U. S. ATOMIC ENERGY COMMISSION
HEADQUARTERS
DIVISION OF COMPLIANCE

November 22, 1966

CO Report No. 237/66-5
245/66-4
247/66-3
263/66-1

Title: COMMONWEALTH EDISON CO. (DRESDEN 2)
LICENSE NO. CPPR-18

CONNECTICUT LIGHT AND POWER CO. (MILLSTONE POINT)
LICENSE NO. CPPR-20

CONSOLIDATED EDISON CO. (INDIAN POINT 2)
LICENSE NO. CPPR-21

NORTHERN STATES POWER CO. (MONTICELLO)
LICENSE NO. Pending

Date of Visits: October 26-27 and November 2-3, 1966

G. W. Reinmuth

By: G. W. Reinmuth, Reactor Inspector (Prog. Stnds.)

SUMMARY

Visits to the Babcock and Wilcox Company (B&W) facilities in Barberton, Ohio, and Mt. Vernon, Indiana, disclosed that B&W is experiencing considerable difficulty in developing suitable procedures applicable to the fabrication of Dresden 2 size (251" ID) pressure vessels. The difficulties are associated with the use of electro-slag welding. B&W is attempting to solve these problems through variations in the heat treatment operations. Other process considerations are reviewed in the report.

A visit was also made to the Combustion Engineering Company (CE) Chattanooga shop. The most significant difference in pressure vessel fabrication techniques employed by CE is substantial use of machining, both for weld joint preparation and for dimensional control. Neither B&W or CE will guarantee to exceed code requirements in this area.

A third visit to the Chicago Bridge and Iron Company (CB&I) Birmingham shop was completed on November 3. The purpose of this visit was to review shop facilities and discuss proposed procedures for the field

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Summary (continued)

assembly of the Northern States Power Company Monticello reactor vessel. Fabrication of the sections and pieces of this vessel will be performed in the Birmingham shop. The report discusses fundamental differences which will be required because of field assembly. Basic differences noted in the CB&I approach to large vessel fabrication is cold plate forming, extensive use of ultrasonic testing (material hot) for in process quality control, minimum machining and a field-oriented organization. The General Electric Company (G-E), the vessel buyer, recognizes the significant differences both in fabrication procedures and organization and is taking supplementary actions to insure an equivalent quality product.

DETAILS

I. Scope of Visits

A series of visits to the three current pressure vessel vendors was made by representatives of the Division of Compliance (CO), the Division of Reactor Licensing (DRL), the Division of Safety Standards (SS), and by Mr. Richard Lofy of Parameter, Inc., consultant.[1] These visits were made for the following purposes:

1. To provide an opportunity for DRL and SS representatives to meet key vendor personnel and to observe shop procedures and practices.

2. To introduce the Regulatory pressure vessel consultant, Parameter, Inc., to the vendors.

3. To gather information for determining whether field fabrication of large pressure vessels can be performed at quality levels equivalent to shop fabricated vessels.

Attendance at the various locations was as follows:

A. Babcock and Wilcox Company, Barberton, Ohio, October 26

James C. Quinn, Manager, Quality Control, B&W
W. C. Buskey, Assistant Chief Inspector, B&W
F. J. Kane, Contracts Division, B&W
I. R. Hicks, Contracts Division, B&W
H. L. Helmbrecht, Engineering Welding, Quality Control, B&W
J. J. Fox, Manager, Quality Control, G-E
A. M. Hubbard, Manager, Materials Engineering, G-E
I. R. Kobsa, Senior Design Engineer, G-E

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[1] A separate report of these visits has been prepared by Mr. Lofy (Parameter, Inc., Report No. DCL-3, dated November 10, 1966) and is attached to a limited number of copies of this report. Additional copies of the Lofy report are available upon request to Compliance.

Scope of Visits (continued)

R. L. Brown, Site Representative, Quality Control, G-E
R. A. Lofy, Parameter, Inc.
G. W. Reinmuth, Division of Compliance, AEC

B. Babcock and Wilcox Company, Mt. Vernon, Indiana, October 27

All those previously listed, plus
L. F. Kooistra, B&W
N. P. Wagner, Plant Manager, B&W
J. A. Lauer, B&W
J. J. Shea, Division of Reactor Licensing, AEC
B. Grimes, Division of Reactor Licensing, AEC
M. Bolotsky, Division of Safety Standards, AEC

