TELEDYNE
ENGINEERING SERVICES

130 SECOND AVENUE

WALTHAM, MASSACHUSETTS 02254

(617) 890-3350 TWX (710) 324-7508

December 11, 1985
6410-25

Mr. Vince Noonan, Project Director
Comanche Peak Project
U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Licensing
Mail Stop P-234
Washington, D. C. 20555

Dear Mr. Noonan:

Attached please find our preliminary Trip Report for our visit to EBASCO's New York Office to audit TUGCO's presentation of the "Senderness Ratio Limitations for Cable Tray Hanger Type Supports."

If you have any questions please do not hesitate to contact me.

Very truly yours,

TELEDYNE ENGINEERING SERVICES

J J Binard for

Donald F. Landers
Executive Vice President

DFL/lh

Attachment (Trip Report No. 2185)

cc: L. Shao (USNRC)
C. Trammell (USNRC)
C. Poslusny (USRNC)
D. Jeng (USNRC)
6410 File (TES)

See Attached
2222
1/1 Per C. Trammell

Project 6410

DRAFT

Trip Report No. 2185

EBASCO's New York Office to Audit TUGCO's Presentation of the "Senderness Ratio Limitations for Cable Tray Hanger Type Supports"

November 26, 1985

The purpose of this trip was to audit the above titled presentation by TUGCO (Ebasco and Impell). The objective of this presentation was to outline the preliminary engineering evaluation to justify that vertical members of hanger-type cable tray supports which have Kl/r values greater than 200 are in compliance with the existing licensing commitment of Comanche Peak, specifically the AISC 7th Edition.

Mr. Harrison gave a brief summary and status of the cable tray supports program at Comanche Peak.

- o Ebasco and Impell performing design verification of all cable tray supports, Unit 1 and Unit 2.
- o Construction complete on Unit 1.
- o Construction not yet complete for Unit 2.
- o 28% of the cable tray supports in Unit 2 require modification.
- o 14% of these modifications due to hanger type supports with Kl/r greater than 200.

Mr. Wheaton (Impell) outlined the TUGCO presentation of the "Slenderness Ratio Limitations for Hanger-Type Supports." This presentation is outlined in Attachment II.

The basic issue of this presentation was should the AISC Code limitations on Kl/r values be applied to hanger-type cable tray supports which do not have any static compression loads? See pages 1 and 2 of Attachment II. Also at issue is if the Kl/r limitations in the AISC Code are not met are these cable tray support members in compliance with the Comanche Peak licensing commitments. The licensing commitment in this case is to apply the 7th Edition of the AISC Code in a proper manner. The real issue is whether the AISC Code intended members similar to the vertical members of the hanger type supports to be treated as compression members.

Mr. Wheaton pointed out that the maximum Kl/r value in the AISC Code is arbitrary. TUGCO has been unable to find the basis for the maximum value of 200. The codes of other countries allow higher values of Kl/r (see page 9 of

Attachment II). The Column Research Council does not recommend a maximum value. One theory Mr. Wheaton gave as to the origin of the 200 limit was that it was based on the buckling equations in the 1923 and 1936 AISC Codes. As the slenderness ratio increased the factor of safety decreased and the limit of 200 was imposed to assure that the factor of safety was greater than 1.0 (see page 7 of Attachment II).

The position outlined in this presentation is that these hanger support members which only see a dynamic compression load are not true compression members (see page 10 of Attachment II). The AISC 8th Edition commentary states that "Impact Loads" (the dynamic portion of traveling wheel loads) have too short a duration to have an effect on column buckling. As stated on page 11 of Attachment II seismic loads have a shorter duration than traveling wheel loads. Also noted during this presentation was that piles see dynamic compression loads larger than their allowable static buckling load and the pile does not buckle due to the short duration of this dynamic load (see page 14 of Attachment II).

