TENNESSEE VALLEY AUTHORITY

DIVISION OF ENGINEERING DESIGN

THERMAL POWER ENGINEERING BRANCHES

CIVIL ENGINEERING BRANCH

REPORT ON

ANALYSIS OF BELLEFONTE MAIN STEAM GUARD PIPE DURING A POSTULATED PIPE RUPTURE

APRIL 15, 1979

BELLEFONTE NUCLEAR PLANT

CEB-78-14

REVISION 1

JUNE 16, 1980

TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

400 Chestnut Street Tower II

September 9, 1980

Director of Nuclear Reactor Regulation
Attention: Mr. B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Youngblood:

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

On July 21, 1978, TVA submitted Topical Report CEB-76-25, Revision 1, "Pipe Rupture Analysis for Guard Pipe, Bellefonte Nuclear Plant Units 1 and 2," for your review. Topical Report CEB-76-25 was revised to incorporate additional information requested by the NRC to allow a meaningful evaluation of the TVA penetration design.

In a letter from O. D. Parr to N. B. Hughes dated March 16, 1979, TVA was requested to provide additional information concerning Topical Report CEB-76-25, Revision 1. Enclosed is TVA's response and 25 copies of Topical Report CEB-78-14, Revision 1, "Analysis of Bellefonte Main Steam Guard Pipe During a Postulated Pipe Rupture," which is referenced by our response. TVA believes the analyses demonstrate that the loading has been justified and that containment integrity is protected considering the postulated rupture of the process pipe. Based upon this conclusion, TVA believes that the requested exemption from inservice inspection of welds in the main steam and feedwater process pipes enclosed by guard pipes should be granted.

TVA has already procured and installed the forgings and guard pipes described in the topical report. Because of the impact changes in this

B001 S/3/25

8009150 460

penetration design would have on plant construction schedules and ultimate fuel loading, we would appreciate an expeditious review of our response and the topical report. We will be glad to answer any questions you may have related to our response and the topical report.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Regulation and Safety

Sworn to and subscribed before me
this 9th day of Sept. 1980
Bryant M. Lowery
Notary Public
My Commission Expires 4/4/82

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

ENCLOSURE

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION
ON TOPICAL REPORT CEB-76-25, REVISION 1

1. Provide the methodology for determining the pipe impact loads required for evaluating the dynamic effects associated with pipe rupture. In Section 7(f) it is indicated that the impingement loads govern the design of the guard pipe insofar as the pipe rupture loads are concerned. Provide justification for arriving at this conclusion.

Response

A finite element analysis has been performed for the actual piping arrangement that shows that under the most adverse postulated break location process pipe impact on the guard pipe cannot occur. This conclusion is documented in Topical Report CEB-78-14, Revision 1.

2. In Section 9.0(b) the structural model of the guard pipe was given as a statically indeterminate beam. This model is considered to be inadequate in providing the stress levels developed from either the jet force or for a pipe impact load. A statically indeterminate, thick walled circular shell model appears to be more appropriate for this analysis. Determine the stress levels under the postulated rupture condition using such a shell model; or, alternatively, provide justification that the use of the statically indeterminate beam model results in more conservative calculated stress levels as compared with the circular shell model.

Response

Since the original analysis referred to in Section 9.0(b) of CEB-76-25, Revision 1, was performed, a more detailed analysis has been conducted. This analysis is a more rigorous finite element nonlinear dynamic analysis which considers the statically indeterminate beam as a shell structure. This is in accordance with the NRC recommendation.

The results of this analysis show that the computed stress levels are within allowable limits.

The results of this finite element analysis are documented in Topical Report CEB-78-14, Revision 1.

TENNESSEE VALLEY AUTHORITY

DIVISION OF ENGINEERING DESIGN

THERMAL POWER ENGINEERING BRANCHES

CIVIL ENGINEERING BRANCH

REPORT ON

ANALYSIS OF BELLEFONTE MAIN STEAM GUARD PIPE DURING A POSTULATED PIPE RUPTURE

APRIL 15, 1979

BELLEFONTE NUCLEAR PLANT

CEB-78-14

REVISION 1

JUNE 16, 1980

Prepared by J. David Loewus

Supervised by B B Neely

Submitted by P. A. Evans

Recommended by W. A. English

Approved by C. O. Barnett

S/SP309

Rev. I

TVA

Title: ANALYSIS OF BELLEFONTE MAIN STEAM GUARD PIPE DURING A POSTULATED PIPE RUPTURE	REVISION LOG

Revision No.	DESCRIPTION OF REVISION	Date Approved
1	General Revision	

TVA 10534 (EN DES-4-78)

TVA 10567 (DED-6-74)

COORDINATION LOG

Plant: BELLEFONTE NUCLEAR PLANT

Report No: CEB-78-14

Report On: ANALYSIS OF BELLEFONTE MAIN STEAM GUARD PIPE DURING A POSTULATED PIPE RUPTURE

Revision: 1

R — Denotes review

A — Denotes approval

Thermal Power Engineering Branches						Thermal Power Design Project						Architectural, Hydro, & Special Projects Engineering & Design Branches							
~~MEB~~ NEB		EEB		CEB		Project Manager: R	Project Manager: A RMH					AD		ME&D		CE&D		EE&D	
R	A	R	A	R	A	MD R	MD A	ED R	ED A	CD R	CD A	R	A	R	A	R	A	R	A
RHB	RHB			mks	MKS														
LAH	LAH			PMW	PMW														
	DTC					BCS	BCS			HRB									
FAK	FAK					JSB	JSB			[illegible]	RW								
	JCC										CWH								
	LAC																		
	[illegible]																		
	[illegible]																		
—	[illegible]																		
	[illegible]																		
	[illegible]																		

TVA 10567 (DED-6-74)

COORDINATION LOG

Plant: BELLEFONTE NUCLEAR PLANT

Design Criteria No.:

Design Criteria For ANALYSIS OF BELLEFONTE MAIN STEAM GUARD PIPE DURING A POSTULATED PIPE RUPTURE

Revision: 0

R – Denotes review A – Denotes approval

Thermal Power Engineering Branches						Thermal Power Design Project						Architectural, Hydro, & Special Projects Engineering & Design Branches							
MEB		EEB		CEB		Project Manager				R	A	AD		ME&D		CE&D		EE&D	
R	A	R	A	R	A						[illegible]	R	A	R	A	R	A	R	A
						MD		ED		CD									
						R	A	R	A	R	A								
RHB	[illegible]			DCP	DCP														
	LWL			KLM	KLM														
LAH	[illegible]					BS	BS			RJD	RJD								
TCP	TCP					JSB	JSB				CWH								
	[illegible]																		
	EEB ([illegible])																		
GJP	[illegible]																		
RJO	RJO																		

TABLE OF CONTENTS

LIST OF FIGURES

FOREWORD

Guard pipes are used in the Bellefonte Nuclear Plant to assure that, in the event of a process pipe rupture inside the guard pipe, the unacceptable pressurization of the annulus or other subcompartments inside containment does not occur.

Report CEB-76-25, Rev. 1, (reference 8.1) contains a chronology of correspondence exchanged between the Tennessee Valley Authority and the Nuclear Regulatory Commission. CEB-76-25, Rev. 1 also describes the design methods and analyses used to qualify the guard pipe for this particular application and a technical justificaton for the jet impingement loads used in the analyses. These analyses were patterned after the ASME Section III analyses requirements.

This report augments CEB-76-25, Rev. 1 in that it demonstrates the ability of all BLN main steam guard pipes to sustain pipe rupture loadings using a shell model type of analysis. The main steam guard pipes are similar in nature to the feedwater guard pipes.

1.0 PURPOSE

The purpose of this report is to document the finite element analyses of the main steam penetration guard pipe and process pipe subjected to pipe rupture loads resulting from a postulated process pipe break inside the guard pipe in the Bellefonte Nuclear Plant.

2.0 SCOPE

This report encompasses the assumptions and finite element models used to determine if the guard pipe design on the containment side of the flued head anchor (see figures 2.0-1 and 2.0-2), is capable of withstanding the effects of a longitudinal break in the process pipe. The circumferential break was not considered because this break would drive the process pipe parallel to the guard pipe and no significant impact would occur. Also the effects of jet impingement loading from the circumferential break would be less severe than those from the longitudinal break.