C. Combustion Engineering Company, Chattanooga, Tennessee, November 2

J. Visnich, Manager, Nuclear Products
W. B. Bunn, Manufacturing Engineering, CE
E. S. Proctor, Manager, Quality Control, CE
G. E. St. Cin, Engineering, CE
R. L. Lumpkin, Jr., Engineering, CE
H. Dolphi, Engineering, CE
F. Hill, Engineering, CE
J. J. Fox, G-E
A. M. Hubbard, G-E
I. R. Kobsa, G-E
R. H. Beers, Engineering, G-E
C. C. Roof, Site Representative, Quality Control, G-E
J. N. Morgan, Field Service, G-E
J. J. Shea, AEC
B. Grimes, AEC
M. Bolotsky, AEC
M. Libarkin, Staff, ACRS, AEC
R. Lofy, Parameter, Inc.
G. W. Reinmuth, AEC

D. Chicago Bridge and Iron Company, Birmingham, Alabama, November 3

All the G-E and AEC persons attending the November 2 meeting, except Mr. Morgan, also were present on November 3. The following CB&I personnel also attended:

O. B. Johnson, Project Manager (Monticello job)
E. E. Varnum, Manager, Quality Control (Monticello job)
H. L. Wailes, Engineer in Birmingham for Monticello work

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Scope of Visits (continued)

Q. W. Kneen, Quality Control in Birmingham for Monticello work
A. G. Smith, Southeast Area Manager
A. J. Larson, Manager of Manufacturing, Birmingham plant
F. L. Corothers, Engineering, Birmingham plant
R. E. Clotfelter, Welding Engineer, Birmingham plant

II. Results of Visits

A. Visits to the Babcock and Wilcox Company, October 26-27

1. General Process Observations

As previously described (CO Report No. 237/66-2, dated April 6, 1966), the Babcock and Wilcox Company (B&W) have invested approximately $25 million in a new heavy vessel fabrication plant at Mt. Vernon, Indiana, in anticipation of capturing a significant proportion of the nuclear pressure vessel market. Their success to date is substantiated by firm orders to construct vessels for Dresden 2 and 3, the two Quad-Cities facilities, the two TVA reactors, Rochester Gas and Electric Company, and two units for the Duke Power Company.

B&W hopes to achieve a favorable competitive position through two basic refinements in fabrication - extensive use of electro-slag welding and full application of automatic welding processes. At the present time, B&W continues to experience significant difficulties with the electro-slag process as applied to vessels in the size range of Dresden 2 (251" ID). The difficulties are characterized by the inability to predict dimensional changes during welding and the succeeding quench and tempering operations. Total circumferential growth of a shell section has varied between $2\frac{3}{4}$" and 5". Stress relieving operations have failed to return the structures to specification tolerances. Current practice is to quench and temper twice rather than the originally planned single cycle. Even with the second quench cycle, final dimensions have not been obtained. In order to move ahead with the production of the Dresden 2 vessel, each of the four shell sections have been cut, resized and rewelded, using conventional submerged arc processes to meet the specification requirement.

The significance of this experience is that until dimensional control can be reliably predicted to preclude rework,

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Results of Visit (continued)

the advantages of electro-slag welding are lost. B&W currently is experimenting with the variables of the quench and temper cycle in attempts to achieve acceptable dimensional control.

2. Characteristics of Electro-Slag Welds

Electro-slag welding results in a coarse grain structure which requires further heat treatment to obtain acceptable physical properties. Typical properties of the weld metal and adjacent heat affected zones, as determined in full thickness, procedure qualification weld structures, were stated to be as follows:

Tensile Strengths - 90 to 95,000 psi

Impact Values (Charpy Tests)

Weld Metal	-	30 to 40 ft.-lb. @ 10°F
Weld Metal	-	57 ft.-lb. average @ 40°F
Heat Affected Zone	-	50 to 54 ft.-lb. @ 40°F
Base Material	-	64 ft.-lb. average @ 40°F

Drop Weight Tests
Weld Metal - +20°F @ the ¼-T thickness

3. Other B&W Process Information

a. Forming at B&W is performed hot (1700 to 1800°F) using a roll-type press. With the large Dresden 2 type vessel plates, some difficulty has been experienced in maintaining a uniform diameter because of sagging. Thinning of the plate has also occurred. These areas are being corrected by improvements in rolling techniques and cold forming to final shape.

b. A minimum of machining is performed by B&W. Machining is primarily limited to the flanges, lower head rod drive hole penetrations, and some edge preparation of the completed shell sections. Machining to final dimension of the shell sections or plate edge preparation of shell segments are not routinely performed.

c. In addition to the usual code required nondestructive tests, B&W performs the following in excess of the code requirements:

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Results of Visits (continued)

(1) Shear wave ultrasonic testing of all plate material with 100% coverage. The latest G-E specifications require all plate ultrasonic testing after forming.

(2) All electro-slag welds ultrasonically tested.

(3) Cladding to base metal bond, ultrasonically tested.