A dynamic analysis was performed on a section of an existing cable tray system. Five hanger type trays were analyzed using the maximum input spectra from the top of the reactor building. Kl/r assumed as high as 394 (see pages 15 and 16 of Attachment II). The results suggest that the members saw no appreciable buckling. The results are shown on pages 18, 19, 20 and 21 of Attachment II.

Mr. Wheaton discussed dynamic instability, pages 22 and 23 of Attachment II, and stated briefly that the load amplitude and duration was too short for dynamic instability to be a problem.

The conclusion of this presentation was that the Kl/r limits are irrelevant. This conclusion is based on the following.

- The results of the dynamic analysis performed on a portion of an existing system.
- The short duration of seismic loads have little effect on the buckling of members (Section 5.1 of the Column Research Council's Guide to Stability Design Criteria for Metal Structures) which deals with dynamic load effects states that seismic and blast loads as well as pile driving loads are of too short a duration to have a significant effect on buckling.
- The 200 limit for Kl/r is arbitrary and AISC intended this limit only for true columns not the members in question.

It is TUGCO's position that the Kl/r limit should not apply to members which do not experience static compression loads but that the allowable com-

pressive stresses for all members experience "ANY" type of compressive load shall be determined in accordance with Section 1.5.1.3 of the 7th Edition of the AISC Code.

As part of this presentation a video was shown of the testing done at ANCO of Seabrook cable tray supports. The supports are similar in configuration to the Comanche Peak supports but were constructed from Unistrut members not structural shapes as are the Comanche Peak supports. The input spectra for these tests (OBE and SSE) was 20% higher than the maximum Seabrook spectra (3 directions) which is higher than the Comanche Peak spectra. There did not appear to be any member damage to the supports tested. There was some damage to cable tray clips and a large number of the cable ties broke. There was no way to determine if there is sufficient slack in the cables to accomodate the large cable movements indicated in the tests due to the damaged tray clips and broken cable ties.

J.J. Rivard

JJR/khc
Attachments (2)

cc: Trip Report File
R.D. Ciatto
J.A. Flaherty
D.F. Landers
E.A. Solla
Vince Noonan, NRC

TELEDYNE
ENGINEERING SERVICES

ATTACHMENT I

Inspection Report List of Attendees

1. Title: Audit of TUGCO's Presentation of the "Slenderness Ratio Limitation for Cable Tray Hanger Type Supports"

2. NRC Consultants:

J.J. Rivard, TES
P.C. Wang, BNL
M. Reich, BNL
P. Bezler, BNL

3. TUGCO/CPRT Staff:

H.A. Harrison, TUGCO
C.R. Hooton, TUGCO
R.C. Iotti, Ebasco
F. Hettinger, Ebasco
S.J. Chen, Ebasco
R. Sullivan, Ebasco
J. Padalino, Ebasco
R. Alexandru, Ebasco
R.D. Wheaton, Impell
K.C. Warayius, Impell
J.L. McLean, R.L. Cloud

ATTACHMENT II

SLENDERNESS RATIO LIMITATIONS FOR HANGER-TYPE SUPPORTS

PRESENTED TO:

U.S. NUCLEAR REGULATORY COMMISSION

PRESENTED BY:

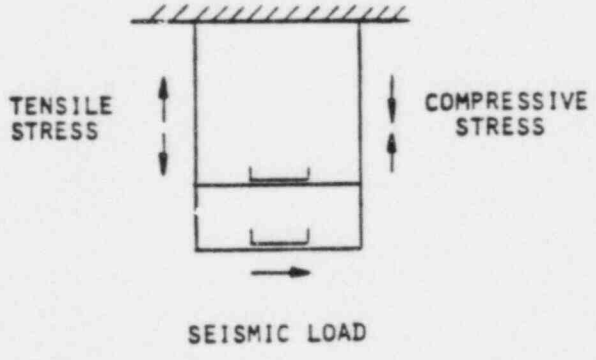
TEXAS UTILITIES GENERATING COMPANY

NOVEMBER 15, 1985

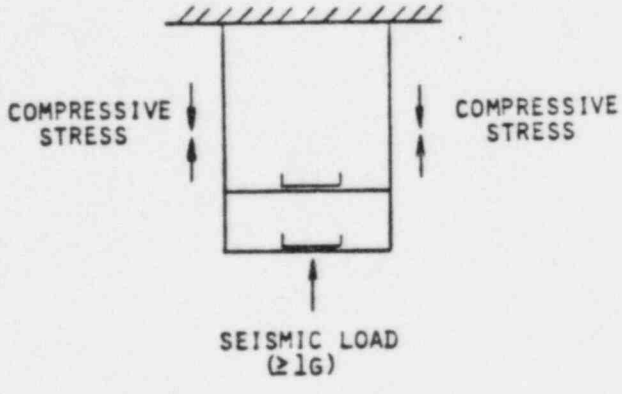
BASIC ISSUE

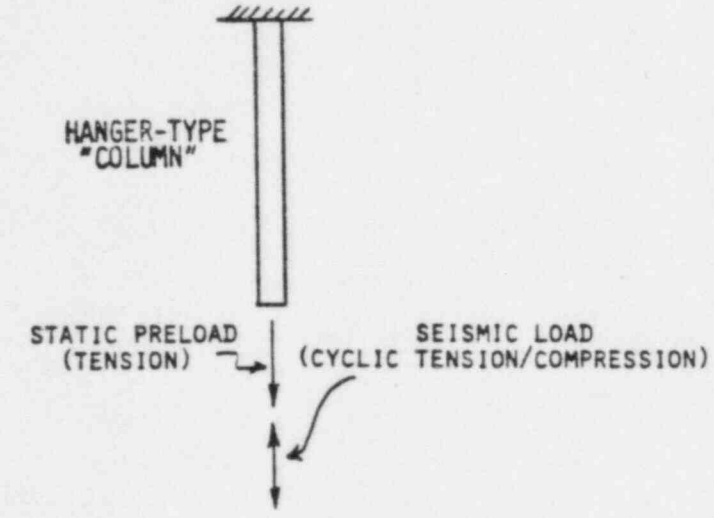
SHOULD AISC CODE LIMITATIONS ON KL/R VALUES BE APPLIED TO HANGER-TYPE RACEWAY SUPPORTS?

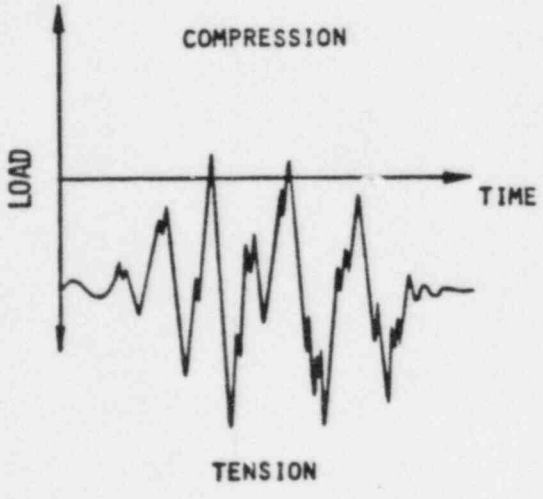
CASE 1:



CASE 2:







AXIAL LOAD IN HANGER-TYPE SUPPORTS

MAJOR CONSIDERATIONS

1. LICENSING COMMITMENTS

2. AISC CODE COMPLIANCE

3. ENGINEERING EVALUATION

1. LICENSING COMMITMENTS

- o FSAR SECTIONS 3.7B AND 3.10B:
  - QUALIFICATION BY TEST OR ANALYSIS
  - DEMONSTRATE STRUCTURAL AND FUNCTIONAL INTEGRITY
- o FSAR APPENDIX 17: AISC CODE DEFINES ACCEPTANCE CRITERIA FOR ANALYTICAL QUALIFICATION
- o APPLICABILITY OF ANY GIVEN CRITERION DEPENDENT UPON SITUATION AT HAND