3.0 METHOD

This task was broken up into two problems:

- o Study the behavior of a ruptured main steam process pipe to ascertain if it would impact the guard pipe.
- o Evaluate, using a shell model, the structural integrity of the guard pipe subjected to the main steam pipe impact (if any), and to the jet impingement loading from the ruptured main steam pipe.

The nonlinear transient dynamic analysis option (type 4) of the ANSYS computer code (reference 8.2) was used to perform the analyses for the above mentioned problems.

4.0 DISCUSSION OF MODELS

4.1 Main Steam Piping

The main steam process pipe was modeled from the flued head anchor to the nozzle on the steam generator (figure 2.0-2). The process pipe was modeled using ANSYS nonlinear pipe elements (STIF 20 and STIF 60). The model consisted of 51 elements with 300 degrees of freedom. The pipe was subjected to the thrust loading which was determined separately using RELAP4, a transient thermal hydraulic program. The pipe was fixed both at the flued head anchor and at the steam generator end. The pipe was fabricated from SA-155 KCF70 CL 1 steel. The stress strain curve for SA-155 KCF70 CL 1 at operating temperature is shown in figure 4.1-1. This data was obtained by in-house testing of a representative sample of this material at room temperature and then scaling the stress strain curve by the ratio of the hot yield to cold yield. The hot yield was obtained from the ASME Code Section III. This is a conservative approach because the ASME yield strengths are representative minimum values. The model was used to determine if the process pipe could deflect through the annular gap and impact the guard pipe.

NOTES:

1. PIPE ELEVATIONS AND DIMENSIONS ARE TYPICAL
2. DIMENSIONS ARE APPROXIMATE

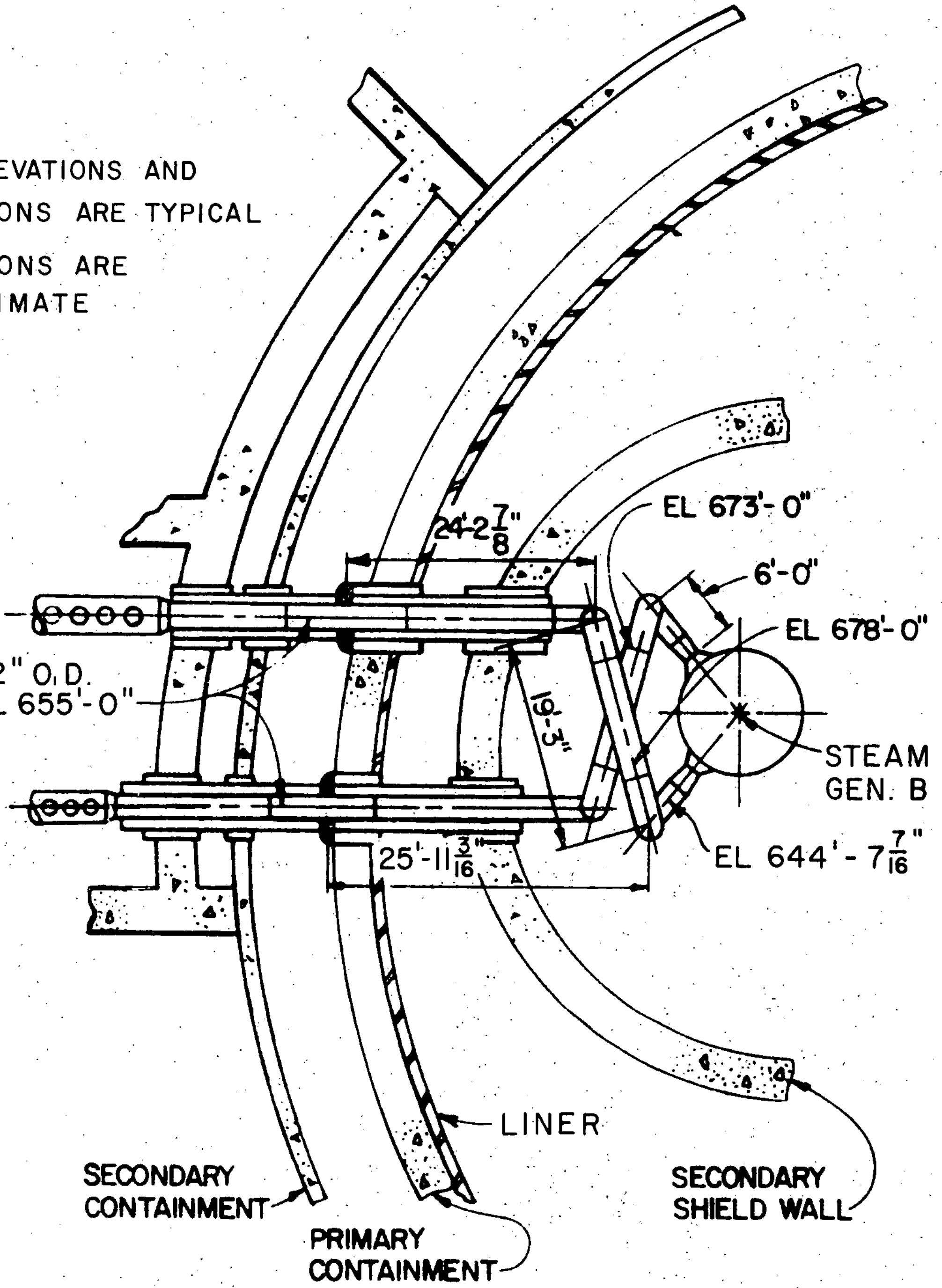


FIGURE 2-0-1 TYPICAL MAIN STEAM PIPING LAYOUT INSIDE CONTAINMENT

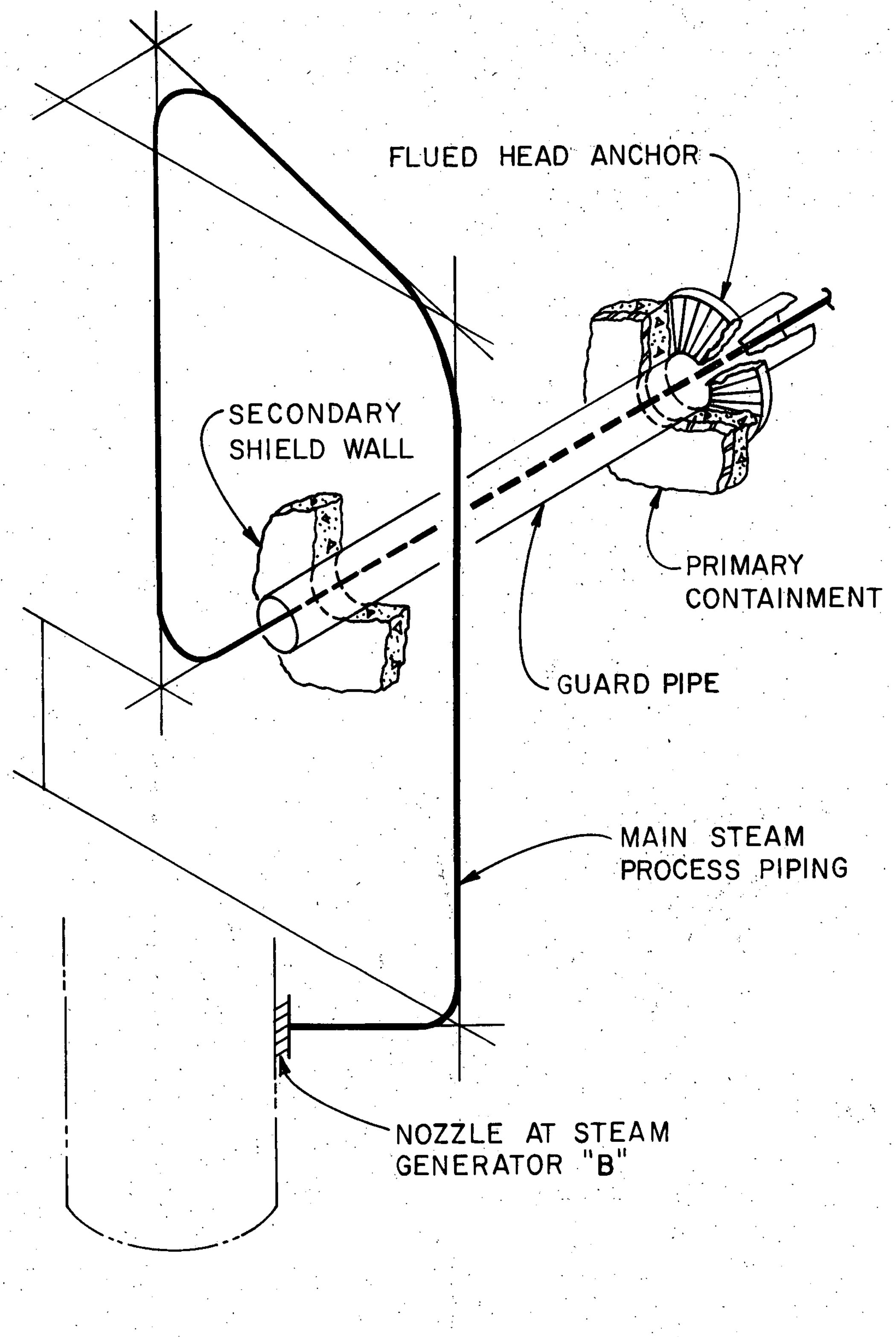


FIGURE 2·0-2 TYPICAL ISOMETRIC OF MAIN STEAM PIPING

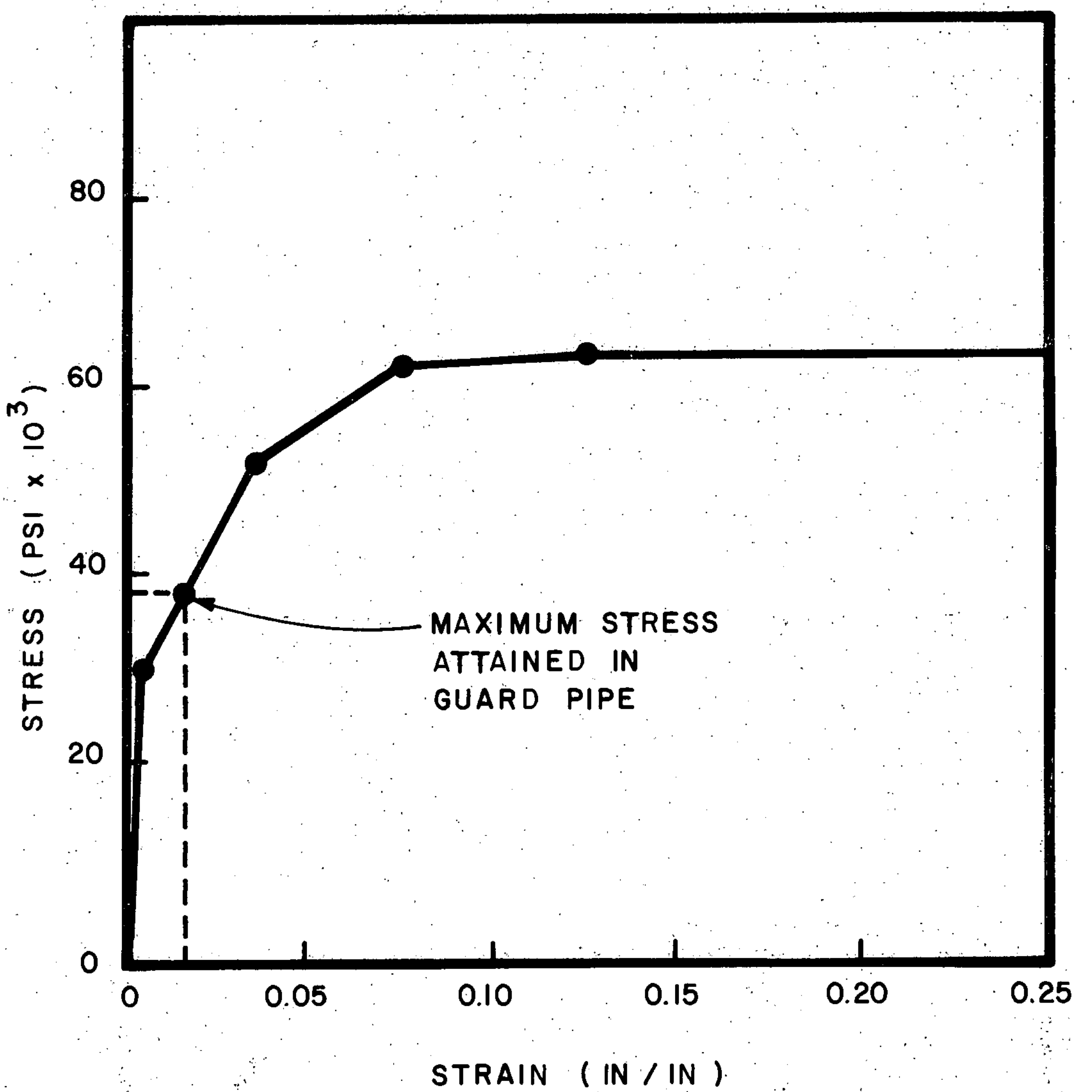


FIGURE 4·1–1 STRESS – STRAIN CURVE FOR SA–155 KCF70 CLASS 1 AT 650° F

The analysis was carried over a time interval from 0.0 to 0.3 seconds.

4.2 Main Steam Guard Pipe

The guard pipe model is shown in figure 4.2-1. Because of the symmetry of geometry and loading about two planes, only one quarter of the guard pipe was modeled. ANSYS three node nonlinear shell elements (STIF 28) were used. The model consisted of 260 elements with 772 degrees of freedom.

The pipe was subjected to a time varying pressure load (simulating jet impingement) at the mid-length between the flued head anchor and the secondary shield wall penetration. The guard pipe ends were assumed to be fixed at both the secondary shield wall and flued head anchor. The guard pipe is fabricated from the same material and conservatively assumed to be at the same operating temperature as the main steam process pipe. The insulation on the main steam process pipe was assumed not to affect the analysis.

5.0 FORCING FUNCTION

5.1 General

The total thrust force 'F_t' on a control volume consists of three components; acceleration force, momentum force, and pressure force and is given by the following equation:

$$F_t = F_a + F_m + F_p \qquad (1)$$

Where,

F_a = Acceleration Force

F_m = Momentum Force

F_p = Pressure Force

The two blowdown curves shown in figure 5.1-1 were developed for a rupture in a main steam line. The lower curve is for the rupture inside a guard pipe and the upper curve is for a rupture occurring without the guard pipe. It can be seen that the guard pipe changes the force time curve. The change was due to an increase in back pressure causing the pressure force term to approach zero. Before the rupture of process pipe the guard pipe is at an ambient pressure of 15 psi. After the rupture the guard pipe pressure rapidly approaches the main steam process pipe pressure due to flow choking in the guard pipe. Thus the pressure drop across the break area approaches zero and the pressure force term approaches zero. Figure 5.1-1 shows the significant effect of the pressure force term on the total thrust force. In general after the acceleration force has dissipated the governing force is the momentum force.

Data for these curves were obtained by using the RELAP4 computer code. The lower curve was used in this evaluation.

