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Program: Materials and Structures

DOE Task: 26 - LMFBR Flexible Pipe Joint Development

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MASTER

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I. PROJECT OBJECTIVES

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The primary objective of the Flexible Pipe Joint Development Program is the qualification of a PLBR-size primary loop flexible piping joint to the ASME B&PVC rules which are currently under development in conjunction with this program. Achievement of this primary objective requires significant efforts in several areas. These areas include: (1) the support of ASME Code rules for the design and construction of flexible piping joints; (2) the design of a PLBR-size gimballled flexible piping joints; (3) the development of a lubricant system for the hinge assembly of the flexible piping joint; (4) the development of manufacturing techniques for fabrication of PLBR-size bellows and flexible joint hardware; (5) the developmental and verification testing of subscale bellows in support of the ASME rules; and (6) the qualification testing of a PLBR-size gimballled flexible piping joint in an elevated-temperature sodium environment. Completion of efforts will culminate in the acceptance of a PLBR-size flexible joint design to the approved ASME Code rules governing these components.

II. PROGRESS DURING REPORTING PERIOD

A. Class 1 FLEXIBLE JOINT CODE APPROVAL SUPPORT

A methodology for accelerating elevated temperature life tests of bellows was established which relies on demonstrating equivalence of predicted damage between the actual service histogram and a basic test histogram. These predicted damages are computed using the failure definitions in Code Case 1592 and a consistent analytical method. Depending on how the predicted damage compares to the acceptable damage per Code Case 1592, a demonstration factor is established for the basic test histogram which dictates how many times the test histogram must be imposed on the expansion joint without failure for the design to be acceptable. This demonstration factor reduces to the Appendix II test factors for low temperature service when the failure mode is either strictly creep or fatigue.

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An interim two day meeting of the TF Class 1 Bellows was held at AI to discuss this proposed revision to the life testing rules and other items pertaining to the Code Case design rules. The proposed revision was well received by the Task Force and will be included in the next draft of the rules. Bob Swindeman of ORNL who had previously commented on accelerated testing difficulties could not identify any specific shortcomings of the proposed approach, however, he would need more time to examine the implications of the approach. Bob Campbell of EDAC presented a summary of his efforts for AI on accelerated testing and was quite active in discussion on the subject.

Dr. Porowski of O'Donnell and Associates discussed a proposed revision to the creep bounding technique he has previously completed for AI. The revision extended the applicability to loadings with cyclic primary stresses, however, it was fairly conservative and further work would be needed to make the technique a more practical design tool.

Other discussions centered on the secondary pressure boundary criteria and written comments received from reviewers of the Code Case. Due to a comment suggesting more definitive guidelines be provided for acceleration of the pressure demonstration tests (as was done for the Life Tests) and a need by some attendees to further digest new revisions, it was agreed to not submit the Code Case for WG-PD approval at June Code week. Nevertheless, the progress made at this interim meeting was very encouraging and it should result in a considerably better Code Case for submittal to the higher committees.

Action Items were accepted to revise the Code Case per the meeting discussions and prepare a position paper supporting particular details of the proposed accelerated testing methodology.

Meeting minutes were prepared and sent to the chairperson for approval prior to mailing out to the attendees.

B. ENGINEERING AND DESIGN

The subscale bellows drawing and assembly drawing (including the flanges) were revised for the shorter end-tangent.

The CRBRP Thermal Transient event descriptions contained in the flexjoint design requirements, document N112TI240003, were combined and enveloped to provide

a worst case design histogram for bellows screening analyses. The screening program used for bellows response predictions was extensively modified to account for: (1) fabrication tolerances, (2) differences in predicted values observed when comparing these to finite element results, (3) end tangent effects on end convolution behavior indicated by finite element results, (4) angulation and creep effects on stability indicated by previously developed stability prediction techniques, (5) parameter computations needed to utilize previously developed bounding techniques on creep ratcheting, and (6) stress intensity calculations considering sign and Poisson effects observed in finite element solutions.

Bellows design runs utilizing the above updated screening program were initiated and results compared to developed acceptance criteria per the proposed Code rules. Early indications are that inelastic solutions will be necessary to show adequacy with respect to the proposed strain limits. Also, the flow sleeves in the expansion joint will need to be considered as a restraint effect preventing bellows squirm under the postulated 100 psi pressure pulse Faulted event. All other design criteria appear to be easily satisfied utilizing elastic analyses. Upon selection of the tentative geometry, detailed finite element analyses will be employed to demonstrate design adequacy. An internal memo covering "Screening Rules for Full-Size Bellows" was completed, and this will be the basis for a topical report.

The expansion joint hardware was redesigned to afford better thermal stress resistance and stress screening calculation are underway to establish reasonable geometry for the followup thermal and stress finite element analyses. Three different layout concepts are being investigated at this time.

Data reduction of the subscale bellows pretest series (P) has been initiated. All data has been retriived and efforts are continuing to reduce it to a format indicative of information needed to establishing a meaningful Test Series 1.

C. MATERIAL DEVELOPMENT

1. Friction and Wear Tests

An internal memo covering "Selection of Bearing Materials for Commercial LMFBR Flexible Joint Applications" was completed, and this will be the basis for a topical report.

2. Fatigue Tests

Fatigue tests data of annealed Type 316 stainless steel were analyzed. The fatigue life of notched specimens was plotted as a percentage of smooth specimen life against the reduction of specimen thickness in the presence of notches (nominal notch depth = 2, 4, and 8 mils in 36-mil thick specimens). Figure 1 shows that there was a considerable reduction in fatigue life between 70° and 1000°F when the thickness was reduced only about 5%.

