATTENUATION CURVES

1. Although the attenuation curve for shear wave examination can be established through a test block made up in steps, this would require a very large test specimen and require a crane to move it. Therefore, the attenuation curves on the attached defect chart have been established for this type of inspection. These

curves were established using various percentage notches as references, also, there were a number of examinations made at various sensitivity levels in order to establish the curves that appear in this chart. These curves are based on quite a background of examination of heavy material welding.

2. When using longitudinal wave examination, an attenuation curve may be established for evaluating defects using appropriate material thickness and the corresponding hole size. By drilling the hole selected for the material thickness to various depths in the material, several points along the attenuation curve may be established. The attached sketch of the reference block for longitudinal wave inspection gives these depths to which these holes should be drilled in order to establish the points along the curve.

For example: Examination of 7" plate weld with longitudinal wave requires that the selection of 5/8" flat bottom hole. This hole may be drilled at various depths, 1/2" deep, 1/4 thickness deep, 1/2 thickness deep, 3/4 thickness deep, and other depths if necessary to establish more points along the curve. The instrument should be set with the 5/8" hole at its maximum distance from the transducer which, in this case, is 1/2" deep hole. The other depths will give the corresponding amplitude of signal from the same size defect at different depths due to attenuation.

IX. DEFECT CHART EXPLANATION

This chart is designed to be used with material 4 inches and thicker in conjunction with the 45° shear wave examination described in this procedure. The variables involved in this defect chart are first signal amplitude which is plotted along the left side of the page (amplitude sensitivity is based on the 1% plate thickness notch reference standard). The second variable, material attenuation, is shown by a series of curves for a corresponding defect at various depths within the material. The depth of the defect within the material is shown on the right hand side of the chart plotted along the X axis. The third variable is the length of the defect which appears on the chart as continuous length of travel and is plotted along the Y axis at the bottom of the chart.

Example of chart use: Using shear wave examination with the sensitivity set as described in this procedure, should a defect be located which gives an amplitude signal of 50% screen height and appears on the cathode ray screen corresponding to a 6 inch depth in the material and through movement of the transducer is determined to have a continuous length of travel of 5 inches by referring to the defect chart; this defect is rejectable. A defect of 50% screen height amplitude 5 inches deep in the material and having a linear travel of 5 inches when referred to

the defect chart is not rejectable. As can be seen from these examples, any defect which having linear dimension and amplitude signal height which falls below the corresponding depth of defect line is acceptable. Any that fall on or above the corresponding defect line are considered rejectable.

X. RECORD OF EXAMINATION

A permanent record shall be made of all indications which are in excess of those produced by the 1% standard notch and the corresponding depth of defect curve shown on the defect chart, cr the corresponding reference hole and its attenuation curve regardless of whether the length is long enough to require repair. This record shall be manually recorded on a sketch showing size, depth and dimension location, the indication with reference to a fixed reference point which is selected at the beginning of the examination at the fabricator's discretion. This manual record shall be kept in accordance with Chicago Bridge & Iron Company's Standard Ultrasonic Test Report.

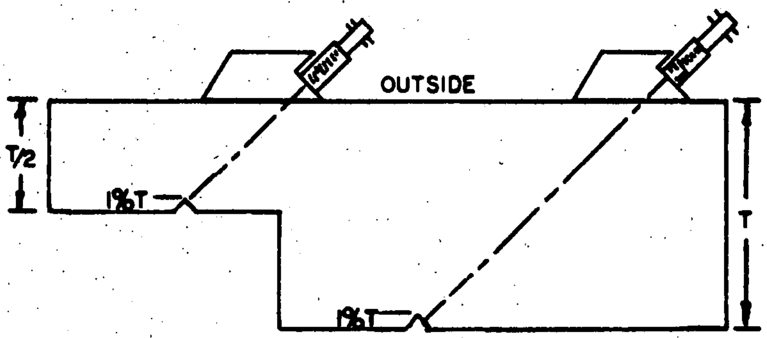
XI. REPAIRS

All rejected areas are to be arc gouged, chipped or ground to remove the defect, magnetic particle inspected after arc gouging, and repaired. After re-welding, re-examination shall be made by the original method of examination. Both the area which has been repaired, and an additional area 6 inches on either side, and on either end of the repair is to be examined.

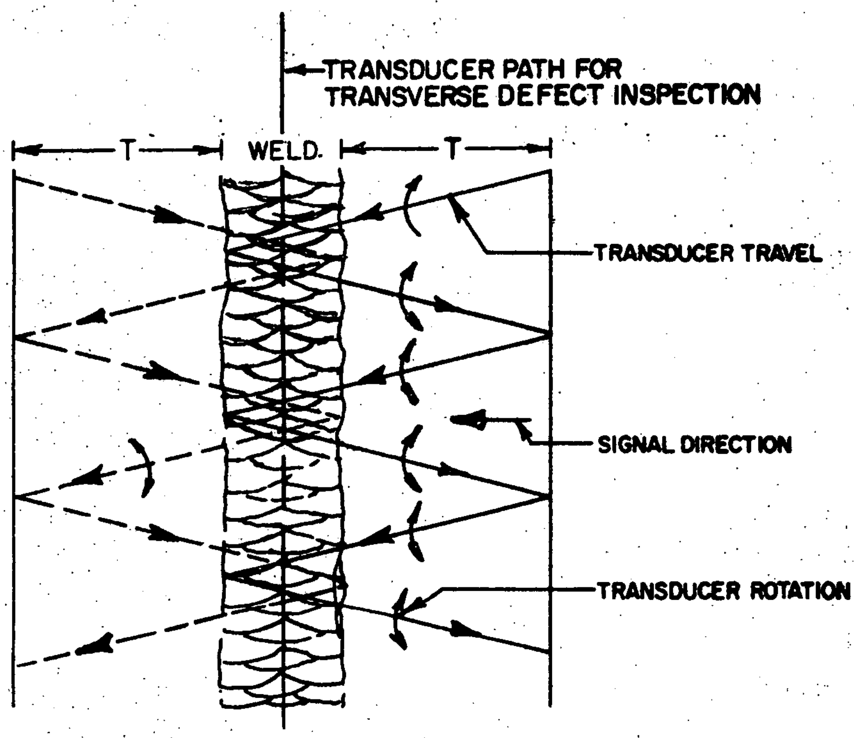
MONTICELLO NUCLEAR GENERATING PLANT

Ultrasonic Test Procedure
(Page 6)

FIGURE F-8

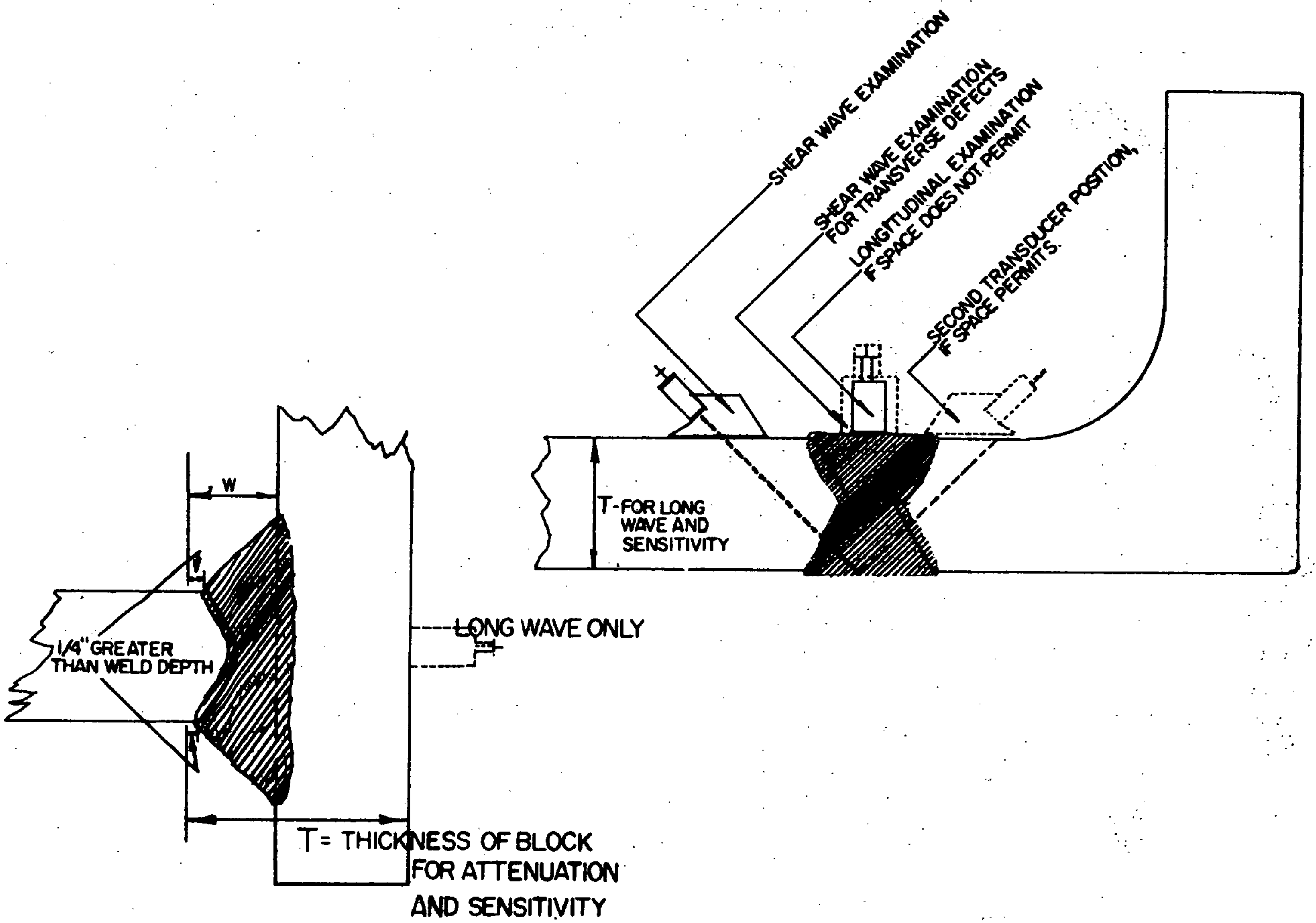


REFERENCE BLOCK FOR SHEAR WAVE EVALUATION



SHEAR WAVE SEARCH PATTERN

MONTICELLO NUCLEAR GENERATING PLANT
(Page 7)   FIGURE F-8



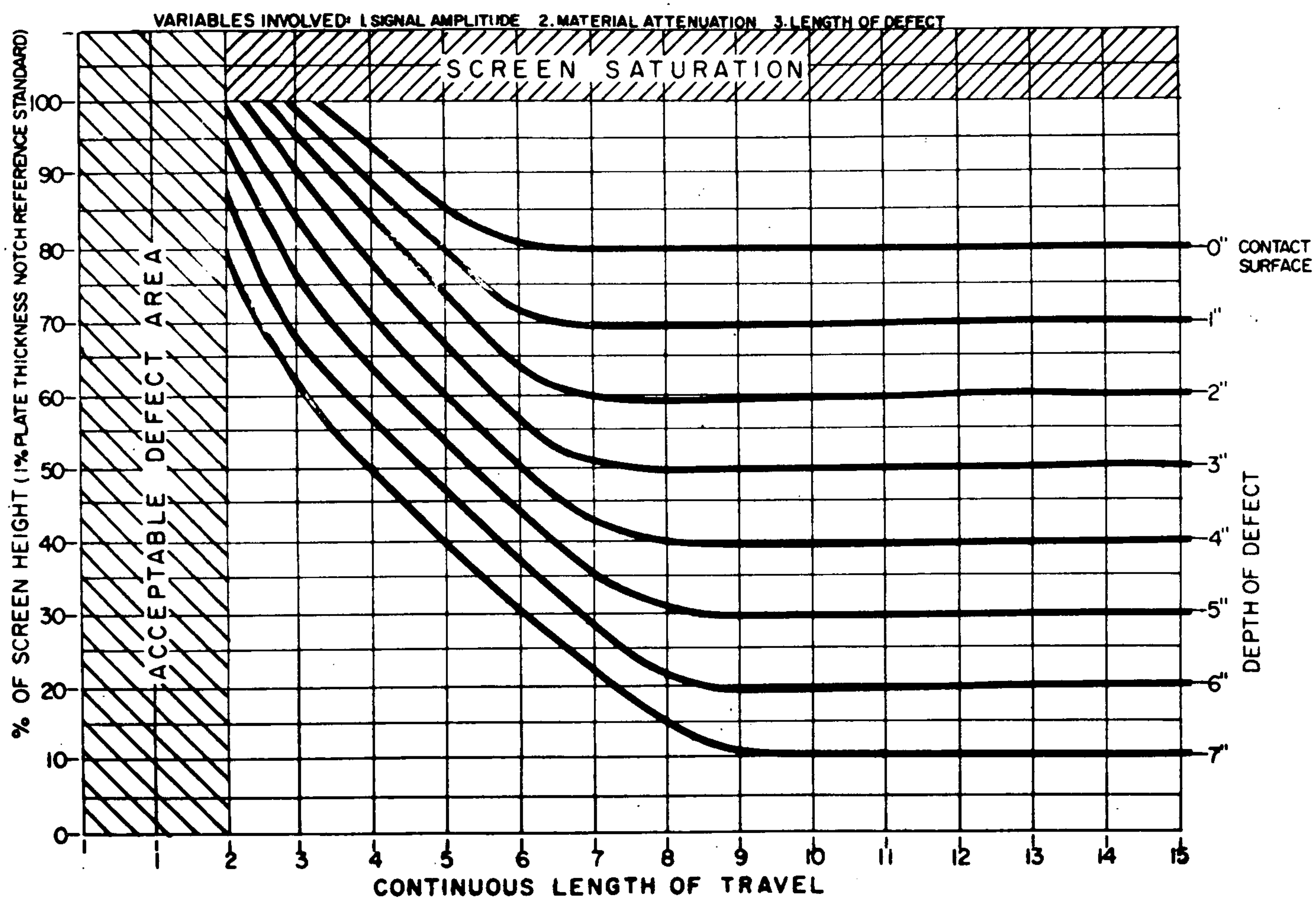
SKETCHES FOR NOZZLE EXAMINATION

MONTICELLO NUCLEAR GENERATING PLANT

(Page 8)

FIGURE F-8

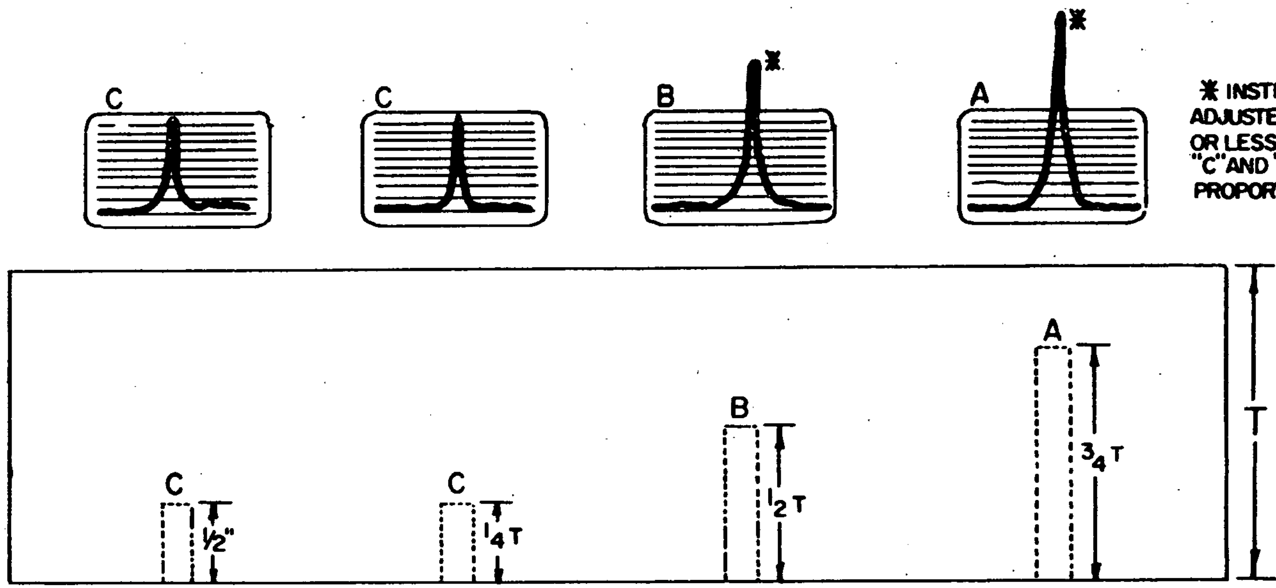
DEFECT CHART



MONTICELLO NUCLEAR GENERATING PLANT

FIGURE F-8

(Page 9)



* INSTRUMENT CAN BE ADJUSTED TO SHOW 100% OR LESS, OF SCREEN HEIGHT. "C" AND "B" WILL BE REDUCED PROPORTIONATELY.

NOTE: SELECTION OF HOLE SIZE FROM TABLE

REFERENCE AND ATTENUATION BLOCK
FOR LONGITUDINAL WAVE

MONTICELLO NUCLEAR GENERATING PLANT

(Page10)

FIGURE F-8

TRAVELER CARD

CARD SET A

PC. MARK: I-28

PAGE 1 OF 2

CONTRACT 9-5624 MONTICELLO, MINN.
1-17'-1" DIA. X 63'-1½" INS. OA REACTOR VESSEL
NORTHERN STATES POWER COMPANY
GE/APED P. O. 205-55582-1 - REACTOR

DESCRIPTION: BOTTOM HEAD PLATE

DRAWING REF: T3 (REV-2); HL-2 (REV-2); and PROCEDURE CFE-1 (REV-1)

HOLD PT. & RELEASE		SEQ. NO	ACTIVITY DESCRIPTION AND NOTES	DRAWING OR PROCEDURE REFERENCE	A DATE COMPLETED & PASSED BY SUPV.	B DATE REVIEWED & PASSED BY CRF INSPECTOR	C DATE REVIEWED & PASSED CBI-QC	D DATE REVIEWED & PASSED GE/QCPM
		A1	UNLOAD @ RECEIVING YARD AND PERFORM "INCOMING" INSPECTION	VIP-1 REV-0		X	X	
HP	B	A2	VERIFY MILL TEST REPORTS & UT PLOT OF DEFECTS (ACCEPT OR REJECT PLATE FROM MILL)	VP-1 REV-0		X	X	X
		A3	ATTACH LIFTING LUGS TO PLATE AS RECEIVED FROM MILL	WP-1 REV-0	X			
		A4	ROUGH CUT TO SIZE. STORE CUT OFF MATERIAL	DRWG T3 REV-2	X			
		A5	ATTACH LIFTING LUGS TO PC I-28	WP-1 REV-0	X			
HP	C/B	A6	PREPARE FOR NON-DESTRUCTIVE TESTS (SEE A7 & A8) (NOTIFY GE/QCPM)	NP-1 REV-0			X	X FIRST PROD. FORM BASIS
HP	D/B	A7	MAGNETIC PARTICLE EXAMINATION OF ALL SIX (6) SURFACES	MTP-1 REV-0		X	X	X FIRST PROD. FORM BASIS
HP	D/B	A8	LIQUID PENETRANT EXAMINATION OF ALL SIX (6) SURFACES	PTP-1 REV-0		X	X	X FIRST PROD. FORM BASIS
		A9	PRESS FORM TO INTIAL RADIUS	CFP-1 REV-0	X		X	X FOR CFE-1 ONLY
HP	D/C	A10	PREPARE FOR HEAT TREATMENT (SEE A11) (NOTIFY GE/QCPM)	REV-			X	X FIRST PART BASIS
		A11	POST FORM HEAT TREAT (INTERMEDIATE)	HTP-1 REV-0	X		X	
HP	D	A12	PREPARE FOR REPAIR OF PLATE DEFECTS (SEE A13) (NOTIFY GE/QCPM)	REV-			X	X
HP	B	A13	REPAIR DEFECTS IN PLATE MATERIAL INCLUDING "IN-HOUSE" HOT UT & MT EXAMINATIONS DURING PROCESS.	WRP-1 REV-0	X	X	X	
		A14	PRESS FORM TO FINAL RADIUS (MAINTAIN PREHEAT)	CFP-1 REV-0	X		X	
		A15	POST FORM/WELD HEAT TREAT (FINAL)	HTP-1 REV-0	X		X	
HP	D	A16	REMOVE TEST COUPONS & PREPARE SPECIMENS (NOTIFY GE/QCPM)	CFE-1 REV-1	X	X	X	X
HP	D	A17	PERFORM QUALIFICATION TESTS	ASTM & CFE-1 REV-1		X	X	X FIRST PROD. FORM BASIS
HP	B	A18	VERIFY TEST REPORTS {IF VERIFIED GO TO A20 {IF NOT VERIFIED GO TO A19	VP-1 REV-0		X	X	X
HP	D/B	A19	HEAT TREAT FOR PROPERTIES, THEN RETURN TO A16 (NOTIFY GE/QCPM)	HTP-2 REV-0	X	X	X	X FOR EACH FIRST PART
		A20	COLD SIZE TO FINAL DIMENSION	CFP-1 REV-0	X	X	X	
HP	C/B	A21	PREPARE FOR NON-DESTRUCTIVE TESTS (SEE A22,23,24,25) (NOTIFY GE/QCPM)	NP-1 REV-0			X	X FIRST PART BASIS

CONTINUED ON PAGE 2

MONTICELLO NUCLEAR GENERATING PLANT

Traveler Card
(Page 1)

FIGURE F-9

TRAVELER CARD

CARD SET A

PC. MARK: I-28

PAGE 2 OF 2

CONTRACT 9-5624 MONTICELLO, MINN.
1-17'-1" DIA. X 63'-1½" INS. OA REACTOR VESSEL
NORTHERN STATES POWER COMPANY
GE/APED P. O. 205-55582-1 · REACTOR

DESCRIPTION: BOTTOM HEAD PLATE

DRAWING REF: T3 (REV-2); HL-2 (REV-2); and PROCEDURE CFE-1 (REV-1)

HOLD PT. & RELEASE		SEQ. NO	ACTIVITY DESCRIPTION AND NOTES	DRAWING OR PROCEDURE REFERENCE	A DATE COMPLETED & PASSED BY SUPV.	B DATE REVIEWED & PASSED BY GE INSPECTOR	C DATE REVIEWED & PASSED CBI-QC	D DATE REVIEWED & PASSED GE/QCPM
HP	D/B	A22	PERFORM RADIOGRAPHIC EXAM. OF DEFECTS REPAIRED UNDER A13 UNLESS STEP A19 IS REQUIRED	RTP-1 REV-0		X	X	X FIRST PART BASIS
HP	D/B	A23	PERFORM 100% VOLUMETRIC UT EXAMINATION	UTP-1 REV-1		X	X	X FIRST PART BASIS
HP	B	A24	PERFORM MAGNETIC PARTICLE EXAM. ON ALL SIX (6) SURFACES	MTP-1 REV-0		X	X	
HP	B	A25	PERFORM LIQUID PENETRANT EXAM. ON ALL SIX (6) SURFACES	PTP-1 REV-0		X	X	
		A26	REMOVE EXCESS STOCK & PREPARE BEVELS FOR SEAMS	SBP-1 REV-0	X	X	X	
HP	D/B	A27	PERFORM MAGNETIC PARTICLE EXAM. ON PLATE EDGES	MTP-2 REV-0		X	X	X FIRST PART BASIS
				REV-				
				REV-				
			TRANSFER	REV-				
			TO	REV-				
			CARD SET "AA"	REV-				
				REV-				
				REV-				
				REV-				
				REV-				
				REV-				
				REV-				
				REV-				
				REV-				
				REV-				
				REV-				

CONTINUED ON PAGE 2

MONTICELLO NUCLEAR GENERATING PLANT

Traveler Card
(Page 2)

FIGURE F-9

PLATE MARK	HEAT NO	SLAB NO	[redacted]			[redacted]			[redacted]			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			STRESS RELIEVE			TOTAL TO DATE	
			DATE	°F	°HR	DATE	°F	°HR	DATE	°F	HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	DATE	°F	°HR	[redacted]	[redacted]

CHICAGO BRIDGE & IRON COMPANY
BIRMINGHAM, ALA.

