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PLANT NAME:
Bellefonte 1 & 2

(1-P)

ENCLOSURE

"Pipe Rupture Analysis for Guard Pipe - Bellefonte Nuclear Plant" - October 6/76 - TVA Report CEB-76-25 -.

DO NOT REMOVE

(9-P)

ACKNOWLEDGED

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NRC FORM 195 (2-76)

830 Power Building

TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

NOV 15 1976

Regulatory Docket File

Director of Nuclear Reactor Regulation
Attention: Mr. Olan Parr, Chief
Branch No. 3
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Parr:

In the Matter of the Application of) Docket Nos. 50-438
Tennessee Valley Authority) 50-439

TVA met with members of the NRC staff on August 20, 1976, to discuss our request for an exemption from inservice inspection of high-energy fluid system piping enclosed in guard pipes. The NRC representatives involved in the meeting requested a formal submittal of an analysis summary showing that the Bellefonte containment would not be violated if the process pipe welds in question failed. Since the meeting, TVA has determined that "long" forgings will be used for process piping at the penetrations in question and thus eliminate the requirements for inservice inspection of the process piping enclosed by the guard pipe.

In accordance with your request regarding containment integrity, enclosed are 20 copies of TVA Report CEB-76-25, "Pipe Rupture Analysis for Guard Pipe - Bellefonte Nuclear Plant" for your review. TVA is now procuring the forging and the guard pipe and because of the impact that changes in this penetration design would have on plant construction schedules and ultimate fuel loading, we would appreciate the NRC completing their review by December 15, 1976.

We will be glad to answer any questions (in a meeting or by telephone) you may have related to this analysis.

Very truly yours,

H. Harris for

J. E. Gilleland
Assistant Manager of Power

Enclosure (20)
CC: Mr. James McFarland (Enclosure)
Senior Project Manager
Babcock & Wilcox Company
P.O. Box 1260
Lynchburg, Virginia 24505

11921

TENNESSEE VALLEY AUTHORITY

DIVISION OF ENGINEERING DESIGN

THERMAL POWER ENGINEERING BRANCHES

CIVIL ENGINEERING BRANCH

PIPE RUPTURE ANALYSIS

FOR

GUARD PIPE

BELLEFONTE NUCLEAR PLANT

October 6, 1976

CEB-76-25

Prepared by D. C. Phung ____________ Reviewed by ____________

Supervised by ____________ Recommended by W A English

Approved by ____________

TVA 10567 (DED-6-74)

COORDINATION LOG

Plant: BELLEFONTE NUCLEAR PLANT

Design Criteria No: CEB-76-25

Design Criteria For PIPE RUPTURE ANALYSIS FOR GUARD PIPE

Revision: R0

Thermal Power Engineering Branches						Thermal Power Design Project						Architectural, Hydro, & Special Projects Engineering & Design Branches							
MEB		EEB		CEB		Project Manager: R	Project Manager: A RMW					AD		ME&D		CE&D		EE&D	
						MD		ED		CD									
R	A	R	A	R	A	R	A	R	A	R	A	R	A	R	A	R	A	R	A
MWB	MWB			DMW	DMW														
	[illegible]			DCP	DCP														
LWL	Law			JMW	JMW	BCS	BCS			BIK	BIK								
GEG	GEG					BQM	BQM			RJD	RJD								
	[illegible] 3					JSB	JSB			LRM	LRM								
	DRF									CWH	CWH								
										CDD	CDD								

R — Denotes review

A — Denotes approval

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FOREWORD

On August 20, 1976, TVA representatives met with the Nuclear Regulatory Commission's Light-Water Reactors Branch No. 3, Division of Project Management, and discussed TVA's proposal to relieve the requirement for inservice volumetric inspection of high-energy fluid system piping enclosed in guard pipes. At this meeting, NRC requested that TVA submit an analysis summary which demonstrates that the containment boundary at Bellefonte is not violated by a break at an uninspectable weld.