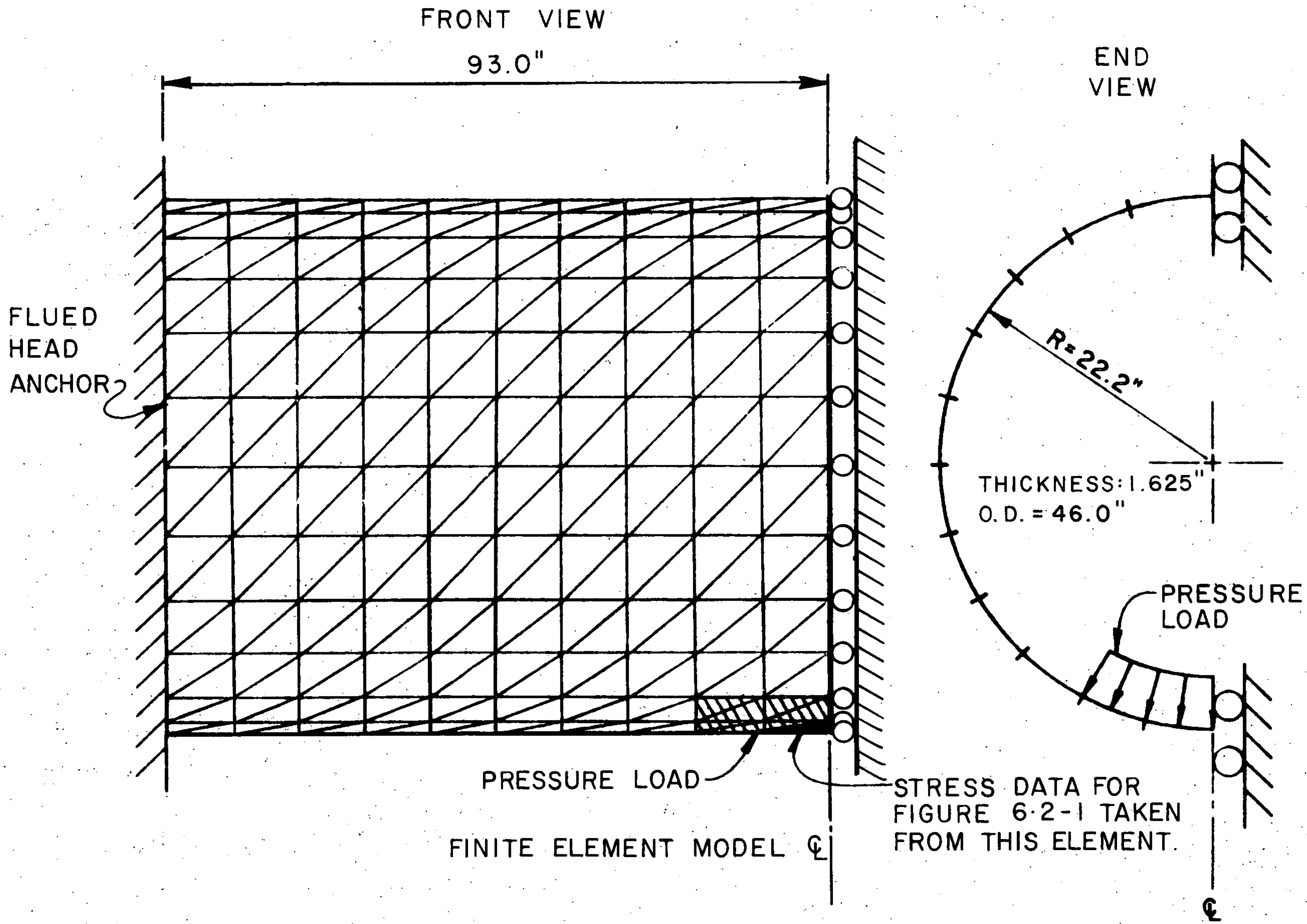


FIGURE 4-2-1 GUARD PIPE FINITE ELEMENT MODEL

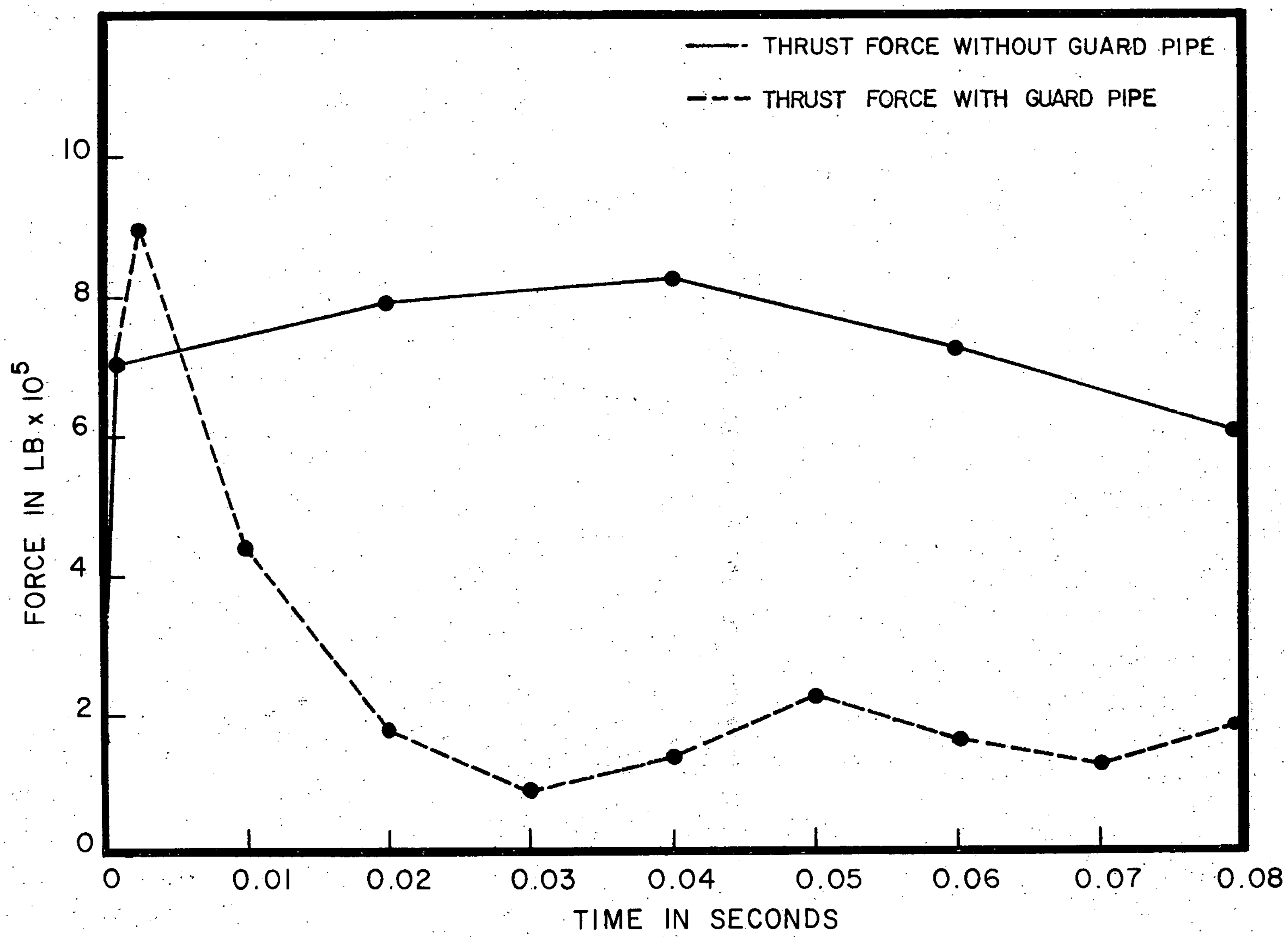


FIGURE 5·1-1 MAIN STEAM THRUST FORCE - TIME HISTORY

5.2 Main Steam Piping

The forcing function used on the process pipe model was a point load. This load was applied on the process pipe near midway distance between secondary shield wall and flued head anchor (figure 5.2-1). This analysis was performed neglecting any intermediate supports between the containment and the steam generator nozzle. This was an extremely conservative analysis since the intermediate supports would yield and thus absorb energy during a pipe rupture event. If intermediate supports had been considered the displacements would be less than those obtained from the analysis presented in this report.

5.3 Main Steam Guard Pipe

The jet impingement foot print was approximated by a rectangle with an area of 764 square inches. The pressure loading intensity was calculated by dividing the ordinates of the thrust curve (without the guard pipe given in figure 5.1-1) by the jet impingement area. From previous static analysis (reference 8.1) it was found that the point of maximum stress for a static load is approximated by locating the load near the center length of the guard pipe. The pressure loading was applied on the central elements of guard pipe model shown in figure 4.2-1.

6.0 RESULTS

6.1 Main Steam Piping

Figure 6.1-1 shows the main steam pipe displacement under the point of application of the load. As seen from this figure the process pipe is oscillating in a stable manner and the amplitude of oscillation is less than the clearance (5-¼ inches) between the guard pipe and the process pipe.

At no time during this analysis does the motion of process pipe exceed the above mentioned clearance, and impact the guard pipe.

6.2 Main Steam Guard Pipe

The maximum stress (Von Mises) in the guard pipe due to the jet impingement loading is reached in the central element of the guard pipe model shown in figure 4.2-1. Figure 6.2-1 shows this stress and displacement versus time history in the middle surface (see figure 6.2-2 for explanation of middle surface) of this element. Figures 6.2-3 through 6.2-6 are contour stress plots of the stress (maximum principal) in the middle surface of the guard pipe at various times during the first cycle of the analysis. These stress contours were plotted on the middle surface of the guard pipe shown as 'Front View' in figure 4.2-1.

