CONF-790363--2

EVALUATION OF THE INFLUENCE OF SEISMIC RESTRAINT CHARACTERISTICS ON LMFBR PIPING

R. H. MALLETT

SUMMARY

Structural evaluation of nuclear power plant piping systems involves consideration of response due to various types of dynamic loadings. Stresses induced in the piping by dynamic loadings depend upon the piping restraints because the response of the piping is inextricably tied to the response of the restraints. For the case of breeder reactor heat transport system piping (large diameter and thin-walled), the piping restraints are comprised of a series of complex components. The representation of these piping restraints in the piping system dynamic analysis involves modeling the structural and dynamic characteristics of these components. Small changes in these component characteristics can result in marked changes in the piping response obtained from the piping system dynamic analysis.

For the Clinch River Breeder Reactor Plant (CRBRP) heat transport system piping within the reactor containment building, dynamic analyses of the piping loops have been performed to study the effect of restraint stiffness on the dynamic behavior of the piping, i.e., changes in frequencies, mode shapes, loads, stresses, and displacements. In addition, analysis and testing of typical CRBRP restraint system components have been performed for the purpose of quantifying and verifying the basic characteristics of the restraints used in the piping system dynamic analysis.

This paper presents the results of the analysis and testing described above. In particular, it is shown that piping restraint effects on breeder reactor piping response are important considerations in the design/analysis process.

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EVALUATION OF THE INFLUENCE OF SEISMIC RESTRAINT CHARACTERISTICS ON LMFBR PIPING

U.S. DEPARTMENT OF ENERGY (DOE)
AND
JAPAN POWER REACTOR AND
NUCLEAR FUEL DEVELOPMENT CORPORATION (PNC)

SPECIALIST MEETING
ON
HIGH TEMPERATURE PIPING
DESIGN AND ANALYSIS

WESTINGHOUSE ADVANCED REACTORS DIVISION
MADISON, PENNSYLVANIA
MARCH 26-30, 1979

Robert H. Mallett, Manager
CRBRP Mechanical Equipment
and Piping Design

Paper No. V - 5

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OUTLINE OF PRESENTATION

- Background to CRBRP Consideration of Piping Restraint Effects
- Dependence of Pipe Stress on Restraint Stiffness
- Time History Analyses With Free Play Effects
- Determination of Restraint Stiffness
- Advanced Studies of Piping Restraint Effects

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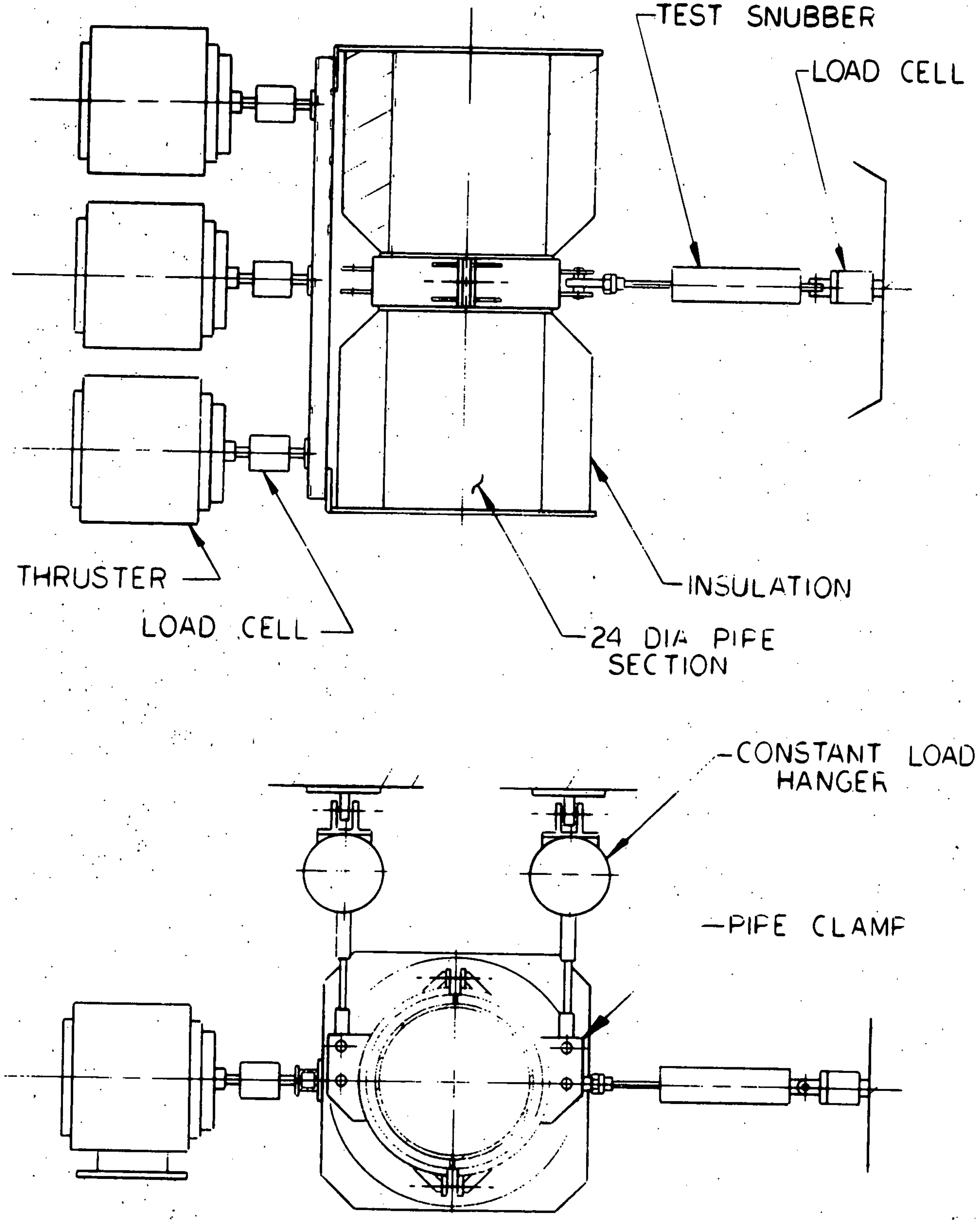
TEST SETUP



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BASIC PIPING SYSTEM TESTS

Preliminary Observations on PSA-10 Results

- Test Frame Stiffness—Input Displacement Ranged From 3 to 12 Times Output Displacement at Test Frame
- Transverse Accelerations—Snubber Transverse Accelerations Approach Value of Axial Acceleration
- Shifting of Pipe Clamp—Accumulated Circumferential Shift of 55 Mils and Radial Settlement of 30 Mils
- Drift From Neutral Position—Maximum Value of 335 Mils
- Failure of Snubber—Structural Failure at Faulted Condition Load Rating

Preliminary Conclusions of PSA-10 Tests

- Pipe Clamp Functioned as Intended—Clamp and Pipe Responded Integrally Rather Than Independently, no Structural Failure
- Seismic Snubber Requires Additional Evaluation—Characterization of Drift and Review of Load Rating

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POTENTIALLY SIGNIFICANT PARAMETERS OF PIPING RESTRAINTS

- Stiffness
- Damping
- Impacting
- Free Play
- Lockup Threshold
- Frequency
- Force Level
- Drift
- Different Tension/Compression Behavior