CONCLUSIONS:

- o LICENSING COMMITMENT IS TO APPLY CODES AND STANDARDS IN A RATIONAL MANNER TO ALL ELECTRICAL SYSTEMS AND SUPPORTS

2. AISC CODE COMPLIANCE

- o AISC SPECIFIES KL/R $\leq$ 200 FOR COMPRESSION MEMBERS
- o TUGCO DOES NOT CHALLENGE LIMITATION - ONLY ISSUE IS WHEN TO APPLY IT
- o APPLICABILITY CAN BE EVALUATED BY CONSIDERING THREE MAIN FACTORS
  - BACKGROUND OF KL/R LIMITS
  - TENSION OR COMPRESSION MEMBER
  - STATIC OR DYNAMIC LOAD

2. AISC CODE COMPLIANCE (CONT.)

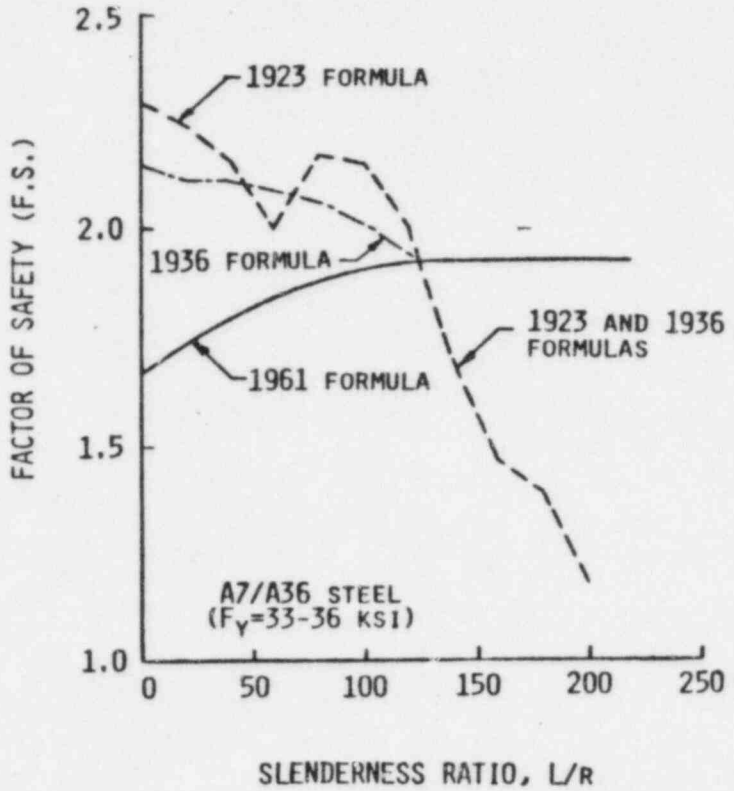
BACKGROUND

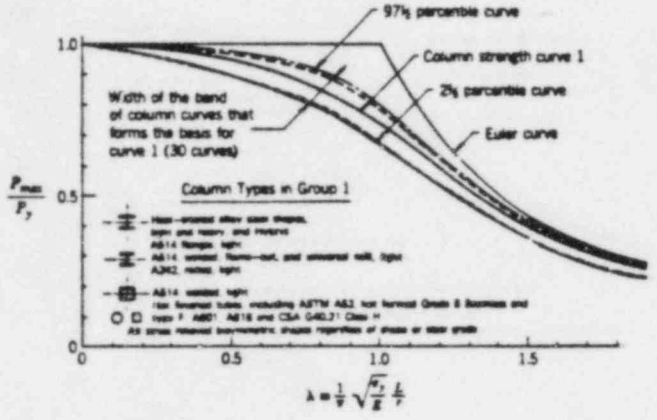
- o KL/R LIMIT OF 200 UNCHANGED SINCE EARLIEST EDITIONS
- o LIMIT APPEARS TO HAVE BEEN BASED ON DECREASING FACTOR OF SAFETY IN BUCKLING EQUATION FOR HIGH KL/R RATIOS
- o SAFETY FACTOR NOW HELD AT 1.92 FOR ALL KL/R GREATER THAN 126