The maximum stress in the guard pipe due to the combined loadings indicated in table 8.0-1 (reference 8.1) by equation 9* should not exceed 2.4 times the allowable stress S_h, as per subsection NC-3611.2

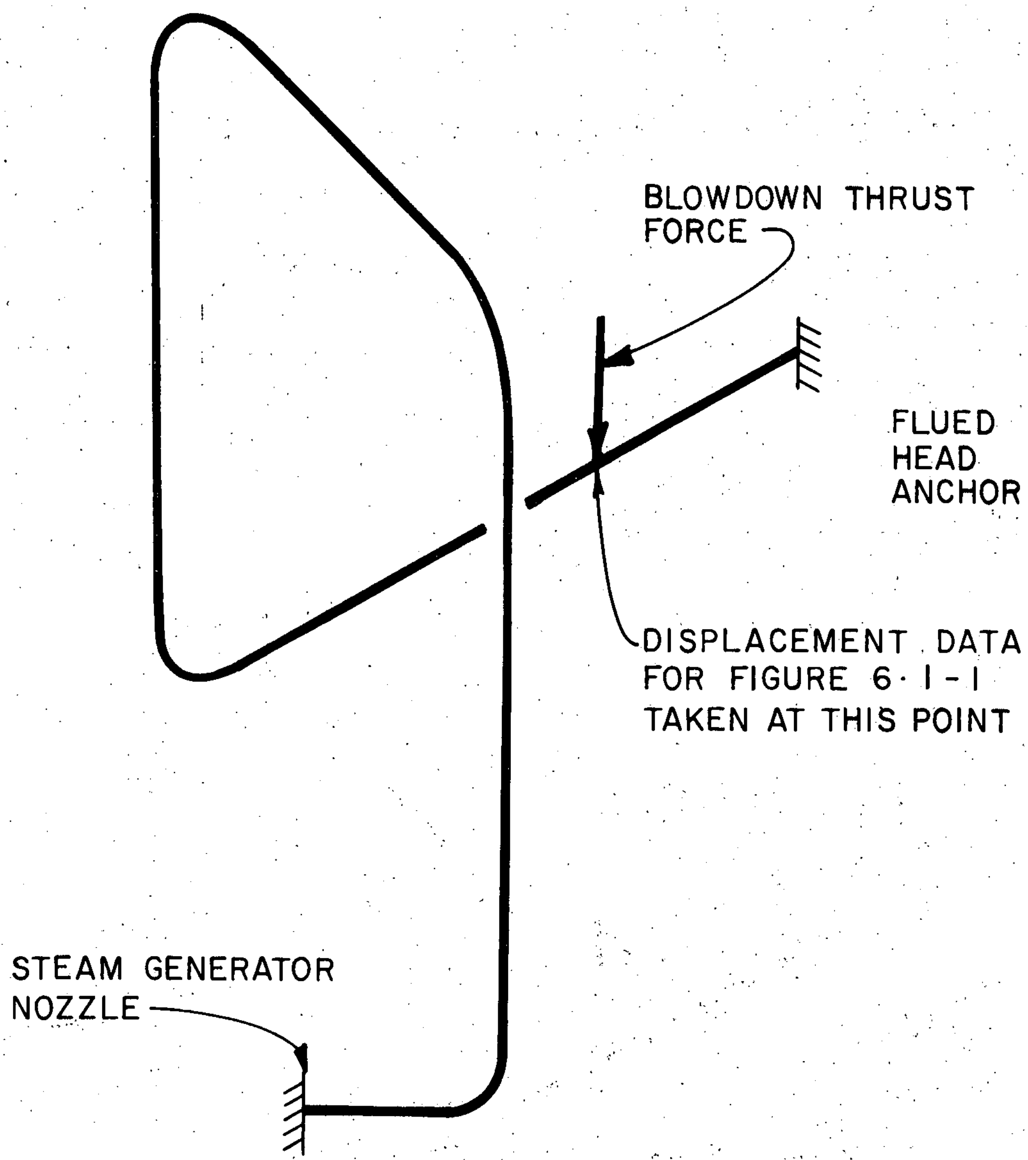


FIGURE 5·2-1 MAIN STEAM PROCESS PIPING

