S. Levine

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Memorandum

TO : Files
(THRU) Roger S. Boyd, Chief
Research & Power Reactor Safety Branch

DATE: June 28, 1966

FROM : M. K. Woodard, Research & Power Reactor Safety Branch
Division of Reactor Licensing

SUBJECT: BABCOCK & WILCOX SEMINAR ON REACTOR PRESSURE VESSELS

On June 14 and 15, 1966, the Babcock & Wilcox Company (B&W) held a seminar for the AEC and its consultants concerning all aspects of the design, manufacture and use of nuclear reactor pressure vessels. The two-day seminar was held at B&W's new nuclear vessel plant located at Mt. Vernon, Indiana. The following persons from DRL and the ACRS were present:

R. L. Doan	DRL	H. Etherington	ACRS
S. Levine	DRL	J. Palladino	ACRS
K. Goller	DRL	S. Bush	ACRS
K. Woodard	DRL	H. Morison	ACRS
C. G. Long	DRL	C. Zabel	ACRS
R. Maccary	DSS	H. Mangelsdorf	ACRS
A. Holt	DSS	A. O'Kelly	ACRS
		R. Fraley	ACRS Staff

Attached to this memorandum is a copy of the text of oral presentations made by members of the B&W staff. Those present from the AEC and ACRS participated in a question and answer session after B&W's presentation of each topic. Informal sessions were held after dinner on June 14 concerning the materials, fabrication and design of nuclear vessels. Information of interest in the review of nuclear vessels which resulted from these discussions (not contained in the attached text) is presented below.

Design

Dr. Doan asked what role the customer played in the design of the vessel. Mr. Harvey stated that the customer usually specifies the dimensions, pressure and temperatures along with the transients, required by Section III of the ASME code, to which the vessel will be subjected during its lifetime. B&W will then work hand-in-hand with the customer to establish nozzle thickness and location. The customer is always given an extensive document of the stress analysis. It has been B&W's experience that the customer usually checks the methods of stress analysis and even the numbers. Dr. Zabel suggested that perhaps an independent group should check the design who was not "in on" the original design effort. His reasoning was that, if the same model was used, the same inaccurate answer would result. Mr. Harvey stated that in practice the customer uses a code to check their work which utilizes a slightly different model.

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B&W explained that in the past the specified transients had changed many times as the reactor design progressed, causing serious delays in the vessel fabrication.

Dr. Palladino was concerned that if B&W was selected to design an entire plant who would check the design. B&W stated that, as in the case of the USS SAVANNAH, several organizations (some within B&W itself) checked the results. Dr. Palladino also asked if the customer specified piping movements and forces. B&W insists that the customer provide such forces at the nozzles but does not perform an analysis to check that these forces are correct for any particular reactor system.

Dr. Bush asked if loads other than static loadings required by Section III are considered. In particular, he was concerned with rapidly applied loads which could result from an earthquake or rod ejection. B&W stated that earthquake loads are always considered but that shock loadings are not specified by the customer in the design and are not analyzed. B&W was not aware that its customers were performing their own analysis of rapid loading, as in the case of rod ejection accidents. Mr. Levine asked how B&W felt about its customers performing their own analysis on the vessels. B&W stated that, since they had not developed a code for such calculations or performed experiments, the customer could probably do as good a job as they could.

Dr. Doan asked who selected the material to be used. B&W stated that they usually selected the material but the customer can select the material if B&W determines that it meets all design requirements. Dr. Doan also expressed concern that perhaps the design transients specified by the customer did not factor in certain transients not common to conventional uses of pressure vessels. These would include safety injection and other cold water perturbations. K. Woodard inquired if safety injection, for instance, had been considered in the design specifications. B&W stated that 10 such injections had been specified for some PWR designs but that no analysis was performed for safety injection after a complete loss of coolant accident. B&W stated that many problems exist with fatigue in the base material and injection nozzles during safety injection of cold water.

Dr. Bush asked who was responsible for design of reactor internals. B&W stated that they designed only the supports and that the customer supplies all loads, moments and shears for the support. These loads include those resulting from water hammer and check valve slamming, etc. Dr. Bush pointed out that perhaps those forces were more of a conventional nature and that perhaps the customer was again not designing for nuclear type accidents. B&W did state that they do perform a more conservative analysis in the design of nuclear vessels. Dr. Palladino was informed that

extrapolation in size or "scale up" did not appear to be a problem but that they were proceeding with caution.