(4) Acceptance standards for all type of nondestructive tests in general are more restrictive than code.

d. Radiography is being performed by both gamma-ray and linear accelerator. Up to the present time the linear accelerator has been available only 20% of the time due to initial installation and calibration efforts.

e. B&W has spent considerable time and money in providing first-class tooling and handling fixtures throughout the shop. This may be expected to pay off in time savings and a better quality product as the process is refined.

f. B&W reports a progressively lower quality in plates as received from the plate vendor (Lukens Steel, the sole industry supplier). It was noted that 20% of the Dresden 2, 50% of the Dresden 3, and up to 70% of the Quad-Cities 2 plates did not meet the B&W purchase specifications. According to B&W, this problem was the result of a lower acceptance standard employed by the steel supplier. The significance of this information is that more repair work must be performed on the plates by B&W to meet the G-E specifications. Higher costs result from this procedure.

4. Status of Vessels in B&W Shop

a. Dresden 2 - all four shell sections assembled to specification dimensions, two shells clad with work in progress on the third. Installation of nozzles in the bottom shell section was in progress. None of the shell sections have been welded together. Assembly of the bottom head orange peel sections was complete. Work was being performed on the core support structure in the lower head. Scheduled delivery date of the completed vessel is December, 1967.

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Results of Visits (continued)

b. Three other G-E vessels (Dresden 3 and Quad-Cities 1 and 2) were in preliminary shell forming and plate inspection stages.

c. The Rochester Gas and Electric Company vessel, the only Westinghouse contract, is less than 50% complete. Noteworthy is that no electro-slag welding is being performed on this thicker-walled vessel (PWR). Also noted was that the upper shell section containing all the primary system nozzles was a forging in contrast to the usual plate formed shell section. Delivery of this vessel is scheduled for late 1967.

B. Visit to Combustion Engineering, November 2

1. Process Considerations

a. In contrast to procedures used by B&W and CB&I in heavy vessel fabrication, CE makes extensive use of machining. All major weld surface preparations are machined to a specific joint design, including both longitudinal and circumferential seams. Internal and external surfaces are machined to dimension (½" excess metal allowed on each side for removal) as a routine practice. CE states, however, they will not always adhere to surface machining if the design and specifications will allow alternate fabrication procedures.

b. Forming is performed hot as at B&W. Quench and tempering of the individual plates are performed after forming but before welding into a ring section. Cold forming of the individual plates to final shape is performed after quench and temper. If dimensional problems occur (out-of-roundness or weld distortion) during the shell ring assembly, CE does not have roll presses or hydraulic jacking equipment for reforming. CE states they control this area through careful design of weld joints and welding procedures, use of conventional submerged arc welding, and machining. On a few occasions, CE has resorted to furnace heating to produce sag to correct out-of-roundness; however, this procedure, as well as jacking, is considered ineffective and unreliable. They state they have had few

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Results of Visits (continued)

problems in this area, although will not guarantee better than code performance.

2. Code Considerations

With the exception of ultrasonic testing of welds, which is not performed routinely, CE also performs the additional tests as described above (Section 3.c.(3)). It has been observed that CE employs a high degree of intermediate testing, principally magnetic particle, to assure that the final product will meet code requirements. In this respect, CE exceeds code.

3. Radiography Procedures

The following table lists the six devices used by CE in performing radiography, the general application range and the sensitivities obtained.

	Equipment	Material Thickness Range (Inches)		Sensivity
		Routine	Extreme	Obtained
a.	1 Million Volt X-ray Machine	3/4 - 6	1/2 - 7 1/2	3/4 to 1%
b.	Cobalt 60 (Nominal 100 curie)	1 1/2 - 7	3/4 - 12	3/4 to 1%
c.	2 Million Volt X-ray Machine	1 - 9	3/4 - 12	1/2 to 1%
d.	Betatron (15 MEV)	4 - 14	2 - 16	1/2 to 1%
e.	Betatron (25 MEV)	3 - 14	1 1/2 - 20	1/2 to 1%
f.	Linear Accelerator (13 MEV)	3 - 18	1 - 26	1/2 to 1%

As noted, all devices are capable of meeting the minimum code requirements on sensitivity. The choice of which device is actually used is dependent upon the material thickness, economic and scheduling considerations.

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Results of Visit (continued)

4. Status of Vessels in CE Shop

a. Millstone

Machining of one shell section, cladding of a second, and installation of nozzles in a third were in progress. Completion of the vessel is scheduled for early 1968.

b. Indian Point 2

The two top shell sections had been joined, including the upper flange. Some of the nozzles were in place. This section was in the linear accelerator room for radiographing. The remaining sections of the vessel have been formed and are in varying stages of completion.

c. Carolina Power and Light Company

Rework of the former Malibu shell sections continues. Completion estimated at 30-40%.

d. Consumers Power Company (Palisades)

Welding of shell plates into ring sections and hemispherical heads still in progress. Completion estimated at 10-20%.