PURCHASER'S NO. CONTRACT NO.
DRAWN BY D.B. DATE 12-30-65
CHECKED BY DATE
ENGINEERING COORDINATOR DWG NO. REV

MONTICELLO NUCLEAR GENERATING PLANT

(Page 1)

FIGURE F-10

QUALITY CONTROL SPREAD SHEET (SAMPLE)

						WELD OR REP NUMBER	
						WELD OR REPAIR PROCEDURE NUMBER	
						PROCEDURE QUALIFICATION DATE	
						Q.C. COORD	
						GE QCPM	
						JOINT COMPLETION DATE	
						Q.C. COORD	
						GE-QCPM	
						DATE	PWHT
						TOTAL HRS	
						QC COORD	
						GE QCPM	
						IDENT	RADIOGRAPHY
						DATE	
						RESULTS	
						QC COORD	
						GE QCPM	
						REPORT NO.	UT
						DATE	
						RESULTS	
						Q.C. COORD	
						GE QCPM	
						REPORT NO	MT
						DATE	
						RESULTS	
						Q.C. COORD	
						GE QCPM	
						REPORT NO	PT
						DATE	
						RESULTS	
						Q.C. COORD	
						GE QCPM	

MONTICELLO NUCLEAR GENERATING PLANT

Quality Control Spread Sheet

FIGURE F-11

CHICAGO BRIDGE & IRON COMPANY
RADIOGRAPHY WORK ORDER

ISSUED BY ____________ DATE ____________ 19__

OPERATION PERFORMED WITH EQUIPMENT LISTED BELOW

25 MEV ☐ 2 MEV ☐ OX-250 ☐ OX-220 ☐ IND-X 175 ☐ COBALT 60 ☐ IRIDIUM 192 ☐

WITH FILTER ☐ WITHOUT FILTER ☐

TYPE SCREENS

LEAD .010" ☐ .005" ☐ or -______ ☐ FLORESCENT ☐

CONTRACT NO.__________ Tk. No.______ SECTION No.__________ PIECE MARK__________

FILM BUILT UP BY & DATE	SEAM No. OR LETTER	THICKNESS Pl or SEAM	EXPOSURE TIME OR No. R	FOCAL FILM DISTANCE	KV	BEAM CURRENT	MILLIAMPERE	TYPE FILM	NO. FILM	SIZE FILM	RADIOGRAPH COMPLETED BY	DATE	WELDER NO. OUTSIDE	WELDER NO. INSIDE

USE ASME CODE PENETRAMETER No.________ or ________

FILM EXPIRATION DATE ____________

REVIEWED BY ____________ DATE ______ 19__

THP 4-20-66

MONTICELLO NUCLEAR GENERATING PLANT

Radiography Work Order

FIGURE F-12

CBI
N D T

ULTRASONIC TEST REPORT

CHICAGO BRIDGE & IRON COMPANY

REGION ______________________ SHOP ☐ FIELD ☐

Page ____ of ____

Contract No. __________ Type of Instrument ______________________

Final Date of Inspection __________ 19__ Inspector in Charge ______________

U. T. Procedure No. ______________ Or Code ______________

U. T. of Weld ______________ Or Pl. ______________

Plate Thickness ______________ Frequency ______________

Transducer Size ______________ Straight ______________

Angle ______° Surface Conditions ______________________

Couplant ______________ ☐. /Or ______________ ☐

U. T. Only ☐ After X-Ray ☐ After Stress Relieve ☐

U. T. After X-Ray & Stress Relieve ☐ Surface Used O. D. ☐ I. D. ☐

U. T. Entire Surface of Weld with Angle Beam Running Parallel to Weld ☐

U. T. Perpendicular to the Longitudinal Axis to Cover Weld ☐

RESULTS OF U. T. INSPECTION, DEFECTS LOCATED PER X-RAY LAYOUT

SEAM	LOCATION FROM REFERENCE POINT	DEFECT LENGTH	DEFECT DEPTH	DEPTH FROM OUTSIDE	DEPTH FROM INSIDE	DATE & INSPECTOR NO.	REMARKS	DATE & ACCEPTED BY

OB 5 F-13(1) 8-70

MONTICELLO NUCLEAR GENERATING PLANT

Ultrasonic Test Report

FIGURE F-13

CBI NDT

REPORT NO. MT-__________

MAGNETIC PARTICLE INSPECTION RECORD

CHICAGO BRIDGE & IRON COMPANY

PROCEDURE #__________ REGION__________ SHOP ☐ FIELD ☐

ISSUED BY__________ DATE __________

OPERATOR(S)__________ DATE __________

CONTRACT__________ SECTION __________

MCH. NO.__________ PROD. SPACING__________ AMP__________ DC

DESCRIBE EXACT PART, PIECE AND LOCATION TNAT WAS CHECKED

	REJECT	OK
1. EDGE OF PL.-PLATE NO. __________	☐	☐
2. RING ENDS OF PL.-PLATE NO. __________	☐	☐
3. EDGE OF CUTOUTS-FITTING NO. __________	☐	☐
4. ROOT PASS-INS. ☐ OUTS ☐ __________	☐	☐
5. BACK CHIP__________	☐	☐
6. WELDED SEAM INSIDE (BEFORE O/L)__________	☐	☐
7. WELDED SEAM OUTSIDE__________	☐	☐
8. PART WELDED SEAM DEPTH__________INCHES		
SEAM __________	☐	☐
9. TRAY BAR NO. __________	☐	☐
10. INSULATION BARS NO. __________	☐	☐
11. MT BEFORE FINAL PWHT__________	☐	☐
12. MT AFTER FINAL PWHT & TEST__________	☐	☐
13. __________	☐	☐

REMARKS__________

DISPOSITION__________

RECEIVED BY__________ DATE __________

EVALUATED BY__________ DATE __________

MONTICELLO NUCLEAR GENERATING PLANT

Magnetic Particle Inspection Record

FIGURE F-14

CBI
N D T

REPORT No PT-__________

LIQUID PENETRANT INSPECTION RECORD

CHICAGO BRIDGE & IRON COMPANY

PROCEDURE #__________ REGION __________ SHOP ☐ FIELD ☐

ISSUED BY__________ DATE __________19____

CONTRACT NO.__________ PIECE MARK__________

INSPECT OVERLAY ON:		REJECT	OK
ENTIRE SECTION__________		☐	☐
WELDED SEAM (SEAM __________)			
	FIRST PASS	☐	☐
	FINAL PASS	☐	☐
NOZZLE __________			
INSIDE NECK __________	FIRST PASS	☐	☐
	FINAL PASS	☐	☐
FACE OF FLANGE __________	FIRST PASS	☐	☐
	FIHAL PASS	☐	☐
NOZZLE TO HEAD/SHELL CONNECTION			
	FIRST PASS	☐	☐
	FINAL PASS	☐	☐
OTHER OPERATIONS		☐	☐

DESCRIBE IN FULL __________

____

DISPOSITION__________

RECEIVED BY__________ DATE __________19____

ACCOMPLISHED BY__________ DATE __________19____

MONTICELLO NUCLEAR GENERATING PLANT

Liquid Penetrant Inspection Record

FIGURE F-15

APPENDIX G
GENERAL ELECTRIC'S REQUIREMENTS FOR FABRICATION, INSPECTION AND TEST PROCEDURES

I. FABRICATION SEQUENCE

The fabrication schedule shall contain all significant steps which relate to the individual parts and subassemblies progressing to the main assembly. Significant steps include:

a. Order and delivery of materials and subcomponents

b. Heat treatment

c. Material tests

d. Welding qualifications

e. Welding

f. Post weld heat treatment

g. Dimensional inspection

h. Machining

i. Cleaning

j. Non-destructive testing

k. Repairs

l. Pressure testing

m. Packing

n. Shipping

The schedule shall also include the name and location of any sub-suppliers of components and the components involved.

II. FORMING PROCEDURE

Required for all forming during fabrication, subsequent to mill forming.

The following information shall be included in the Forming Procedure:

1. Identification number of each procedure specification
2. Method of forming (roll, brake, press, swage, die)
3. Estimate minimum thickness after forming thinning allowance

4. Temperature range (maximum and minimum) at which forming will take place and complete time-temperature cycle

5. Method of heating for forming

6. Methods for determining the temperature (optical pyrometer, thermocouple/furnace atmos. or metal surface)

7. Reference to any post-forming heat treatment

8. Method of dimensional check (ultrasonic thickness, calipers)

9. Method of calculating thinning allowance

III. HEAT TREATMENT PROCEDURE

Required for all thermal processes after the mill or foundry forming operation.

Each procedure shall include the following information:

1. Identification for each procedure and type of heat treatment (normalize, temper, solution heat treat)

2. Cleaning procedure prior to heat treatment

3. Furnace description - type of fuel or method of heating, atmosphere, type of furnace and controls

4. Description of temperature-monitoring equipment (recording or indicating instruments):

   a. Accuracy and calibration of thermocouples

   b. Number and location of thermocouples

5. Method of supporting the parts in the furnace

6. Heat treatment parameters:

   a. Heating rate (degrees per hour) and tolerance

   b. Holding temperature and tolerance

   c. Holding time at temperature and tolerance

   d. Cooling rate (degrees per hour) and tolerance

      Note: When accelerated cooling is used, all information regarding the cooling medium, such as chemical composition, volume and method agitation, shall be described.

   e. For slow cooling, the maximum temperature permitted for opening of furnace. For accelerated cooling, the maximum temperature permitted for discontinuing cooling

7. For local postweld heat treatment, also include:

   a. Maximum axial thermal gradients within heated area, and outside heated area

   b. Maximum circumferential thermal gradients within the heated area and outside the heated area

   c. Maximum radial thermal gradients within the heated area and outside the heated area

   d. Maximum thermal gradients at any nozzles

   e. Type, thickness, location and method of supporting insulation

IV. WELDING AND SURFACING PROCEDURE

Each procedure specification shall include the following information

1. Identification number of each procedure specification
2. Welding process or combinations of processes, consumable or non-consumable electrodes, single or multiple arcs, and number of arcs if multiple. Automatic, semi-automatic or manual operation. The hard surfacing, spray, arc or torch application
3. Base metal specification and thickness range
4. Filler metal specification and analysis, bare wire or coated, sizes. Material for non-consumable electrode
5. Submerged-arc welding flux composition
6. Shielding gases, purging gases, and flow rates
7. Welding positions and direction of welding progression, if vertical
8. Preheat and if maintained until post weld heat treatment
9. Postweld heat treatment
10. Treatment of the root of the weld, including back chipping/gouging, the use of consumable insert rings, or the use and removal of non-consumable backing strips
11. Single or multiple passes per side
12. Method of preparing edge of base metal for welding
13. Method of cleaning before and after welding, including flux removal
14. Electrical characteristics such as a-c or d-c, electrode polarity, and use of high frequency
15. Electrode sizes, voltages, currents, and for manual welding the bead sequence in relation to the electrode size
16. Weave or bead technique
17. Controls of appearance of welding layers, defects, and slag removal

18. For machine welding, the travel speed and bead sequence
19. Moisture control of electrodes and flux
20. Peening, if used, shall either be noted in detail on the welding procedure or cross-referenced to the peening procedure
21. Welding end preparation, including dimensions and tolerances. (If not shown on detail drawings.)
22. For hard surfacing: Fusion temperature and control for spray application; control of cooling rate; surfacing thickness limits; if not shown on drawing; method and sequence of inspection of deposit and acceptance limits; range of acceptable hardnesses.

V. CLEANING AND PRESERVING PROCEDURES

In-process and final cleaning and preserving procedure specifications. Each specification shall include the following information.

1. <u>Degreasing, Chemical Cleaning</u>
   a. Identification number of each procedure
   b. Chemical composition and concentration, including tolerances
   c. Method of application and type of equipment
   d. Temperature, time and tolerances
   e. Rinsing
   f. Method for checking cleanliness
   g. Control of metal ion buildup
2. <u>Mechanical Cleaning</u>
   a. Identification number of each procedure
   b. Type of process (wet, dry, pneumatic, mechanical)
   c. Type of particle (sand, grit, shot, beads, shells)
   d. Size of particles
   e. Method of assuring low iron content of cleaning material (for stainless steels)
3. <u>Preserving</u>
   a. Identification number of each procedure
   b. Chemical composition and concentration, including tolerances for preservatives other than paint
   c. Method of application and type of equipment (spray, brush, dip)
   d. Medium or method for removal, if required

e. If used as temporary rust inhibitor, what is useful life expectancy

f. Reaction to presence of rainwater, salt water, salt spray, long exposure to sunlight, humidity extremes, and tropical heat as applicable to method of shipment and storage at site.

g. Specification of paint

h. Number of coats

i. Area or portion of equipment to be preserved

VI. FERRITE CONTROL PROCEDURE

Required for austenitic stainless steel weld metal. The procedure shall be in accordance with one of two alternates:

Alternate 1

a) One quantitative test of each heat of wire for the gas tungsten arc and gas metal arc welding processes

b) One quantitative test of each manufacturing lot of electrodes for the shielded metal arc welding processes

c) One quantitative test of each heat of wire and each manufacturing lot of flux for the submerged arc welding processes

Alternate 2

One quantitative test from each proposed brand type and size of wire and flux followed by periodic qualitative audits of production welds for indications of magnetism, for all welding processes.

The test reports shall be considered acceptable, and fulfill the specification requirement, when they contain the following information:

1. Manufacturer's name and equipment identification number

2. Statement of test conditions

   a. For gas tungsten arc and gas metal arc welding processes: quantitative tests are made either on the bare wire (undeposited) or as in b. below

   b. For all welding processes: quantitative tests are conducted on undiluted weld deposits made in accordance with ASTM A-298, paragraph 19

   c. For all welding processes: qualitative audits for indication of magnetism are conducted on as-welded deposits of production welds

   d. Chemical analysis for all elements except carbon may be either "wet" or "spectrographic". Chemical analysis for carbon shall be by either "wet" or "carbon train" method.

3. Statement of Type of Quantitative Test – one or more of the following:

   a. Certified chemical analysis for chromium and nickel content where percent Cr $\geqq$ 1.9 x percent Ni

   b. Certified chemical analysis for Cr, Mo, Si, Cb, Ni, C, and Mn which when plotted as chromium and nickel equivalents on the Schaefler* diagram show at least 5 percent ferrite content

   c. Certified results of Magna-Gage test, or equal quantitative magnetic test, with at least 5 percent ferrite content

   d. Certified results of quantitative ferrite count by metallographic techniques approved by General Electric with at least 5 percent ferrite content

4. Statement of Qualitative Audit

   Frequency of audit and results of audit indicating the presence or absence of detectable magnetism.

VII REPAIR PROCEDURES

It is anticipated that two types of documents will be prepared, namely: a) a <u>general</u> repair procedure covering the information outlined below and intended for application to "minor" defects and the general plan for repairing all defects and b) one or more <u>specific</u> repair procedure(s) covering the information outlined below and intended for application to "major" defects requiring specific GE approval.

Each procedure, or request, shall include the following information:

1. General repair procedure (and for minor defects)

   a. Identification number of each specification

   b. Method of removal of defect, and any preheat requirements for defect removal

   c. Method of inspection for complete removal of defect

   d. Conditions when re-welding is or is not required

   e. Minimum cavity dimensions for welding or for leaving as-is

   f. Welding procedure specification, if repair welded

   g. Method of inspection of completed repair

   h. Minimum surface conditions for completed repair

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*Schaefler, A. L., Metal Progress, 56, 680 (1949) or AWS Welding Handbook, Sect. I, Table 4.17

2. Specific repair procedure (major defects)

   a. Identification of each specification

   b. Either reference to 1-a above or the information required by 1-b-h above

   c. Type of defect and probable cause of defect

   d. How defect was detected

   e. Components involved

   f. Materials involved

   g. Fabrication status of the part

TYPE OF SUBMITTAL: RADIOGRAPH INSPECTION PROCEDURE

VIII RADIOGRAPH INSPECTION PROCEDURE

Required whenever this inspection method is to be used on shell welds, nozzle welds, and castings

Each specification shall include the following information:

1. Identification number of each procedure.

   a. For X-ray; voltage and current limitations for given type of material and range of thickness.

   b. For gamma ray: type of isotope, maximum focal spot size (or minimum specific activity), and approximate strength (curies) for given type of material and range of thickness.

3. Film brand and type. Number of films in the cassetts.

4. Type and thickness of intensifying screens and filters.

5. Blocking or masking techniques, if used.

6. Thickness and type of material radiographed.

7. Exposure conditions, including minimum ratio of material thickness versus source distance from film.

8. Range of film density and nominal film density.

9. Minimum overlap of multiple exposure films.

10. Type of penetrameter. If not ASME penetrameter, material and dimensions.

11. Number and location of penetrameters. If other than ASME code, give details.

12. Use of shims under penetrameter.

13. Image quality level.

14. Major steps for film processing such as developing, short stop, fixing, washing, and controls on same such as temperature, time and renewal of spent solution and agitation.

15. Viewing conditions:
    a. Type of viewing apparatus for film densities over 2.5 (adjustable high intensity
    b. Use of darkened room for viewing.
16. Provisions for identification and location of films, including stamping or marking on the part.
17. Method of recording test results.
18. Note: Double film technique shall consist of duplicate films.
19. Acceptance criteria for welds, castings. as applicable.
20. For gamma ray:
    a. The specific component, area or seam involved.
    b. Reason why gamma rays are suitable.

IX ULTRASONIC INSPECTION PROCEDURE

Required whenever this inspection method is to be used on forgings, plate, welds, cladding, tubular products, castings, or weld buildup

Each specification shall include the following information:

1. Identification number of each procedure
2. Statement of application to plate, forgings, welds, tubing. casting and/or cladding. weld buildup
3. Description of equipment used:
    a. Crystal material and size
    b. Testing frequency
    c. Straight or angle beam, min. and max. angles for angle beam
    d. Immersion or contact and coupling medium
    e. Brand name of equipment and model
    f. Mechanized or manual. If mechanized, description of equipment.
    g. Surface conditions·
4. Reference standards and calibration technique
5. Search pattern for plate, cladding. welds, pipe. tubing, casting and/or forgings as applicable.

6. Acceptance criteria for plate, cladding, welds, tubing, pipe, castings, and/or forgings, as applicable.
7. Methods of marking and recording the test results
8. Upon which side of the material is the transducer located for cladding bond inspection
9. Method of removal of couplant

X MAGNETIC PARTICLE INSPECTION PROCEDURE

Required whenever this inspection method is to be used on forgings, bolting, edge preparation, welds, weld build-ups, or castings

Each procedure shall include the following information:

1. Identification number of each procedure
2. Statement of application to forgings, bolting, edge preparations, welds and/or weld build-ups
3. Type of inspection (wet or dry, and fluorescence)
4. Pre-cleaning procedure
5. Type of equipment — d-c or a-c, direct or induced. If induced, circular or longitudinal
6. Demagnetization
7. If fluorescent, description of viewing facilities to include the minimum brilliance of the ultraviolet light (distance and watts)
8. For wet types, method of maintaining magnetic particle content in suspension
9. Procedure of applying magnetic particles and removing excess particles, including temperature limitations
10. Control of the minimum magnetic field, such as prod spacing versus amperes/amp-turns
11. Cleaning after inspection
12. Method of marking and recording the test results
13. Type of particles for dry use (red or grey), and temperature range at which it will be used.
14. Acceptance criteria for forgings, bolting, edge preparation, welds, weld build-ups, or castings, as applicable.

XI LIQUID PENETRANT INSPECTION PROCEDURE

Required whenever this inspection method is to be used on castings, claddings, welds, forgings, edge preparations, weld buildup or bolting

Each specification shall include the following information:

1. Identification number of each procedure
2. Type of cleaner, penetrant, emulsifier (if used), and developer by trade name and chemical composition
3. Method of cleaning prior to testing
4. Method of applying penetrant and penetrant contact time
5. Temperature range of material at time of test
6. Method of removing excess penetrant
7. Method of applying developer and drying time
8. When fluorescent penetrant is used, the type of viewing facilities including the brilliance of the ultraviolet light (max. welding distance and min. watt rating of light)
9. Method of removing developer materials
10. Acceptance criteria for cladding welds, castings, edge preparations, weld buildups, bolting and forgings, as applicable.
11. Method of marking and recording the results of the test.

XII SPECIAL DIMENSIONAL INSPECTION PROCEDURE

Required for

1. Centerline plumb.
2. Core support plane
3. Nozzle azimuth and alignment
4. Control rod drive penetration diameter, alignment, location

Each procedure shall include the following information

1. Identification number of specification
2. Type of measuring instruments
3. Accuracy of instruments
4. Reference line, plane, or point
5. Number of readings and locations
6. Method of recording and reporting results

XIII TEST SPECIMEN LOCATION DRAWINGS

Required for material acceptance tests, special code and specification weld tests, fabrication tests and surveillance tests.

The drawings shall show the location and orientation of specimens within the material and shall include the following information:

1. Principal direction of grain flow during hot working
2. If weld test specimen, the axis of the weld and the weld preparation
3. The major axis of the specimens
4. For impact test specimen, the axis of the notch
5. The size, shape or thickness of the part, or the coupon, from which specimens were removed.
6. The distance between the axis of the specimens and the nearest two as-quenched edges.