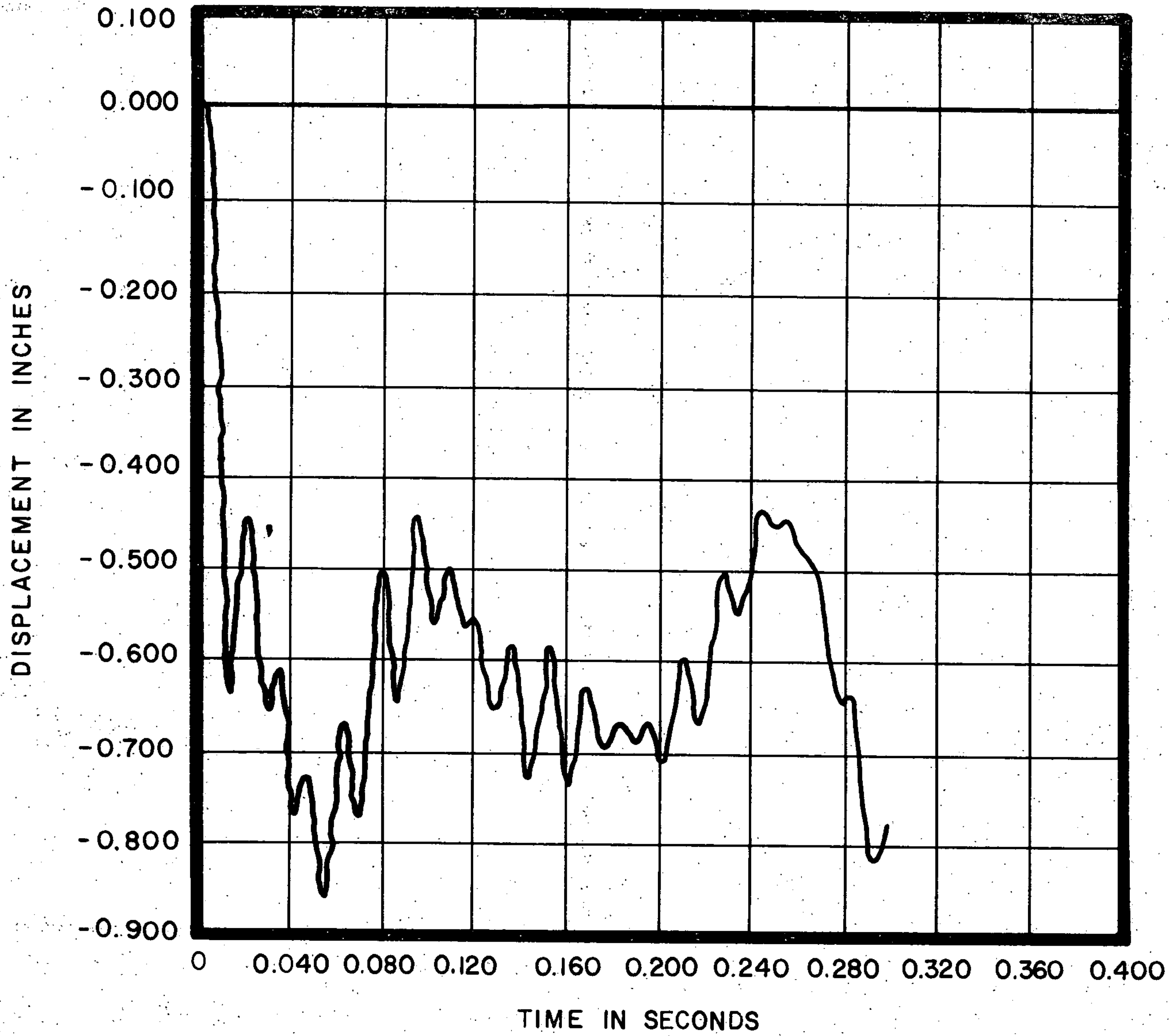


FIGURE 6-1-1 MAIN STEAM PIPE DISPLACEMENT - TIME HISTORY AT POINT OF LOADING

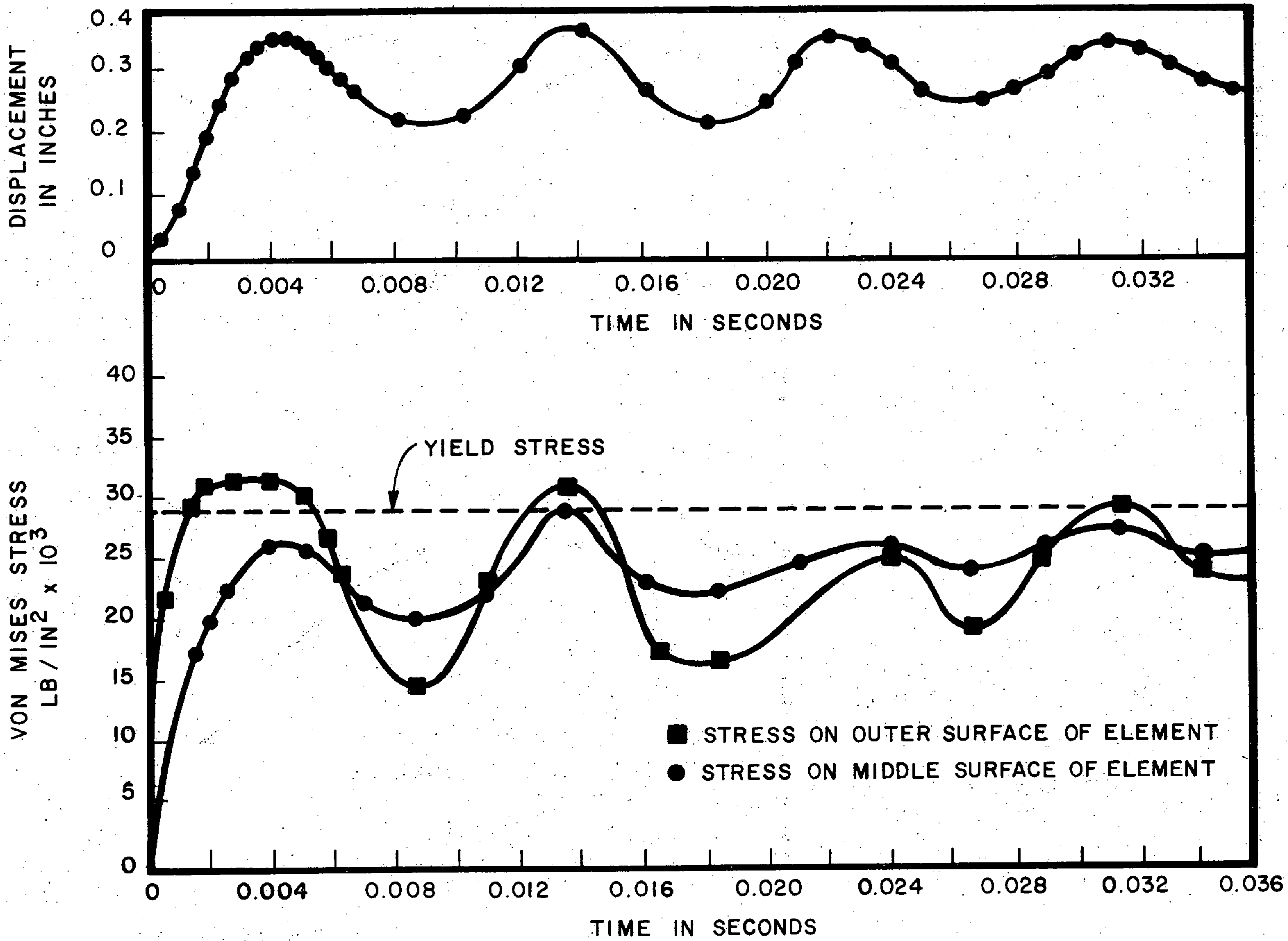


FIGURE 6·2-1 GUARD PIPE MAXIMUM STRESS AND DISPLACEMENT - TIME HISTORY

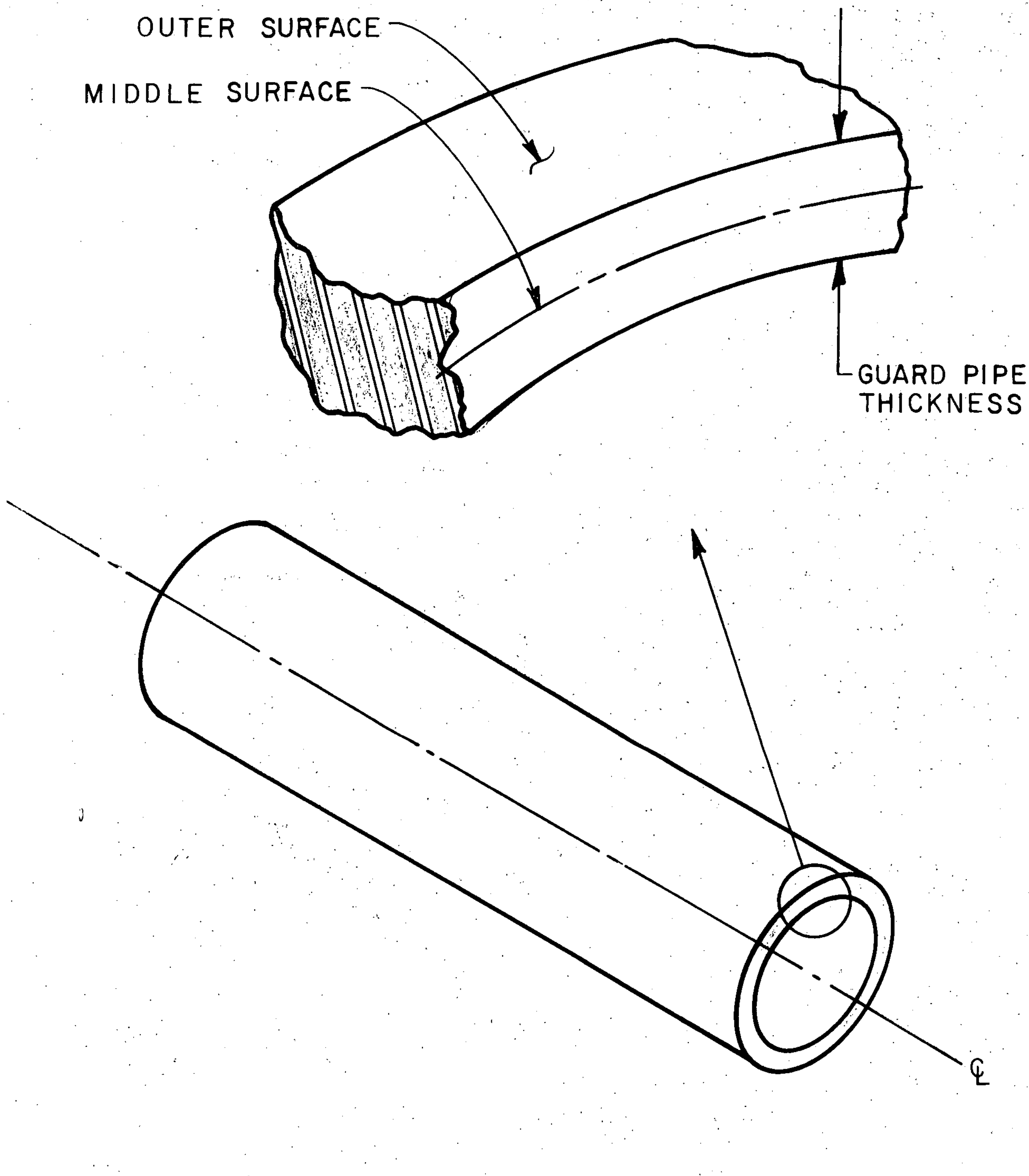
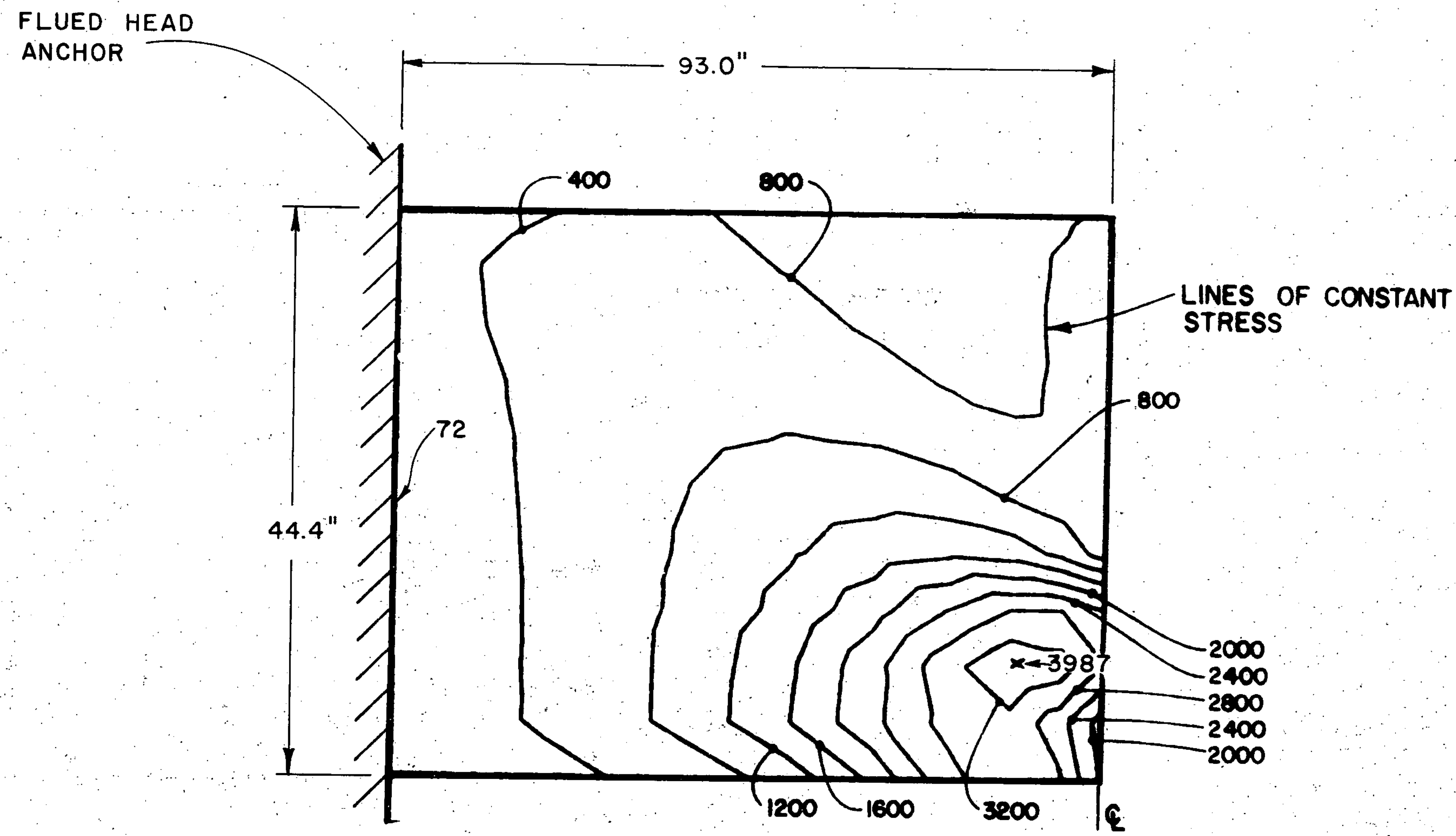