Since the August 20, 1976, meeting, because of schedule concerns, TVA has decided to procure a "long" forging for the process pipe which will eliminate the seam weld and place the circumferential butt weld at least three pipe diameters from the centerline of rigid pipe anchors. Therefore, as stipulated in Table IWC-2520 of the ASME Boiler and Pressure Vessel Code, Section XI, inservice inspection of the process pipe-anchor interface welds will not be required for this type of design, and TVA's initial request for an exemption from the inservice inspection requirements is no longer applicable. However, NRC's concern related to containment integrity, should the process pipe fail at the rigid anchor, does need to be addressed even with the long forgings. The purpose of this attached analysis is to address the containment integrity concern. We believe the attached analysis demonstrates the adequacy of the penetration design to contain the effects of a circumferential or a longitudinal break and that the containment boundary will not be breached as a result of the postulated breaks.

1.0 PURPOSE

The purpose of this submittal is to present the design criteria and the analysis summary for the guard pipes for the main steam and feedwater lines.

2.0 SCOPE

The guard pipes addressed by this submittal are the guard pipes for the main steam and feedwater lines for the Bellefonte Nuclear Plant beginning at the secondary shield wall and penetrating through the primary containment to the flued head and from the flued head through the secondary containment to the main steam valve room wall (figure 2.0-1).

3.0 FUNCTIONAL DESCRIPTION

The penetration assembly (figure 2.0-1) shall have the penetration sleeve anchored in the primary containment wall and welded to the liner. A flued head shall attach the process line to the penetration sleeve, thereby restricting movement of the process line within the penetration sleeve. The process line in the penetration shall be insulated and the flued head shall be located at sufficient distance from concrete structures to prevent the surface temperature of the concrete adjacent to the penetration from exceeding 200 F.

A guard pipe shall encase the process line between the secondary shield wall and the main steam safety valve room wall or secondary containment structure. The guard pipe is an enclosing protective structure to ensure that a rupture in the process line will not pressurize the annulus between the containment walls or other subcompartments not designed for process pipe breaks, but will be exhausted to either the main steam valve room, or to the interior of the secondary shield wall. Excessive movement will be controlled by guides as indicated in figure 2.0-1. The radial guides limit the lateral motion of the guard pipe.

4.0 GENERAL DESIGN REQUIREMENT

The loads that are considered in the design of the guard pipe are as follows:

a. Internal pressure - The design pressure (P_g) shall not be less than the maximum operating pressure of the enclosed pipe under normal plant conditions.

b. Deadweight - The deadload shall include the weight of the guard pipe and any other permanently applied loads.