- o CURRENT BUCKLING EQUATIONS MORE ACCURATE FOR HIGH KL/R THAN FOR LOW - EXTENSIVE EXPERIMENTAL VERIFICATION
- o LIMIT OF 200 NOW APPEARS TO BE ARBITRARY - OTHER CODES VARY LIMIT FROM 180 TO 260 - COLUMN RESEARCH COUNCIL DOES NOT RECOMMEND ANY KL/R LIMITS
- o WORLDWIDE, ALL CODES DISCUSS KL/R ONLY IN RELATION TO "TRUE COLUMNS"
  - STATIC COMPRESSION AND BENDING LOADS
  - ALL PRIMARY LOADS
  - NO LOAD REDISTRIBUTION
  - UNSTABLE BUCKLING FAILURES
- o HANGER-TYPE SUPPORTS DO NOT MEET ANY OF THE CRITERIA FOR A TRUE COLUMN

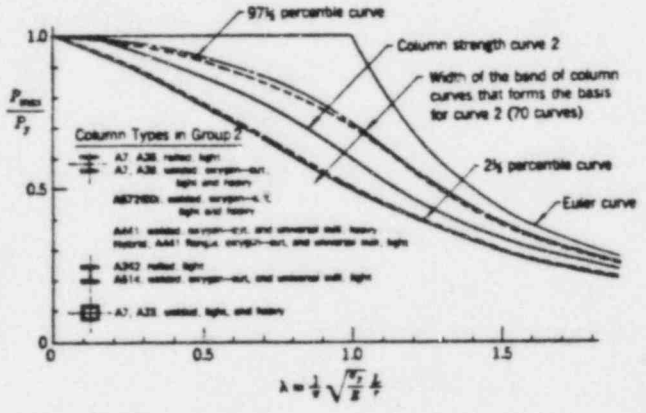
CONCLUSION:

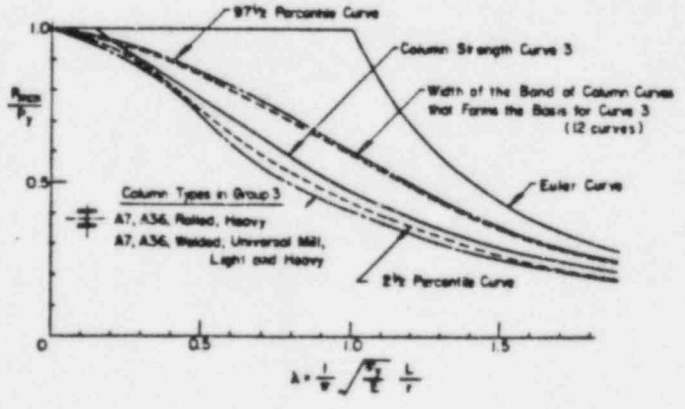
MAXIMUM KL/R VALUE IS ARBITRARY - SOME LIMIT MAY BE ADVISABLE FOR TRUE COLUMNS BUT RELEVANCE TO HANGER-TYPE COMPONENTS IS QUESTIONABLE