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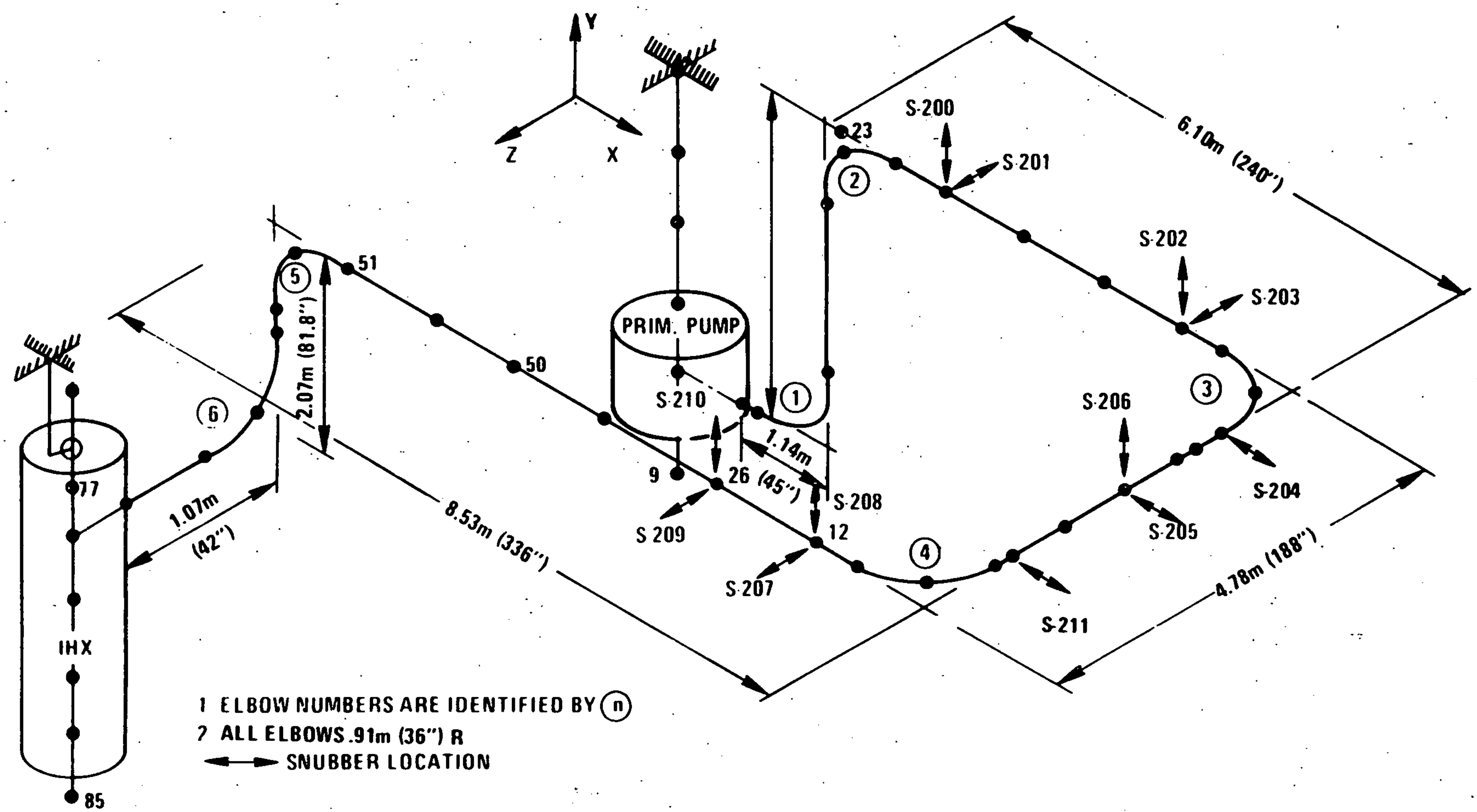
SEISMIC MODEL FOR CRBRP PRIMARY HEAT TRANSPORT SYSTEM CROSS-OVER PIPING LEG



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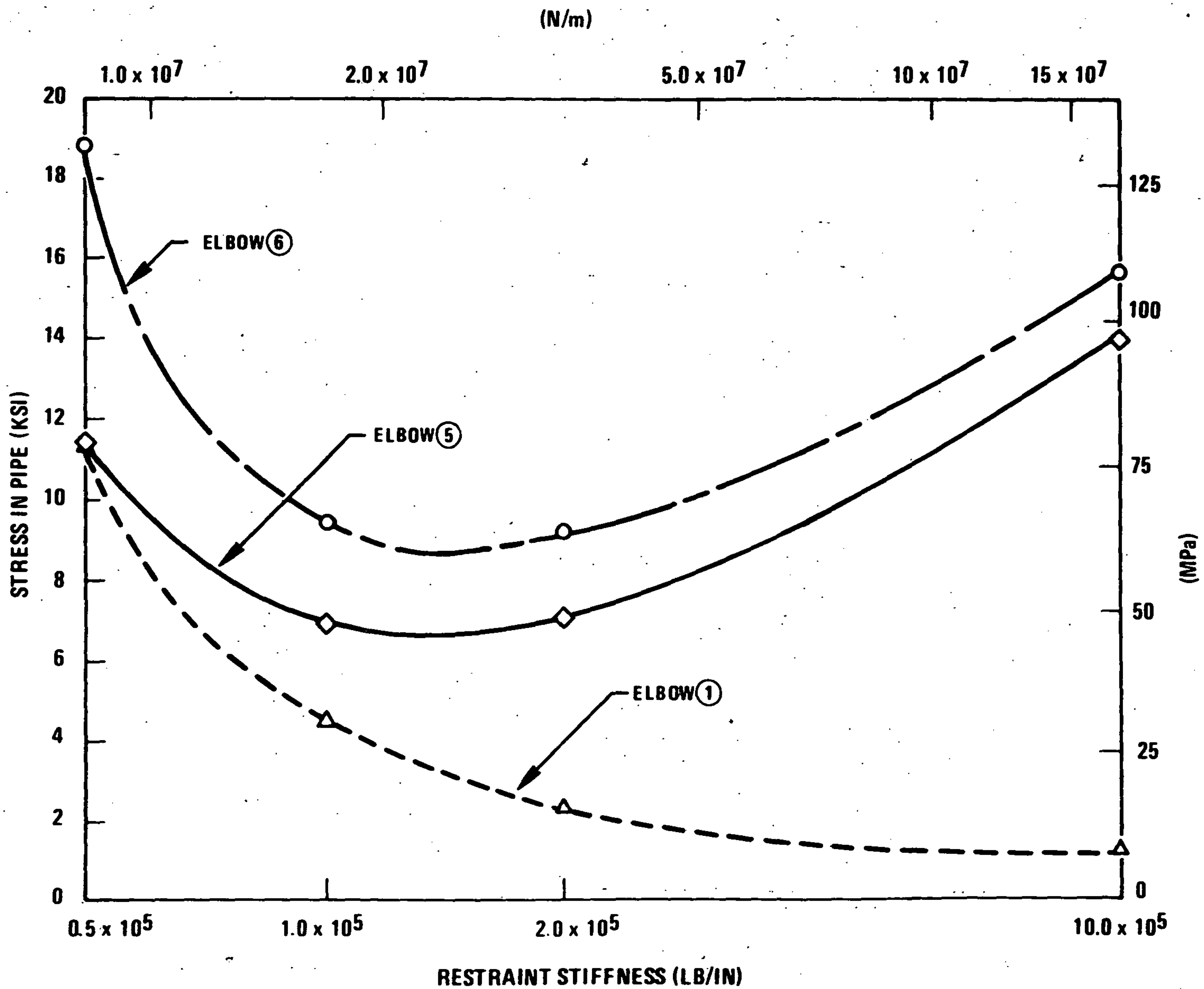
SEISMIC STRESS RESULTS AS A FUNCTION OF RESTRAINT STIFFNESS FOR CRBRP PHTS CROSS-OVER PIPING



