Consumers Power Company

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March 18, 1976

Director of Nuclear Reactor Regulation
Att: Mr Robert A. Purple, Chief
Operating Reactor Branch No 1
US Nuclear Regulatory Commission
Washington, DC 20555

DOCKET 50-255, LICENSE DPR-20
PALISADES PLANT, ANSWERS TO ALLOWABLE
TUBE WALL DEGRADATION ANALYSIS QUESTIONS

A number of questions have been raised by members of your staff concerning our February 12, 1976 submittal entitled "Analysis to Determine Allowable Tube Wall Degradation for Palisades Steam Generators."

These questions and our responses are presented below:

Question No 1

Justify the hot leg break area and break opening time, and discuss the sensitivity of the hydrodynamic load vs break area.

Response

An elastic-plastic analysis was used to predict the movement of the hot leg pipe after a hypothesized guillotine break. This analysis had indicated that the relative displacements of the two severed ends of the pipe would be of such magnitude to make 425 square inches of area available for the escape of fluid.

In the original issue of "Analysis to Determine Allowable Tube Wall Degradation for Palisades Steam Generators," dated January 29, 1976, the break area considered for the hot leg pipe was 425 square inches. The resulting value of ΔP (rarefaction wave differential pressure) within the tube of interest was listed as 175 psi. The ΔP resulting from the full area break of the cold leg pipe was listed as 185 psi. Actually the 175 psi for the 425 square inch break in the hot leg is in error. The correct value is 152.8 psi. The ΔP for the full area break of the hot leg pipe (1385 square inches) is 173.8 psi. The ΔP values for hot leg break areas of 100, 425, 1000 and 1385 square inches are 57.6, 152.8, 172.2 and 173.8 psi, respectively. This indicates that even if the hot leg pipe were conservatively assumed to displace such that the entire area of 1385 square inches were available the resulting value of ΔP within the tube would be only 173.8 psi which is less than that which results from the cold leg break, which is 185 psi. In any case the cold leg break causes the largest energy loading on the tube.

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With this in mind, the explanation of the details of the elastic-plastic analysis used to predict the severed hot leg pipe movement is not included in this submittal.

Question No 2

In calculating the centrifugal force, there appears a factor of $4/\pi$ missing. Please verify.

Response

The formula on Sheet 5 of Reference (2) for the horizontal component of the centrifugal force should read:

$$F_c = \frac{4}{\pi} \frac{W^2V}{D^2g} = 1.273 \frac{W^2V}{D^2g}$$

The correction reduces this component of horizontal in-plane load from a maximum value of -1.3 lb to the new maximum value of -1.17 lb. The difference in load is -0.13 lb as compared to the reported load on the tube of 56.0 lb for the worst case tube. The loading error in the analysis is 0.23% which has a negligible effect upon results.

Question No 3

In computing the friction force, a normal force of 40 lb was assumed. Provide justification for the value, and discuss in detail its effect on the maximum bending stress due to rarefaction wave.

Response

In the Palisades steam generator tube Rows 115 through 140 are supported in the cross flow region by three vertical grids. During the LOCA event, the horizontal rarefaction load produces frame type lateral sideway deformations of the tube which in turn produces vertical reactions at the two outside vertical grids (see Figure A.11 of Reference (2)). The vertical reactions for tube Row 140 were calculated to be 20 lb each for a peak horizontal rarefaction load of 66.4 lb. The 40 lb total load was reported in Reference (2).

The worst case tube row (Row 110) has only a single vertical support grid which develops a vertical reaction due to normal flow loads, differential thermal expansion between tube rows and differential tube displacement due to internal pressure. The out-of-plane lateral motion of the tube during a LOCA also produces normal forces on the tube at the vertical grid support point. These factors contribute to an overall "binding" force of considerable magnitude. The quantity of the resultant vertical support reaction normal to the tube is judged to be on the order of 20 to 30 lb. It is of no value, however, to justify a higher allowable degradation for LOCA plus SSE loading than exists for the NRC staff criteria. Therefore, a value of 6 lb normal force was conservatively used in the analysis, manifesting itself in a horizontal friction load of 4 lb. This loading, in turn, results in an allowable degradation of 64% of wall thickness for the analyses performed in Reference (2).

The actual restraining forces associated with the vertical "binding" loads were developed experimentally in a simulated Palisades support arrangement. The results indicate a "coefficient of binding" of 0.7. This value when applied to the vertical load of 6 lb results in the frictional load of 4 lb which was used in the analysis of tube Row 110.