XIV HYDROSTATIC TEST PROCEDURE

Each specification shall include the following information:

1. Identification number
2. Test temperature range, method of heating, if heated.
3. Controlling NDT temperature, if required by specification
4. Instrument locations
5. Type and sensitivity of instruments
6. Method of recording results
7. Gasket material for each test
8. Bolt tensioning each test, if required by specification
9. Anticipated pressure histogram for each test
10. Inspections and measurements at each pressure increment

XV SEAL LEAK RATE CHECK PROCEDURE

The specification shall include the following information:

1. Identification number of specification
2. Test temperature range
3. Test pressure range
4. Method of collecting leakage water
5. Method of measuring leakage water

APPENDIX H

REVIEW OF RADIOGRAPHIC INSPECTION PROCEDURES

I DESCRIPTION

This instruction establishes the basis for acceptability for a radiographic inspection procedure by delineating the minimum information required and the level of acceptability of the information in terms of (1) acceptable, (2) marginal, and (3) unacceptable.

It is the intent that marginal practices shall require demonstration and further evaluation to determine whether or not the practice is acceptable. Demonstration radiographs may, therefore, be required to determine the acceptability of the conditions permitted by the radiographic procedure.

It is intended that General Electric may retain any demonstration radiographs.

II PROCEDURE SPECIFICATION CONTENT

The procedure shall contain the following information:

1. Identification number of each procedure.

2. Description of radiation source.

   (a) For x-ray: the voltage and applicable material thickness.

   (b) For gamma ray: type of isotope and applicable material thickness range.

3. Focal spot size and minimum source film distance.

4. The basis for establishing exposure time and nominal source to film distance.

5. Film brand(s) and type(s). Number of films in the cassettes.

6. Type and thickness of filters and screens.

7. Blocking techniques, if used.

8. Range of film density and nominal film density.

9. Minimum film overlap of multiple exposures.

10. Type of penetrameter, if other than ASME.

11. Number and location of penetrameters.

12. Use of shims under the penetrameter.

13. Major steps for film processing such as developing, short stop, fixing, washing, and controls on same, such as temperature, time, renewal of spent solutions, and agitation.

14. Image quality level, if other than ASME.

15. Viewing conditions.

16. Provisions for identification and location of films, including stamping or marking on the part.

17. Statement specifying governing code or codes.

18. Acceptance standards for welds, castings, or as applicable, if different than governing code.

III REQUIREMENTS AND LIMITATIONS

Procedures shall be written individually or collectively to cover the energy range of the equipment to be used.

1. Procedure Identification: Each individual procedure shall be identified in a manner which clearly distinguishes it and its revisions for reference on drawings and correspondence.

2. Radiation Source.

   (a) X-ray energy levels shall meet the requirements of Figure H-1. Marginal conditions shall require demonstration radiographs in accordance with paragraph IV.

   (b) Gamma ray radiography shall be acceptable with Iridium 192 for steel thicknesses of one-quarter (1/4) inch to two and one-half (2-1/2) inches, and with Cobalt 60 for thicknesses of one and three-quarter (1-3/4) inches to five (5) inches. Other isotopes and thicknesses shall be considered marginal and shall require demonstration radiographs in accordance with paragraph IV.

3. Source to Film Distance: The relationship between focal spot size, material thickness and source to film distance shall meet the requirements of Table H-1. Source-film distances less than minimum shall be considered marginal. Marginal conditions shall require demonstration radiographs in accordance with paragraph IV.

4. Exposure Time: X-ray exposure times greater than 20 minutes are to be considered marginal. Gamma-ray exposure times greater than two hours are considered marginal for complex contours and shapes. Gamma-ray exposure times greater than 8 hours are considered marginal for simple contours and shapes. Marginal conditions shall require demonstration radiographs in accordance with paragraph IV.

5. Film Type: Acceptable film brands shall be well-known, such as Kodak, Ansco, Dupont, Gaevert, for which characteristic curves, film speeds, grain size and contrast are readily available. Acceptable film types shall be fine grain, or extra fine grain such as Kodak Type AA, M, or L or equal. Coarser grain film shall be considered marginal. Marginal conditions shall require demonstration radiographs in accordance with paragraph IV.

6. Type and Thickness of Filters and Screens.

   (a) Lead filters and screens shall be used within the following limitations. Other filters and screens are marginal. Marginal conditions shall require demonstration radiographs in accordance with paragraph IV.

	FRONT		BACK	
X-Ray	Min.	Max.	Min.	Max.
Up to 500 Kv	0.005	0.010	0.005	0.020
500 Kv to 2 Mev	0.010	0.020	0.020	0.040
2 Mev to 30 Mev	0.010	0.020	0.020	0.060
Gamma Ray				
Cobalt 60				
Up to 100 Curie	0.010	0.030	0.020	0.100
100 to 1000 Curie	0.020	0.080	0.040	0.125
Iridium 192				
Up to 10 Curie	0.005	0.010	0.010	0.020
Over 10 Curie	0.010	0.020	0.040	0.060

   (b) Flourescent intensifying screens shall be considered marginal. Marginal conditions shall require demonstration radiographs in accordance with paragraph IV.

7. Blocking: Blocking is required whenever it is necessary to obtain 100% inspection of an area which is adversely affected by end or edge effects which may cause masking of defects.

8. Film Density: Film density shall be within the following limitations. Other densities are marginal. Marginal conditions shall require demonstration radiographs in accordance with paragraph IV.

	Minimum H & D	Nominal H & D
X-Ray	2.0	2.6
Gamma Ray	2.0	2.9

For duplicate films, these limitations apply to each individual film. For double film technique, the density of any individual film shall be one-half of the above film densities.

9. Film Overlap: Where radiographic coverage requires multiple films, the overlap shall be planned. The nominal film overlap shall be one (1) inch and the minimum film overlap shall be one-half (1/2) inch.

10. Penetrameter Types: All penetrameters shall be in accordance with ASME Section III, paragraph N-624. If a penetrameter other than ASME is required for local jurisdiction authorities, both types of penetrameters shall be used unless it can be demonstrated that the proposed penetrameter is equal to or more conservative than the ASME penetrameter.

11. Penetrameter Location: The penetrameter shall be placed on the source side of the material. In the case of small pipe welds, the penetrameter may be placed to one side of the pipe on a shim meeting the requirements of 12 below. In this case, the shim shall be sufficiently large to prevent edge effects from obscuring the image of the penetrameter. In special cases where this is not possible, alternate placement of the penetrameter is considered marginal and test radiographs shall be made to demonstrate that alternate placement of the penetrameter provides a valid measure of sensitivity. Multiple film exposures shall have at least one (1) penetrameter for every three (3) films and one (1) penetrameter on each end film.

12. Shims: Shims shall be used under the penetrameters to produce a total thickness under the penetrameter equal to the nominal thickness being examined plus the total thickness of the crown, or reinforcement, on each side of the weld.

13. Film Processing: A standard film processing procedure is required for controlled film quality, with means provided for temperature control of all solutions, a planned program of replenishment of all solutions, a planned program of temperature measurement of developing solution, and a planned program of film agitation in the developing solution.

    (a) The temperature of the developer shall be controlled as closely as practical to the optimum temperature reccommended by the film manufacturer, usually considered to be 68° F. Deviations greater than plus or minus seven degrees (7°) F from the optimum temperature shall be considered marginal. Demonstration of the marginal condition shall be in accordance with paragraph IV and compared to the nominal conditions. A chart or curve of time compensation versus temperature shall always be available for ready reference, and compensation shall be made for temperature changes greater than 2° F. "Slight" developing is unacceptable.

    (b) Developing shall preferably be terminated by immersion of the films in a stop bath. The omission of a stop bath is considered marginal, because of potential film streaking, unless films are either rinsed in running water for at least 2 minutes before fixing, or if not rinsed, the films are agitated continuously in the fixing solution, and a special program of replenishing fixing solutions is established.

(c) A definite schedule of fixing time shall be established which meets the film manufacturers recommendations and accounts for the varying strength of the fixing solution, the fixing temperature and type of film. The total fixing time shall generally be at least twice the clearing time. Total fixing times of less than five minutes and more than fifteen minutes in a fresh solution shall be considered marginal. Lesser fixing times shall be evaluated for retention of the image over long periods of time (more than five years) without darkening or loss of sensitivity. Greater fixing times shall be evaluated for loss of lower density image.

(d) Washing after fixing will be acceptable if films and hangers are totally immersed in running water for at least 30 minutes, and if the water is well circulated to all films at a temperature greater than 60^{O} F with complete change of water volume at least 4 times per hour. Other washing conditions shall be considered marginal and must be evaluated for staining of the film and/or fading of the image over long periods of time (more than five years).

14. Image Quality Level: If the image quality level is other than ASME code, a statement shall be made defining the image quality similar to ASME Sec. III, Para. N-624.3 (h).

15. Film Viewing: Film viewing shall be done in a darkened room. For film densities less than 2.5, either a high intensity or a fluorescent viewer may be used, whichever is more suitable. For film densities greater than 2.5, a high intensity viewer shall be used.

16. Film Identification and Correlation to the Part

(a) Each individual film shall be identified and include the following information: Weld joint or casting identification and number, film numbers (on each end of each film in a sequence) and identification as to repair or reshot status.

The area radiographed shall be marked to permit accurate relocation of the film for evaluation or repair. The area shall be (1) low stress steel stamped, (2) stamped steel tag attached, (3) marked by electric pen, or (4) temporarily marked plus an accurate radiograph map.

(b) Each film packet shall be accompanied by the equipment piece number, the information described by ASME Section III, paragraph N-624.7 (g), a film grading slip which accounts for and evaluates all the enclosed films, and the code to which they are evaluated.

17. Codes: A statement indicating the governing code, or codes is acceptable.

18. Acceptance Standards: Special applications may possibly require acceptance standards other than the acceptance standards in the governing code. Special applications shall be evaluated individually.

IV DEMONSTRATION RADIOGRAPHS

Where required in the preceeding paragraphs, demonstration radiographs shall be made representing the least sensitive combination of conditions to be used for production radiography as permitted by the proposed procedure. The demonstration radiographs shall contain a penetrameter with a hole one-half the diameter required by the ASME code.

TABLE H-1

MATERIAL THICKNESS (Inches of Steel)

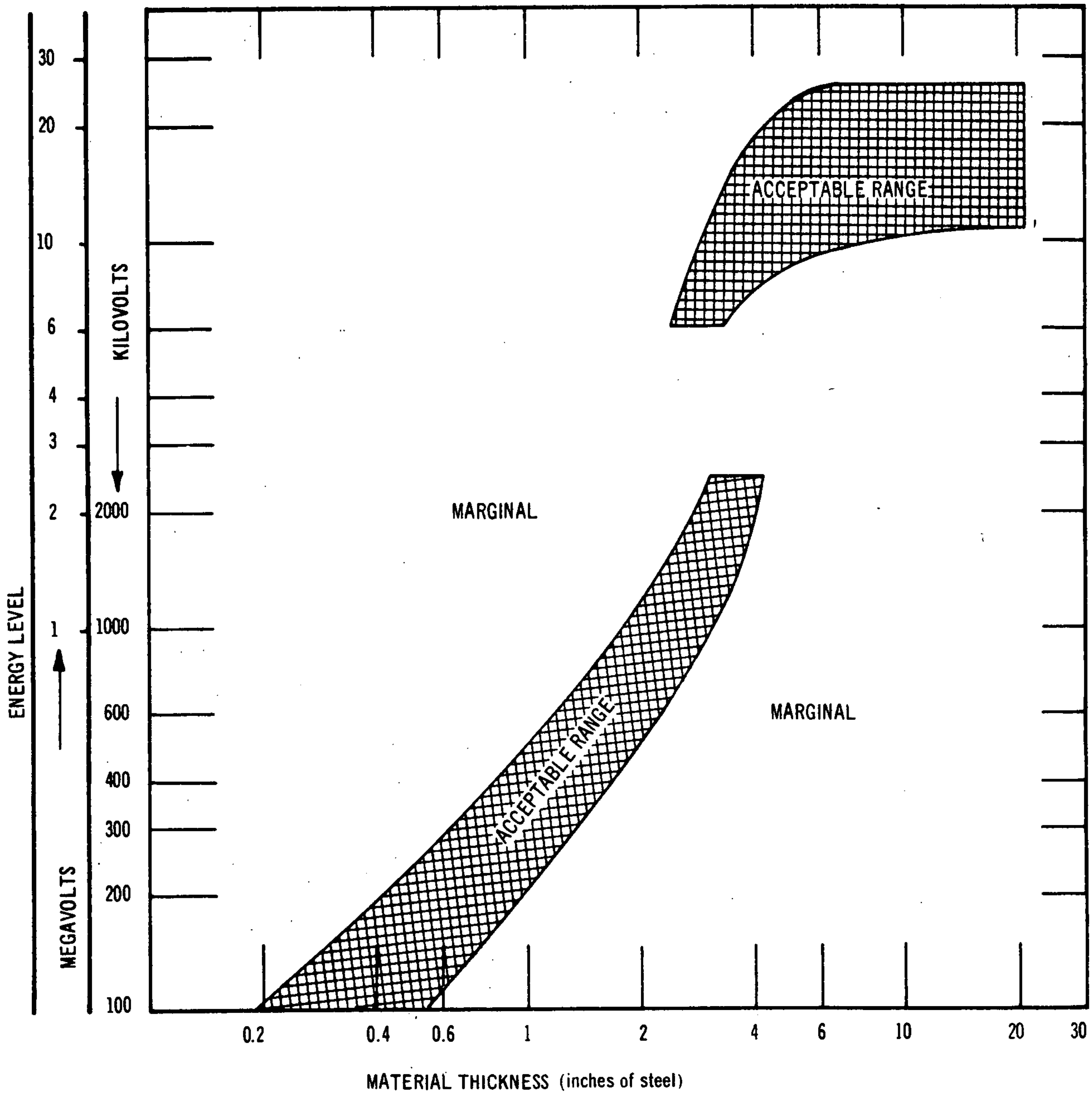
Focal Spot Size, (millimeters)	0.5	1	1.5	2	2.5	3	4	5	6	8	10	12	14	16
1	8.5	9	10.5	14	17.5	21	28	35	42	56	70	84	98	112
1.5	12.5	13	13.5	14	17.5	21	28	35	42	56	70	84	98	112
2.0	16.5	17	17.5	18	18.5	21	28	35	42	56	70	84	98	112
2.5	20.5	21	21.5	22	22.5	23	28	35	42	56	70	84	98	112
3.0	24.5	25	25.5	26	26.5	27	28	35	42	56	70	84	98	112
4.0	32.5	33	33.5	34	34.5	35	36	37	42	56	70	84	98	112
5.0	40.5	41	41.5	42	42.5	43	44	45	46	56	70	84	98	112
6.0	48.5	49	49.5	50	50.5	51	52	53	54	56	70	84	98	112
8.0	64.5	65	65.5	66	66.5	67	68	69	70	72	74	84	98	112
10.0	80.5	81	81.5	82	82.5	83	84	85	86	88	90	92	98	112

MINIMUM SOURCE TO FILM DISTANCES

(INCHES)

NOTE: (1) Focal spot size is considered to be the longest projected dimension perpendiculat to the beam.

(2) Straight line interpolation may be used for intermediate material thicknesses and focal spot sizes.



MONTICELLO NUCLEAR GENERATING PLANT

X-Ray Source-To-Film Distance Requirements

FIGURE H-1

APPENDIX J

GENERAL ELECTRIC REACTOR VESSEL QUALITY CONTROL PLAN MONTICELLO REACTOR VESSEL

I SCOPE

This plan defines how the quality control requirements of the purchase specification for the nuclear reactor pressure vessel is met.

This plan does not circumvent any inspection or requirement as defined by the reactor vessel specification, applicable codes, purchase order or drawings. It is intended to further clarify and define the quality requirements of GE-APED.

II RESPONSIBILITY

2.1 Supplier

Upon request Chicago Bridge & Iron Co. shall provide the General Electric Quality Control Procurement (QCP) Representative with the latest revisions of approved engineering drawings, instructions, fabrication procedures, manufacturing instructions and other such documents pertinent to the fabrication of the reactor vessel. The GE-QCP Representative shall have free access to all inspection records, reports, and documents and shall be free to witness and/or audit all phases of manufacture and inspection relative to the fabrication of the vessel.

2.2 General Electric Quality Control Procurement

The General Electric Quality Control (QCP) Representative's primary function is to audit the quality control efforts of CB & I to assure compliance to the stated and intended quality requirements in the reactor vessel specification, codes, and drawings. The QCP representative shall not accept any job task or fabrication operation prior to General Electric Company review and approval of the appropriate procedural document.

III SYSTEMS REVIEW AND FAMILIARIZATION

3.1 A plant survey form shall be completed by CB & I and returned to Quality Control Procurement, General Electric. This document is for internal information only and provides an outline of the manufacturing capabilities such as machine sizes and types, crane capacities, etc.

3.2 After receipt of the Plant Survey and prior to the start of fabrication, a QCP Engineer will review the CB & I manufacturing and quality control systems to assure General Electric of CB & I's understanding, capability and method of complying with the Quality Control requirements of the contract.

IV FABRICATION, PROCESS, INSPECTION AND TEST PROCEDURE REVIEW

4.1 Fabrication, process, inspection and test procedures shall be submitted to the General Electric resident Quality Control Representative for review and concurrence prior to submittal to General Electric for final approval.

All questions, additions, or deletions shall be resolved with the resident Quality Control Representative prior to submittal to General Electric for final approval.

4.2 The Resident Quality Control Representative will not accept any job task prior to final General Electric approval of the applicable procedures.

V DEVIATION AND REPAIR PROCEDURE REVIEW

5.1 All deviations and repair procedures involving major defects shall be reviewed by the General Electric Quality Control Representative.

5.2 The General Electric Quality Control Representative must concur with CB & I's defect description and the recommended disposition prior to submittal for final General Electric approval.

5.3 The General Electric Quality Control Representative will, at his discretion, witness major repairs for conformance General Electric approved procedures.

VI QUALITY CONTROL RECORDS

6.1 Records, Index and Depository

(a) An index section listing project title, drawings, specification number and revisions, approved procedures and current engineering data sheets. Document change control system must be agreed upon between CB & I and the QCP Engineer. Four (4) copies of the above document listing must be submitted to the QCP Representative monthly, showing the most current documents that are approved and issued for shop use.

(b) A chronological listing of all tests and inspections including the date of inspection, inspector's identification, results, disposition and date of repair, if any.

(c) Index of all Material Review Board actions, repair actions or other General Electric approved variations from the purchase order.

(d) Index of all material certifications including chemical analysis and mechanical property reports, inspection and test reports and ASME reports.

(e) A file or data section containing all the documents indexed or listed above.

6.2 CB & I shall prepare and maintain a quality control spread sheet or equivalent depicting material location and identification, weld joints, and weld overlays.

Sequential numbers shall be assigned to each welding operation. The tabulation shall provide for insertion of the following:

(a) Weld number.

(b) Approved weld procedure number and revision.

(c) Welding procedure qualification date.

(d) Weld joint completion date.

(e) Date of post weld heat treatment and total hours at temperature to the date of entry.

(f) Radiography identification numbers and date of review and results (each joint).

(g) Magnetic particle inspection report number, date, and results.

(h) Liquid penetrant inspection report number, date and results.

(i) Ultrasonic inspection report number, date, and results.

(j) Approved repair procedure and date of repair (as required).

(k) CB & I QC personnel shall initial or stamp each date entry.

(l) Space shall be provided for the QCP Representative to initial each completed date entry.

6.3 All data and information required in paragraph VI-1 and 2 shall be kept current with the manufacturing progress of the vessel.

6.4 Procurement, Procedure, and Test Records

(a) Procurement and fabrication schedules and progress reports shall be issued at least monthly.

(b) CB & I's material identification and marking system must be acceptable to the QCP Representative. The material identification systems include all marking during operations such as receiving, forming, heat treating, trimming, machining and other similar operations that may obliterate the marking.

(c) Material certifications, mill reports, chemical analysis, mechanical properties and material location as identified by part number and name shall be maintained for all parts. Also, prior to material testing, a test plan shall be prepared to show the number of specimens and types of tests, test methods, location and orientation of specimens and identification of each specimen. The test plan and the resultant test report, must be acceptable to the QCP Representative.

(d) Complete thermal history of all parts shall be kept with respect to time and temperature starting from the finished forged shape and prior to heat treatment for development of mechanical properties. The applicable heat treatment procedure shall also be listed.

(e) Approved detailed welding procedure, repair welding procedures and procedure qualification test records are required. The detailed welding procedure and repair welding procedure shall include both essential and nonessential variables.

(f) Welders performance qualification certificates and test results shall be current and available at all times for review by the QCP Representative.

(g) A record of all weld repairs shall be maintained to identify type of defect, location, depth and method of detection for each weld joint.

(h) Chemical analysis reports of carbon content at the surface for manual and automatic welding of stainless steel weld overlay cladding shall be made for each procedure qualification.

(i) Nondestructive test reports shall be written for each inspection. All reports shall reference the applicable approved test procedure for the product form being tested and include sufficient information to duplicate the test. All inspections shall be listed as required in paragraph VI-1(b) and (c).

(1) Ultrasonic test reports shall include a brief statement describing equipment, calibration standards, calibration, and the applicable procedure. A detailed plot shall be made of all major defects that require repair.

(2) Liquid penetrant test reports shall include a brief description of test materials. A detailed plot shall be made of all major defects that require repair.

(3) Magnetic particle test reports shall include a brief description of test materials and applied current or current density. A detailed plot shall be made of all major defects that require repair.

(4) Radiographic test reports shall include film type, film focal distance, energy (Mev), amperage and time for exposure. Defective areas shall be related to film number for record; however, only acceptable radiographs shall be retained for future record.

(j) Dimensional Test Reports

Measurements during fabrication and for final as-built drawings of critical areas such as attitude and location of control rod drive penetrations, perpendicularity of support skirt to axis of the vessel, material thickness before and after forming, ovality after forming and welding and machining, flange stud hole alignment, o-ring grooves, nozzle azimuth and elevation and final diameter, thermal sleeve size and clearance, and the measuring technique and assumptions shall be approved by the QCP Representative prior to inspection and shall also be included with the measurement report.

(k) Pressure and Seal Testing

Pressure test report shall include all details of the test and list all incremental measurement readings such as flange rotation and control rod drive stub tube movement.