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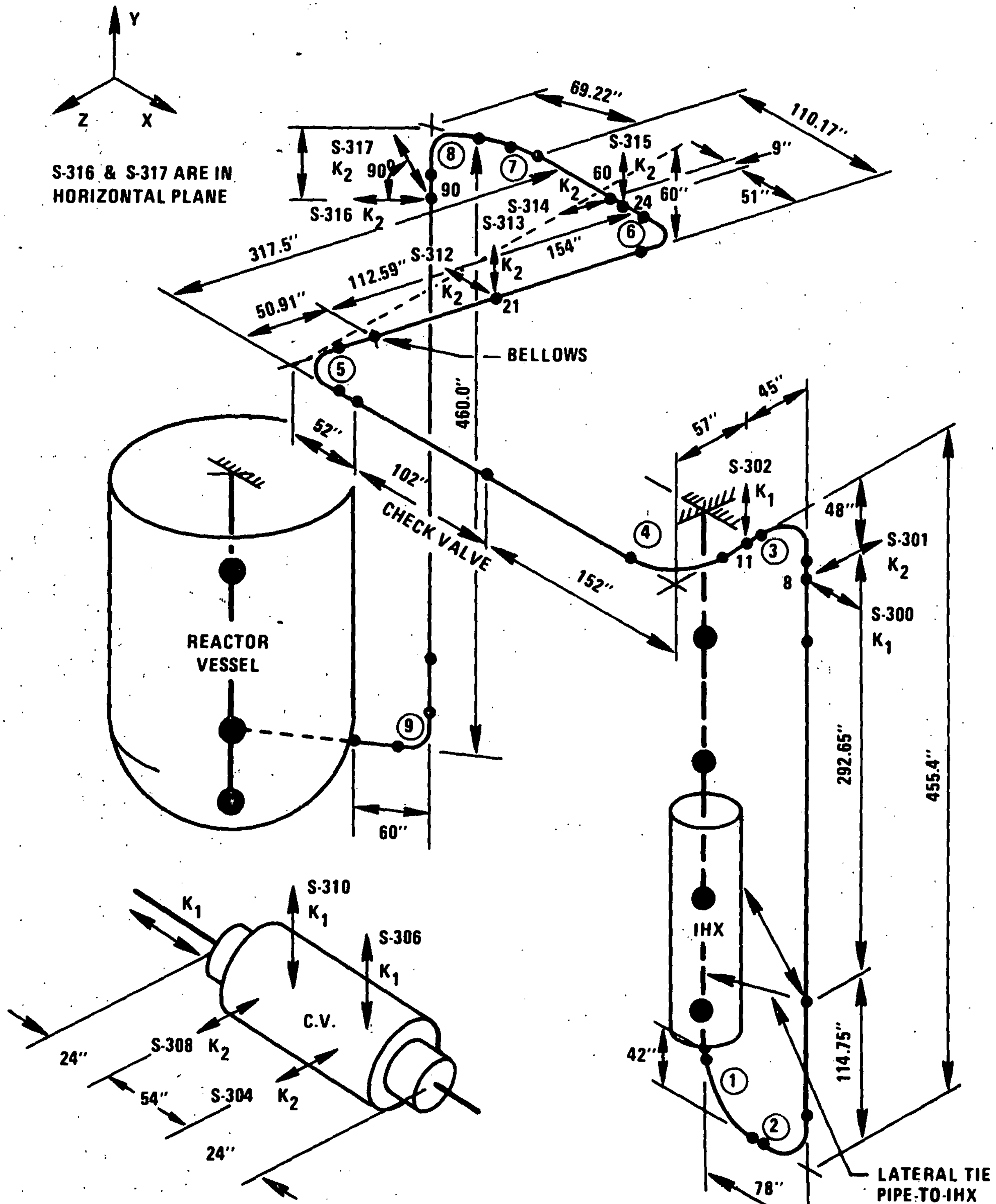
SEISMIC MODEL FOR CRBRP PRIMARY HEAT TRANSPORT SYSTEM COLD LEG PIPING



1. ELBOW NUMBERS ARE IDENTIFIED BY (n)
2. ALL ELBOWS 36" R

←→ SNUBBER LOCATION

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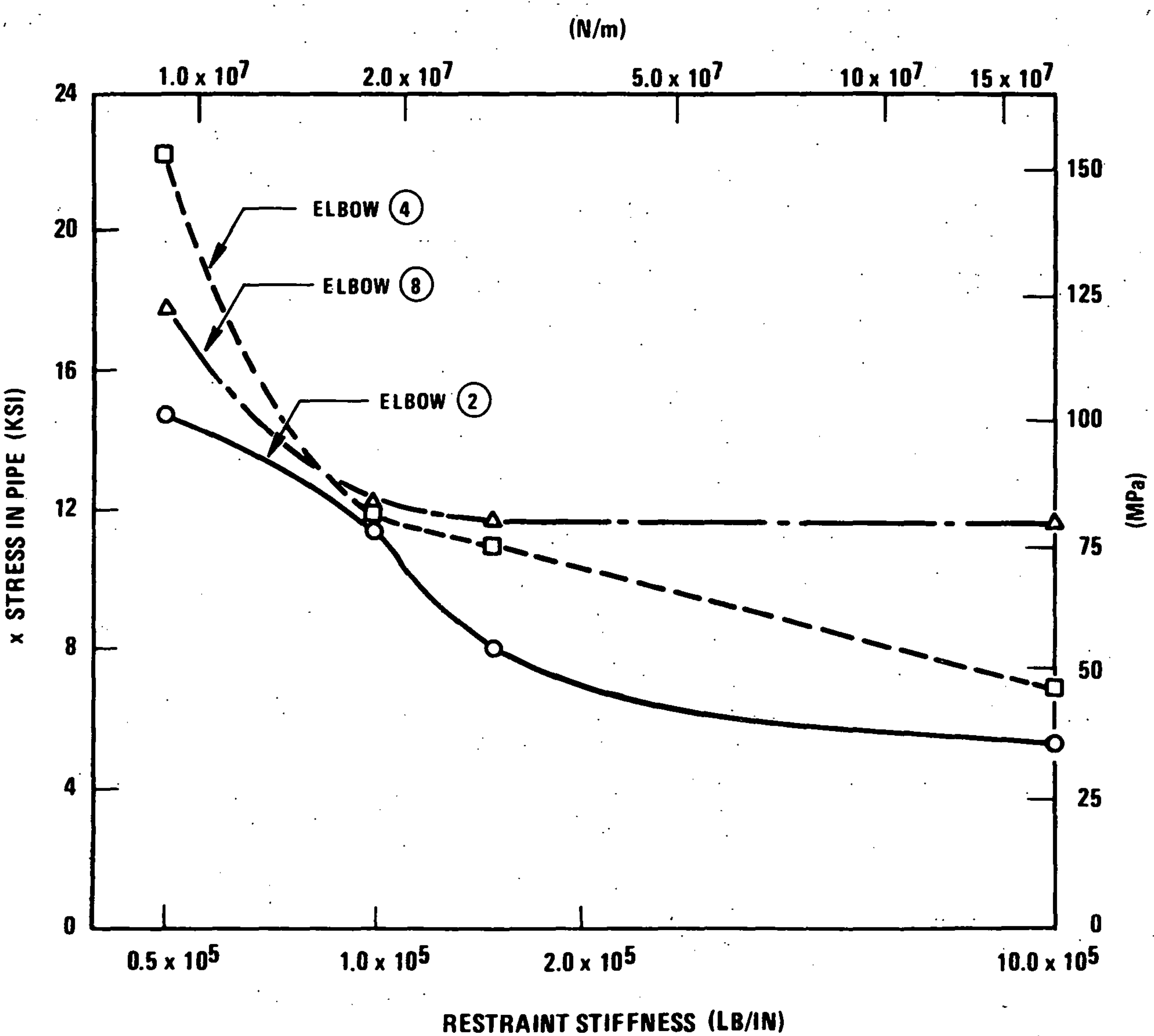
SEISMIC STRESS RESULTS AS A FUNCTION OF RESTRAINT STIFFNESS FOR CRBRP HTS COLD LEG PIPING