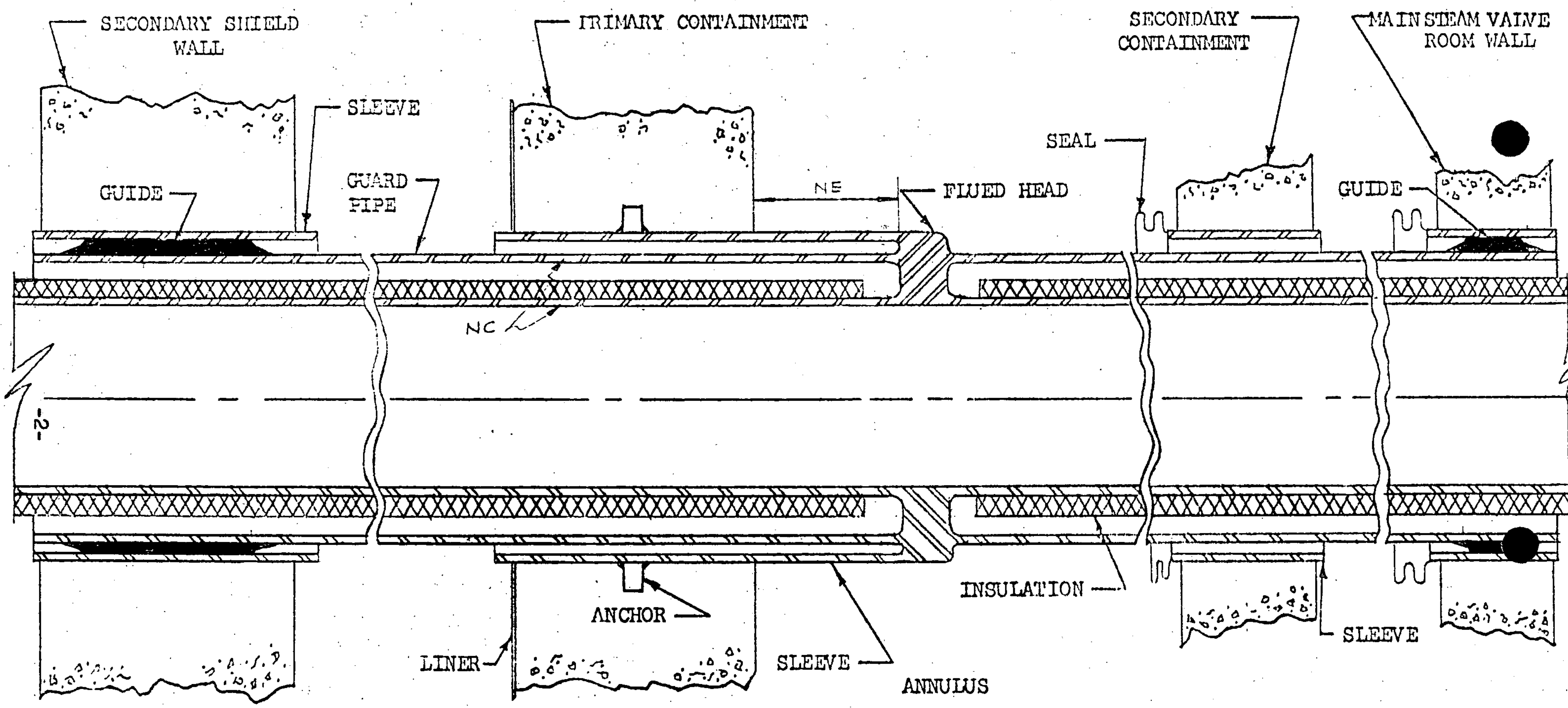

FIGURE 2.0-1, TYPICAL PENETRATION ASSEMBLY WITH GUARD PIPE, BELLEFONTE NUCLEAR PLANT

c. Thermal expansion - The design temperature shall not be less than the maximum operating temperature of the enclosed pipe under normal plant conditions.

d. One-half safe shutdown earthquake (1/2 SSE) - Includes inertial and displacement loading effects.

e. Safe shutdown earthquake - Includes inertial and displacement load effects.

f. Dynamic effects associated with rupture loads.

Seismic loadings are determined using response spectra techniques. It was assumed that there was zero clearance between the guides and the sleeves.

5.0 SPECIFIC DESIGN CRITERIA

a. Codes - The guard pipe is classified as seismic Category I and will be designed to the requirements of Subsection NC of Section III of ASME Code. The actual code classification and design requirements for the guard pipe shall be in accordance with Subsubarticle NE-1120 of ASME Section III. The analysis requirement of NC-3600 is an acceptable method for conducting the stress analysis of the guard pipe.

b. Load combinations - The load combinations considered in the design of the guard pipe are shown in table 5.0-1. The 1/2 SSE earthquake loads shall be considered as a normal load case for the design of guard pipe.

c. Stress limits - The stress limits will be in accordance with ASME, Section III, Subsection NC. The stress limits for the guard pipes addressed in section 6.0 of this report are shown in table 5.0-2. In addition to the rupture load conditions indicated in table 5.0-2, the following methods shall be utilized to account for the rupture condition loads:

(1) Provide a guard pipe whose wall thickness is equal to or greater than the process pipe, or

(2) Design the guard pipe on the basis that the circumferential strain due to pipe rupture loads is limited to 50 percent of the strain at ultimate strength (to account for hoop stresses). The comparisons are shown in section 7.0 of this document.