6.5 Fabrication Procedures to be Reviewed by the QCP Representative

(a) Details for fitting of components, i.e., fit hot or cold, use of strong backs and location, amount of misalignment and gap, and safeguards against movement during initial welding.

(b) Details of machining critical components such as type of machining equipment, description of cutting tools, method of alignment, in-process check points (including method and equipment involved in checking), and final inspection before removal from the machine.

(c) Details of stress relief such as protective measures during transport of the vessel from the welding station to the furnace, methods of support to prevent sag during heat treatment, type of thermocouples and graphical location, and permanent time-temperature records of various heat treatments.

VII INSPECTION AND WITNESS POINTS

The following shall be considered as mandatory notification points pending review and release by the QCP Representative.

7.1 Heat Treatment

(a) Normalizing, austenitizing and quenching, and tempering operations or solution heat treatment shall be reviewed prior to the operation on a first part basis by the QCP Representative for details such as cleanliness, thermocouple location, thermocouple calibration, handling technique, expected out-of-furnace time before quenching method and equipment.

(b) Post weld heat treatment shall be reviewed for each general geometric shape on a first part basis as described in paragraph 7.1(a).

7.2 Fitting of the following parts shall be witnessed prior to tacking or welding: (a) shell plates forming a strake; (b) nozzles in the shell or head; (c) one strake to another or to the closure flanges; (d) stub tubes in the bottom head; and (e) support skirt to the vessel.

7.3 Welding

(a) Weld overlay cladding shall be witnessed during set-up and for the first several passes.

(b) Manual groove welding shall be witnessed to confirm accessibility, electrode surveillance at the welding station, cleaning technique and other general work practices.

(c) The nondestructive tests performed on the excavations for major base material defects shall be witnessed prior to weld repair.

7.4 Impact Testing (Charpy V and Drop Weight)

(a) All impact test specimens shall be inspected by the QCP Representative before testing.

(b) The first impact tests of all product forms shall be witnessed by the QCP Representative.

7.5 Tensile and Bend Test

(a) Material qualification tensile specimens shall be inspected by the QCP Representative. The first tensile tests of each product form shall be witnessed by the QCP Representative.

(b) If special tests are required by General Electric Engineering during the course of fabrication, the specimens must be inspected prior to testing by the QCP Representative.

7.6 Nondestructive Testing

(a) All nondestructive tests shall be witnessed on a first test basis, i.e., for each product form geometry and condition and test results will be audited thereafter.

7.7 Measurements

Instruments and measurement equipment shall be calibrated prior to use and it shall be deomonstrated that the measuring equipment accuracy is within the tolerance specified for the measurement to be made, and that the dimensions are within the tolerance less then accuracy of the equipment.

7.8 Inspection

Plate edge inspection shall be witnessed on a first part basis by the QCP Representative.

7.9 Testing

Pressure and seal testing shall be witnessed by the QCP Representative.

7.10 Cleaning

Final cleaning, painting and sealing before shipment shall be inspected by the QCP Representative for compliance with the appropriate specification and adequacy.

APPENDIX K

CHICAGO BRIDGE & IRON COMPANY EXPERIENCE

CODE COMMITTEE ASSIGNMENTS OF CB&I PERSONNEL

The following CB&I personnel are assigned to the Pressure Vessel Code Committee:

P. C. ARNOLD, Vice President and Manager Welding Research

American Welding Society Board of Directors
National Director-at-Large

ASME Task Force Means of Fabrication Inspection During Fabrication and Tests of Completed Vessels

ASME Subcommittee on Welding -- Chairman
ASME Subcommittee on Nuclear Power
ASME Subcommittee on Nondestructive Testing

A.P. BUNK

ASTM (American Society of Testing Materials)
- Committee A-1 Subcommittee II and XI
- Low Temperature Panel (Part of Committee on Effect of Temperature)

PVRC (Pressure Vessel Research Committee)
- Main Committee (Executive Committee)
- Materials Division, Vice-Chairman
- Fabrication Division
- Subcommittee on High Strength Steels, Chairman
- Subcommittee on Heavy Sections, Chairman
- Subcommittee on Preheat and Post Heat
- Subcommittee on Mechanical and Thermal Treatments (FAB) Evaluation Committee

WRC (Welding Research Council)
- Main Weldability Committee
  - Lehigh University Projects Subcommittee
- Welding Procedures Committee

D. W. CHROSTOFFERSON

SSPC (Steel Structures Paint Council Research Committee)

NFPA (National Fire Protection Association Committee on Water Tanks)

NACE (National Association of Corrosion Engineers)

Unit Committee T-6D, Application and Use of Coatings for Atmospheric Service

Unit Committee T-6G Surface Preparation for Protective Coatings

SPFA (Steel Plate Fabricators Association Research Committee)

R.V. MC GRATH

API (American Petroleum Institute)

Manufacturers Subcommittee on Tanks and Vessels, Chairman

Task Group on Design

Task Group on Materials

Task Group on Refrigerated Storage

ASA (American Standards Association)

Sectional Committee B96 on Welded Aluminum-Alloy Field-Erected Storage Tanks

Subcommittee on Fabrication, Chairman

W.R. MIKESELL

ASME (American Society of Mechanical Engineers)

Boiler and Pressure Vessel Subcommittee

Unfired Pressure Vessel Subcommittee, Secretary

Subcommittee on Openings and Bolted Connections, Member

Task Group on Design of Subcommittee on Nuclear Power, Task Group Member

PVRC (pressure Vessel Research Committee)

Design Division, Member

Subcommittee on Bolted Flanged Connections, Chairman

Subcommittee on Pressure Vessel Heads, Member and Task Group Chairman

C.D. MILLER

CGA (Compressed Gas Association)

Barge and Tanker Committee

J.N. PIROK

AWWA-NEWWA-AWS

Conference Committee on Elevated Steel Water Tanks, Standpipes and Reservoirs - D56

J. N. PIROK (Cont.)

AWS (American Welding Society)

Advisory Committee to the Area Committee on Welded Storage Tanks and Elevated Tanks for Railroad Service - D5C

ASAE

Subcommittee on Steel Grain Storage Tanks (FS-0311) (Steel Fabricators Association Representative)

ASCE (American Society of Civil Engineers)

Power Section - Subcommittee Penstocks and Penstock Fittings

G.S. SANGDAHL

WRC (Welding Research Council)

Subcommittee on Stress Relief of Stainless Steels of High Alloys, Chairman

AWS (American Welding Society)

W. E. Joors' Committee to Rewrite Chapter 96 of AWS Handbook

ASM - Metal Progress Editorial Committee

I. L. WISSMILLER

AGA (American Gas Association)

Committee on LP Gas Utility Code

Liquid Natural Gas Task Group

AAI (American Ammonia Institute)

General Technical Committee

Standards Committee

Technical Liaison Committee

API (American Petroleum Institute)

Division of Science and Technology

Evaporation Loss Committee Task Group Covered Floating Roofs

ELC Planning Committee

Paint Factors

Petrochemical Losses

Division of Refining

Manufacturers Subcommittee on Safety and Relief Valves

CGA (Compressed Gas Association)

Ammonia Storage Committee

Subcommittee Technical Data, Chairman

Research and Development Committee

I. L. WISSMILLER (Cont.)

ASA (American Standards Association

K-61 Sectional Committee Standards for Storage and Handling

Anhydrous Ammonia

L.P. ZICK, Vice President and Chief Engineer

ASME (American Society of Mechanical Engineers)

Boiler and Pressure Vessel Committees

Executive Committee

Main Committee

Unfired Pressure Vessel Subcommittee, Chairman

Special Committee to Review Code Stress Basis

ASA (American Standards Association)

Subcommittee on Nuclear Containment ASA N6.2

Working Group 3 on Nuclear Containment of International Standards

Organization (ISO) Technical Committee 85

Subcommittee 3 on Nuclear Safety, Chairman

USA Committee for ISO TC = 11 Boilers and Pressure Vessels

PVRC (Pressure Vessel Research Committee)

Executive Committee, Member

Field Stress Relieving of Large Field Erected Vessels

BY J. B. CHRISTOFFERSON

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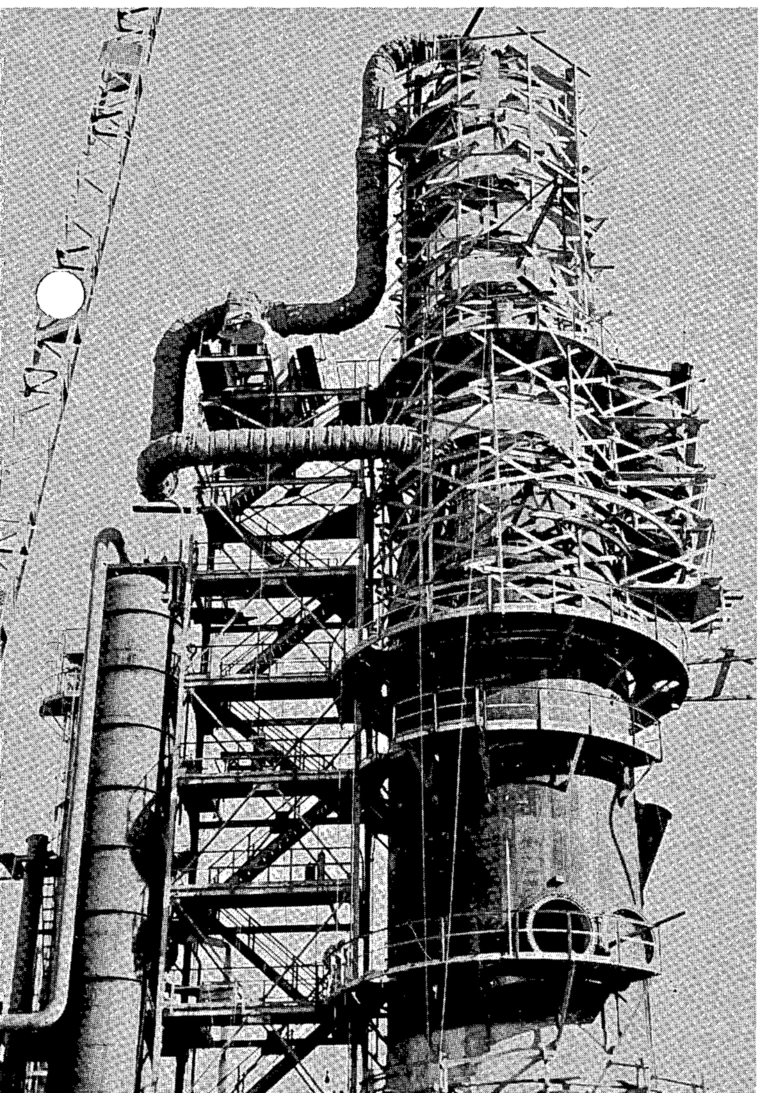
APRIL 1963

Field **Stress Relieving** of Large Field Erected Vessels

can be done on almost any size or shape of vessel with exceptionally good results using induction heating, gas ring burners, hot air or the luminous flame method

BY J. B. CHRISTOFFERSON



Large reactor vessel being field stress relieved by hot air method

In the past few years the little known art of fully stress relieving vessels in the field has taken a big step forward. Great strides in new stress relieving techniques have been developed until today almost any size or shape of vessel can be done in the field. Many vessels now being erected are so large and heavy that it is a physical impossibility to stress relieve them in even the largest of shop stress relieving furnaces.

First Field Stress Relieving Job

The Chicago Bridge & Iron Company performed its first stress relieving in the field in the year of 1946. At that time the closing joints in several propane storage tanks were done in Mexico. These original closing joints were stress relieved by the electrical induction method. This method, as is generally known throughout industry, requires large quantities of single phase alternating current which for safety reasons must be reduced, usually from 440 to 32 v, by means of variable transformers.

The induction coils used for these original joints were made up by taking several wraps around the vessel with large 500,000 circular mil copper cables. As the coils were completed, a layer of insulation was applied over the coils and out onto the vessel shell for a short distance back on each side of the welded joint, both inside and outside. This was done for the purpose of containing the heat on the welded joint being stress relieved, as well as to avoid harmful temperature gradients in the shell on either side of the joint being stress relieved.

The use of the heavy transformers and cumbersome induction coils made the job costly and difficult to perform. Nevertheless, many joints on paper mill digesters have been done by the same method

J. B. CHRISTOFFERSON is with the Chicago Bridge & Iron Co., Oak Brook, Ill.

Paper to be presented at the AWS 44th Annual Meeting in Philadelphia, Pa., during April 22–26, 1963.

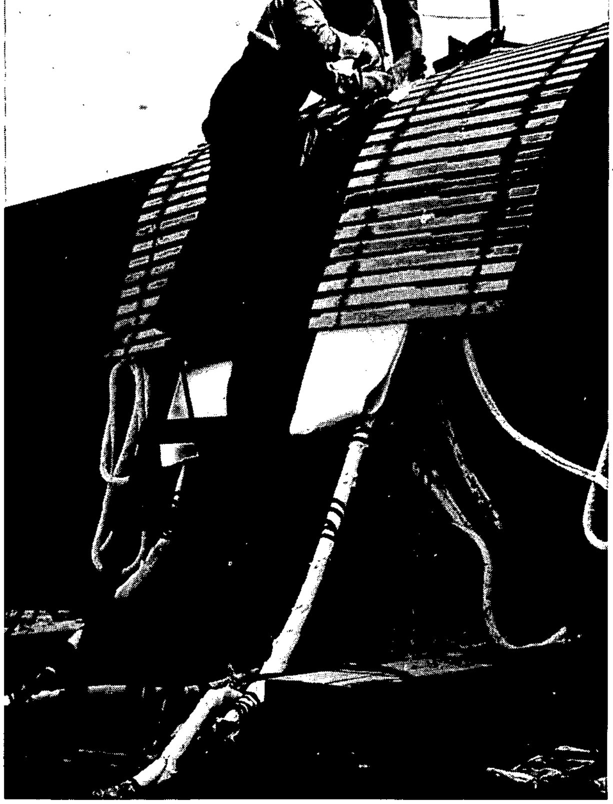


Fig. 1—One 500,000 circular mil cable provides preheat for welding

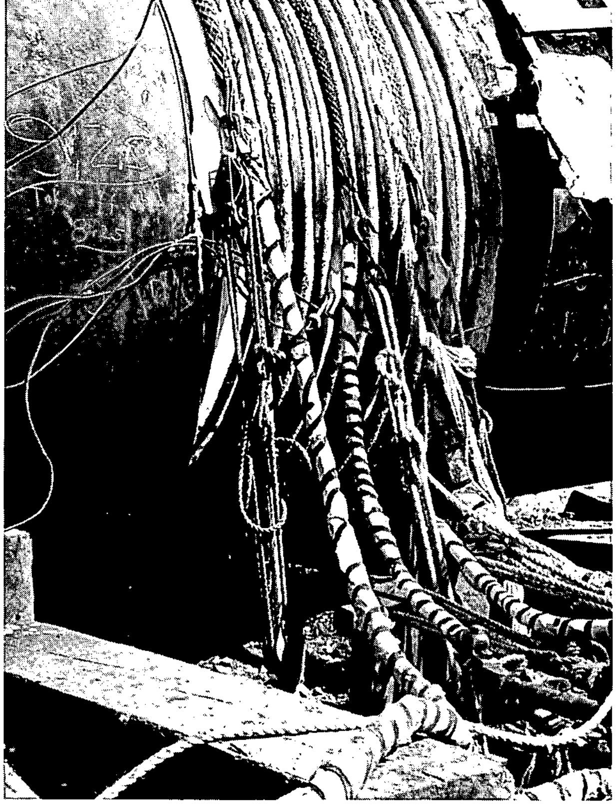


Fig. 2—Local stress relieving of girth joint by electrical induction method

since that time. The use of the induction coil does, however, prove to be extremely advantageous during the welding of the joint in that one wrap of the cable will adequately preheat the joint during the welding operation—Fig. 1. Then after the welding is completed, the joint can be prepared for stress relieving by merely taking additional wraps with the cable—Fig. 2. This is followed by the required insulation of the joint.

Number of Vessels Stress Relieved

The number of vessels being fully field stress relieved has been steadily increasing since 1946. To date, the author's company has stress relieved a total of 220 vessels of all sizes and shapes which were fabricated of steels ranging from the plain carben steels to the high alloy and stainless type steels. Of this grand total, 29 were coke drums for the petroleum industry, 50 were digesters for the pulp and paper industry, 56 were large reactor-regenerator units and 26 were spheres. Finally, 15 were flat bottom storage tanks mostly for the chemical industry, with the remaining ones being various and widely different types of vessels too numerous to mention. In one special case, several large sections of a hypersonic wind tunnel for the aircraft industry were stress relieved.

The "Whys" of Stress Relieving

It is well at this time to consider "why" some vessels are required to be stress relieved, as well as "why" a stress relief is actually possible. First of all, the ASME Code is now in the process of changing

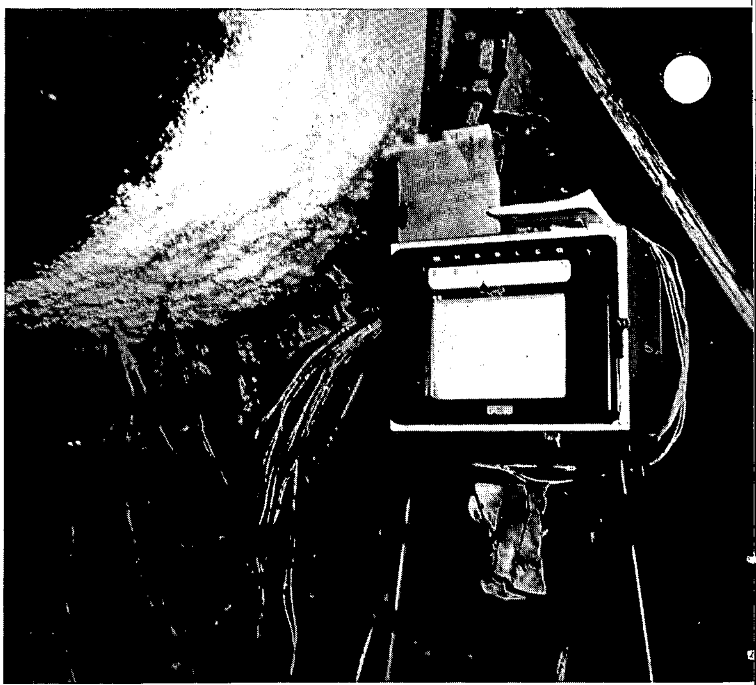


Fig. 3—Local stress relieving of girth joint by gas ring burner method

the term "stress relieving" to the more appropriate term, "postheat treatment," since the latter more nearly describes the accomplishments of the heat treatment.

It is common knowledge that the various governing codes specify stress relieving for the different

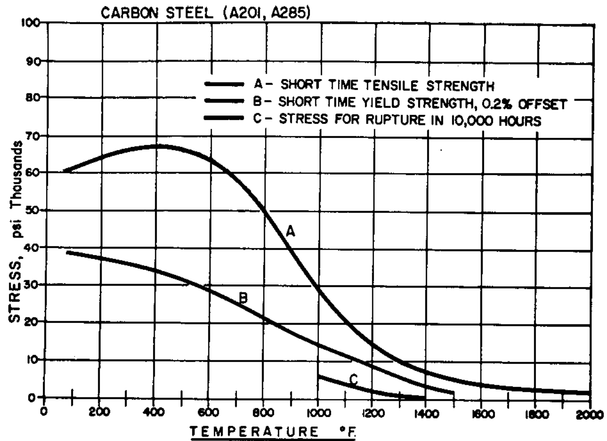


Fig. 4—High temperature data for carbon steels

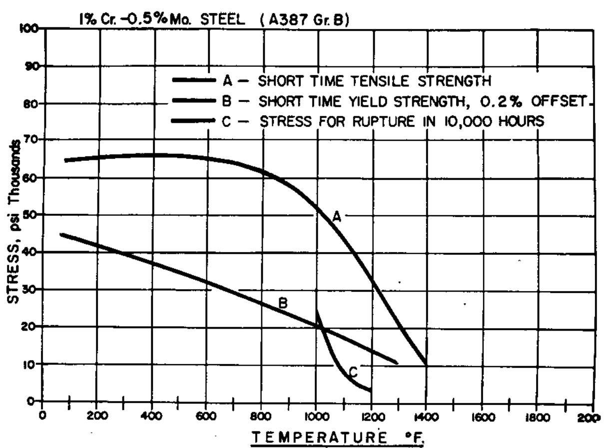


Fig. 5—High temperature data for low alloy steels such as A387-B

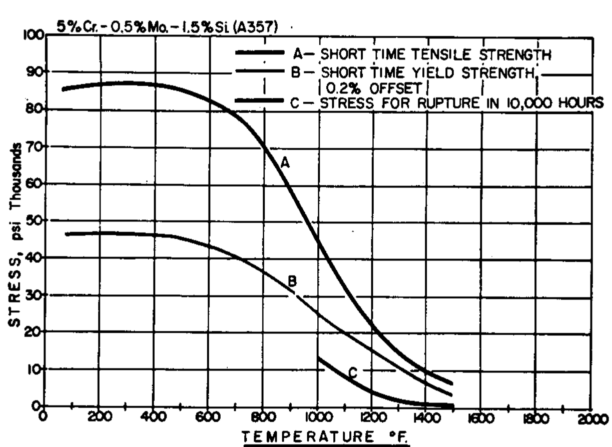


Fig. 6—High temperature data for alloy steels in the 4 to 6% chromium range

types of mild and alloy steels when the thickness of the material exceeds certain limitations. However, in addition to relieving the stresses during a postheat treatment, two other metallurgical changes as listed usually occur:

1. The tempering of the heat-affected zone.
2. The imparting of more ductility to both the weld metal and the heat-affected zone.

Typical properties at both high and low temperatures for several of the more common types of steel used for plate steel fabrication of vessels are presented for comparison purposes—Figs. 4, 5 and 6.

For common mild steels such as A285 or A201, the short time tensile strength at 1100° F is approximately 20,000 psi; similarly, the short time yield strength is approximately 10,000 psi, while the stress for rupture in 10,000 hr is approximately 5000 psi—Fig. 4. If these mild steels are heated to 1100° F for a short length of time, the residual welding stresses will be relieved to a value somewhere between 5000 and 10,000 psi. It should be noted here that weld shrinkage during the cooling cycle often leaves stresses in the weld metal and heat-affected zone at levels up to 40,000 psi at room temperatures.

Referring to Fig. 5, the same physical data for a 1% chrome – 0.5% moly steel (A387B) clearly show that this material has to be heated to 1300° F in order to reach its short time yield strength of 10,000 psi. This explains clearly why the chrome-moly steels are used extensively for high temperature applications. The stress for rupture of this type material is approximately 20,000 psi at 1000° F.