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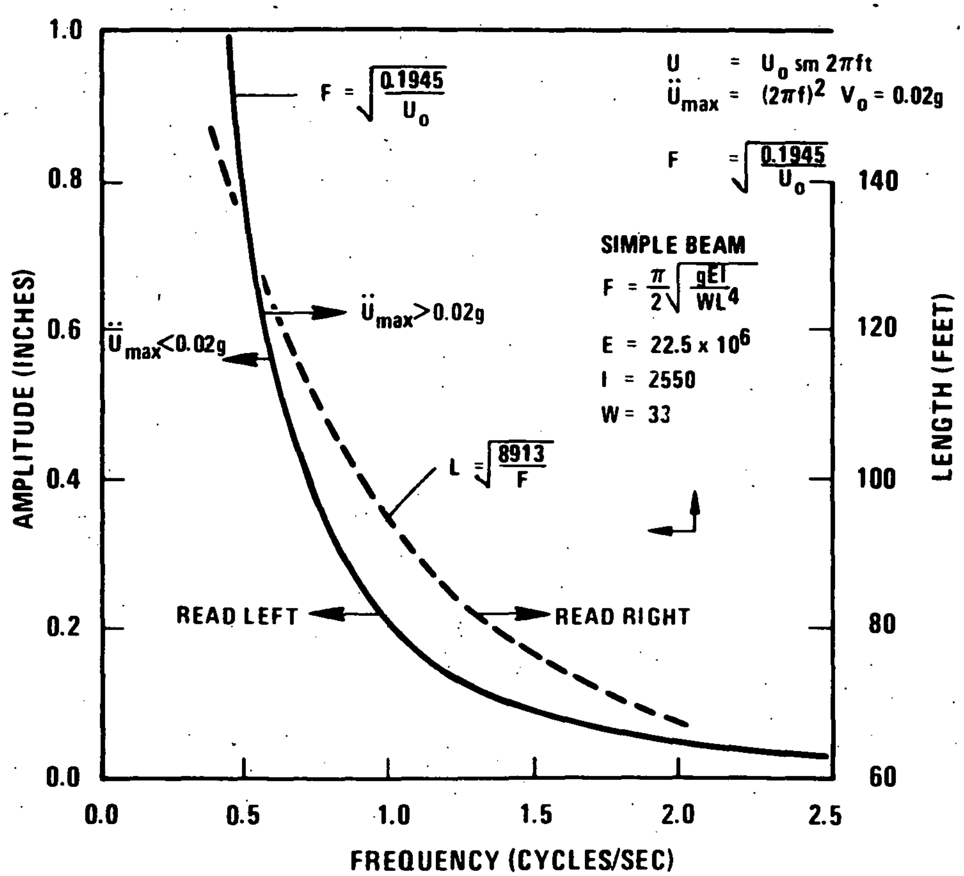
CONSIDERATION OF ACCELERATION LOCK-UP THRESHOLD

- DESCRIPTION
  - ASSUME SNUBBER LOCKUP IS GOVERNED BY 0.02G ACCELERATION THRESHOLD; INDEPENDENT OF AMPLITUDE
  - AT FREQUENCIES LESS THAN 2 CPS, LARGE DISPLACEMENT AMPLITUDES CAN DEVELOP WITHOUT ACTIVATING SNUBBERS
  - NATURAL FREQUENCIES LESS THAN 2 CPS ARE PLAUSIBLE IF ANCHOR-TO-ANCHOR PIPE LENGTHS ARE CONSIDERED

- ILLUSTRATIVE EXAMPLE
  - A 24" PIPE 95' ANCHOR-TO-ANCHOR HAS A NATURAL FREQUENCY OF 1 CPS AND MAY VIBRATE WITH 0.2" AMPLITUDE WITHOUT ACTIVATING 0.02G SNUBBERS

- CONCLUSION
  - INVESTIGATION OF PIPE RESTRAINT EFFECTS SHOULD INCLUDE CONSIDERATION OF RESPONSE BELOW LOCK-UP THRESHOLDS



