UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUN 7 1980

Docket Nos.: 50-329/330

APPLICANT: Consumers Power Company

FACILITY: Midland Plant, Units 1 and 2

SUBJECT: SUMMARY OF THE MAY 23, 1980 MEETING ON PRESERVICE FAILURE OF THREE REACTOR VESSEL HOLD-DOWN STUDS

On May 23, 1980 the NRC staff and its consultants met in Bethesda, Maryland with representatives from Consumers Power Company (the applicant), Bechtel, Babcock & Wilcox (B&W) and Teledyne to review three reactor vessel holddown studs which have failed during preservice at the Midland Plant, Unit 1. This meeting follows an earlier meeting on May 2, 1980 with the NRC's Office of Inspection and Enforcement (I&E) in which I&E noted that any remedial actions whereby the studs would not be used in their original intended design would have to be reviewed by NRR. Meeting attendees are listed in Enclosure 1. Enclosure 2 is the meeting agenda.

Background

The holddown design for the Midland reactor vessels is shown on Slides 1, 2 and 3 of Enclosure 3. Further detail is shown on FSAR Figure 3.8-30. The design utilizes 96 anchor studs, each 7 feet 4 inches long and 2 1/2 inches in diameter, embedded vertically in the reinforced concrete reactor vessel pedestal and arranged in two concentric rows of 48 studs each. All studs were purchased by Bechtel to a modified version of ASTM-A354-66, Grade BD standards under Bechtel Specification 7220-C-223(Q), Rev. 3. The modification was a waiver of the maximum diameter allowed in the 1966 version for Grade BD bolts. The studs for Midland Unit 1 are nominally AISI 4140 and 4145, while the studs for Unit 2 are all nominally AISI 4340. Stud failure has occurred in Unit 1 only. The Unit 1 failed studs were purchased from Mississippi Valley Structural Steel of St. Louis, Missouri and fabricated by Southern Bolt and Fastener of Shreveport, Louisiana. The stud material originated from Bethlehem Steel and the studs were heat treated by J. W. Rex of Lansdale, Pennsylvania.

The studs were received on site by Bechtel in early 1976, embedded in Unit 1 concrete by Bechtel in April 1977, and tensioned by B&W on July 26, 1979 with a Biac anchor bolt tensioner. Each stud was preloaded to an initial nominal stress of 75 ksi in the unthreaded region (A=4.9 square inches) before relaxation losses are taken into account. It was intended to obtain

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a final pretension of 55 ksi. The initial prestress force should have been calculated on the basis of the effective tensile area (A=4.0 square inches) of the threaded region. This error resulted in a higher than planned preload, 92 ksi. The allowable design stress of the material, 105 ksi, was not exceeded.

As shown on Slide 2, the vessel skirt design also includes shear pins, 2 inches in diameter and 6 1/16 inches in length, to transmit lateral loads to the 5 1/2 inch thick annular sole plate segments beneath the skirt. Shear lugs are welded beneath the sole plate. Lateral and torsional loads therefore, are resisted by friction, bearing, shear pins, and shear lugs, and transmitted to an inner ledge of the primary shield wall. The studs are intended to resist overturning moments and uplift forces acting on the reactor vessel, such as would result from a loss of coolant accident located so as to pressurize the reactor vessel subcompartment.

Failure History

The identification of individual studs relative to position on the reactor vessel skirt are indicated in Slide 4 of Enclosure 3. The points of failure along the length of the three failed studs are shown by Slide 5.

On September 14, 1979 as B&W personnel were installing jam nuts on the anchor bolts, it was discovered that the stud and nut of stud 3 (inside row) were missing. A search by Bechtel personnel recovered the stud fragment on September 18th. Several minute dimples on the surface of the reactor vessel were caused by the ejection of the stud at the time of the spontaneous failure. A second failed stud (number 36, outside) was discovered on December 19, 1979.

On February 5, 1980, an I&E Regional Inspector visiting the site to observe the first two broken studs noticed that stud 35 (outside row and adjacent to failed stud 36) was off its seat about an inch. The stud was removed during the week of March 31, 1980 and was observed to be broken about 1/2 inch below the top of the bottom heavy hex nut. (Note: to prevent the studs from bonding to the concrete, a bond breaker was used from the top of the bottom anchor plate to the upper threads - the breaker consisted of Pennzoil lubricant No. 952 and Visqueen.)

Investigations

Shortly after the initial failure, the applicant enlisted the services of Teledyne Engineering Services of Waltham, Massachusetts for testing to determine the cause of the failures. Results of the Teledyne efforts to date were summarized by Dr. William Cooper. Tests and inspections for the first failed stud were:

1. Visual and non-destructive examinations, including dye penetrant, magnetic particle and ultrasonic techniques.

2. Tensile tests for ultimate and yield strength, reduction in area, elongation, modulus of elasticity.

3. Charpy V notch impact energy and lateral expansion.

4. Plane strain fracture toughness (K_{IC}).

5. Hardness.

6. Chemical composition.

7. Microstructure analysis.

8. Fractography.

The second stud failure occurred during the course of the above investigation and the failed end was forwarded to Teledyne for investigation. Tests 1, 5, 7 and 8 above were performed for the second failed stud. A hardness survey on all remaining vessel anchor studs was performed in both Unit 1 and Unit 2.