TABLE 5.0-1

SAFETY CLASS 2 LOADING CONDITIONS COMBINED IN ACCORDANCE WITH TABLE 5.0-2

	Load Combination	Equation Number
Normal	$P_g + D$	eq 8
	$P_g + D + E_i$	eq 9
	$T + S_d + E_d$	eq 10
	$P_g + D + T + S_d + E_d$	eq 11
Emergency	$P_g + D + E_{ii}$	eq 9
	$P_g + D + E_{ii} + F_j$	eq 9*

D = Deadweight load including pipe, and other permanently applied imposed loads

E = Seismic anchor displacement due to one-half of the displacement range for 1/2 SSE

E_i = Inertia load from the 1/2 SSE

E_{ii} = Inertia load from the SSE

F_j = Jet impingement or pipe impact load

P_g = Internal design pressure

S_d = Thermal support displacement load

T = Thermal expansion

*Including rupture loads

TABLE 5.0-2

ASME SECTION III EQUATIONS AND STRESS LIMITS FOR CLASS 2 GUARD PIPES

Load Condition		Equation from ASME Section III, NC-3650	Stress Limit	Equation Number
Normal	(1)	$\frac{P_g d^2}{D_o^2 - d^2} + \frac{0.75iM_A}{Z} \leq$	$1.0S_h$	eq 8
	(2)	$\frac{P_g d^2}{D_o^2 - d^2} + 0.75i\frac{(M_A + M_B)}{Z} \leq$	$1.0S_h$	eq 9
	(3)	$\frac{iM_C}{Z} \leq$	S_A	eq 10
		or		
		$\frac{P_g d^2}{D_o^2 - d^2} + \frac{0.75iM_A}{Z} + \frac{iM_C}{Z} \leq$	$S_h + S_A$	eq 11
Emergency	(1)	$\frac{P_g d^2}{D_o^2 - d^2} + 0.75i\frac{(M_A + M_B)}{Z} \leq$	$1.8S_h$	eq 9
	(2)	$\frac{P_g d^2}{D_o^2 - d^2} + 0.75i\frac{(M_A + M_B)}{Z} \leq$	$2.4S_h$	eq 9*

*Including rupture loads

TABLE 5.0-2 (Continued)

d = Inside diameter of guard pipe, inches

D_o = Outside diameter of guard pipe, inches

f = Stress range reduction factor for cyclic loadings from table NC-3611.2(c)-1, ASME Section III

i = Stress intensification factor, see Figure NC-3673.2(b)-1, ASME Section III, $i \geqq 1$, $0.75i \geqq 1$ for moment intensification

M_A = Resultant moment loading due to weight and other sustained loads, inch-pounds

M_B = Resultant moment loadings due to occasional loads E_i, for normal conditions, E_{ii}, for emergency conditions, and E_{ii} and F_j for emergency plus pipe rupture conditions, where E_i, E_{ii}, and F_j are as defined for table 5.0-1. (Note: Seismic anchor movement, E_d, is included in equations 10 and 11)

M_C = Range of resultant moments due to T, S_d, and E_d for normal conditions

P_g = Internal design pressure, psig

S_A = Allowable stress range for expansion stresses per NC-3611.2(c) and NC-3611.2(d) of ASME Section III $S_A = f\ (1.25S_c + 0.25S_h)$

S_c = Material allowable stress at minimum temperature from ASME Section III, 1974 Edition, Subsection NA, Appendix I.

S_h = Material allowable stress at maximum temperature from ASME Section III, 1974 Edition, Subsection NA, Appendix I.

Z = Section modulus of pipe, $inch^3$ as calculated per ASME code

6.0 DISCUSSION OF ANALYSIS

a. Selection of guard pipe for study - The process pipe enclosed by the guard pipes studied are:

   1. Main steam

   2. Main feedwater

   To adequately determine the responses of the guard pipes mentioned above due to the combined loadings indicated in section 4.0, it was determined necessary to analyze the guard pipes at penetrations X28 and X46. Based upon a comparison of all main steam and feedwater penetration assemblies, X28 and X46 were determined to be the limiting designs, for this consideration, due to their greater lengths (drawing Nos. 3BW0400SM01 and 3BW401CF01).

b. Structural model and analysis performed - The structural model for the guard pipe selected in section 6.0.a was analyzed for the loadings discussed in section 4.0. The guard pipe was considered as a statically indeterminate beam with a fixed end at the flued head.