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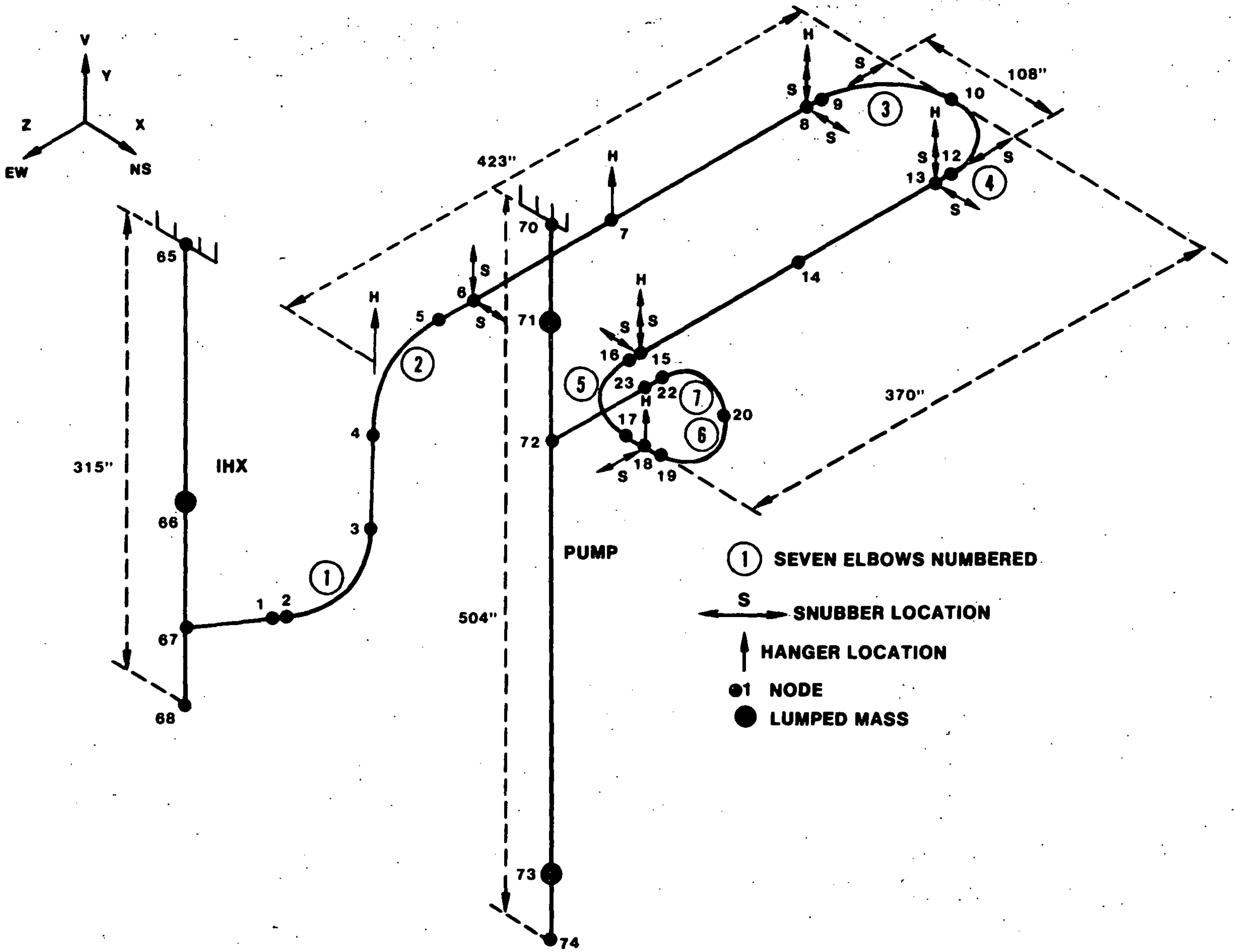
REPRESENTATIVE LMFBR PRIMARY PIPING FOR STUDY OF SNUBBER FREE PLAY



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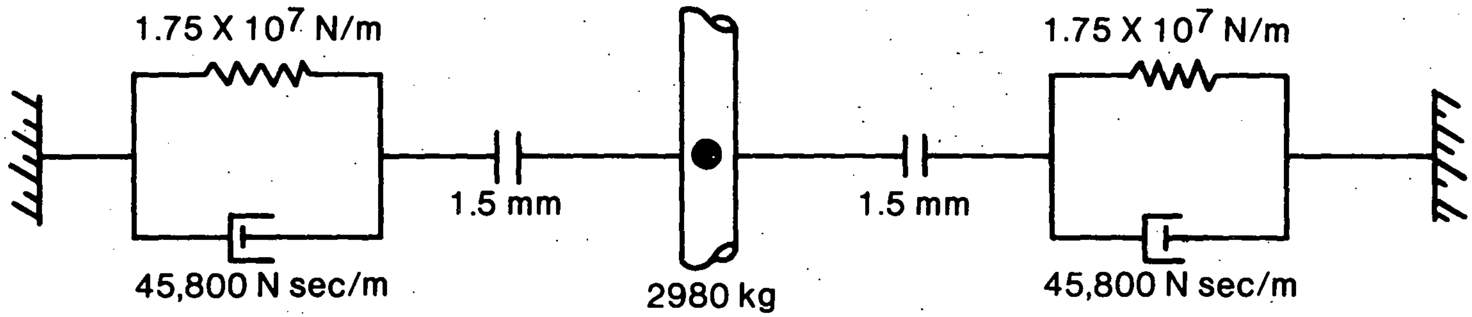
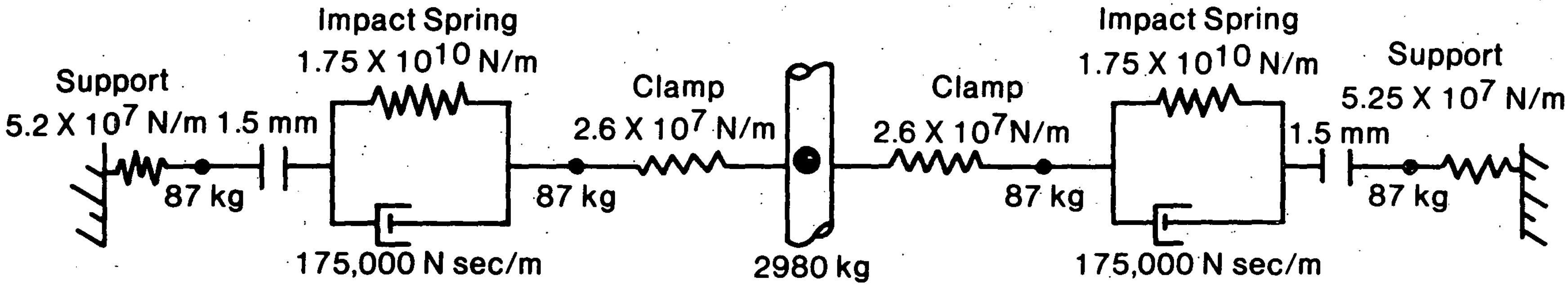
SNUBBER MODELS FOR STUDY OF FREEPLAY EFFECTS

Simplified Representation of Snubber/Pipe Area



Detailed Representation of Snubber/Pipe Area



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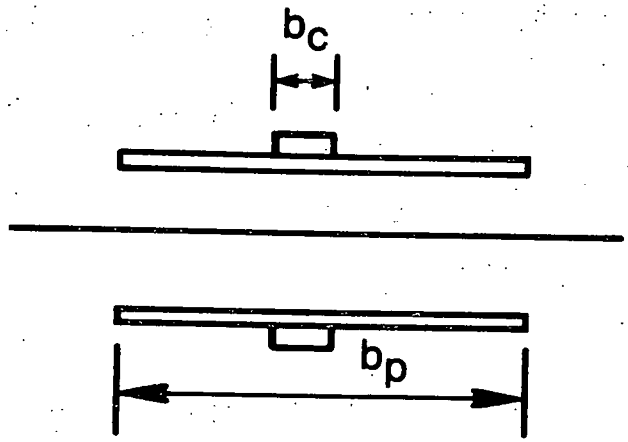
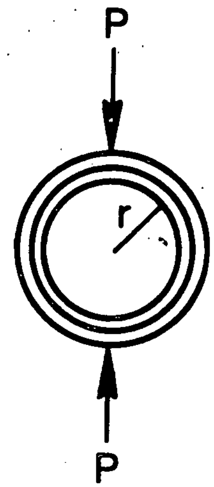
RESULTS OF SNUBBER FREE PLAY STUDY