In the analysis of the worst case tube, the frictional restraint is considered only for the LOCA rarefaction loading. For this case, the restraining frictional force of 4 lb is relatively insignificant in comparison with the peak rarefaction load of 56 lb. However, the friction force produces damping of the tube motions and effectively reduces tube stresses subsequent to the initial load impulse. Based on the dynamic response of tube Row 110, the amount of structural damping available from the 4 lb friction load is estimated to be 1% of critical damping.

Question No 4

Provide a detailed discussion of the interaction curve as shown in Figure A.21.

Response

The curves of Figure A.21 of Reference (2) define the combination of membrane and bending stress which will produce a complete plastic hinge for a healthy tube and a 64% degraded tube. The basis for these curves is consistent with the ASME Code Section III as defined in the "Criteria of Section III," Reference (3). The corresponding curve is presented for a rectangular section in Reference (3) and is reproduced in Figure C along with the curve for the 64% degraded tube for purposes of comparison.

In order to alleviate concern as to the ability of the degraded tube to develop its full shape factor rather than buckle in a mode which would erode the section modulus, the following discussion of the tube bending test is offered. The test is schematically described in Reference (2), Figure C.1, and the results are presented in Figure C.4. The mode of buckling was a radially outward bulging on the compression side of the tube corresponding to a lateral load of 40 lb on the end of the cantilever. The section remained nearly circular and actually experienced an increase in section modulus due to the buckling deformation. It was possible to further increase the load to 45 lb before reaching the load carrying capacity of the cantilever.

A 40 lb load corresponded to a maximum stress of 90 ksi at the beginning of buckling (60% degraded tube used in this test) while a maximum stress of 101 ksi existed when the load reached 45 lb. The highest stress intensity reported in the Palisades LOCA and SSE analysis was 79.6 ksi for a 64% degraded tube.

Question No 5

Discuss the feasibility of using lower plugging limits in the region above the top "eggcrate" support.

Response

It would be possible to establish more than one plugging criterion for the Palisades steam generators. The multiple criteria could be established based upon elevation in the generator, tube location, or a combination of these factors.

The need for a multiple plugging criteria, however, has not been established. The report submitted to you on February 12, 1976 entitled "Analysis To Determine Allowable Tube Wall Degradation for Palisades Steam Generators," establishes the need for a 0.017-inch wall below the top eggcrate to meet the "Knight criteria" first offered in Prairie Island testimony.

The elastic analysis performed for the upper portion of the steam generator demonstrates that this same wall thickness provides satisfactory resistance to failure in the event of a hypothetical Loss of Coolant Accident acting in concert with a safe shutdown earthquake. A dynamic plastic analysis of this same event has been presented to demonstrate the conservatism of the elastic analysis. This plastic analysis shows a substantial margin between the calculated strain and failure strain for Inconel 600.

Consumers Power Company is confident that a single plugging criterion, based upon a structural requirement of 0.017 inch remaining wall thickness (64% allowable degradation), provides adequate safety margins for both normal operation and postulated accidents.

References

1. CENPD-168, Design Basis Pipe Breaks, July 1975, With Supplement, Combustion Engineering, Inc.

2. Report "Analysis To Determine Allowable Tube Wall Degradation for Palisades Steam Generators," forwarded by Consumers Power Company letter of February 12, 1976 from D. A. Bixel to Director of Nuclear Reactor Regulation, "Docket 50-255, License DPR-20, Palisades Plant, Steam Generator Tube Plugging Criteria."

3. "Criteria of Section III of the ASME Boiler and Pressure Vessel Code for Nuclear Vessels," American Society of Mechanical Engineers, New York.