Evening Seminar - Design

During the evening session the areas of design and stress analysis were discussed further. Dr. Doan asked if standardization would eventually be achieved. B&W stated that in the case of BWR reactors there is very little difference in the design. PWR's, on the other hand, seem to vary considerably for each plant. This variance does not cause a problem in the lead time for ordering the base materials since, knowing the size, they can "ball park" the size of plate material needed. Most of the critical design work is in the nozzles, especially the fatigue analysis. B&W has had serious problems arise requiring redesign after material has been ordered or fabrication begun. For example, they cited that since the power blackout last year, the customer now wants his vessels to be designed to endure the type of thermal transient which would ensue in restarting the plant rapidly.

Dr. Doan asked what level of confidence B&W placed in their stress analysis. B&W stated that they always insisted on a shop hydro which was invariably instrumented sufficiently to prove the design. In looking to the future B&W stated that higher strength steels would probably be used. This would reduce the thickness of the vessel and possibly result in more accurate stress analysis work. New steels will always be developed in full scale shop tests. The higher strength steels must be used if pressures and diameters exceed those in the present designs. If the nuclear industry goes to supercritical steam applications new steels must be developed.

Dr. Dohrman of the B&W experimental staff discussed the advances in analysis capabilities which have come out of the computer age. Equations and mathematical relations 100 years old have only recently been solved in conjunction with complex design problems. Unfortunately, he explained, the trend toward thicker walled multi-nozzle vessels, more severe use cycles and rapid thermal transients has not allowed the computers to entirely replace experimental models. B&W is hopeful of developing computer codes which can be used to predict strains in the plastic region. With this technology, design for fatigue failure around nozzles and weldments would be greatly simplified.

As a result of the DRL staff's safety analyses of PWR's, the applicant has agreed to provide a core drop support structure in the vessel bottom below the core. K. Woodard asked if B&W had been involved in the design of this structure as it could affect the stress analysis. B&W stated that they perform the design of this support. Mr. Woodard was also interested in the results provided by one applicant which indicated that

in a loss of coolant accident, safety injection could cause a 4-inch crack in the vessel. B&W was not aware of this analysis.

Dr. Palladino asked what part B&W assumed in the specification of a surveillance program. B&W stated that the surveillance program is specified by the plant designer; however, B&W makes recommendations for each vessel design. B&W is not required to follow the life cycle of the vessel. B&W does check the customers' design criteria to make sure that they have not neglected any important considerations. They have programs in their own labs for development of expected parameters, such as nvt, which could affect design.

Quality Control

The second day quality control and inspection were discussed. B&W discussed non-destructive testing and emphasized that their techniques surpassed the code requirements. However, B&W explained that they considered the code requirements to be adequate and that they went beyond the code to assure that a component was not rejected after considerable time and money had been expended.

The Ultrasonic Testing (UT) method of inspection was discussed. It was stated that UT was used to inspect 100% of the plate material, but weld metal clad is not inspected (except by dye penetrant methods) and no permanent records are kept except for defects which do not pass the inspection. Dr. Doan asked what B&W's experience had been in finding flaws in welds. B&W stated that when the UT indicated a flaw, it was there in almost all cases. Further, they can, by triangulation, locate within a few thousandths of an inch its location. B&W's experience with welding shows that it is about 99 percent effective which B&W stated is equivalent to about one bad inch per 1000 inches of weld.

Field fabrication was discussed and B&W indicated that the cost of the vessel would be much higher than if it were fabricated in the shop. The time to complete such vessels would be 2-1/2 to 3 years; whereas, the Mt. Vernon plant is designed to complete large vessels in 1-1/2 years. Construction of the vessel can begin as soon as the foundation is complete. All necessary stress relief and tempering can be done at Mt. Vernon before the components are shipped to the site. No new weld technology is required and each type of weld will be fully qualified and tested full scale in the laboratory before field use.

Conclusion

At the conclusion, Dr. Doan was interested in B&W's thoughts on the development of prestressed concrete pressure vessels which could possibly

replace steel vessels. B&W stated that there appeared to be obvious advantages for lower pressure gas cooled reactors but they doubted that concrete vessels could be used for the high pressure water reactors. They argued that on a cross sectional area basis concrete did not seem feasible since an equal amount of steel would be required.

The seminar was very informative and confirmed that a considerable degree of extrapolation of size and usage is taking place rapidly in the nuclear vessel industry. It appears that B&W's design methods, use of materials and quality control methods surpass the requirements of the ASME code requirements and should assure a high quality vessel for nuclear use. The only obvious shortcoming appeared to be that the customer has not fully specified to B&W that the vessel must be capable of withstanding certain loadings, which could exist under accident conditions.

Attachment:
"Reactor Vessel Design and
Construction Seminar,
June 14-15, 1966"

Distribution:
R&PRSB Reading
DRL Reading
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Tech. Publications Unit.
175 Curtner Ave. San Jose, Calif.

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