CASE	MODEL	SUPPORT K (N/m)	CLAMP K (N/m)	RESTITUTION COEFFICIENT	MASS ASSOCIATED WITH SNUBBERS (kg)	SNUBBER K (N/m)	SNUBBER TOTAL GAP (mm)	MAX. BEND. STRESS ELBOWS 5, 6 & 7 (MPa)
1	Resp. Spect. Phase II	1.75×10^7		NA	0	NA	0	28.5
2	Resp. Spect. Phase II	1.75×10^8		NA	0	NA	0	14.6
3	Time His. Simplified	--	--	.5	2977	1.75×10^7	1.5	28.6 for .67 sec
4	Time His. Detailed	5.2×10^7	2.6×10^7	.5	87 & 87	1.75×10^{10}	1.5	55.1 for .60 sec
5	Time His. Detailed	5.2×10^7	2.6×10^7	.5	175 & 175	1.75×10^{10}	1.5	59.3 for .60 sec
6	Time His. Detailed	5.2×10^7	2.6×10^7	.8	87 & 87	1.75×10^{10}	1.5	57.9 for .60 sec
7	Time His. Detailed	5.2×10^7	2.6×10^7	.5	87 & 87	1.75×10^9	1.5	53.8 for .60 sec
8	Time His. Detailed	5.2×10^7	2.6×10^7	.3	87 & 87	1.75×10^{10}	1.5	55.8 for .60 sec
9	Time His. Detailed	5.2×10^7	2.6×10^7	.5	87 & 87	1.75×10^{10}	.75	31.7 for .65 sec
10	Time His. Detailed	5.2×10^7	2.6×10^7	.5	87 & 87	NA	.000	20.0 for .60 sec
11	Time His. Detailed	3.5×10^8	3.5×10^8	.5	175 & 175	3.5×10^8	1.5	36.5 for .65 sec
12	Resp. Spect. Detailed	5.2×10^7	2.6×10^7	NA	175 & 175	NA	0	65.2
13	Resp. Spect. Detailed	3.5×10^8	3.5×10^8	NA	175 & 175	NA	0	14.5
14	Time His. Detailed	5.2×10^7	2.6×10^7	.5	87 & 87	1.75×10^7	1.5	25.5 for .62 sec
15	Time His. Simplified	--	--	.5	2977	1.75×10^7	.75	14.5 for .67 sec





$$K = \frac{P}{\Delta r}$$

- Ring Stiffness

  $K = 1.12\,Eb\,(t/r)^3$

  or

  $K = 19400\,bt^3$

Where $E = 30X10^6$ psi, $r = 12$ in

- Simplified Model of Clamp/Pipe Stiffness

  $$K = 19400\left[b_c t_c^3 + b_p t_p^3\right]$$

- Introduction of Estimated Effective Pipe Length

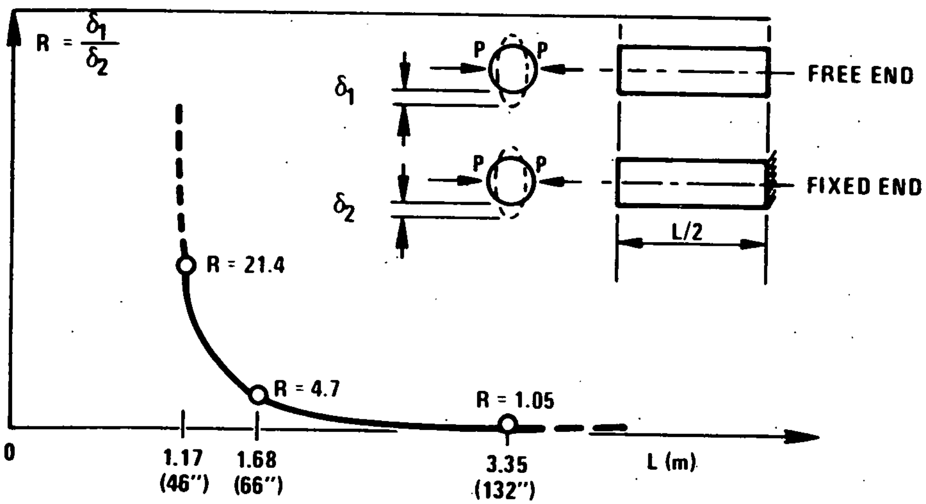
  $$K = 19400\left[b_c t_c^3 + 50\,t_p^{2.6}\right]$$ Where $b_p = 1.68\,r\,(r/t)^{0.366}$

- Example: $t_c = t_p = 0.5$in., $b_c = 8.0$ in.

  $$K = 19400\left[1.0 + 8.2\right]$$

- Conclude: Clamp/Pipe Stiffness is Due Primarily to Pipe

POINT LOAD ESTIMATE OF STIFFNESS

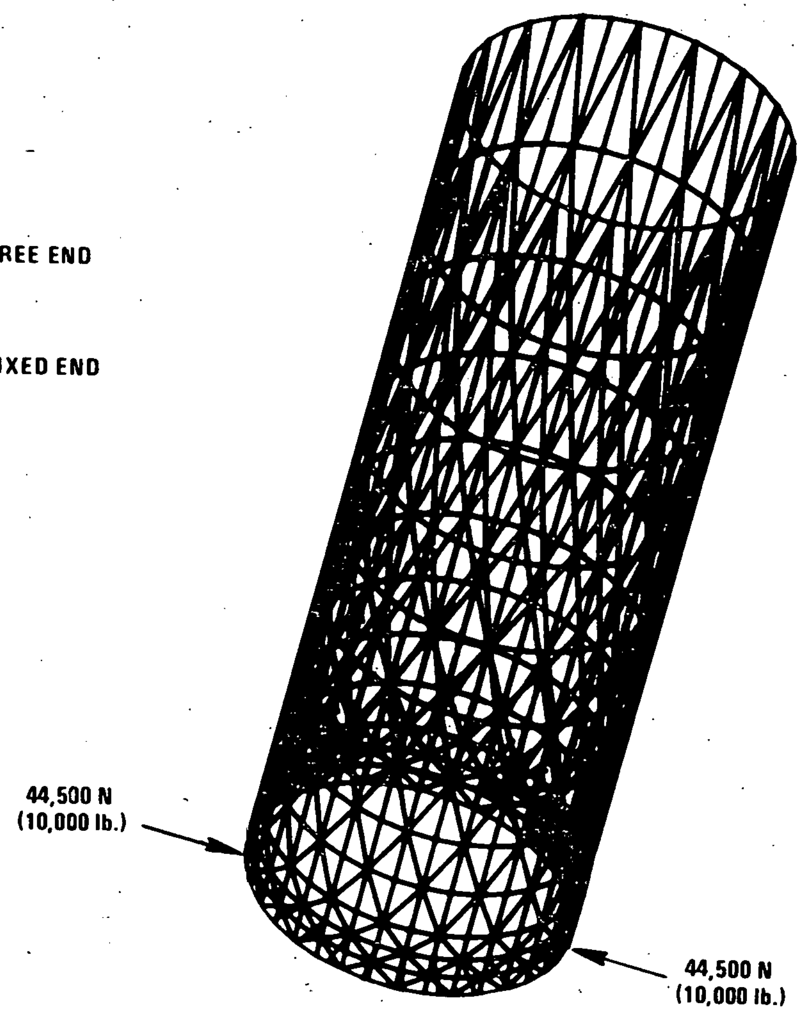


(b) COMPARISON OF END CONDITION

(c) STIFFNESS DETERMINATION

- DISPLACEMENT UNDER APPLIED LOAD = .213 cm
  K_{pipe} = 44,500/.213 = 2.1×10^7 N/m (1.2×10^5 lb/in)