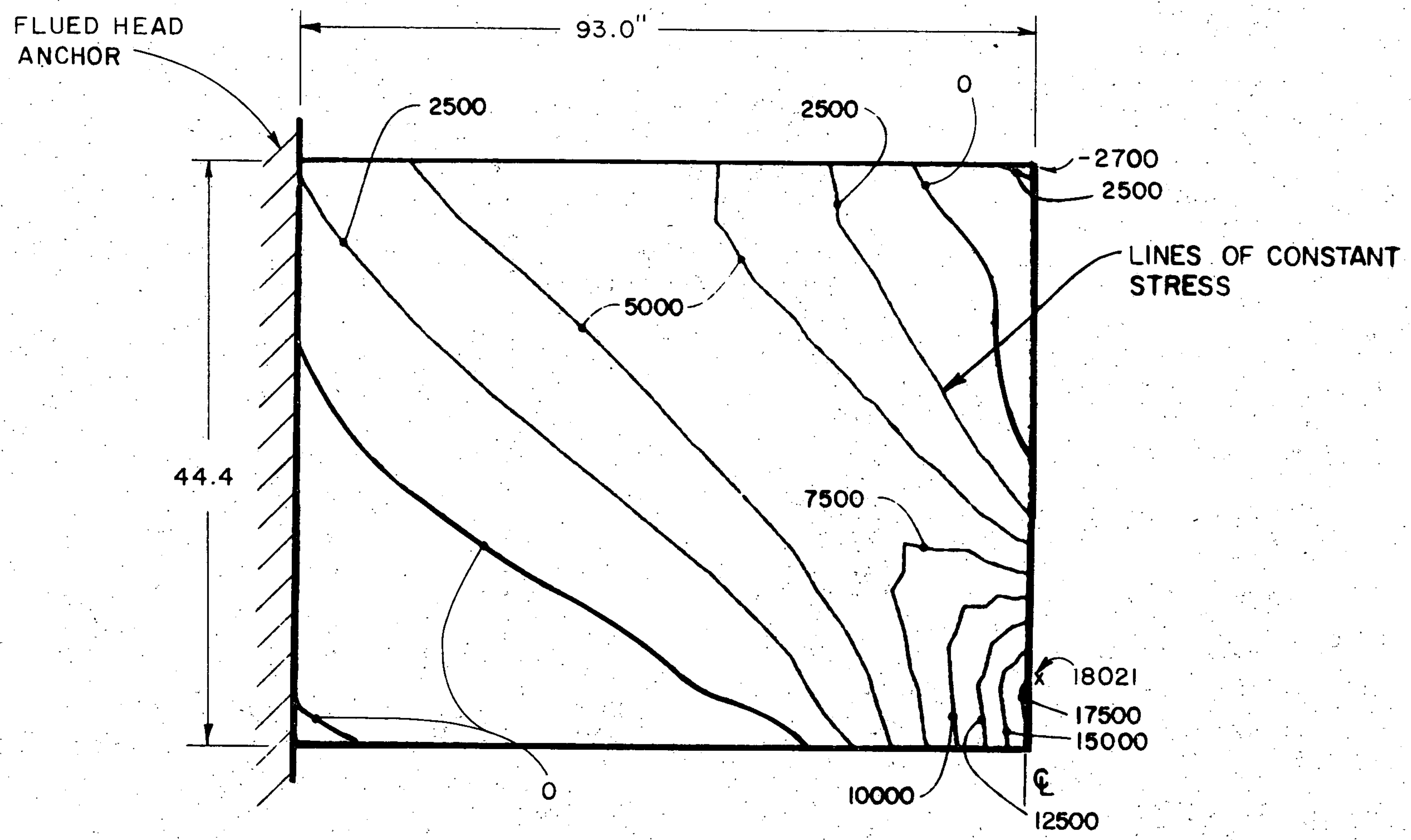
FIGURE 6-2-2 DIAGRAM OF SURFACES FOR STRESSES