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CC: JGKeppler, USNRC

CIRCUMFERENTIAL BREAK FLOW AREA VS TIME
HOT LEG TERMINAL END AT STEAM GENERATOR

C-E Combustion Engineering Inc

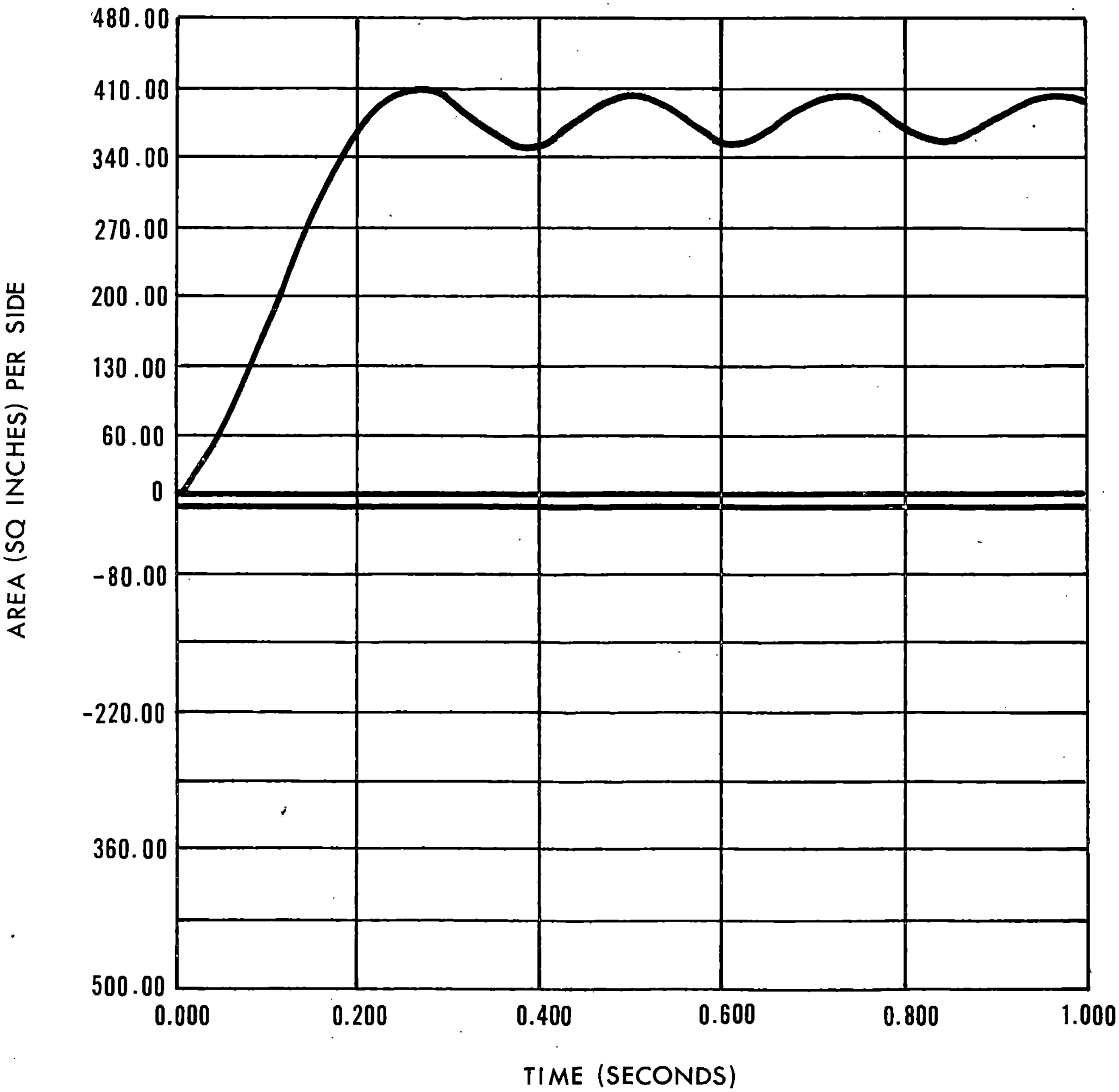


FIGURE A