   The maximum values of the response acceleration from both 1/2 SSE (damping ratio = 0.01) and full SSE (damping ratio = 0.02) was applied to obtain the seismic loads. These loads were uniformly distributed over the entire length.

   It was assumed that the circumferential rupture or longitudinal split could occur anywhere along the process pipe. The pipe rupture load was calculated by using the following equation:

   $$F_j = (1.26\ P_g\ A_b)(DLF)(SF)$$

   Where $(1.26 P_g A_b)$ is the blowdown force; $P_g \geq$ maximum operating pressure of the enclosed pipe; A_b = cross-sectional flow area of the enclosed pipe at the break location;

   DLF = dynamic load factor accounting for a rapid application of load was conservatively assumed equal to 2.0 for this evaluation; SF = target shape factor equal to 1.0 for this evaluation.

7.0 SUMMARY OF RESULTS

a. Stress results:

Main steam (penetration X28)

Stress (psi)	Normal Condition		Emergency Condition	
	Eq 9	Eq 10	Eq 9	Eq 9*
Calculated Stresses	7,884	4,136	7,517	37,417
Allowable Stresses	17,500	26,250	31,500	42,000

Main feedwater (penetration X46)

Stress (psi)	Normal Condition		Emergency Condition	
	Eq 9	Eq 10	Eq 9	Eq 9*
Calculated Stresses	5,867	3,039	5,821	33,796
Allowable Stresses	17,500	26,250	31,500	42,000

*See note 6 below

Notes: (1) Main steam guard pipe

Material = SA155 KCF70 CL.1
Outside diameter = 46 inches
Wall thickness = 1.625 inches

(2) Feedwater guard pipe

Material = SA155 KCF70 CL.1
Outside diameter = 32 inches
Wall thickness = 1.8 inches

(3) Equation 9 (normal condition)

$$\frac{P_g d^2}{D_o^2 - d^2} + 0.75i \frac{(M_A + M_B)}{Z} \leq 1.0S_h = 17,500 \text{ psi}$$

M_A = Resultant moment loading due to deadweight

M_B = Resultant moment loading from 1/2 SSE

(4) Equation 10 (normal condition)

$$\frac{iM_c}{Z} \leq S_A = 26{,}250 \text{ psi}$$

Where
M_c = Resultant moment loading due to seismic anchor displacement from 1/2 SSE

(5) Equation 9 (emergency condition)

$$\frac{P_g D^2}{D_O^2 - D^2} + 0.75i \frac{(M_A + M_B)}{Z} \leq 1.8\ S_h = 31{,}500 \text{ psi}$$

Where
M_B = Resultant moment loading from SSE

(6) Equation 9* (emergency condition)

$$\frac{P_g D^2}{D_O^2 - D^2} + 0.75i \frac{(M_A + M_B)}{Z} \leq 2.4\ S_h = 42{,}000 \text{ psi}$$

Where
M_B = Resultant moment loading from SSE and rupture load

(7) There is no thermal load inducing bending moments in this particular problem. Equation 8 in Table 5.0-2 has been enveloped by Equation 9 under normal conditions.

b. Wall thickness comparison

Wall Thickness (inches)		
Lines	Main Steam	Main Feedwater
Guard Pipe	1.625	1.8
Process Pipe	1.474	1.625

Wall thickness of guard pipe > Wall thickness of process pipe

c. Circumferential strain results

$\epsilon_{ultimate}$ = 0.21 inch/inch

$\epsilon_{allowable}$ = 0.50 x 0.21 = 0.105 inch/inch

ϵ_T (main steam) = 0.037 inch/inch < 0.105 inch/inch

ϵ_T (main feedwater) = 0.060 inch/inch $<$ 0.105 inch/inch

Where ϵ_T = Total calculated circumferential strain.

8.0 CONCLUSION

The main steam and main feedwater guard pipes for Bellefonte Nuclear Plant within the scope of this report were analyzed for the most critical condition resulting from the postulated circumferential rupture and longitudinal split in the process pipes. It is concluded that, when analyzed in accordance with the methods, procedures and assumptions as described in this report, the guard pipes are adequately designed to withstand the imposed pressure, deadweight, thermal, dynamic, and rupture loads.