- DISPLACEMENT AT 90° TO LOAD = .137 cm
  K_{pipe} = 44,500/.137 = 3.2×10^7 N/m (1.8×10^5 lb/in)



(a) PIPE FINITE ELEMENT MODEL

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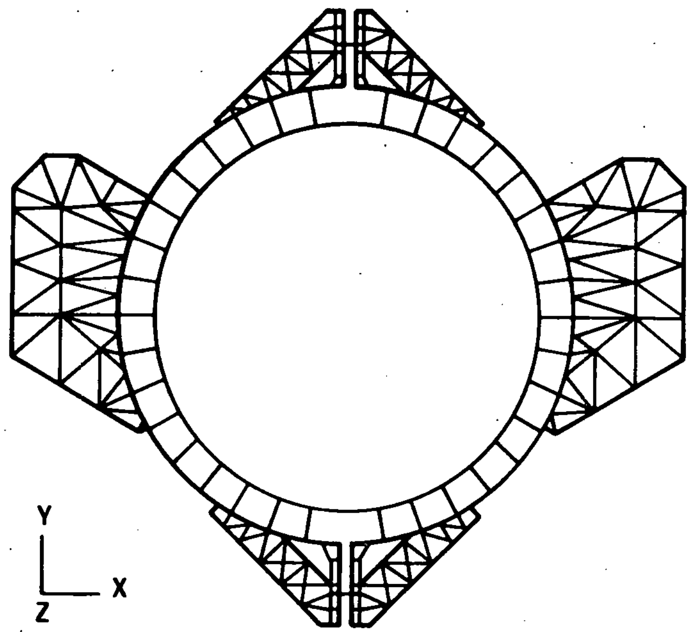
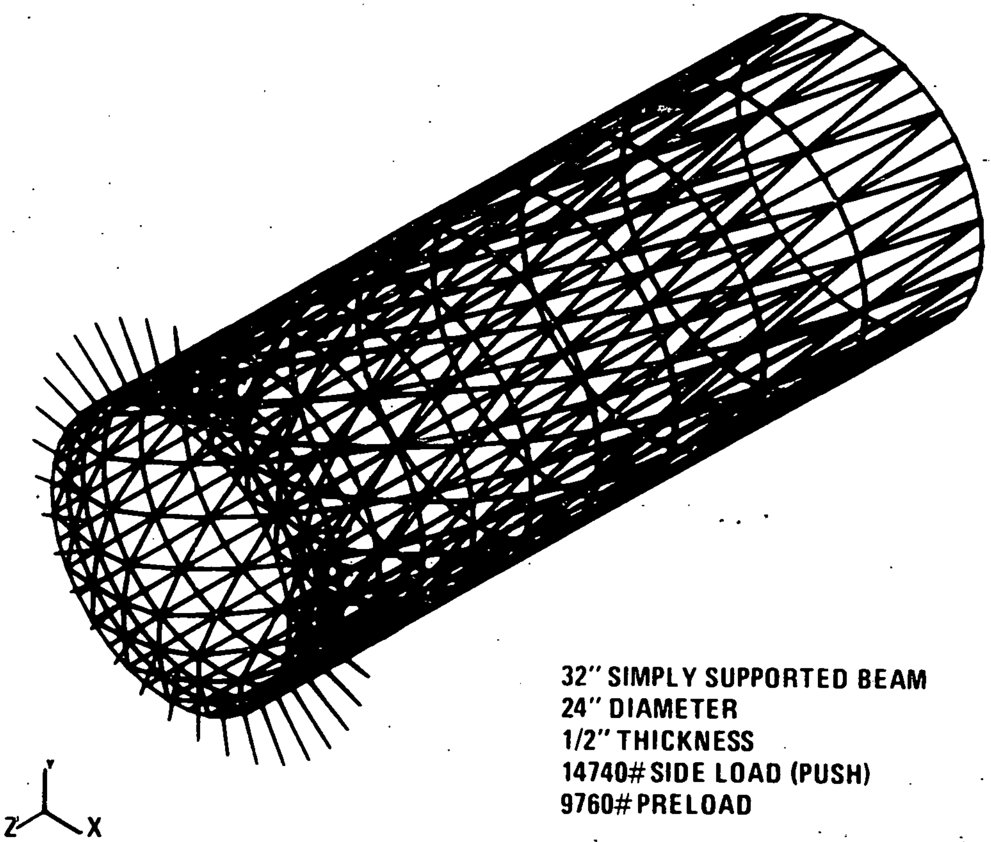
CLAMP/PIPE STIFFNESS BY DETAILED ANALYSIS

- DESCRIPTION OF FINITE ELEMENT MODEL





32" SIMPLY SUPPORTED BEAM
24" DIAMETER
1/2" THICKNESS
14740# SIDE LOAD (PUSH)
9760# PRELOAD

- SUMMARY OF RESULTS
  - 0.013 INCH BEAM CENTERLINE DISPLACEMENT
  - 0.021 INCH LUG DISPLACEMENT RELATIVE TO CENTERLINE
  - 7.0×10^5 LB/INCH CLAMP/PIPE STIFFNESS, $K_{CLAMP/PIPE}$