SENSITIVITY OF PRESSURE LOAD
TO HOT LEG BREAK AREA

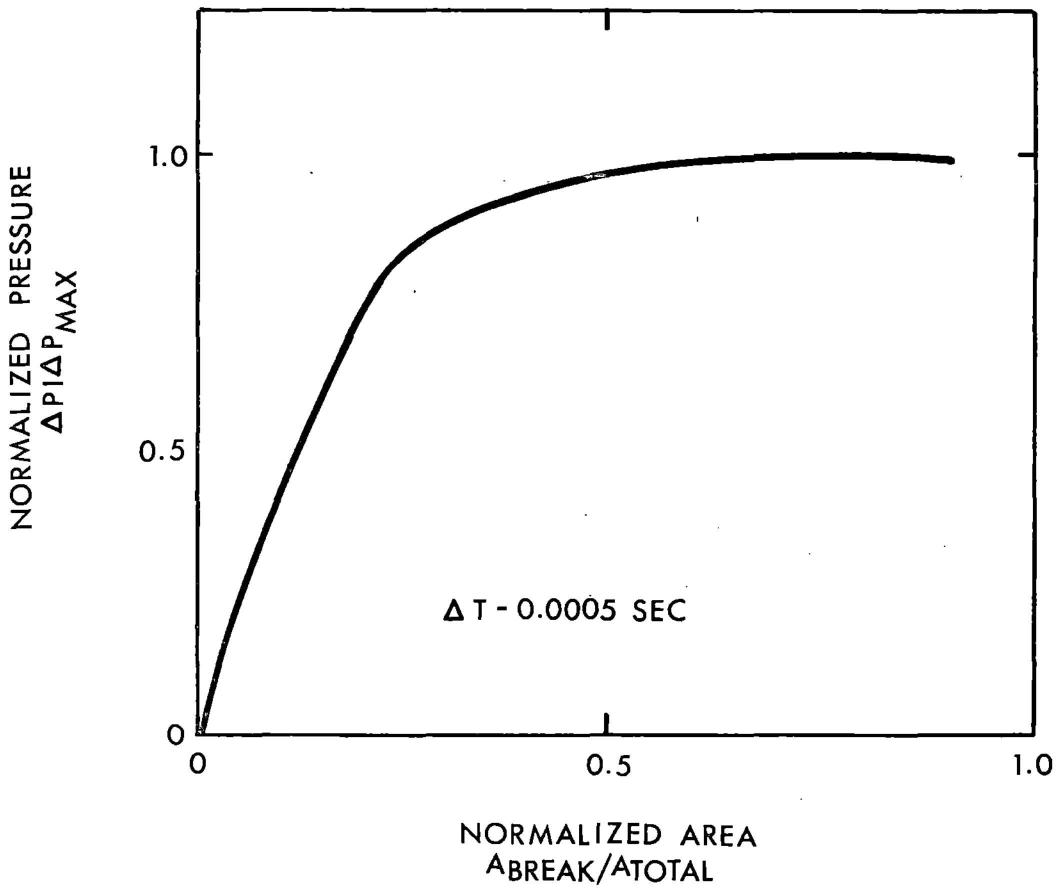


FIGURE B

MEMBRANE AND BENDING INTERACTION