Similar data for a still higher alloy steel (5% Cr – 0.5 Mo – 1.5 Si (A357) is shown—Fig. 6. This material is used extensively for high temperature service and is highly resistant to oxidation. The material is air-hardenable. It is usually preheated to a minimum of 400° F prior to welding and then stress relieved at temperatures from 1375 to 1400° F before being allowed to cool. The weldments of air-hardenable material such as this must be heat treated to 1375 or 1400° F or to a lower temperature for a longer period of time in order to impart some ductility to the weldment. Without the tempering or softening treatment, the welds will often crack, sometimes just in cooling to room temperature. A slight straining will often cause severe cracking.

Another important benefit derived from a postheat treatment for this same type material is the removal of the effects of cold working the material. A prestrain of 3–5% greatly decreases the impact toughness of the material, while a postheat treatment to 1100° F or higher will almost completely restore its impact properties. Thus frequently in cold forming this material, heat treatment is necessary before the material can be completely formed to the desired shape.

A real advantage exists for the chemical industry when the mild steel weldments are given a postheat treatment specifically to eliminate stress corrosion

cracking (caustic embrittlement) on tanks used for the storage of caustic solutions. It is well known that residual welding stresses will frequently accelerate corrosion and even lead to stress corrosion cracking. Tanks that are given postheat treatment to lower these residual stresses will usually give satisfactory service in the storage of the caustic solutions. To date a total of 15 caustic storage tanks ranging in size from 15 ft diam by 16 ft high to 120 ft diam by 21 ft high have been stress relieved in the field.

Flame and Hot Air Methods

Gas Ring Burners

As previously mentioned, closing joints in propane storage tanks were stress relieved in 1946 using the electrical induction method. Another method commonly used to accomplish the same type of stress relieving is known as the gas ring burner method. This method employs various types of gas ring burners—Fig. 6. These are made in a variety of styles to suit the size and configuration of the joint to be stress relieved. Elaborate burners are often used for special shapes.

Regardless of their design, gas ring burners are commonly fired with propane, butane or natural gas. By using these burners with the various techniques of insulation now being employed, they are highly efficient in supplying the required number of Btu's to the welded joint. Here again, the burners are used to preheat the joint during welding.

Hot Air Method

In the fall of 1952, a reactor-regenerator unit to be stress relieved for the petroleum industry was fully field stress relieved by using a portable hot air heater. The heater by necessity was set atop a 110 ft high stairwell—lead photograph. This furnace weighing very nearly 10 tons was rated to produce 8,000,000 Btu/hr. It utilized a 20,000 cfm blower (capable of handling 1400° F air) to circulate the heated air through the vessel.

In an effort to effect a more even heating as well as to conserve on the amount of heat required, approximately 200 ft of a 36 in. diam duct were arranged into an elaborate recirculation system to carry the hot air to the different parts of the vessel. By means of a large butterfly valve in the line, it was even possible to change the direction of flow of the air so that it could be blown into the top of the vessel and exhausted out of the bottom of the vessel or vice versa. Even so, with the complex setup employed, the heating was extremely slow and several days were required to complete this initial complete stress relieving operation.

A recirculation system appears very attractive in theory from the standpoint of conserving heat. In actual practice, however, it is usually more costly to provide the long runs of duct than it is to simply heat the air one time only, pass it through the vessel, and exhaust it to the atmosphere.

It is interesting to note the construction of these large capacity high temperature blowers. The drive shaft and blades of the fan are both subjected to temperatures as high as 1400° F on the type of blower used with the furnace shown in the lead photograph. With other large blowers more recently used, the blades and other parts are subjected to temperatures as high as 1650° F. This, of course, means that special heat resisting stainless steels must be used in the construction of these blowers. Even so, it is necessary to cool the shaft so as to eliminate the possibility of warpage and distortion. This is accomplished by forcing either air or water through the passages in the core of the shaft.

The hot air method of stress relieving, mostly because of its economic disadvantages, is not used as often today as it has been in the past. On the other hand, on occasion it is still used when the geometry of the vessel is such that other methods are impractical. The end results when using the hot air method are very favorable, since the temperature of the heated air can be controlled to a fine degree; this, coupled with the fact that the high volume blower tends to scrub all parts of the vessel with approximately the same temperature air, combines to produce an exceptionally uniform job of heating. This feature makes it especially suited for vessels having numerous internals in them, since an open flame fired directly onto internals can cause considerable differences in temperature and thereby produce high thermal stresses.

In several instances it has proved advantageous to perform the stress relieving of a vessel with internals in it in two or more heats. In most of these cases, the lower portion of the vessel was erected and stress relieved before any of the internals were installed. Then as the upper portion of the vessel was being erected, the internals were simultaneously installed in the lower portion and, at the completion of all erection, the upper portion was finally stress relieved. Valuable erection time can often be saved by following this sequence, and the more costly hot air method of stress relieving can be eliminated.

Luminous Flame Method

Almost immediately after the stress relieving of the reactor vessel in 1952, two 17 ft diam x 90 ft overall height coke drums were stress relieved by a new and different process. This process consisted of firing a luminous flame gas burner directly into the bottom opening of the vessel. The results proved excellent, and each vessel was completed in much less time than if the hot air system had been used. The 9,000,000 Btu/hr burner in Fig. 7 weighed nearly 2000 lb and was supplied secondary air for combustion by means of a 4700 cfm blower.

Several vessels were subsequently stress relieved using this original gas burner and other variations of it before a luminous flame oil burner was first used on four 18 ft diam x 78 ft tangent length coke drums. Again the results were excellent with this new type burner, and other variations of this same type burner are still being used today. Unlike the earlier gas

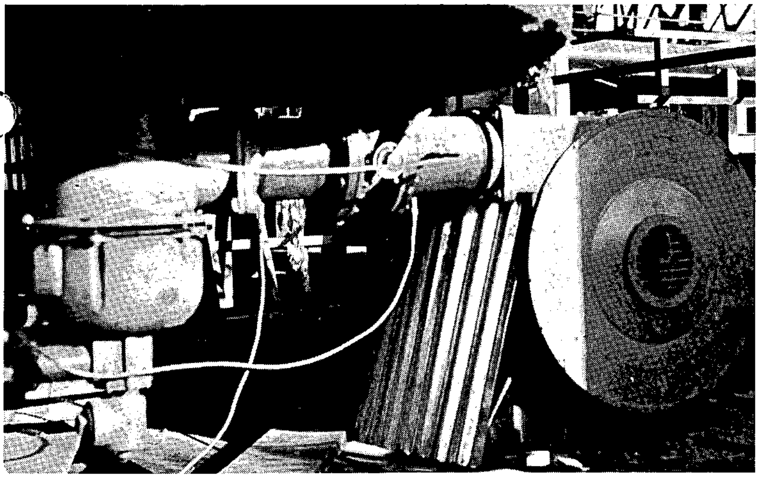


Fig. 7—Luminous flame gas burner using secondary air for combustion as suppliod by a 4700 cfm turbo-blower

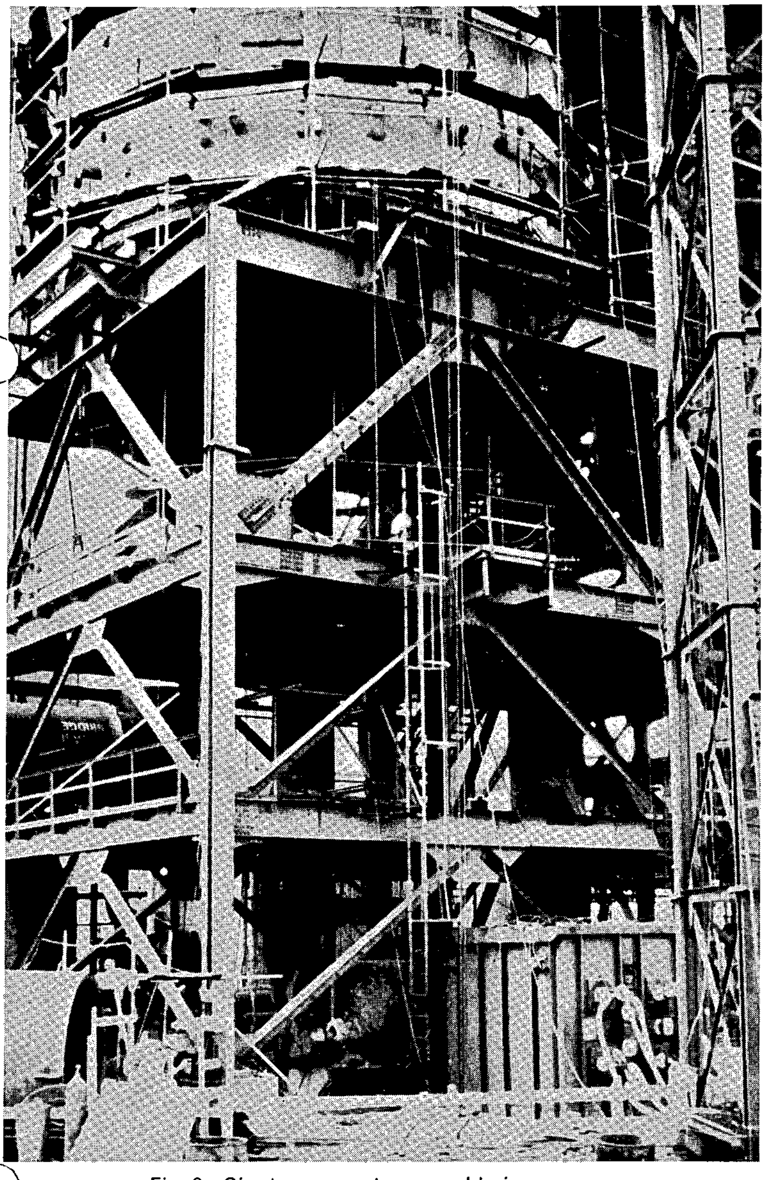


Fig. 8—Giant regenerator vessel being stress relieved by a combination of the hot air and luminous flame methods

burners, the oil burners have a larger capacity and are capable of producing up to 30,000,000 Btu/hr. The limitations of these oil burners are few; almost any size or shape of vessel being built today can be stress relieved by using one or more of them.

Preplanning

At this point it should be emphasized that, before attempting to stress relieve any vessel in the field, a careful evaluation of the problems involved must be undertaken. This is necessary to choose the technique that will do the job properly and satisfactorily without damaging the vessel or its supporting structure. Temperature gradients are especially important as it is entirely possible to set up thermal

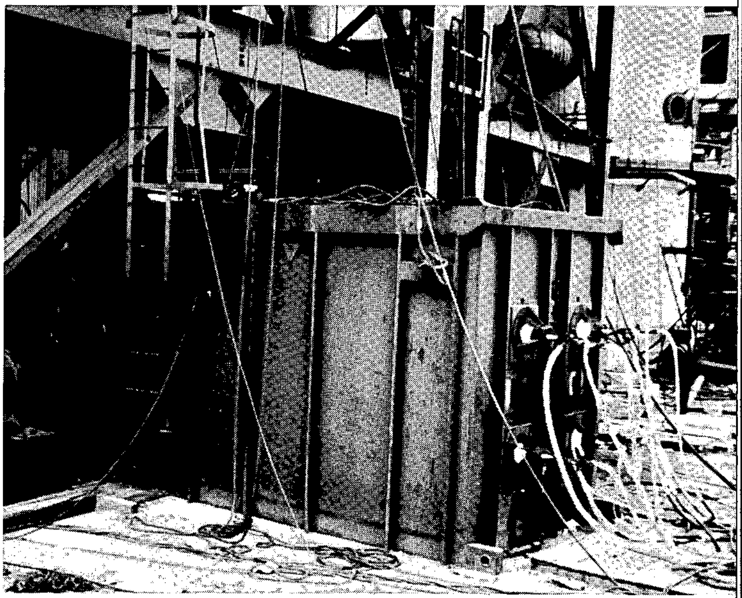


Fig. 9—Firebox for 25,000,000 Btu/hr field stress relieving unit

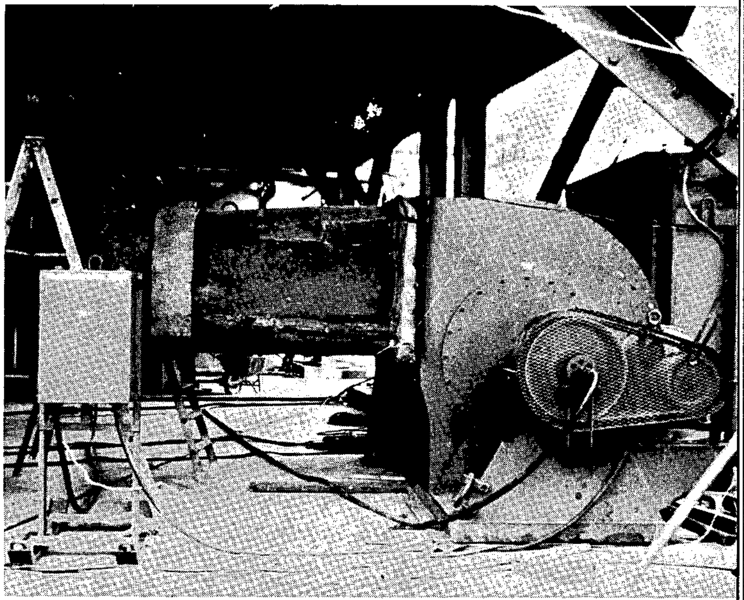


Fig. 10—50,000 cfm blower capable of handling 1650° F air

stresses (as well as eliminate them) if the heating is done improperly. The large amount of expansion involved in heating a vessel to 1100 or 1200° F or even higher can cause considerable damage if provision or allowances are not made for it.

Many times the hot air method will be more satisfactory to use because of internals in the vessel, while other vessels may lend themselves to the use of a luminous flame fired internally. At times even a combination of the two methods may be used advantageously.

Types of Vessels Stress Relieved

Regenerator Vessel

The giant regenerator vessel in Fig. 8 exemplifies the type of vessel which has been stress relieved in the field. This was recently stress relieved by using a hot air source of heat supplemented by a luminous flame oil burner. The source of hot air for this vessel was supplied by an exceptionally large furnace (weighing over 25 tons) designed especially for stress relieving large vessels in the field. The furnace is rated to supply 25,000,000 Btu/hr and utilizes a 50,000 cfm blower capable of handling 1650° F air.

The firebox in Fig. 9 and blower in Fig. 10 were connected to the bottom inlet of the vessel by means of a 42 in. diam run of duct which extended from the ground elevation up to the bottom of the vessel some 30 ft in the air. The supplemental luminous flame burner was fired internally through a side manway located 6 ft above the bottom tangent line of the vessel. An extremely heavy grid plate, $2^3/_8$ in. thick, was welded to a short skirt; this in turn was welded to the bottom cone of the vessel, thereby completely separating the lower portion of the vessel from the upper portion except for numerous 2 in. diam holes drilled through the grid. The hot air, by means of a slight positive pressure, was forced through the numerous 2 in. diam holes in the grid and then circulated through the upper part of the vessel before it was exhausted to the atmosphere through the fittings in the top of the vessel. The luminous flame burner was simultaneously fired through the shell manhole located above the grid.

The bottom cone presented a special heating problem, since it contained two large fittings (approximately 4 ft diam) which protruded down from the bottom cone for several feet. A large furnace enclosure built completely around the bottom cone of the vessel enclosed the fittings and allowed hot air to be circulated both inside and outside of the bottom cone to effect an even heating of the large fittings and bottom cone.

This vessel, which was 35 ft 6 in. diam x 76 ft overall height, weighed 757,000 lb and contained up to $3^1/_4$ in. thick shell insert plates. It was stress relieved at a minimum temperature of 1100° F and cooled back down to 600° F in approximately 40 hr. A total of 44 thermocouples were used to assure that representative temperatures from all parts of the vessel were being recorded. Several of these thermocouples were placed in the inside of the vessel on the grid and plenum chamber in addition to the ones normally employed on the outside of the shell. Due to the special provision taken to assure an even heating of this vessel, the maximum temperature variation throughout the vessel as a whole during the holding period was a mere 100° F.

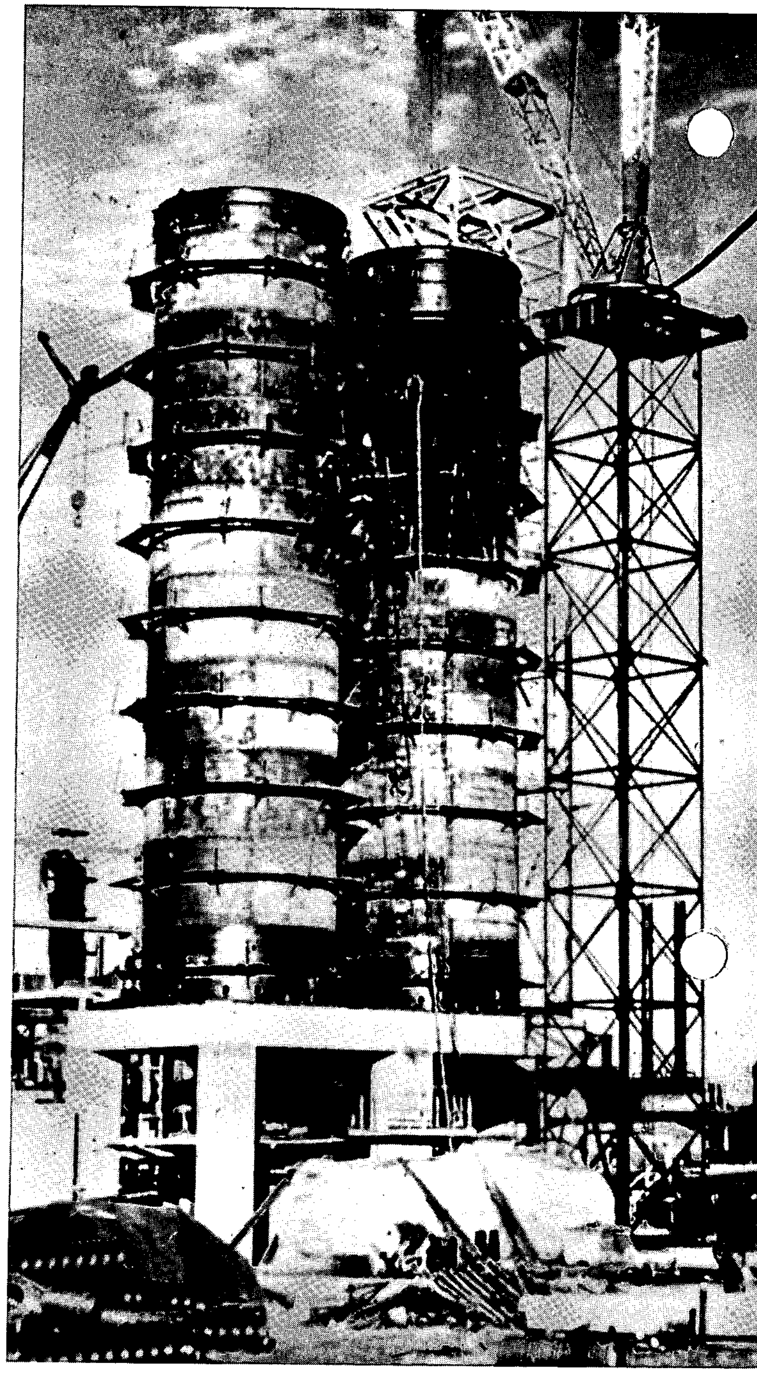


Fig. 11—Two coke drums being insulated prior to field stress relief

Umbrella Roof Tanks

Late in 1959 a mammoth undertaking was accomplished when two 88 ft diam x 48 ft high self-supporting umbrella roof tanks, built for the storage of a highly caustic solution, were stress relieved to eliminate the possibility of stress corrosion cracking which is so prevalent in this type of storage tank. During the early stages of planning, certain inherent problems were encountered and had to be solved before such an undertaking could be possible. One problem was presented by the sand base, normally employed under tanks of this type, since sand in a wet or damp condition would seriously hinder the stress relieving due to the large heat losses through the base. Secondly, it was conceived that a rough sand pad base might affect the way the tank would expand during the heating cycle, as it is altogether possible for one side of a tank to remain stationary while all of the expansion takes place in the opposite direction.

With these problems in mind, it was considered wise to employ a slab of perlite concrete under the bottom of the tank. This was done to provide a smooth sliding surface and also one which would limit the heat losses through the base to a reasonable amount. Then as an added precaution, the center of the tank was anchored so that equal expansion would take place in all directions. Actual measurements taken during the stress relief cycle showed that each of these tanks expanded uniformly from the center and returned to its original position at the completion of the cycle. As a note of interest, the actual expansion amounted to $8^{13}/_{16}$ in. diam for each tank. The heating was accomplished by using three luminous flame oil burners spaced equally around the periphery of each tank and fired internally through three shell manholes.

The weight of each of these extremely large tanks was 595,000 lb. Consequently, stress relieving required around-the-clock operation for several days to heat all parts to a minimum temperature of 1100° F, hold them according to the code requirements, and then cool them slowly and evenly down to ambient temperature. The temperature distribution was extremely uniform from the start to the finish of the stress relief cycle; during the holding period all points on the shell, roof and bottom were brought within a 40° F temperature range. (The codes allow 150° F.) The temperature of each thermocouple, which as usual were placed at representative locations over the entire tank, was automatically recorded on a strip chart by means of a multipoint electronic recording potentiometer type instrument.

Rofinery Towers

As a direct contrast to the two large flat bottom tanks previously described, one of the largest and tallest crude refinery towers in the world was recently brought up to heat in approximately 24 hr before the start of the holding period. After the holding period it was slowly cooled down to 600° F at the rate of 50° F per hr. Thirty-five thermocouples were employed to assure even heat distribution. The physical dimensions of this tower were as follows: 26 ft x 23 ft diam x 173 ft 4 in. overall height. It weighed 738,000 lb and, in some places, the shell plates were as much as $3^{1}/_{4}$ in. thick.

A large 30 in. diam nozzle posed a special heating problem to avoid the large temperature gradients which can crack the welds if allowed to become too high. This nozzle was welded tangentially into a heavy insert plate and then further reinforced with heavy stiffener bars welded longitudinally along the nozzle neck which extended several feet out from the shell. To adequately heat this nozzle, a special insulation detail was devised whereby the heat was allowed to radiate from the shell plate to the protruded nozzle neck and stiffeners; at the same time a flow of hot air was exhausted out the nozzle by means of a special high temperature air mover. By means of the special heating and insulation details used, this large nozzle was very successfully heated along with the vessel as a whole.