C. Visit to Chicago Bridge and Iron Company, Birmingham, Alabama, November 3

1. Purpose of Visit

The purpose of the visit to CB&I was to review the shop facilities and to discuss planned procedures in the field assembly of the Northern States Power Company Monticello pressure vessel. Since the Monticello vessel is to be the first nuclear field fabricated vessel and the first nuclear heavy wall vessel to be built by CB&I, an evaluation of the organization, the facilities and the proposed methods are considered necessary. The information which follows is reported to aid in this evaluation.

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Results of Visit (continued)

2. Process Considerations

Because of shipping limitations, the Monticello vessel is to be prefabricated in large segments in the Birmingham shops and the pieces shipped to the site for final in-place assembly. The principal variations from the usual shop procedures which will be utilized in the field by CB&I are the following:

a. All welding will be manual.

b. The circumferential welds will be performed in the vertical rather than the usual horizontal position.

c. Preheat and final stress relief will be performed in-place employing temporary structures.

d. Final machining to finish tolerances will be performed with temporary, vessel-mounted tooling.

e. Extensive use of ultrasonic testing (UT) equipment for in-progress weld quality control. CB&I has developed a method of using this equipment on hot surfaces at preheat temperatures (3-500°F).

f. All field radiography will be performed with a cobalt source.

All of the above procedures have been used by CB&I in the field fabrication of Section III vessels for petroleum companies. While the petroleum company vessels differ in material (A387-D vs A302-B), diameter and detail (nuclear vessels contain a substantially greater number of nozzles and penetrations, in addition to a large flanged head), the proposed techniques of assembly have been demonstrated as capable of meeting code requirements.

Other process considerations which differ from the practices of the other two vendors and which could affect the ultimate quality of the vessel produced are:

a. Plate material will be heat treated (quench and temper) in the flat condition and cold formed. In the case of the thicker orange peel head sections, two cold forming operations will be required to achieve final shape.

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Results of Visits (continued)

Stress relieving will be required after each cold forming operation.

b. The G-E specifications require 100% coverage, shear and longitudinal UT inspection by CB&I of the formed plate. CB&I will utilize the flat bottom hole acceptance criteria rather than the calibrated back reflection method used by CE.

c. Material test coupons (tensile and impact) will be prepared from the weld procedure qualification test plates rather than from production welded material. This procedure is acceptable according to code.

d. Very little, if any, shop machining will be performed. Weld edge preparations and nozzle cut-outs will be flame cut and hand ground.

e. No electro-slag welding will be used. Some automatic shop welding may be employed.

f. All nozzles, except one 2" drain nozzle in the lower head, will be installed in the shop. Radiographing may be performed by either a betatron or by cobalt source. The nozzle design provides for a large flange which allows the nozzle to vessel wall weld to be the approximate thickness of the vessel wall. This permits the use of source radiography because of the thinner weld cross section.

g. Roll-type forming equipment is available in Birmingham to correct out-of-roundness of the shell sections if required.

3. Organizational Considerations

a. CB&I

One of the strong arguments voiced by CB&I in support of field fabrication is the high degree of on-the-job inspection. For the Monticello vessel, a welding supervisor is to be assigned on the job 24 hours a day, is to inspect each welding pass (a circumferential weld requires in excess of 200 passes), and is to supervise six to eight welders. This degree of supervision

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Results of Visits (continued)

is substantially greater than normally assigned to conventional work and will be used both in the shop and field.

It was noted that the CB&I organization does not have an independent inspection or quality control department. Production personnel perform the inspection work although the individual performing the inspections does not make the decision as to disposition or correction of flaws. This decision is made by engineering personnel.

b. G-E

To assure specification conformance, G-E will assign two full-time inspectors to the Monticello site and one to the Birmingham shop. From past association with these inspectors, only experienced and well qualified individuals are placed in these positions.

Other G-E efforts to assure a high quality job is insistence upon a "traveler" type of record system used by the other two vendors. This type of system helps to assure orderly procedural conformance and documentation of each step of the fabrication cycle. The system will be required in both field and shop. A distinct lack of any kind of written record in the CB&I shop was observed on conventional work.

G-E also expresses concern over the suitability of cobalt source field radiography. To obtain greater assurance of adequate sensitivity, G-E will require penetrameters with 1-T holes, as well as the larger code specified 2-T to 4-T holes. The acceptance standard will require that the 1-T hole be visible.