FACTORS OF SAFETY IN AISC BUCKLING EQUATIONS

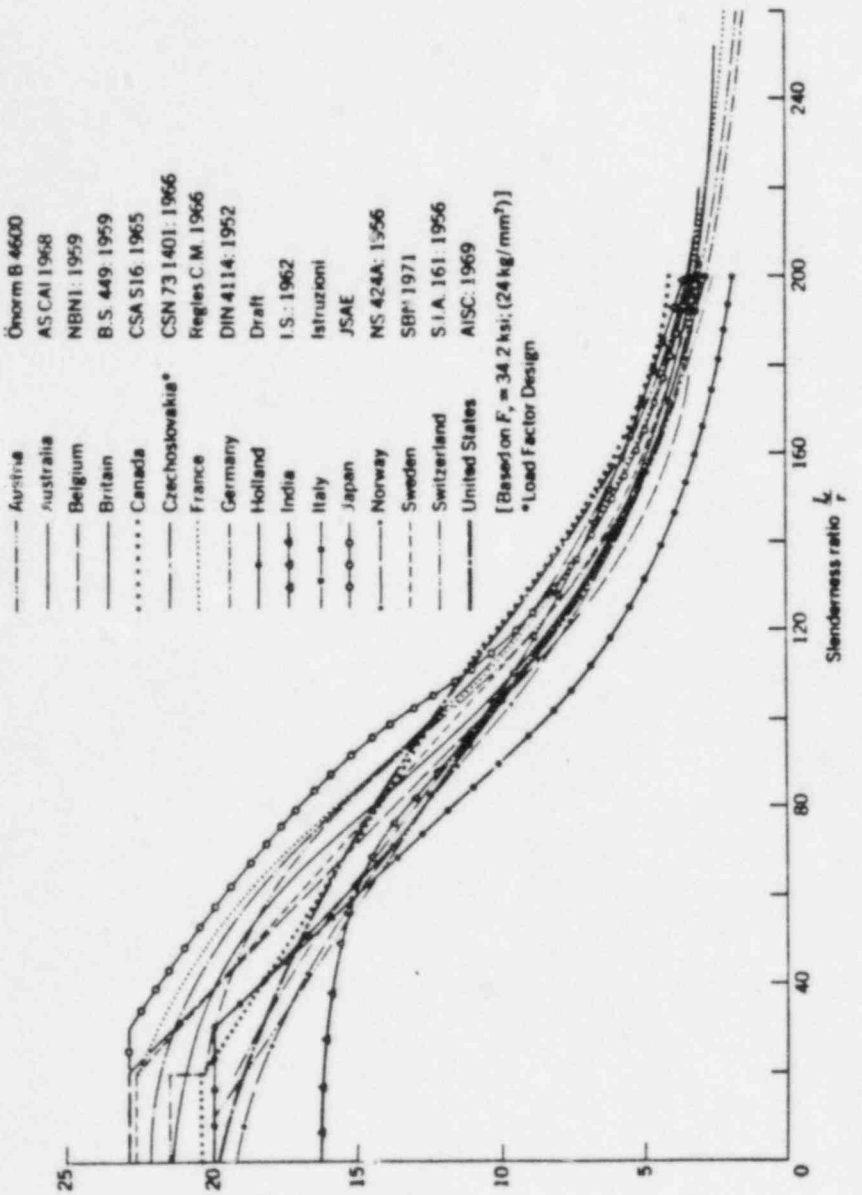








CRC RECOMMENDED COLUMN STRENGTH CURVES



TYPICAL COLUMN STRENGTH CURVES WORLDWIDE

2. AISC CODE COMPLIANCE (CONT.)

TENSION vs. COMPRESSION MEMBERS

- AISC CODE PROVIDES NO DEFINITIONS - INTERPRETATION REQUIRED
- CODE DISCUSSES KL/R ISSUE FOR BOTH TENSION AND COMPRESSION MEMBERS - NOT ALL MEMBERS FALL INTO COMPRESSION CATEGORY
- ANY MEMBER CAN SEE AN INCIDENTAL DYNAMIC COMPRESSION DURING AN EARTHQUAKE
- ONLY CODE REFERENCE TO DYNAMIC LOADS ALLOWS THEM TO BE NEGLECTED IN COLUMN BUCKLING PROBLEMS
- DYNAMIC COMPRESSION ALONE MUST NOT BE A SUFFICIENT BASIS FOR CLASSIFICATION
- ENGINEERING EVALUATION MUST BE PERFORMED TO ASSESS STRUCTURAL FUNCTION, NATURE OF LOADS AND CONSEQUENCES OF POSSIBLE OVERLOADS