Coke Drums

The two 20 ft diam x 70 ft tangent length coke drums shown in Fig. 11 are typical of the many coke drums field stress relieved for the petroleum industry. Made of A204-B backing material and integrally clad with Type 410 stainless steel, they were successfully stress relieved during February in 1959 when the ambient temperature hovered near and below freezing during the complete cycle. The upper three rings on the right-hand drum are in the process of being insulated with a mineral wool type insulation when the photograph was taken. Each vessels had an average shell thickness of $^{5}/_{8}$ in. and weighed 170,000 lb. A condition imposed by the weight of a drilling rig, not shown but later erected on top of the coke drums, limited the stress relieving temperature of the skirt to shell connection to 1175° F. This was necessary since the combined weight of the vessel and drilling rig would overstress the connection at any temperature over 1175° F. This condition was successfully met; all other points on the vessel were heated to a minimum of 1075° F, which meant that all points were brought within 100° F during the holding period. The bringing up period required 12 hr with the use of a specially designed gas burner to utilize the refinery gases available in the existing refinery.

Subassemblies

In addition to fully stress relieving complete vessels in the field, a radically different type of stress relieving is often necessary in the field when individual parts of vessels are required to be stress relieved before being welded into vessels. The large equipment hatches required in nuclear containment vessels must often be welded and stress relieved in the field. This is necessary since the heavy forgings and attaching insert plates are nor-

mally too large to be shipped to the job sites in one piece. By means of a temporary type furnace enclosure erected at the job site, these sections are stress relieved much as a vessel would be stress relieved in a shop. To date, various parts of vessels weighing up to 50 tons have been successfully stress relieved in this type of field furnace. Much larger sections can undoubtedly be done if it becomes necessary.

Insulation

One of the most important aspects of any field stress relieving operation is the selection of a suitable type insulation and its method of attachment to the vessel. The size of a vessel plays an important part in the selection, since the radiation and convection heat losses are directly proportional to the surface area of the vessel. Winds can cause excessive losses and must be taken into consideration when determining the type and thickness of insulation to use. Wind breakers and rain barriers are often advisable in a rainy or windy climate.

Unless particular care is exercised during the insulation operation, bare spots are often left between blankets and particularly around fittings and projections. In addition to being a source of heat loss, these bare spots allow cold spots on the vessel and as such should be thoroughly hand packed before stress relieving. Also, due to the large amount of expansion encountered during the stress relieving operation, additional bare spots may develop. Accordingly, additional insulation and plenty of manpower should be available if needed during the actual stress relieving operation.

Special care and consideration should definitely be afforded all large fittings and projections protruding from the vessel wall to assure that high temperature gradients are not set up in these areas. Even though most standard nozzles will heat satisfactorily by insulating them in a normal manner, it is sometimes necessary to exhaust hot gases out of large and unusual fittings. In some cases it may even be necessary to apply external heat to them.

The attachment of the insulation poses a special problem on certain vessels. As a general rule, the attachment problems become more critical as the size of the vessel increases. It is imperative that the attachment be designed to allow for the large amount of expansion encountered when heating to 1100 or 1200° F, since serious damage to a vessel may occur should parts of the insulation fall off. At stress relieving temperatures, it is virtually impossible to repair insulation that has become loose and fallen off. Therefore, even if the vessel is not seriously damaged by the loss of insulation, a restress relief will be mandatory. This alone is very costly, not to mention the loss of the usually valuable erection time.

Heat Control—Thermocouples and Recorders

The control of the heat entails using an adequate number of thermocouples attached to representative parts of the vessel. Enough should be used to assure that the vessel is heated evenly. Although no hard fast rules can be stated as to where or how many thermocouples should be used, the shape of each vessel will usually dictate its own requirements. Past experience is undoubtedly the greatest help in determining these requirements for individual vessels. On extremely large and complicated vessels, as many as 50 thermocouples have been used at one time. On the smaller and more standard vessels, relatively few are required in comparison.

Several methods of attaching thermocouples to the vessel are available. In this respect, it should be noted that erroneous readings are common unless careful attention is exercised to see that each one is attached and insulated properly. Persons thoroughly experienced in this type of work should supervise the thermocouple installation. Furthermore, a multipoint recording type instrument should, if at all possible, be used to record the temperatures during the cycle.

The recording type of instrument gives the operator a clear picture of tbe heating cycle at any time. By visual inspection of the chart, the operator can adjust the flame and make certain the vessel is heating evenly. To manually record the temperatures is time-consuming as well as cumbersome and will often detract from the more important problem at hand.

Conclusion

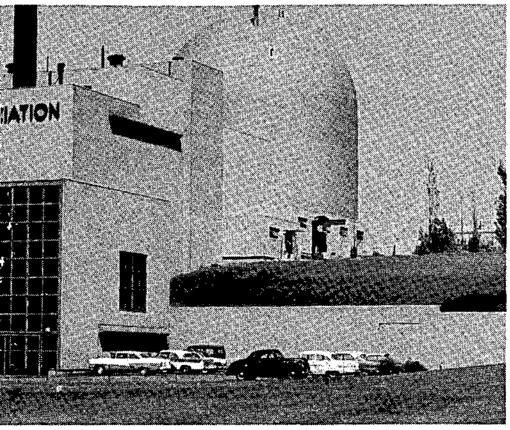
It cannot be emphasized too strongly that careful planning is a prerequisite for each and every vessel to be field stress relieved, since very few vessels present identical problems in heating. Qualified and experienced personnel should personally supervise each stress relieving job in its entirety. Many problems are commonly encountered during the actual heating operation, and these problems must be solved and the necessary action taken during the actual stress relieving operation.

With the improved equipment available today, coupled with the vast experience and know-how gained during the last decade or so, it is entirely possible to fully field stress relieve almost any size or shape of vessel now being built. Spherical pressure vessels as large as 69 ft diam have been successfully stress relieved. Even larger ones are contemplated. Flat bottom storage tanks of sizes up to 120 ft diam x 21 ft high with self-supporting umbrella roofs have been successfully field stress relieved. Huge refinery vessels weighing 400 to 500 tons with extensive complications have been successfully completed, to mention just a few of the many types of vessels that have been stress relieved. If the vessel is self-supporting at stress relieving temperatures, there is not much question that it can be field stress relieved.

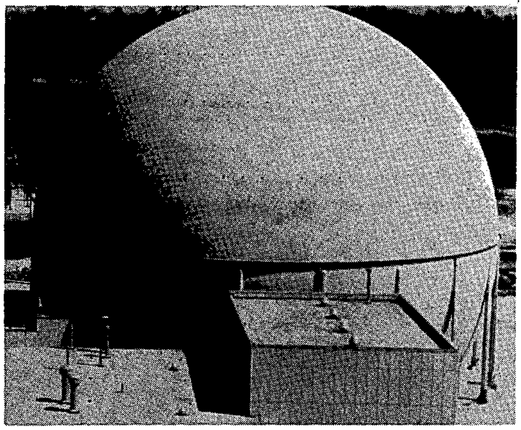
The results attained in the field have been exceptionally good. In all probability they will be getting better with the added experience, better equipment and insulation available today.

BULLETIN NO. B500

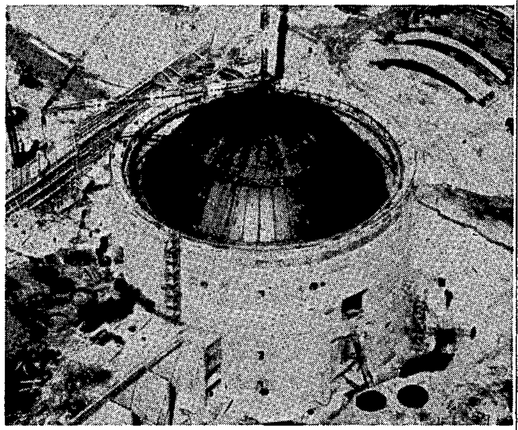
Sound reasons why CB&I experience can be valuable when you require containment heusing for nuclear pewer



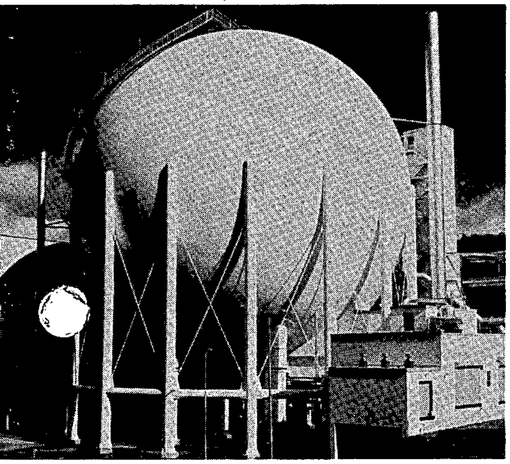
Elk River, Minn. (BWR)



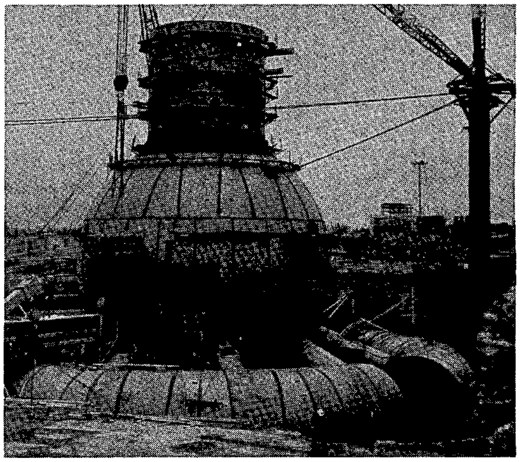
Dresden, Ill. (BWR)



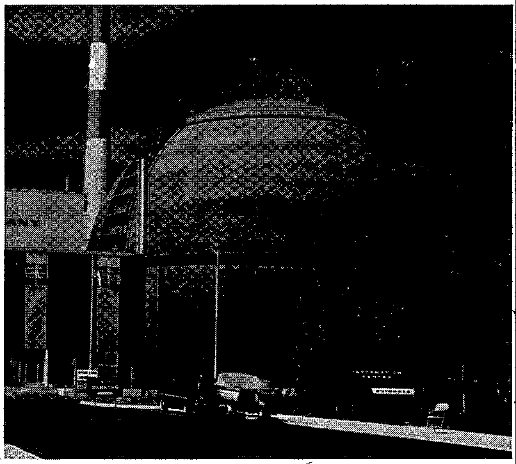
Indian Point, N. Y. (PWR)



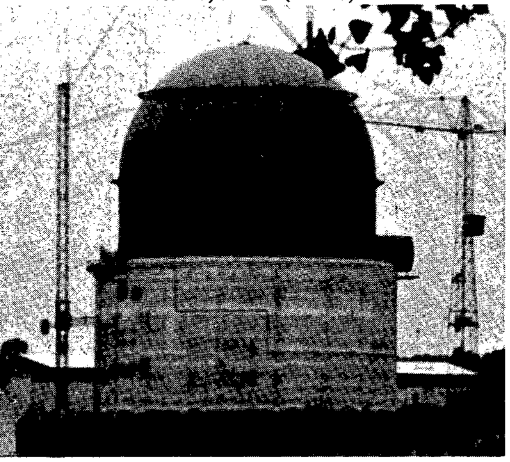
Rowe, Mass. (PWR)



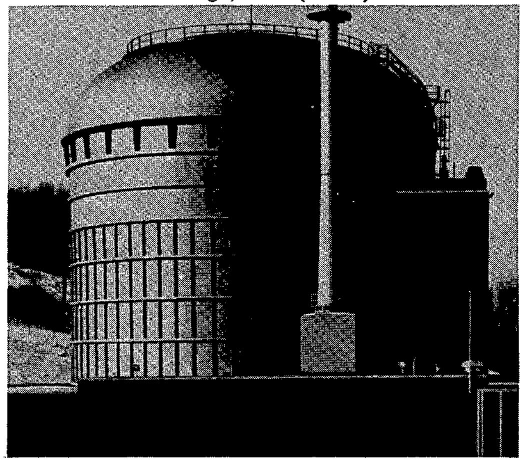
Oswego, N. Y. (BWR)



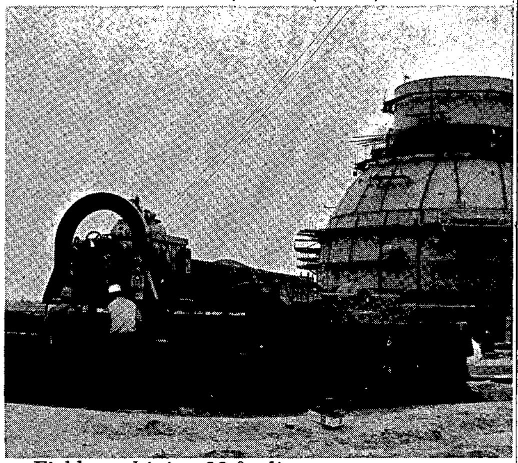
Charlevoix, Mich. (BWR)



Trino Vercellese, Italy (PWR)



Peach Bottom, Penna. (HTGR)



Field machining 33-ft. dia. pressure vessel flange at Oyster Creek, N. J.

CB&I
built them

CHICAGO BRIDGE & IRON COMPANY

Chicago Bridge & Iron Company

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Oak Brook, Illinois

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Tulsa
Walker Process Equipment Division, Aurora, Illinois

Fabricating Plants

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Houston
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New Castle, Delaware

Field Construction Offices

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New Castle, Delaware
Houston
Salt Lake City
Oak Brook, Illinois (International)

International Contracting Office

Oak Brook, Illinois

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Chicago Bridge S.A., Rio de Janeiro, Brazil
Chicago Bridge Limited, Wembley, Middlesex, England
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SWITZERLAND
Giovanola Freres S.A., Monthey

REPUBLIC OF SOUTH AFRICA
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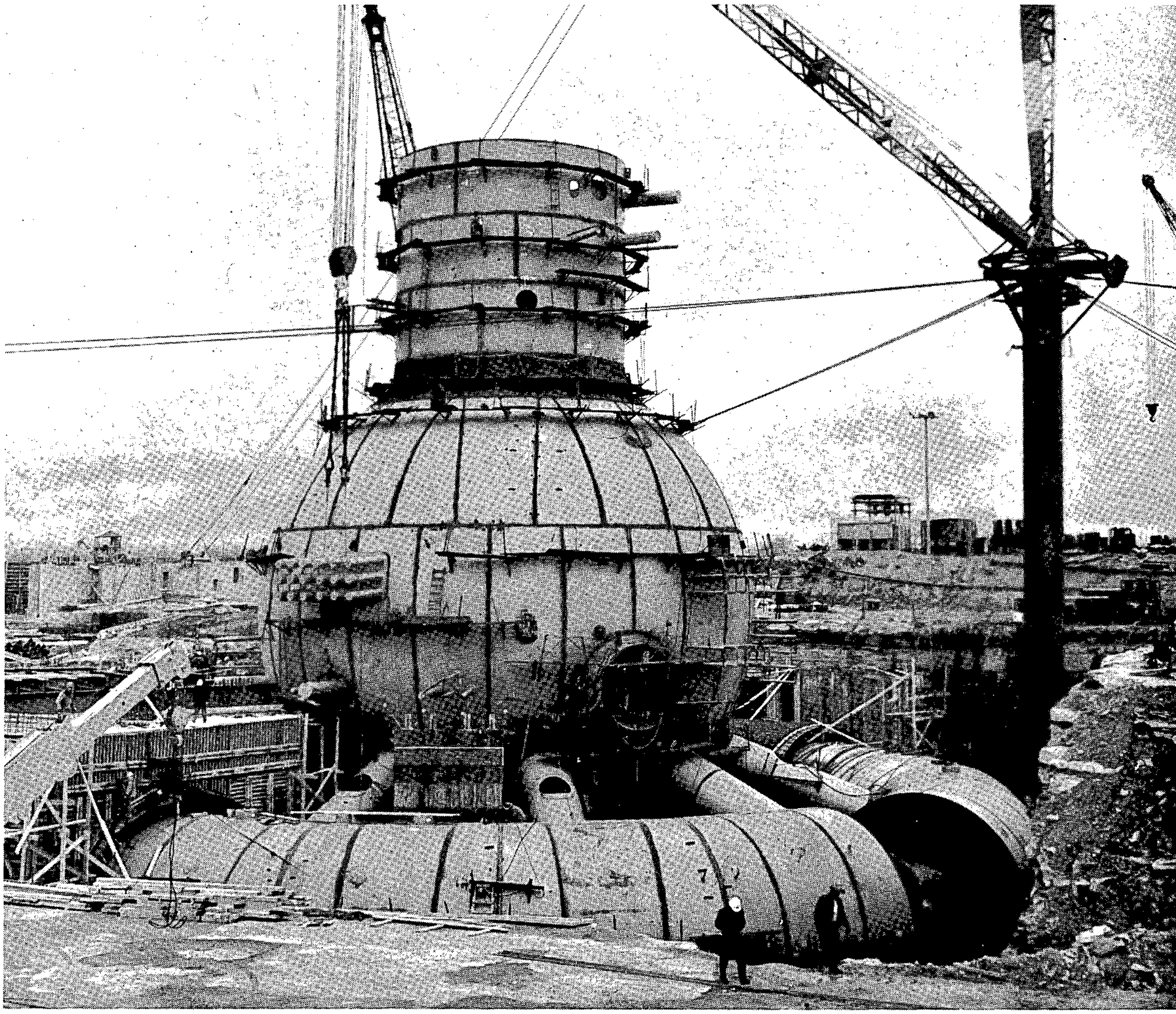


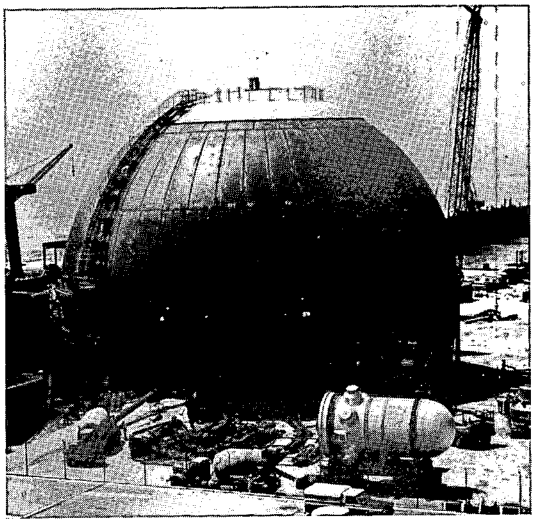
Pressure suppression containment vessels under construction by CB&I for a boiling water nuclear reactor-type power plant.

Since the advent of nuclear power reactors in 1952, CB&I has been the leader in the design, fabrication, construction and testing of containment pressure vessels. The nuclear reactor and primary coolant circuits are housed within these vessels. In the event of a reactor system failure, toxic gases would be expelled into the containment vessel rather than into the atmosphere of the surrounding locale.

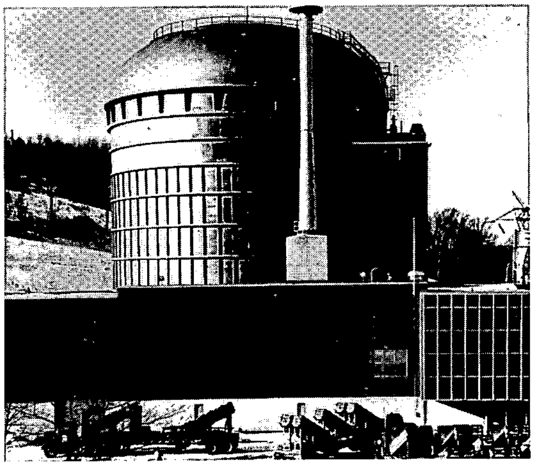
There are many styles of containment, each peculiar to the plant size (as large as 714 megawatts electrical) and type of reactor; i.e., gas cooled, pressurized water or boiling water.

CB&I and its subsidiaries offer a turnkey service for furnishing complete design and construction of the vessels and locks as well as leak rate testing, anywhere in the world.

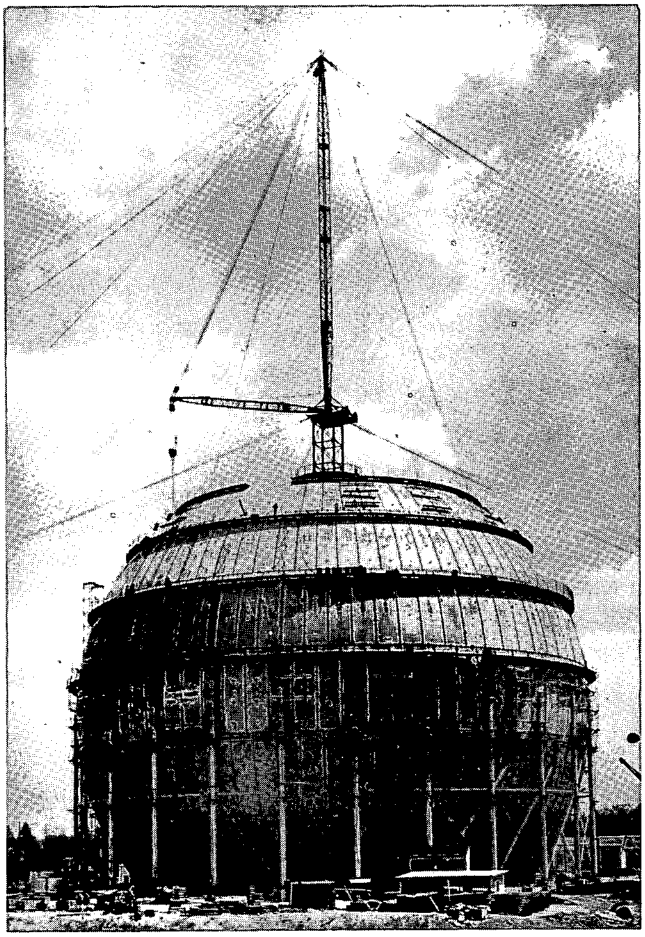
Unique methods of welding and heat treating are offered to field fabricate heavy weldments. Techniques to field machine closure flanges 33 feet in diameter and larger have also been perfected in recent years.