Similar fatigue tests were also conducted on annealed Type 321 stainless steel. Figure 2 shows that Type 321 is not as notch-sensitive as Type 316. Note also that Type 321 is more notch-sensitive at 1000°F than at 70°F.

Some additional tests will be carried out to substantiate the trends indicated in both Figures 1 and 2. Additional tests at other strain rates have been proposed.

D. COMPONENT VERIFICATION TESTING AND DEVELOPMENT SUPPORT

Testing on the Series P bellows was completed with a demonstration for the ASME Task Force on Class 1 Bellows. Large amplitude ($\pm 1\frac{1}{2}$ in.) axial strain cycling and pressurization to end tangent deformation failure (≈ 175 psig) were demonstrated. Movie footage was taken of this testing.

To reduce the overall test program time, Test Series 3 has been rescheduled ahead of Test Series 2. This will prevent a need for the MTS setup used in both Test Series 1 and 3 to be dismantled in order to setup for Test Series 2.

E. MANUFACTURING DEVELOPMENT

1. Subscale Bellows Procurement

The final unit of the initial subscale procurement from Metal Bellows was received. The units from Zallea Brothers are now scheduled for June receipt.

Bids for the procurement of 30 additional 12 convolution bellows and seven 30-convolution bellows (for stability testing) were received. These bellows will provide the units required to complete the subscale test program. The order will be placed in June with delivery this fiscal year.

Figure 1. Effect of Notch On Fatigue Life At 1.08% Strain Amplitude of Annealed Type 316 Stainless Steel

Figure 2. Effect of Notch On Fatigue Life At 1.08% Strain Amplitude of Annealed Type 316 Stainless Steel

The end tangent test bellows was received from Metal Bellows. Design for modification of the weld fixture for the shorter end tangents was completed. Modification of the tooling, welding of the flanges, and hydrostatic test to demonstrate the shorter end tangent should be completed next report period.

Quotes were received from Metal Bellows and Ametek-Straza for shortening the end tangents on their three test bellows. The bellows will be shipped to them with a hold pending outcome of the hydrostatic test.

2. Subscale Bellows Examination

Bellows S/N 008, the last production unit to be delivered, was visually examined for surface defects. Very minor defects were observed; however, dimples caused by their expanding die forming process are still detectable although less pronounced.

A portion of a test bellows has been potted and cut out for destructive examination including grain size determination, photo-micrographs and convolution profile measurements.

3. Weld Radiography Study

Welds on 0.036 and 0.062 stainless steel sheet stock failed to produce porosity (other than a pore or two) even though weld engineering performed the welds under the most adverse conditions. Attempts to drill 0.005, 0.007, and 0.010 pores in the welds did not materialize because the drills broke due to bushing clearance in the high speed motor utilized.

III. IMPACT ON LMFBR PROGRAMS

This project specifically addresses the use of bellows expansion joints in the primary loop of a large-scale LMFBR. Design and fabrication development, coupled with ASME approval of flexible joints, would allow minimization of primary piping runs and component-to-component spacing. The reduction in primary piping size is directly equatable to containment building size reductions and much reduced overall plant costs.

IV. SCHEDULE

The various activities and milestones for the Flexible Joint Development Program are shown in Figure 3. The schedule has been revised to reflect the impact of the shortened end-tangents required for the subscale bellows.

**FLEXIBLE JOINT DEVELOPMENT PROGRAM
GFY 1978 SCHEDULE (REVISED 6-12-78)**

FLEXIBLE JOINT DEVELOPMENT PROGRAM (CONTINUED)
GFY 1978 SCHEDULE (REVISED 6-12-78)

FLEXIBLE JOINT DEVELOPMENT PROGRAM (CONTINUED)
GFY 1978 SCHEDULE (REVISED 6-12-78)

ACTIVITY	GFY 1978												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
SUBTASK E — MANUFACTURING DEVELOPMENT													
E1. RECEIVE 3 SUBSCALE BELLOWS FROM VENDOR 1	E1 E1												
E2. RECEIVE 3 SUBSCALE BELLOWS FROM VENDOR 2				E2 E2									
E3. COMPLETE INSPECTION OF BELLOWS FROM VENDOR 1				E3 E3									
E4. COMPLETE INSPECTION OF BELLOWS FROM VENDOR 2					E4 E4								
E5. COMPLETE FABRICATION OF SUBSCALE BELLOWS ASSY. FOR TEST SERIES P					E5 E5								
E6. COMPLETE END-TANGENT TRIM OF END-TANGENT TEST BELLOWS									E6 E6				
E7. PLACE FULL TEST LOT SUBSCALE BELLOWS PURCHASE ORDER							E7						
E8. COMPLETE BELLOWS LONGITUDINAL WELD RADIOGRAPHY STUDY AND TESTS						E8							
E9. COMPLETE FABRICATION OF END-TANGENT TEST BELLOWS ASSEMBLY								E9					
E10. RECEIVE 3 SUBSCALE BELLOWS FROM VENDOR 3										E10			
E11. COMPLETE END-TANGENT TRIM OF VENDOR 1, 2, AND 3 SUBSCALE BELLOWS											E11		
E12. COMPLETE INSPECTION OF BELLOWS FROM VENDOR 3												E12	
E13. COMPLETE FABRICATION OF SUBSCALE BELLOWS ASSY. FOR TEST SERIES 1												E13	
E14. RECEIVE FULL-LOT SHIPMENT OF SUBSCALE BELLOWS FOR COMPLETE TEST PROGRAM													E14