Results of the tests for the first two failed studs are reported in Teledyne technical report TR-3887-1, Rev. 1, "Investigation of Preservice Failure of Midland RPV Anchor Studs", May 15, 1980 which was submitted by the applicants letter of May 16, 1980. The metallurgical study test results for the third failed stud will be reported before the end of June 1980 by Addendum 1 to TR-3887-1, Rev. 1.

The Rockwell hardness tests (HRC) performed by Teledyne behind the fracture surface and on the ends of the failed studs indicated a significant hardness gradient across the diameter of studs 35 and 36. It is also believed that a gradient exists along the axis of the studs. However, stud 3 had no hardness gradient across its diameter nor along its length. Teledyne concludes that the maximum permissible surface hardness for the Unit 1 or Unit 2 material should be 41 HRC for the specified maximum center hardness of 38 HRC. Results of the hardness traverse across the diameter of the three failed studs are shown on Slide 6 of Enclosure 3. Field hardness testing of the remaining studs of Unit 1 and Unit 2 show that some of the Unit 1 studs also have a hardness gradient, but none of the Unit 2 studs exhibited a gradient. The Unit 2 studs had a nominal hardness of 38 HRC, for which 14 were at this nominal value, 42 were softer, and 40 were harder.

The Teledyne reports indicate that the failures resulted from stress corrosion cracking which propagated to the point that the studs failed by cleavage fracture. The decreased resistance to stress corrosion resulted from excessive surface hardness. The crack originated as a very small surface discontinuity such as that typical of surface oxide film cracking or corrosion pitting. The corrosive environment may have been humid air. The root cause of failure, i.e., the cause of the excessive hardness, has not yet been established.

Special inspections have been conducted by I&E to review the applicant's records for the Units 1 and 2 vessel anchor studs. I&E has also attended meetings with the applicant and Southern Bolt and Fastener Corporation and Mississippi Valley Structural Steel. Inspector C. M. Erb summarized findings regarding contents of the Bechtel purchase specification, noted that Charpy V notch results were provided for information purposes only and were below the foot pound and lateral deformation requirements, expressed concern that 19 of the Unit 2 bolts were above the 38 HRC level, described the modification in minimum shank size allowed by Bechtel, and explained the stud quenching procedure used. These items are discussed in IE Inspection Report 50-329/80-05; 50-330/80-05, attached as an appendix to this meeting summary.

Applicant's Remedial Actions and Acceptance Criteria

The applicant noted that the stud deficiency for Unit 1, if not corrected, could adversely affect plant safety. Therefore, for Unit 1, the applicant proposes to detension the remaining studs and to modify the vessel support concept so that the studs are used, but are subjected to reduced service stress. The revised support concept would modify the existing A-36 shield plug support brackets which would be shimmed tight (a 1/32 inch hot gap) to the reactor vessel to achieve additional lateral support. The revised concept is shown in Slides 7, 8 and 9.

The applicant's position is that the following criteria are acceptable for the Unit 1 studs:

> The Unit 1 RPV support studs are being detensioned, with the existing preload determined during detensioning. Retensioning is permitted if the average tensile stress computed on the basis of the nominal net cross-sectional area does not exceed 6 ksi. Short-term service loadings are permitted if the stress does not exceed 43 ksi, subject to the restriction that:
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> 1. When in detensioning a lower as-relaxed preload is measured, the short-term allowable stress value for all studs shall be reduced to one-half of the lowest measured detensioning load on any stud which is considered to contribute to load carrying capability in the new design concept.

2. The detensioning load may be increased above the prestress load required for nut rotation in order to determine the allowable short-term service stress.

For Unit 2, it is the applicant's position that these studs are acceptable for service in the manner originally planned. (Notwithstanding this position, the applicant also noted its intention to modify the lateral support brackets for Unit 2 as for Unit 1, although this modification for Unit 2 is for design enhancement purposes). Unit 2 will be detensioned to the original intended value appropriate to achieve the final value of 55 ksi.

The basis for the above positions by the applicant for Units 1 and 2 are developed in Teledyne report TR-3887-2, Rev. 1, "Acceptability for Service of Midland RPV Anchor Studs", May 20, 1980. The applicant requested that the NRC provide its position regarding the indicated criteria for Unit 1 and the applicant's position that Unit 2 is acceptable as-is. This initial information from the staff is needed so that the applicant can continue to develop the concept with reasonable assurance of the approach.

The applicant presented the preliminary results of forces and moments at the reactor vessel skirt support for various LOCA break types and locations. These results are shown in Slide 10. The analytical model and vessel foundation spring rate are shown in Slides 11, 12 and 13. The staff also noted that the upper lateral support design would require a finite element analysis of the interaction of the vessel and bracket support.