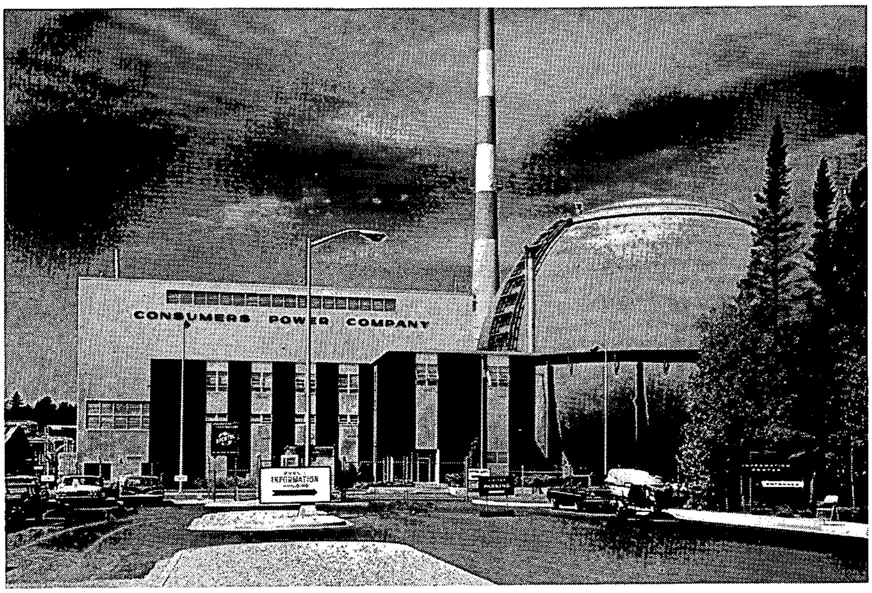
A 140-foot diameter steel Hortonsphere reactor containment vessel nears completion for San Onofre Nuclear Generating Station of Southern California Edison Company and San Diego Gas & Electric Company.



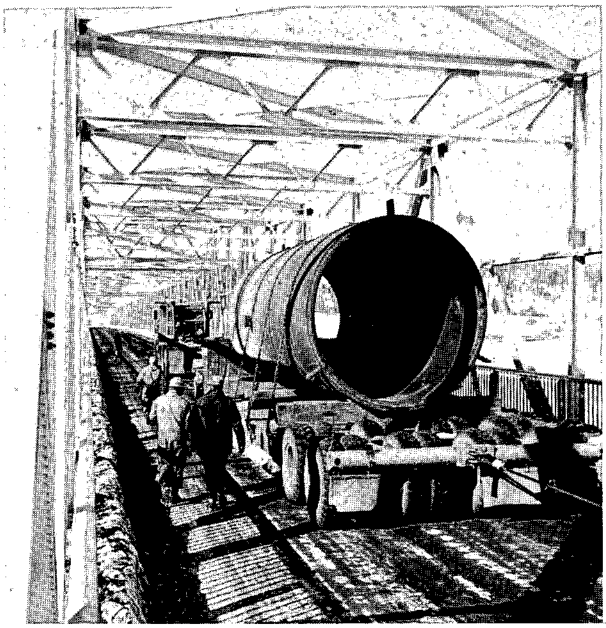
One hundred feet in diameter and 165 feet high, this steel vessel was designed and built by CB&I to house the reactor, primary coolant system and associated equipment for Peach Bottom Atomic Power Station in Pennsylvania.



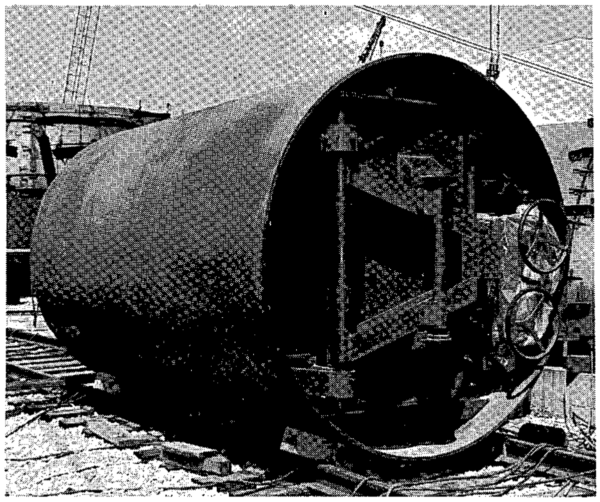
A 225-foot diameter steel Hortonsphere vessel – the world's largest–under construction (1953) by CB&I for Knolls Atomic Power Laboratory, West Milton, New York.



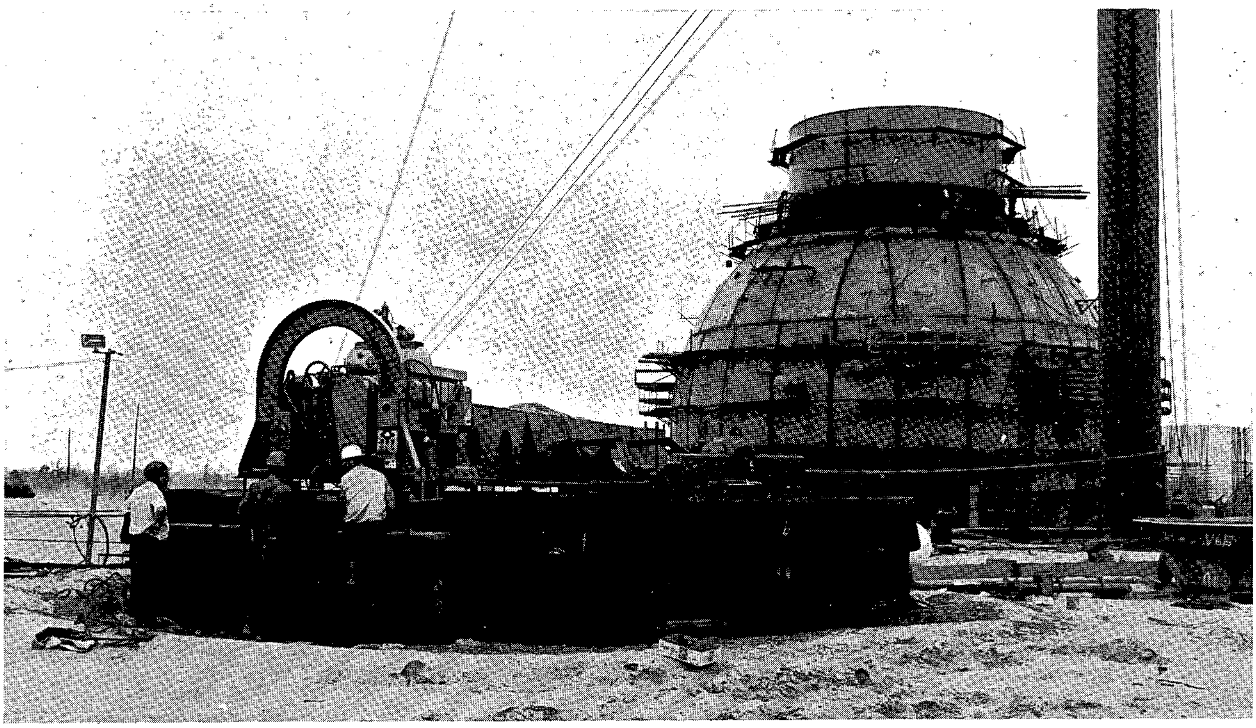
Steel Hortonsphere vessel–130 feet in diameter–encloses nuclear reactor for Consumers Power Company near Charlevoix, Michigan. Note maintenance scaffold which is rolled on track around sphere's equator ring.



Heavy wall (5½ inches thick) steel section for a field constructed vessel in Canada.

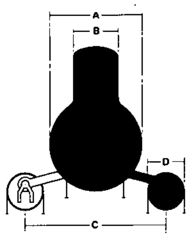


Main personnel access lock for steel suppression containment vessel. The door is 2½ feet wide, 6 feet high.



Field machining a 33-foot diameter pressure vessel flange.

PRESSURE SUPPRESSION CONTAINMENT VESSELS



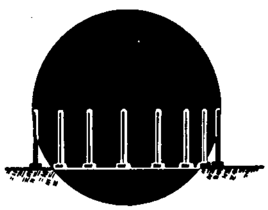
LOCATION		TOTAL VOLUME	DESIGN PRESSURE INT	DESIGN PRESSURE EXT	DIMENSION A	DIMENSION B	DIMENSION C	DIMENSION D	MATERIAL	ASME CODE STAMP SECTION	YEAR BUILT
TARAPUR, INDIA 2 VESSELS	DRYWELL		45	2	65	23			A201-A300	NO	1965
	SUPPRESSION CHAMBER		STEEL LINED BY OTHERS								
OYSTER CREEK, NEW JERSEY	DRYWELL	440,000	62	2	70	33			A212-A300	VIII	1965
	SUPPRESSION CHAMBER		35	.5			101	30	A212-A300		
OSWEGO, NEW YORK	DRYWELL	440,000	62	2	70	33			A212-A300	III	1965
	SUPPRESSION CHAMBER		35	1			124	27	A201-A300		
DRESDEN, ILLINOIS 2 VESSELS	DRYWELL	440,000	62	2	66	38			A212-A300	III	UNDER CONST.
	SUPPRESSION CHAMBER		62	1			109	30	A212-A300		
MILLSTONE POINT, CONNECTICUT	DRYWELL	420,000	62	2	64	34-2			A516-GR70 A300	III	UNDER CONST.
	SUPPRESSION CHAMBER		62	1			102	29-6	A516-GR70 A300		
MONTICELLO, MINNESOTA	DRYWELL	430,000	56	2	62	33			A516-GR70 A300	III	UNDER CONST.
	SUPPRESSION CHAMBER		56	1			98	27-8	A516-GR70 A300		
VERNONDAM, VERMONT	DRYWELL	430,000	56	2	62	33			A516-GR70 A300	III	UNDER CONST.
	SUPPRESSION CHAMBER		56	1			98	27-8	A516-GR70 A300		
CORDOVA, ILLINOIS 2 VESSELS	DRYWELL	440,000	56	2	66	37			A516-GR70 A300	III	UNDER CONST.
	SUPPRESSION CHAMBER		56	1			109	30	A516-GR70 A300		

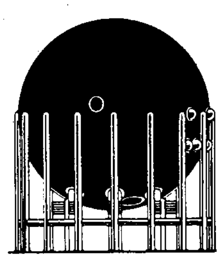
	LOCATION	VOLUME CU. FT.	DESIGN psi INTERNAL (EXTERNAL)	DIMENSIONS	MATERIAL	ASME CODE STAMP	YEAR BUILT
	EUREKA, CALIF.	15,200**	72	17-6"Ø 67'-7"	0.61"-1.50" A201-A300	VIII	1961

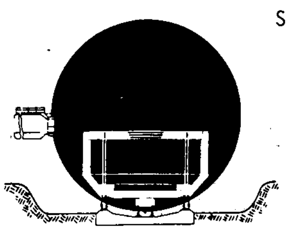
**Not including piping and chamber of pressure suppression system.

SPHERICAL CONTAINMENT VESSELS

LOCATION	VOLUME CU. FT.	DESIGN psi INTERNAL (EXTERNAL)	DIAMETER	MATERIAL	ASME CODE STAMP SECTION	YEAR BUILT
W. MILTON, N.Y.	6,000,000	20 (.8)	225'	.9"-1.1" A201-A300	NO	1953
DRESDEN, ILL.	3,600,000	29.5 (1)	190'	1.25"-1.4" A201-A300	VIII	1958
INDIAN PT., N.Y.	2,140,000	25 (1.25)	160'	.89"-1.03" A201-A300	VIII	1959
CHARLEVOIX, MICHIGAN	1,150,000	27 (.5)	130'	.702"-.774" A201-A300	VIII	1960
SAN ONOFRE, CALIFORNIA	1,435,000	46.4 (2)	140'	A212-A300	VIII	1965
GARIGLIANO,** ITALY	2,140,000	26 (1)	160'	.832"-.947" A201-A300	NO	1961
ROWE, MASS.	1,020,000	31.5	125'	.875"-1.25" A201-A300	VIII	1959
DOUNREAY,* SCOTLAND	1,290,000	18 (TEST) (4) TEST	135'	1"-1.75" Coltuf	NO	1956





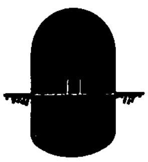


*Built by Motherwell Bridge & Engrg. Co., Inc. (CB&I Licensee)

**Built by Chicago Bridge Ltd. (CB&I Subsidiary)

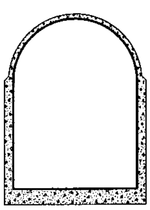
VERTICAL CONTAINMENT VESSELS

CYLINDRICAL SHELL WITH FORMED TOP AND BOTTOM



LOCATION	VOLUME CU. FT.	DESIGN psi INTERNAL (EXTERNAL)	DIMENSIONS	MATERIAL	ASME CODE STAMP SECTION	YEAR BUILT
DAYTON, OHIO	744,700	16 (TEST)	82'-8"Ø 159'-4"OA	9/16"-1" A201-A300	NO	1957
LAGOONA BEACH, MICH.	415,800	32 (2)	72'Ø 120'OA	1.03"-1.25" A201-A300	VIII	1957
ELK RIVER, MINN.	415,000	21 (0.5)	74'Ø 115'OA	0.70"-.875" A201-A300	VIII	1959
FORT GREELEY, ALASKA	89,600	15 (NOT Spec.)	40'8"Ø 79'OA	0.25"-0.50" A201-A300	NO	1960
PLEASANTON, CALIFORNIA	202,600	58 (1)	48'Ø 128'OA	0.513"-1.015" A201-A300	VIII	1961
TRINO* VERCELLESE, ITALY	1,295,900	33.7 (0.9)	100'Ø 190'OA	9.616"-1.50" A201-A300	NO	1962
PEACH BOTTOM, PENNSYLVANIA	1,141,500	8.0 (0.2)	100'Ø 162'OA	5/16"-0.703" A201-A300	VIII	1964
LA CROSSE WISCONSIN	364,800	52 (0.5)	60'Ø 144'OA	0.60"-1.16" A201-A300	VIII	1964
FAYETTEVILLE ARKANSAS	215,200	30 (1)	50'Ø 105'-6"OA	A212-A300	VIII	1966

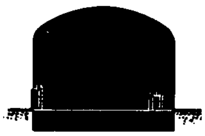
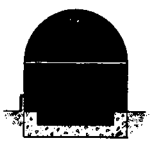
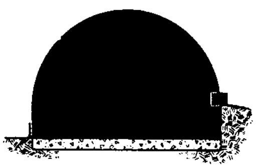
STEEL LINERS FOR CONCRETE CONTAINMENT VESSELS



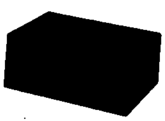
LOCATION	DIMENSIONS	MATERIAL	YEAR BUILT
HADDAM, CONNECTICUT	135'Ø 188'-6"OA	A442-GR60 SHELL 3/8" DOME 1/2"	UNDER CONST.
ROCHESTER, NEW YORK	105'Ø 149'-6"OA	A442-GR60 MOD. SHELL 3/8" DOME 1/2"	UNDER CONST.
INDIAN POINT, NEW YORK	135'Ø 209'-6" OA	A442-GR60 MOD. SHELL 3/8" DOME 1/2"	UNDER CONST.
SANDUSKY, OHIO	136'Ø 158'OA	A285-GRC FBX SHELL 1/4" DOME 1/4"	1966

*Built by Chicago Bridge Limited (CB&I Subsidiary)

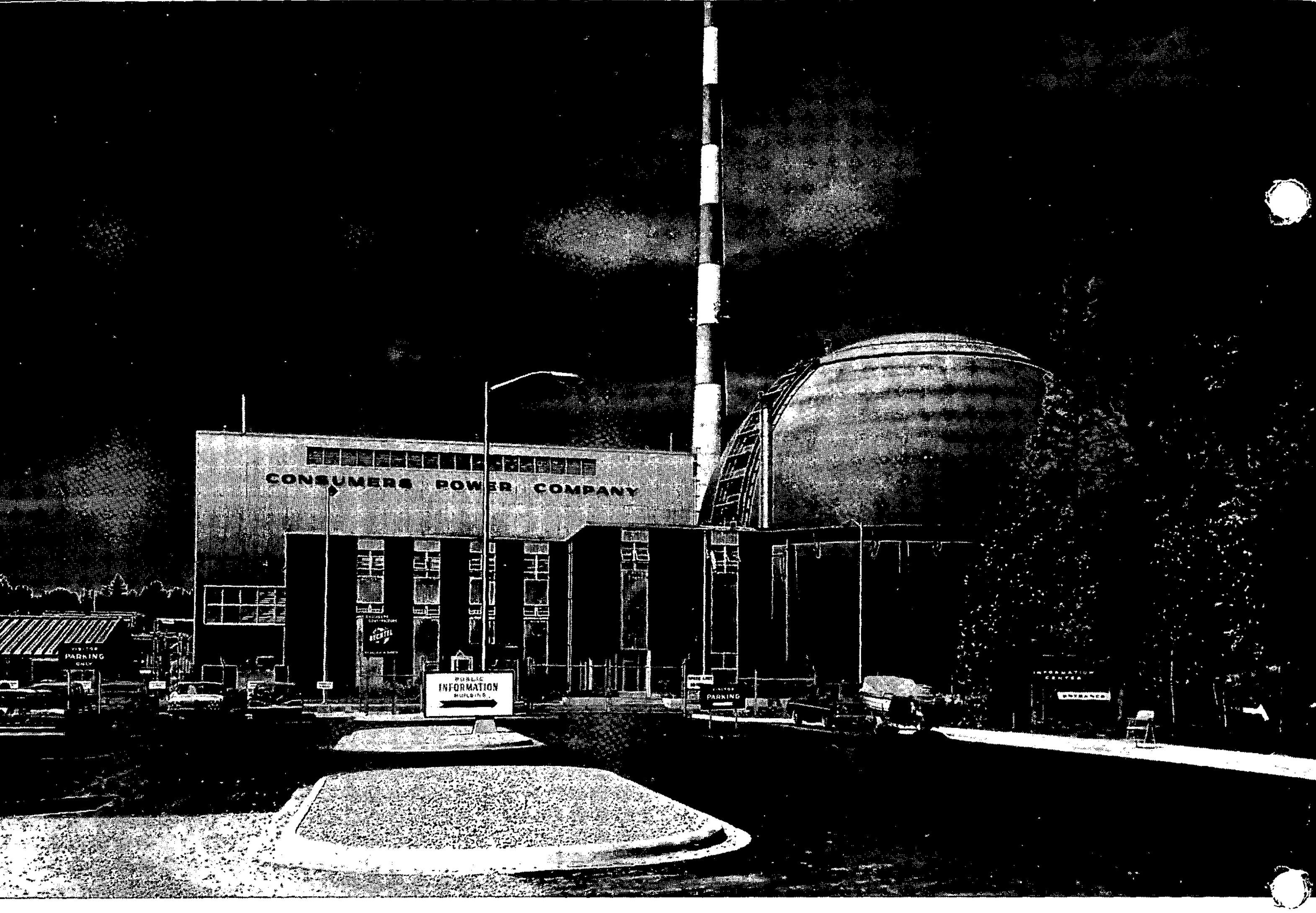
VERTICAL CONTAINMENT VESSELS
CYLINDRICAL SHELL, FORMED TOP AND FLAT BOTTOM

	LOCATION	VOLUME CU.FT.	DESIGN psi INTERNAL (EXTERNAL)	DIMENSIONS	MATERIAL	ASME CODE STAMP SECTION	YEAR BUILT
	LIVERMORE, CALIF.	257,500	2 (.083)	80'Ø 38'TL	1/4" SHELL A283	NO	1957
	CAMBRIDGE, MASS.	258,700	2 (.1)	74'Ø 48'TL	3/8" SHELL A283	NO	1958
	LOWELL, MASS.	380,000	2	84'Ø 95'7"OA	7/16" SHELL A201-A300	NO	UNDER CONST.
	ATLANTA, GEORGIA	263,500	2 (0.2)	82'-2" Ø 71'OA	7/16" to 1.75" A201-A300	NO	1962
	LYNCHBURG, VIRGINIA	542,000	5 (0.4)	33' 66'-3"OA	1/4" SHELL A201-A300	NO	1964
	AIKEN, SO. CAR.	214,000	24 (.25)	70'Ø 67'OA	.375"-.67" A201-A300	NO	1960
	RINCON, PUERTO RICO	1,780,000	5 (.25)	166'-8"Ø 109'-4"OA	0.40" SHELL 5/16" A201-FGP-	NO	1961

MISCELLANEOUS CONTAINMENT VESSELS

	LOCATION	VOLUME CU.FT.	DESIGN psi INTERNAL (EXTERNAL)	DIMENSIONS	MATERIAL	ASME CODE STAMP SECTION	YEAR BUILT
	OAK RIDGE, TENN.	28,100	30 TEST	26'x20'x54'	.79" A285 PART CLAD	NO	1955
	LAGOONA* BEACH, MICH.	10,800	6 (15)	24'Ø 56'-3"OA	5/8"-1-1/4" A285	NO	1960
	RICHLAND, WASHINGTON	31,000	75	25'Ø 54'-0½"TL	A212-A300	VIII	1965

*Intermediate containment vessel.



1050 tons of safety at Big Rock Point Nuclear Plant

N The power of the atom has been harnessed and put to work by Consumers Power Company at the Big Rock Nuclear Plant, near Charlevoix, Mich. Now the atom's might peacefully generates electricity for thousands of homes, farms, commercial buildings and industries in Michigan.

Several types of safety systems give fullest protection to plant personnel and neighboring residents. The 130 ft. steel Hortonsphere® containment vessel was selected to prevent radioactive material from reaching the atmosphere in the unlikely event it escapes from the reactor inside.

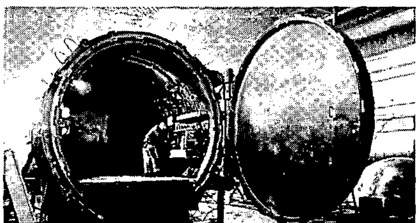
This huge leakproof sphere, designed and built by CB&I under assignment by prime contractor Bechtel Corporation, has a design working pressure of 27 psi. Integrity of every inch of welding in the mammoth steel safety shield was precisely and carefully checked by X-ray.

Three custom-built locks–designed and built by CB&I–keep the vessel leakproof during entry and exit of equipment and personnel. CB&I has complete "in house" capability to design and build these precision locks–your assurance of safe and successful construction when CB&I handles the job!

Backing this installation is CB&I's world leadership in the design and construction of containment vessels, with 30 vessels built or under contract in the last dozen years. Some of the larger Hortonsphere containment vessels are:

- West Milton, N. Y., 225-ft. dia.
- Dresden, Ill., 190-ft. dia.
- Indian Point, N. Y., 160-ft. dia.
- San Onofre, Calif., 130-ft. dia.
- Rowe, Mass., 125-ft. dia.
- Scauri, Italy, 160-ft. dia.
- Downreay, Scotland, 135-ft. dia.