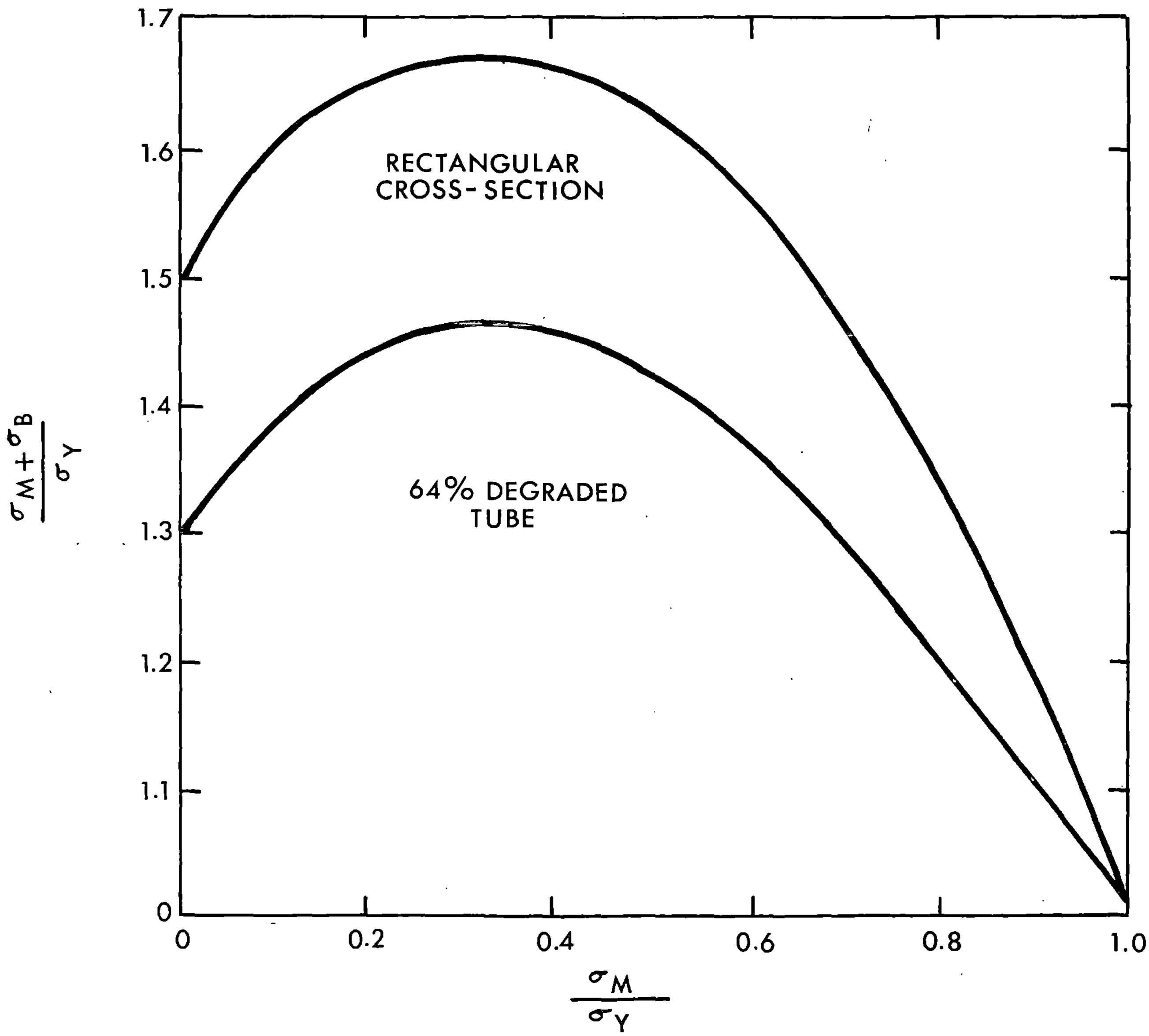
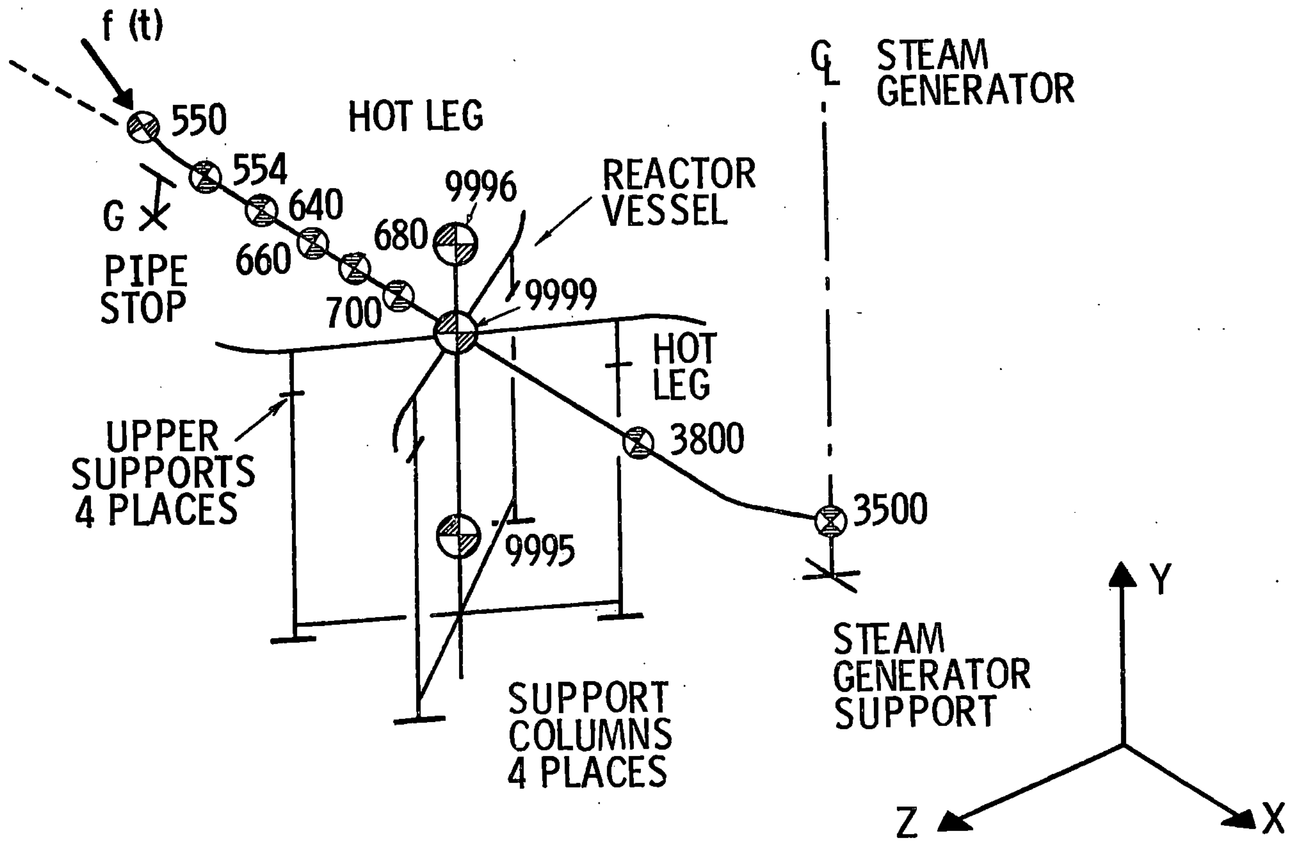
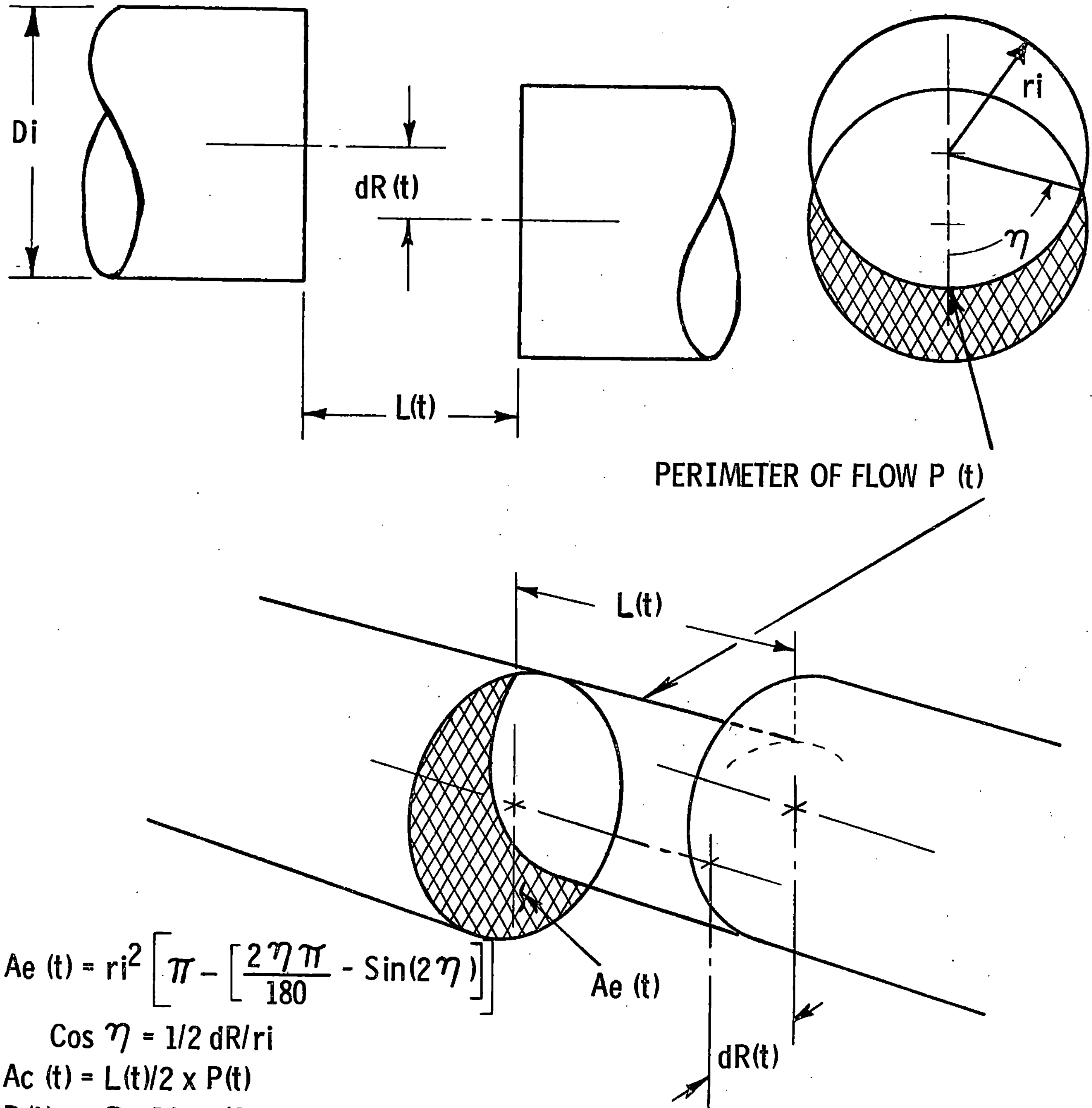