NOTE: UNITS OF STRESS ARE LB/IN^2

X = MAXIMUM STRESS

FIGURE 6-2-3 GUARD PIPE MAXIMUM PRINCIPAL STRESS AT TIME = 0.0005 SEC



NOTE : UNITS OF STRESS ARE LB/IN^2

X = MAXIMUM STRESS

FIGURE 6·2-4 GUARD PIPE MAXIMUM PRINCIPAL STRESS AT TIME = 0.0014 SEC

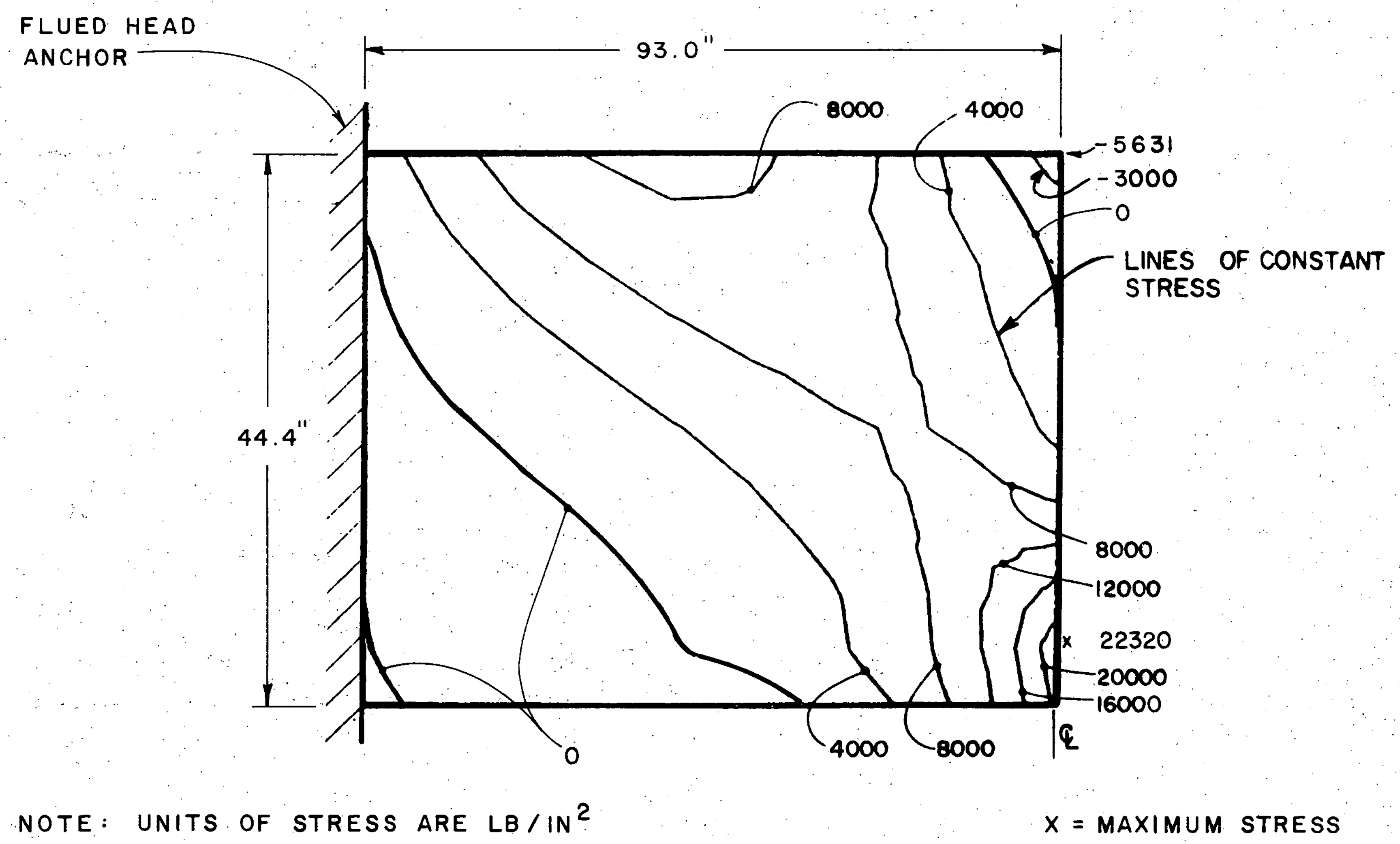
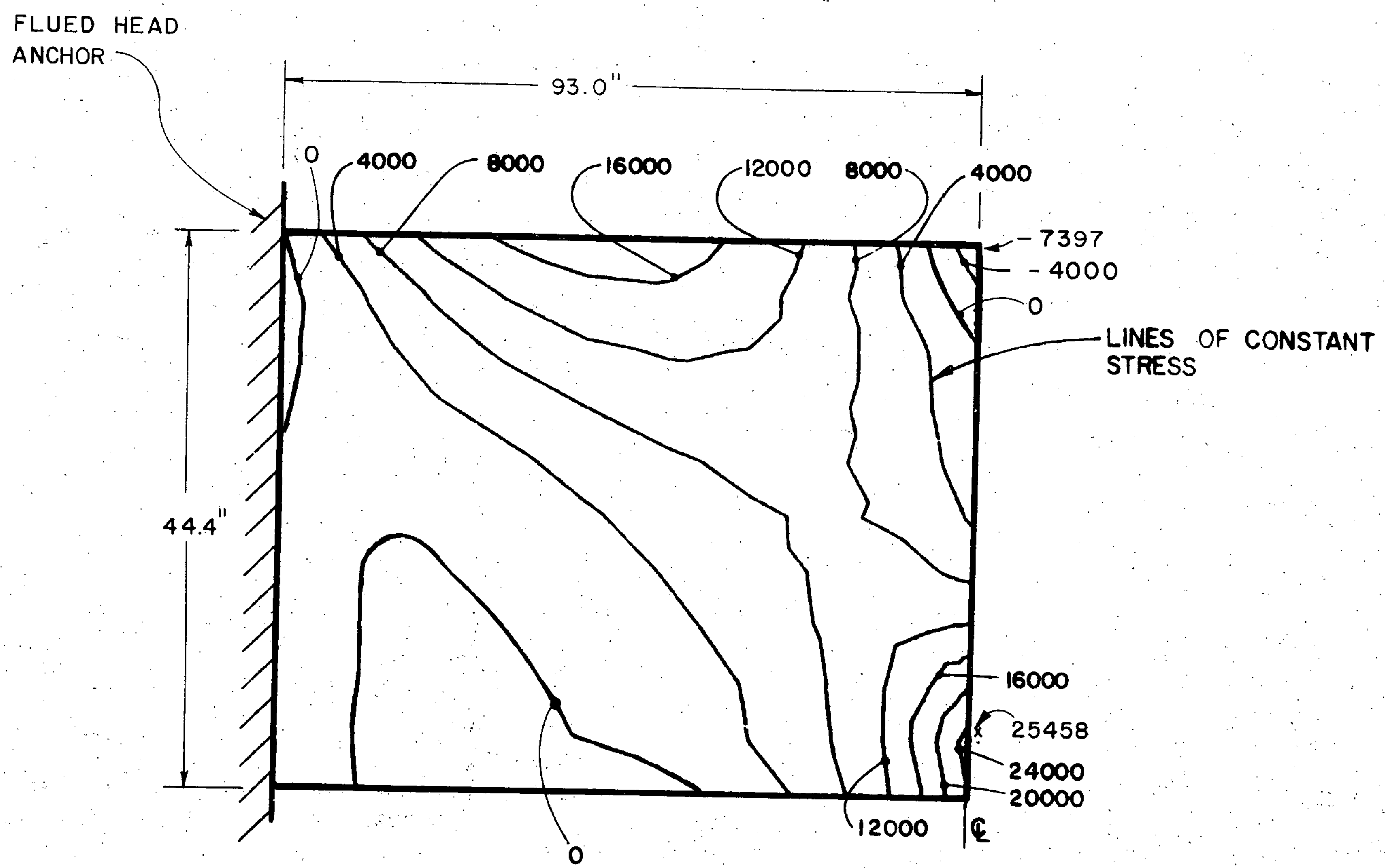


FIGURE 6-2-5 GUARD PIPE MAXIMUM PRINCIPAL STRESS AT TIME = 0.0022 SEC



NOTE: UNITS OF STRESS ARE LB / IN^2

X = MAXIMUM STRESS

FIGURE 6-2-6 GUARD PIPE MAXIMUM PRINCIPAL STRESS AT TIME = 0.0030 SEC

of ASME Section III. The guard pipe stresses for this loading condition were found to be maximum at 0.0315 seconds after the rupture of the process pipe. The maximum longitudinal stress in the guard pipe due to the jet impingement loading was 31664 psi. The longitudinal stress due to pressure, dead weight and seismic (SSE) loading was 7517 psi (reference 8.1, section 9.0). Thus,

Total calculated stress = 31664 + 7517 = 39181 psi.
Allowable stress = 2.4 S_h = 2.4 x 17500 = 42000 psi.

The maximum stress in the guard pipe, therefore, is less than the maximum stress limit specified in ASME Section III.

It is interesting to note that the longitudinal stress in the guard pipe as calculated in reference 8.1, section 9.0 using equation 9* was 37417 psi. This compares extremely well with 39181 psi obtained by the computer analysis using a shell element model of the guard pipe.

7.0 CONCLUSIONS

From these analyses, it was shown that for a postulated longitudinal split in the main steam process pipe, impact between the process pipe and the guard pipe would not occur. Also, the guard pipe would sustain the resulting jet impingement loading with only an insignificant amount of local yielding. Maximum stress reached in the guard pipe and its location on the stress strain curve is shown in Figure 4.1-1. It is evident from this figure that only a very small portion of the available strain energy of the material has been used. Since impact does not occur and the jet impingement effects on guard pipe are acceptable, the overall guard pipe design is adequate.

8.0 REFERENCES

8.1 CEB Report 76-25, Rev. 1, Pipe Rupture Analysis for Guard Pipe Bellefonte Nuclear Plant Units 1 and 2, Tennessee Valley Authority, Knoxville, May 22, 1978.

8.2 ANSYS User's Manual, Rev. 2, Swanson Analysis Systems Inc., Elizabeth, Pennsylvania, March 1, 1975.