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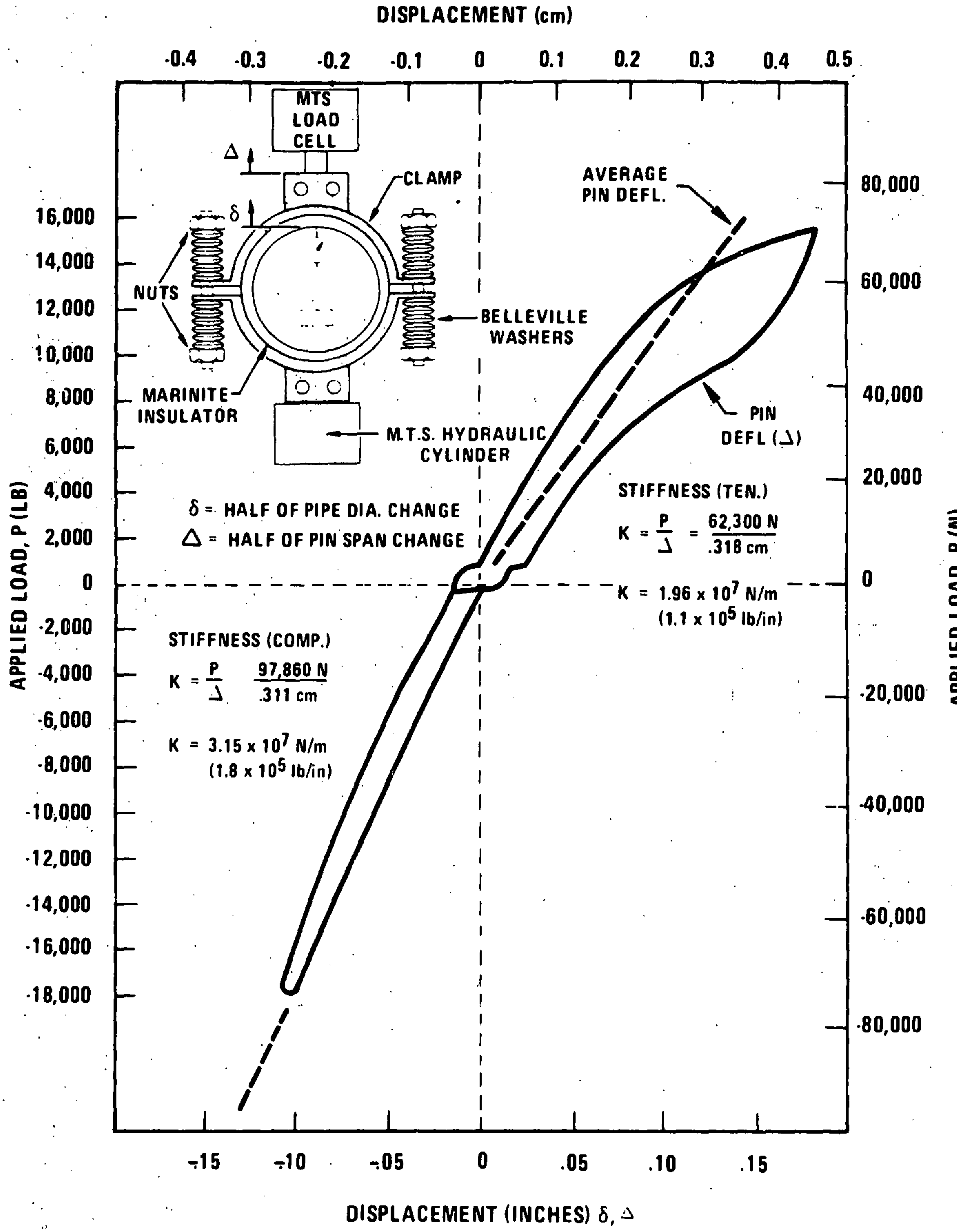
TEST OF CLAMP/PIPE STIFFNESS



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SUMMARY OF PHTS 24 INCH HOT LEG CLAMP/PIPE STIFFNESS DETERMINATION

No.	Basis of Clamp/Pipe Stiffness Approximations	Clamp/Pipe Compression 10^{-5} (K_c Lb/In)	Stiffness Tension 10^{-5} (K_c Lb/In)
1	Ring-Plus Clamp Pinched by Point Loads, Ring Width of 48 Inches	1.1	—
2	Preliminary Clamp/Pipe Stiffness Test, Preload O.O. Compression	1.6	—
3	Preliminary Clamp/Pipe Stiffness Test, Preload 5000	1.8	0.9
4	Preliminary Clamp/Pipe Stiffness Test, Preload 10000	1.8	1.1
5	Cylinder Pinched by Point Loads Using Displacement Under Load	1.2	—
6	Cylinder Pinched by Point Loads Using Displacement 90° to Load	1.8	—
7	Detailed Finite Element Model of Clamp/Pipe	7.0	3.3
	Best Estimate for Preliminary Support Flexibility Effects Study	2.0	2.0

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ADVANCED STUDIES OF PIPING RESTRAINT EFFECTS

PIPING RESTRAINT EFFECTS ON PIPING INTEGRITY

Session Chairman: R. H. MALLETT
Westinghouse, Advanced Reactors Division

Session Vice Chairman: R. J. BOSNAK
U. S. Nuclear Regulatory Commission

Technical Papers and Presentations:

1. "AN OVERVIEW OF EFFORTS TO RESOLVE SAFETY ISSUES ASSOCIATED WITH SNUBBERS UTILIZED IN NUCLEAR POWER GENERATING FACILITIES"
   J. Kovacs, U. S. Nuclear Regulatory Commission

2. "MECHANICAL SNUBBER CHARACTERISTICS"
   B. T. Lothers, Pacific Scientific Company

3. "THE EFFECT OF SUPPORT STIFFNESS UPON THE SEISMIC RESPONSE OF PIPING SYSTEMS"
   J. D. Stevenson and L. A. Bergman, Woodward Clyde Consultants

4. "A SNUBBER RESPONSE SENSITIVITY STUDY"
   A. T. Onesto, Energy Technology Engineering Center

5. "EVALUATION OF THE INFLUENCE OF SEISMIC RESTRAINT CHARACTERISTICS ON BREEDER REACTOR PIPING SYSTEMS"
   R. M. Mello and L. P. Pollono, Westinghouse jAdvanced Reactors Division

6. "COMPARISON OF NON-LINEAR ANALYSIS, LINEAR ANALYSIS, AND TEST RESULTS FOR CANTILEVER BEAL WITH SNUBBER SUBJECT TO SINUSOIDAL LOAD"
   E. O. Swain, H. L. Hwang, C. T. Nieh, J. L. Thompson, General Electric Company

7. "EFFECTS OF RESTRAINT STIFFNESS AND GAP ON THE DYNAMIC RESPONSE OF PIPING SYSTEMS"
   K. C. Chang, E. R. Johnson, and P. J. Kotwicki, Westinghouse Electric Corporation

8. "NON-LINEAR SEISMIC ANALYSIS OF LMFBR PIPING"
   W. G. Brussalis, Westinghouse Electric Corporation

9. "NON-LINEAR RESPONSE OF PIPING"
   N. Varadarajan, S. Levy, M. Triplett, J. Thompson, G. Esswein, General Electric Company

10. "EFFECTS OF ENERGY ABSORBING RESTRAINERS ON SEISMIC STRESSES IN PIPING"
   G. H. Powell and D. G. Row, University of California

11. "STATUS REPORT-A DYNAMIC TESTING AND ANALYSES RESEARCH PROGRAM ON THE NON-LINEAR RESPONSE OF PIPING SYSTEMS AND COMPONENTS"
   G. E. Howard and P Ibanez, ANCO Engineers, Inc.
   C. Chan, Electric Power Research Institute

12. "STATUS REPORT-US NRC STUDY TO DETERMINE EFFECTS OF POSTULATED EVENT DEVICES ON NORMAL OPERATIONS OF LWR PIPING SYSTEMS"
   K. D. Desai, Nuclear Regulatory Commission
   R. Hookeway, Teledyne Engineering Services

ASME TECHNICAL SESSION AND SPECIAL PUBLICATION

ASME National Congress on Pressure vessels and Piping San Francisco, California
June 25-29, 1979

CRBRP DEVELOPMENT ACTIVITY DESCRIPTION

- Objective of Development Program
  - To Develop and Verify Models of Piping Restraints for use in Design of HTS Piping
- Reason for Development Program
  - Preliminary Analyses and Tests Indicate That Piping Restraint Effects on Piping Integrity are More Important and More Complex Than Presently Reflected in Conventional Piping Design Practice
- Technical Approach
  - By Correlation of Predicted and Measured Responses of Representative Piping Systems
- Expected Results
  - Guidance for Locating and Designing Pipe Clamps
  - Models of Piping Restraints for use in Plant Piping Design Analyses
  - Design Requirements to Place on Piping Restraint Devices and Structures

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