FIGURE C



MODEL JOINT	D.D.O.F. DIR.
550	XYZ
554	YZ
640	YZ
660	XYZ
680	YZ
700	YZ
9996	XYZ
9999	XZ
9995	XZ
3800	XYZ
3500	X

C-E Combustion Engineering Inc.	DYNAMIC ANALYSIS MODEL CIRCUMFERENTIAL PIPE BREAK STEAM GENERATOR INLET NOZZLE	Figure 22



$$Ae\,(t) = ri^2 \left[\pi - \left[\frac{2\eta\pi}{180} - \mathrm{Sin}(2\eta) \right] \right]$$

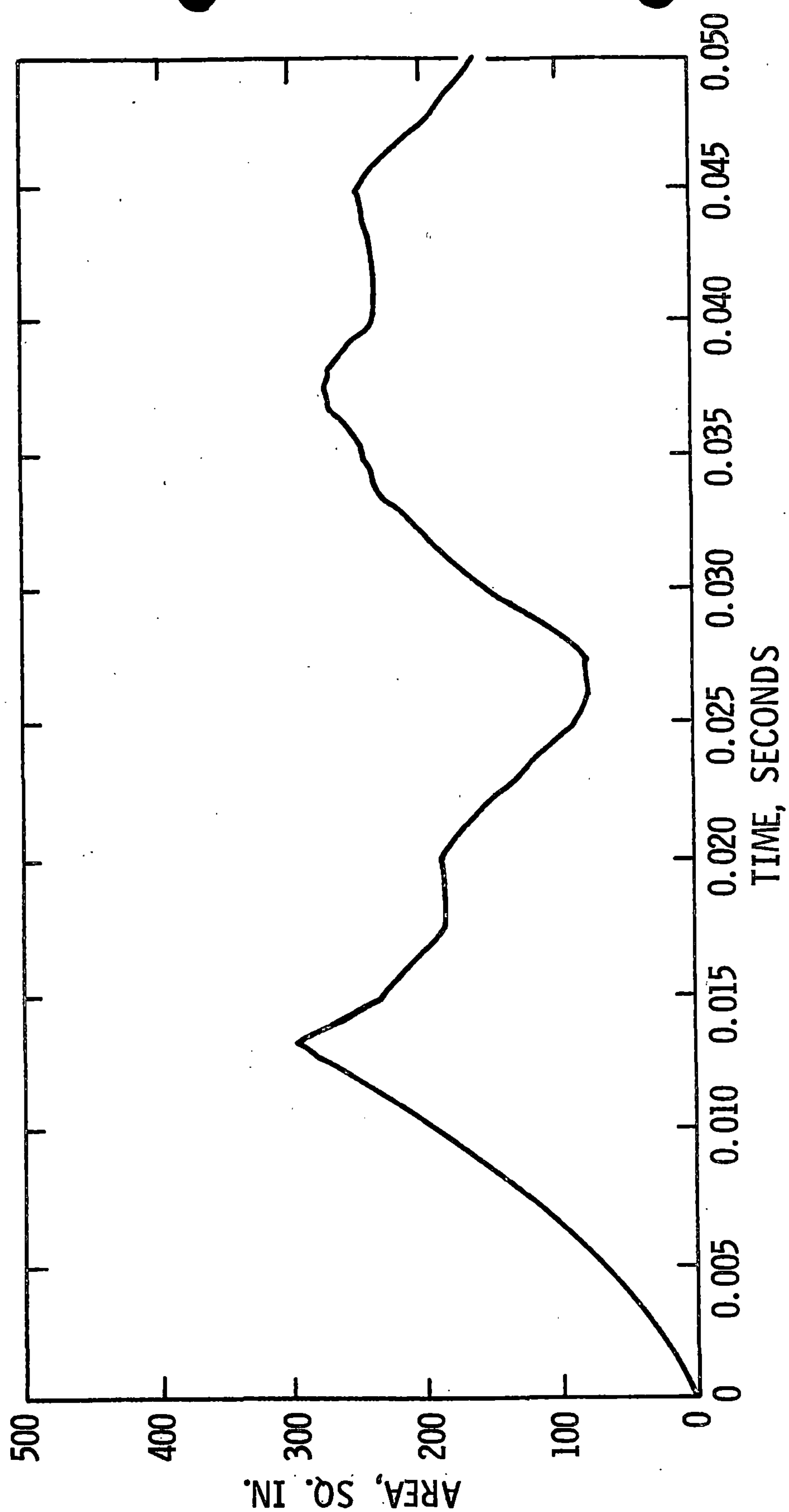
$$\mathrm{Cos}\,\eta = 1/2\; dR/ri$$