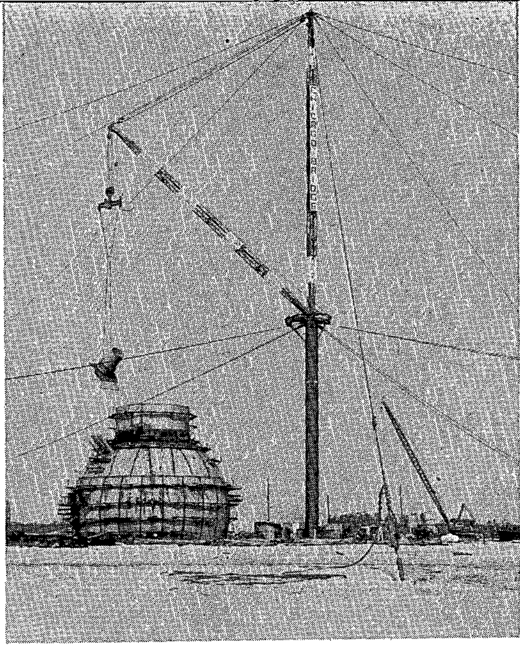
For more information, write to Chicago Bridge & Iron Company, Oak Brook, Illinois.



Equipment lock for the Hortonsphere shortly before its shipment to Big Rock Point from CB&I's Chicago plant.

CB&I

designed and built it



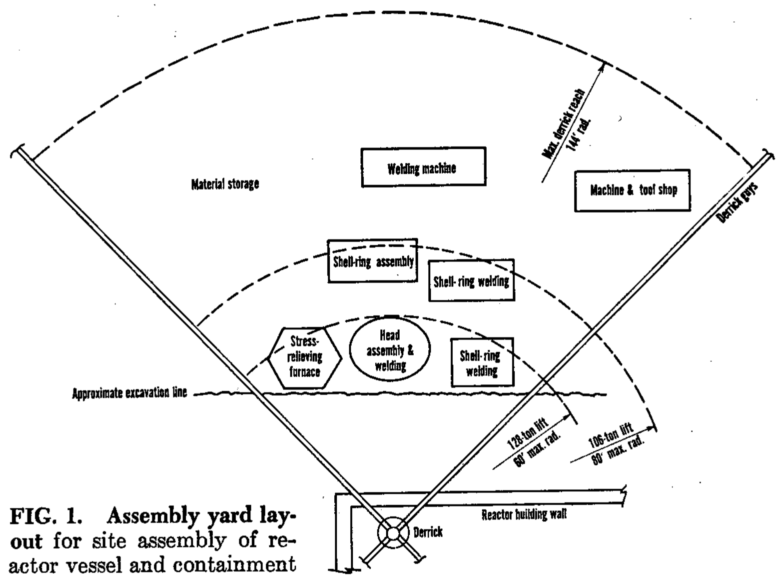


FIG. 1. Assembly yard layout for site assembly of reactor vessel and containment

Site assembly: A new approach for U. S. reactor vessels

T. L. CRAMER, *Associate Editor*

Chicago Bridge & Iron's proposal to assemble on-site the reactor pressure vessel of the 545-Mwe Monticello, Minnesota, boiling-water-reactor plant should have significant consequences for nuclear power: Sites with limited accessibility for hauling in finished vessels will receive more serious consideration; fabrication will not be a limiting factor on vessel size; fabricators without the spacious shop facilities of Combustion Engineering and Babcock & Wilcox can enter the large-vessel field.

Knowledgeable people on all sides—AEC, utilities and vendors—agree that pressure vessels can be assembled at the site with the same quality attainable in the shop. Necessary departures from shop practice, however, will prompt AEC to look carefully at how well the proposed methods will assure quality. Of major concern will be heat treatment to stress-relieve welds and radiographic inspection.

Experience

Site assembly is not without precedent in the nuclear field. Vessels for both the French and British gas-cooled reactors have been manufactured in this way as well as U. S. containment structures. All of these, however, are designed for much lower operating pressures and have thinner wall thicknesses, e.g., 4⅛ in. for 268 psi.

More nearly comparable with the reactor pressure vessels are oil refinery vessels being site-assembled by Chicago Bridge & Iron. As most reactor vessels, some refinery vessels must meet ASME Code III requirements for Class A vessels. One refinery vessel under construction in the eastern United States has a 13-ft diameter, 90-ft height and 7⅟16-in. wall thickness and weighs 575 tons. The plate material is 2¼% chrome, 1% molybdenum overlayed with type 347 stainless steel.

Vessel fabrication

The following procedure has been suggested by Chicago Bridge & Iron to site-assemble a reactor vessel for a power plant the size of Dresden-2 (800 Mwe). (Vessel dimensions are 20 ft 11 in. ID, 70 ft high, 6⅜ in. thick.)

The project organization, including quality control, will be set up similarly to that for a shop-fabricated vessel. An advantage of site assembly is that once the vessel components arrive at the site, all fabrication and assembly efforts will be focused on this one vessel rather than being shared with several others.

In the shop, bottom head plates, shell and top head plates would be hot-formed in a hydraulic press, quenched and tempered, cold-sized and the plate edges prepared for welding. The plates will be assembled and temporarily fit together as complete shell rings (20 ft 11 in. diameter, 11 ft long) and overlay-welded. The rings will be postweld heat-treated, the overlay ultrasonic tested and dye-checked, and the ring then disassembled for shipment to the site. (On smaller-diameter vessels, complete rings and heads will be shipped to the site with the nozzles installed.)

The forged flange rings, weighing as much as 60 tons, will be rough-machined at the forge works and shipped directly to the site. The small nozzle forgings will be shipped to the vessel manufacturer's shop where they will be overlayed or lined and prepared for installation in the shell at the reactor site.

The heads will be hot-formed as orange-peel segments and a center dollar plate, quenched and tempered and cold-sized as required. If the site is not accessible for shipment of complete heads, the plates will be temporarily joined together, overlay-welded and postweld heat-treated, disassembled and shipped to the site.

The 13-ft-diameter bottom-head center section will be shop-welded by multiple-pass submerged-arc welding,

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NUCLEONICS, November, 1966

ultrasonically tested while hot and postweld heat-treated. After heat treatment, the welds will be radiographed with either a betatron or a high-energy gamma source and again ultrasonically tested. The overlay weld will be made with austenitic stainless steel to ASTM A371 to meet the ER 308 specifications.

The support skirt and the internal shroud-support rings will be fabricated and final-machined in the shop. The lower base of the reactor skirt, instead of being furnished with the customary machined base plate, will be edge-prepared for double-butt welding to an extended tubular support skirt, supported in turn by the containment drywell.

Site assembly

At the reactor site, an assembly yard (Fig. 1) will be within reach of a large derrick that will pick up vessel components and set them in final position on a support skirt in the reactor drywell. The yard will be equipped with work tables, positioner rolls, stress-relieving furnace, storeroom, tool room, darkroom, materials-testing lab, preheating and welding equipment and lifting and handling equipment.

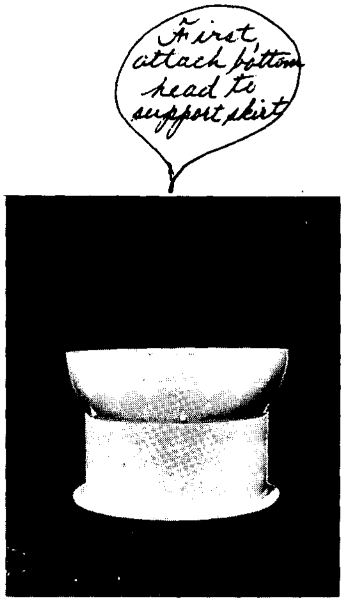
Assembly-yard operations. The basic assembly-yard fabrication process will proceed as follows on both head and shell components:

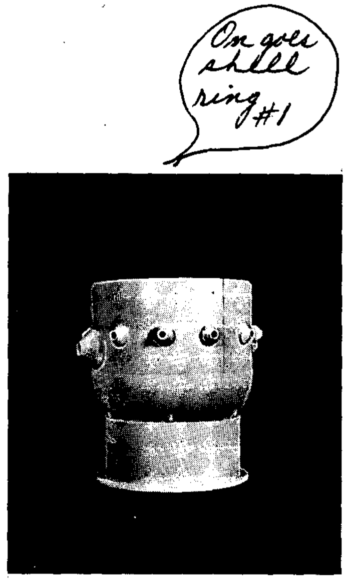
1. Fit shell rings or head, skirt and/or flange sections together on level work tables.
2. Preheat to 350°F and weld sections together, i.e., four shell rings, one bottom head with skirt and one top head with flange.
3. Hot-ultrasonic-test welds before postweld heat treatment.
4. Postweld heat treat at 1,150°F.
5. Cool and radiograph welds.
6. Ultrasonic inspect welds again.
7. Hand-overlay welds.
8. Postweld heat treat.
9. Cool and ultrasonic inspect overlay.
10. Dye-check overlay.

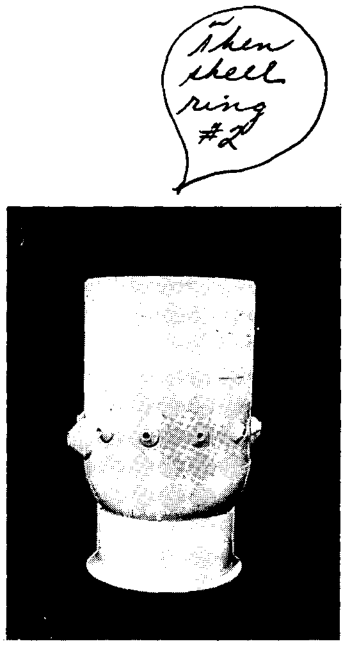
The same procedure will be repeated on welds joining the six basic vessel sections (illustrations at right).

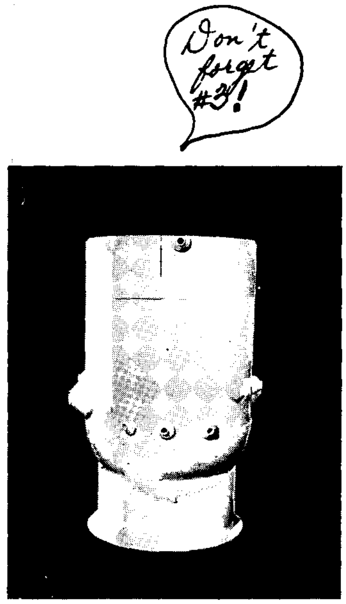
Weather-protection devices will shelter the vessel weldments during site fabrication, both during ground assembly and during final welding, postweld heat treatment, etc., in position on the vessel. Figure 2 shows a typical example of summertime weather protec-

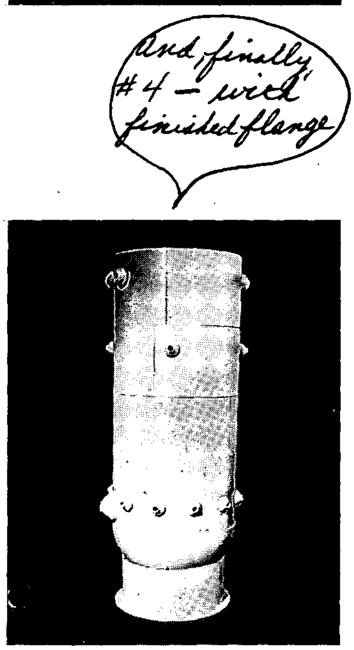
A pressure vessel in six easy steps . . .

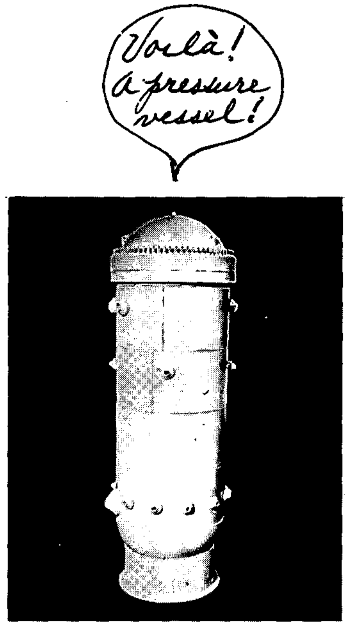












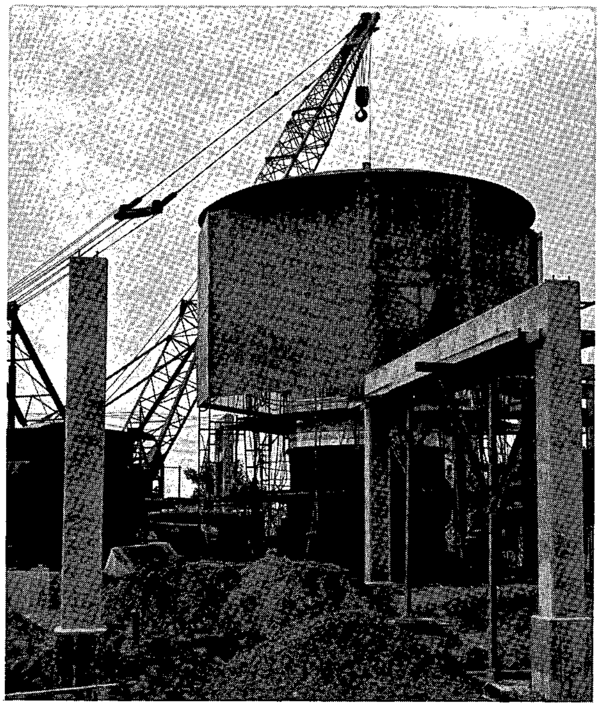


FIG. 2. Temporary structure provides weather protection during welding

tion inside which welders are joining plates 7⅙ in. thick.

The need for equipment portability in the field will require cobalt-60 for radiography rather than the betatrons and linear accelerators available in the shop. With the high-specific-activity cobalt sources now available, radiographs of comparable sharpness are obtainable. Cobalt, however, is limited in its usefulness—with a half-thickness value (thickness of material that will reduce the radiation intensity by one-half) of ¾ in. for steel, cobalt provides a 1% sensitivity for steel thicknesses up to only about 6 in. A 24-Mev betatron, with a half-thickness value of 1.3 in., has a practical limit of about 20-in.-thick steel. For vessels of the thickness planned for Monticello (5¼ in.), this is not a problem. A more important consideration for the fabricator is the longer exposures needed with cobalt. Six-inch steel requires about a 1-hr exposure with a 150-curie cobalt source and ½ to 2 min with a linear accelerator or betatron.

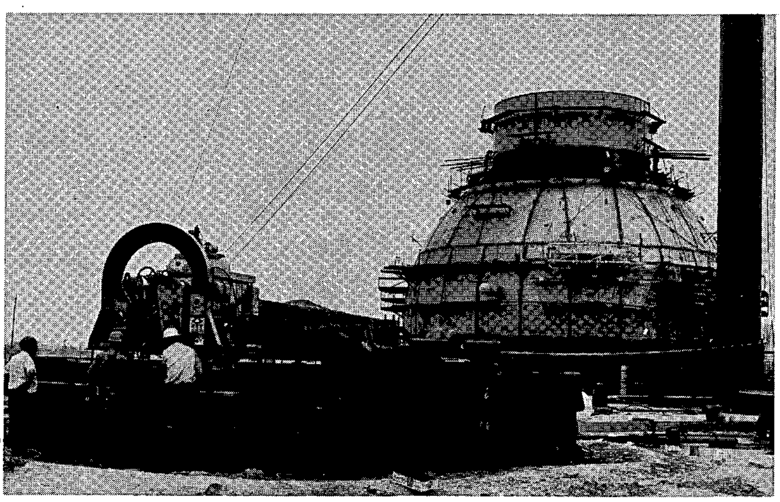
Patented field machining equipment (Fig. 3), similar to that used on the containment-vessel flanges, will be used to machine the reactor cover flange on the ground and the shell flange after it is welded in place. The stud holes can be drilled using a radial-drill set-up (Fig. 4).

In-position operations. The bottom head and stub support-skirt assembly will be set in place on an 18½-ft-diameter tubular support skirt provided in the drywell base of the containment structure. (Erection inside the containment structure is optional. Erection of the vessel off to the side in the assembly yard might be more compatible with other types of containment or for project-schedule reasons.)

The No. 1 shell ring, assembled and welded in the assembly yard, complete with the 36-in., 28-in.-diameter recirculation and other nozzles, is placed as an integral ring in position atop the bottom head. The girth seam will be fit, preheated and the hand welding started. The No. 2 ring will then be placed, fit and welded before any postweld heat treatment is done in place on either ring. Temporary weather protection will be provided during this period. The preheat will be maintained on the bottom head to No. 1 ring girth seam until the No. 1 to No. 2 girth seam is ready for postweld heat treatment. The two rings will be stress-relieved simultaneously in a temporary furuace.

After the No. 1 and No. 2 girth seams have been heat treated, the temporary furnace will be converted into an air-conditioned and ventilated workroom around the bottom head and No. 1 shell ring. A temporary cover will be installed above this work area so that the balance of the vessel can be erected without interfering with the bottom head work (other than for in-place radiographic work on the closure girth seams of subsequent rings). The holes and sleeves for the 185 6-in.-diameter control-rod-drive thimbles and 94 2-in.-diameter holes for the in-core flux sensors will be drilled using techniques adapted from similar site fabrication projects.

As the containment vessel is completed, it will form a perfect weather enclosure for the balance of the in-



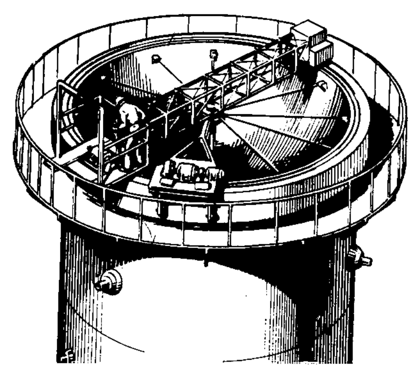


FIG. 3. Grooves for O-ring flauge seals can be machined in the field to close tolerances with equipment such as the patented device CB&I used at left on the Oyster Creek containment flange

place assembly of the reactor vessel.

The vessel closure flange, welded to the No. 4 ring in the assembly yard, will be drilled and machined in place, assuring a horizontal flange surface and plumb stud holes.

As a final step, the reactor cover will be installed and the vessel prepared for hydrostatic testing.

* * *

The site-assembly procedures described in this article are based on the paper "Large Steel Nuclear Vessels" presented by J. T. Dunn (Chicago Bridge & Iron Co.) at the Nuclex Conference, Basel, Switzerland, September, 1966.

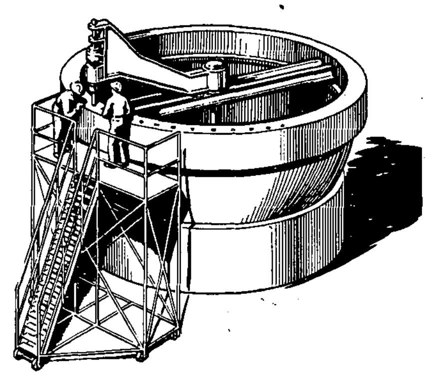


FIG. 4. Field-boring equipment can be adapted to bore small holes: 32-in.-diameter holes 38 in. long and 35 ft apart were bored to ±0.001 in. with less than 0.0005-in. taper and 0.020-in. parallelism between holes

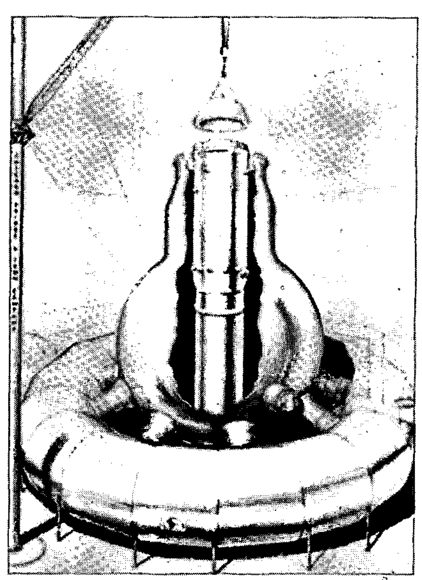
Site assembly proposals and possibilities

The Northern States Power Company's Monticello site is some 40 miles northwest of Minneapolis. Since the 600-ton reactor vessel can be shipped by water only as far as Minneapolis on the Mississippi, the General Electric Company has chosen site assembly as an alternative to expensive overland hauling by truck or rail. (Vessel dimensions: 17 ft dia × 63 ft high × 5¼ in. thick.)

The stainless-clad, low-alloy-steel vessel and carbon-steel pressure-suppression containment structure (shown at right) will be assembled simultaneously by Chicago Bridge & Iron Company from plates fabricated in its Birmingham plant. Portable equipment will be used for heavy welding, postweld heat treatment, machining and radiographic and ultrasonic testing.

Monticello construction plans are now under review by the AEC regulatory staff with a decision expected in early 1967. Although the AEC Advisory Committee on Reactor Safety has approved only the site for the Monticello station, ACRS emphasized that this "does not imply concurrence with the concept of field fabrication" of the vessel. The Committee has never expressed itself publicly on the feasibility of maintaining adequate quality-control standards on field welding. However, the Committee raised in a letter of last November to AEC Chairman Seaborg the question of pressure-vessel integrity in connection with siting plants closer to metropolitan centers. With assurances that vessels built in the field are as good as the shop product, this conservatism should not affect the question of site assembly.

A second proposal for field assembly will be submitted shortly to AEC by the GE-CBI team for the nuclear station planned by Central Vermont Power Company and Green Mountain Power Company. A third candidate for site assembly is the Keowee Dam plant of the Duke Power Co.—alternative shop and on-site plans were provided by Babcock & Wilcox Co. and a decision is expected momentarily.



Reactor vessel and pressure-suppression containment of type planned for Monticello

Pennsylvania Power & Light Co., whose service area is virtually landlocked, has gone to considerable effort to evaluate overland shipment. One official called the cost "fantastic." One route investigated, from the Great Lakes through New York State, would entail a shipping cost of $1–2,000,000. The PPL studies also indicate that 3–5 months may be cut off the construction schedule; for a $100,000,000 job, this may mean savings of $1,000,000 per month. Further, the fallout of such hauling—traffic obstruction, damage to landscape and roads—would be a "terrible blow" to public relations.

According to J. L. Kelehan, Combustion Engineering vice president, it is too early to know the extent to which reactor vessels will be assembled at the plant site. ". . . we estimate maybe 15–20 percent during the next five years. We don't ever anticipate on-site assembly to go over 50 percent, since most populous areas of the country have water access for delivery." He said further: "With field assembly will come major problems. Building will have to be erected to house special equipment . . . the shop welders it takes years to train won't be available . . . and field radiography presents greater problems than doing it in our own shop."