The applicant noted that detensioning of the anchor studs began in April 1980 and is presently underway. To date, 29 studs have been detensioned. The actual tension in these, as determined by the lift-off force, are:

ksi	Quantity of Studs
54	1
56	1
63	1
≥ 72	26

The maximum lift-off force measured was 94 ksi and the average value for the 29 is 81.85 ksi. Procedures for the detensioning process have included precautionary measures for personnel safety. Dr. Cooper predicted that additional failures for Unit 1 during detensioning may occur.

Future Activities

The applicant described plans for continued investigation of the failed Unit 1 studs. Anomalies are being identified and mechanisms to explain the anomalies will be developed and tested. Some of the anomalies identified at present are listed in Slide 14. The applicant is also checking for excessive hardness in bolts for other components and supports, including steam generators supports and pipe hangers.

The staff will comment within a few weeks on the applicant's criteria for Unit 1 and the applicant's finding of acceptability for Unit 2 studs.

By the end of June, the applicant will submit Addendum 1 to TR-3887-1, Rev. 1 providing test results of the third failed stud.

By the end of June, the applicant will submit a report describing the revised design to achieve additional lateral support of the vessel, including the design allowable stresses to be used.

The applicant will further describe analytical techniques in the autumn of 1980 and provide results of detailed analyses of the reactor vessel loads during the first quarter of 1981. Installation of the upper lateral supports is presently scheduled to begin about May 1, 1981.

Staff Conclusions

After a brief caucus, the staff acknowledged the applicants plans to pursue development of the lateral support concept and stated that it could see no reasons why such an approach cannot be successfully developed to fulfil the commitment in Section 1.5 of the PSAR. The staff expressed some concern for some of the Unit 2 studs which had hardness measurements in excess of 38 HRC and will consider this matter further. The staff also wishes to be advised of the results of the present detensioning effort, once completed.

Darl S Hood

Darl S. Hood, Project Manager
Licensing Branch No. 3
Division of Licensing

Enclosures:
1. Attendees
2. Agenda
3. Viewgraph Slides
4. Appendix: Fiorelli 3/20/80

cc: See next page

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ENCLOSURE 1

ATTENDEES

MAY 23, 1980

NAME	ORGANIZATION	TITLE
Darl Hood	NRR/DOL/LB#3	Licensing Project Manager
Dennis M. Budzik	CPCO	Midland Project Manager
John Rutgers	Bechtel	Midland Project Manager
Jim Cook	CPCO	VP-Midland Project Manager
G. Fiorelli	Region III	Branch Chief
A. J. Cappucci	NRR/DE/MEB	Midland Reviewer
D. Yuan	Bechtel	Midland Civil Engineer
M. Elgaaly	Bechtel	Assistant Project Engineer
W. Belke	NRC/QA Branch	
C. D. Sellers	NRC/MTEB	
R. Bosnak	NRC/DE/MEB	
C. M. Erb	Region III	Reactor Inspector
R. E. Schewmaker	NRC/IE	Senior Structural Engineer
Pao C. Huang	NAVSWC	Consultant
Frank Rinaldi	NRR/DE/SEB	
Frank Schuer	NRR/DE/SEB	
Geoff Egan	Aptech. Engineer Services	Technical Director
Randy Howard	B&W	Task Engineer Loading Analysis
Roland Reed	B&W	Assoc. Project Manager
W. R. Bud	CPCO	QA Department Manager
T. R. Thiruvengadam	CPCO	Section Head Civil Engineer
H. L. Brammer	NRC/DE/MEB	
H. W. Slager	CPCO	Section Head Materials Engr.
W. G. Dobson	Teledyne	Project Manager
P. C. Hearn	CSB, DSI, NRR	
W. E. Cooper	TES	Consultant Engineer
S. Hou	NRC/DE/MEB	
J. P. Matra, Jr.	NSWC/WO	Consultant
W. S. Hazelton	NRR/DE/MA	

ENCLOSURE 2

PROPOSED MEETING AGENDA
REACTOR ANCHOR STUDS
Friday, May 23, 1980
At 9AM
PHILLIPS BUILDING - ROOM P-114
BETHESDA, MD

I. Opening Remarks (JWCook/DHood) - (10 minutes)

II. Reactor Vessel Anchor Studs

A. Description of Hold-down Design and Criteria (TRT) - (20 minutes)

B. Background of Anchor Bolt Occurrences (HWS) - (10 minutes)

C. Results of Teledyne Investigations (HWS/WEC) - (90 minutes)

1. Investigations of first two failed studs
2. Investigations of the third failed stud
3. Conclusions as to cause of failure
4. Acceptability of the Unit 2 studs
5. Allowable stresses for the Unit 1 studs

D. Proposed Unit No 1 RV Support Design Revision (TRT/ME) - (30 minutes)

III. Investigations and Findings of Other Areas of Plant (HWS) - (20 minutes)

IV. Administrative Aspects of NRC Review (DMBudzik) - (30 minutes)

ANTICIPATED ATTENDEES

Consumers Power	Bechtel	B&W	Teledyne	APTECH
WRBird	BDhar	JGalford	WECooper	GEgan
DMBudzik	MElgaaly	CEMahaney	WGDobson	
JWCook	JARutgers			
HWSlager				
TRThiruvengadam				

CC: WRBird
DMBudzik (30)
JWCook
HWSlager
TRThiruvengadam