$$Ac\,(t) = L(t)/2 \times P(t)$$

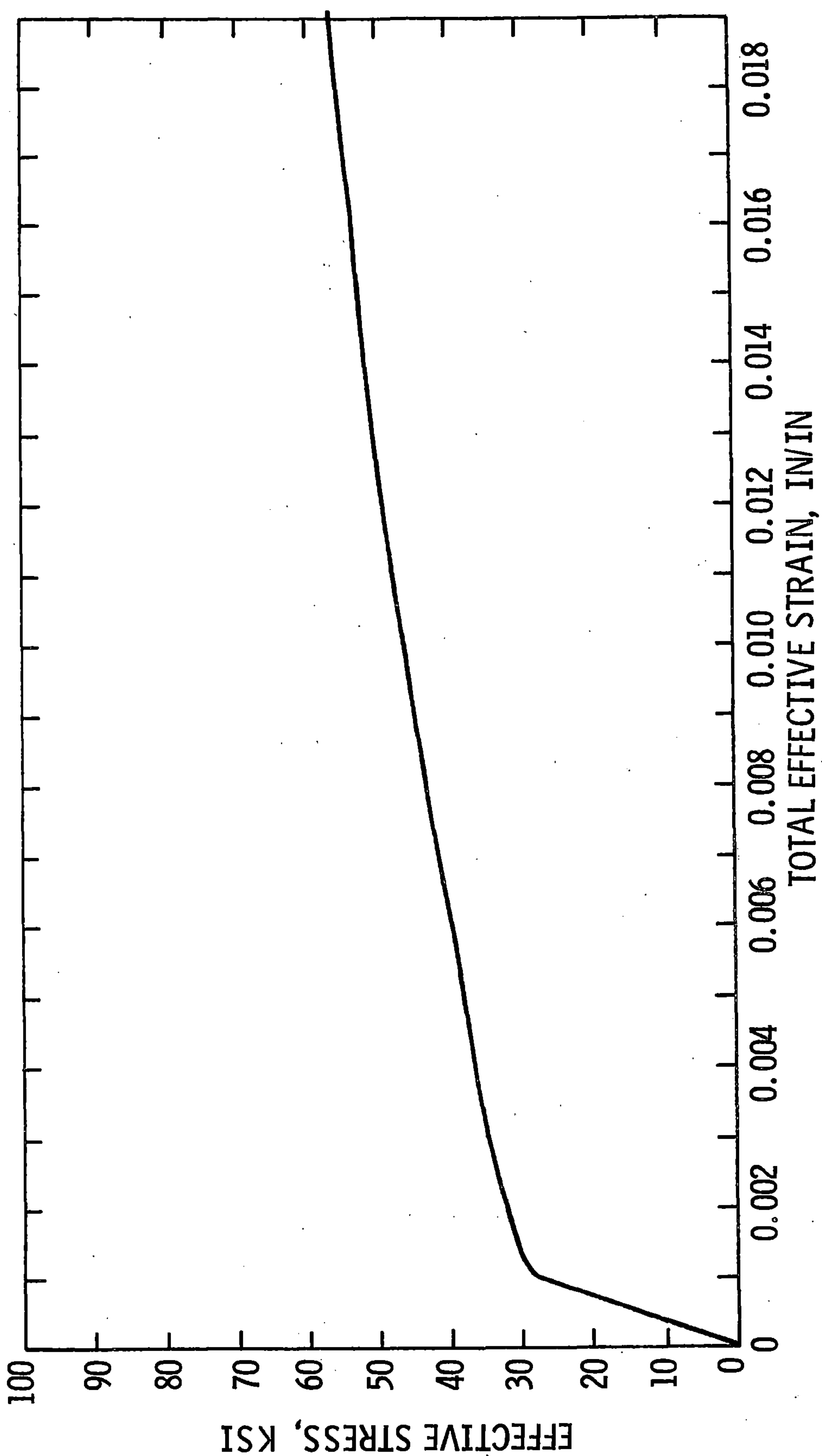
$$P\,(t) = \pi\; Di\; \eta\,/90$$

TOTAL BREAK AREA = Ac (t) + Ae (t)

C-E Combustion Engineering Inc.	CIRCUMFERENTIAL PIPE BREAK FLOW AREA FORMED BY AXIAL PLUS RADIAL DISPLACEMENT	Figure 26



C-E Combustion Engineering Inc.	CIRCUMFERENTIAL BREAK FLOW AREA vs TIME HOT LEG TERMINAL END AT STEAM GENERATOR	Figure 29



C-E Combustion Engineering Inc.	STRESS - STRAIN CURVE	Figure 33