CONCLUSIONS:

- NO RIGOROUS OR GENERALIZED CLASSIFICATION POSSIBLE
- CODE TREATMENT OF DYNAMIC COLUMN LOADS SUGGESTS THAT HANGER-TYPE SUPPORTS WOULD FALL INTO TENSION MEMBER CATEGORY

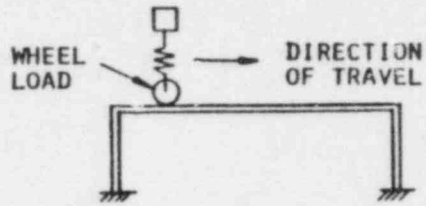
2. AISC CODE COMPLIANCE (CONT.)

STATIC vs. DYNAMIC LOADS

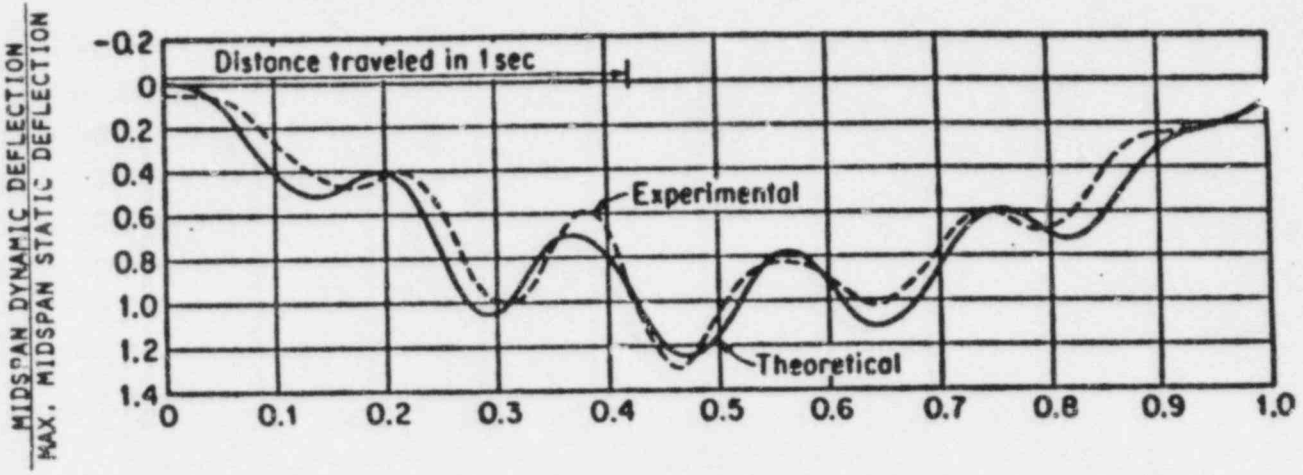
- o AISC CODE SPECIFICALLY ALLOWS "IMPACT" LOADS TO BE DISREGARDED IN COLUMN BUCKLING PROBLEMS
  - "IMPACT" LOAD IS DYNAMIC PORTION OF TRAVELING WHEEL LOAD
  - DURATION OF DYNAMIC LOAD TOO SHORT FOR COLUMN BUCKLING TO OCCUR
- o DYNAMIC LOAD EFFECTS IN TUGCO HANGER-TYPE SUPPORTS ARE LESS SIGNIFICANT IN EVERY RESPECT THAN "IMPACT" LOADS
  - SEISMIC LOADS ARE OF SHORTER DURATION THAN WHEEL LOADS
  - SEISMIC LOAD IS DYNAMIC COMPRESSION SUPERIMPOSED ON STATIC TENSION
  - MAXIMUM COMPRESSIVE LOAD IS FAR LESS THAN P_{CR}
  - DYNAMIC INSTABILITY IS NOT A CREDIBLE PHENOMENON
  - TRUE BUCKLING IS NOT A CREDIBLE PHENOMENON

CONCLUSION:

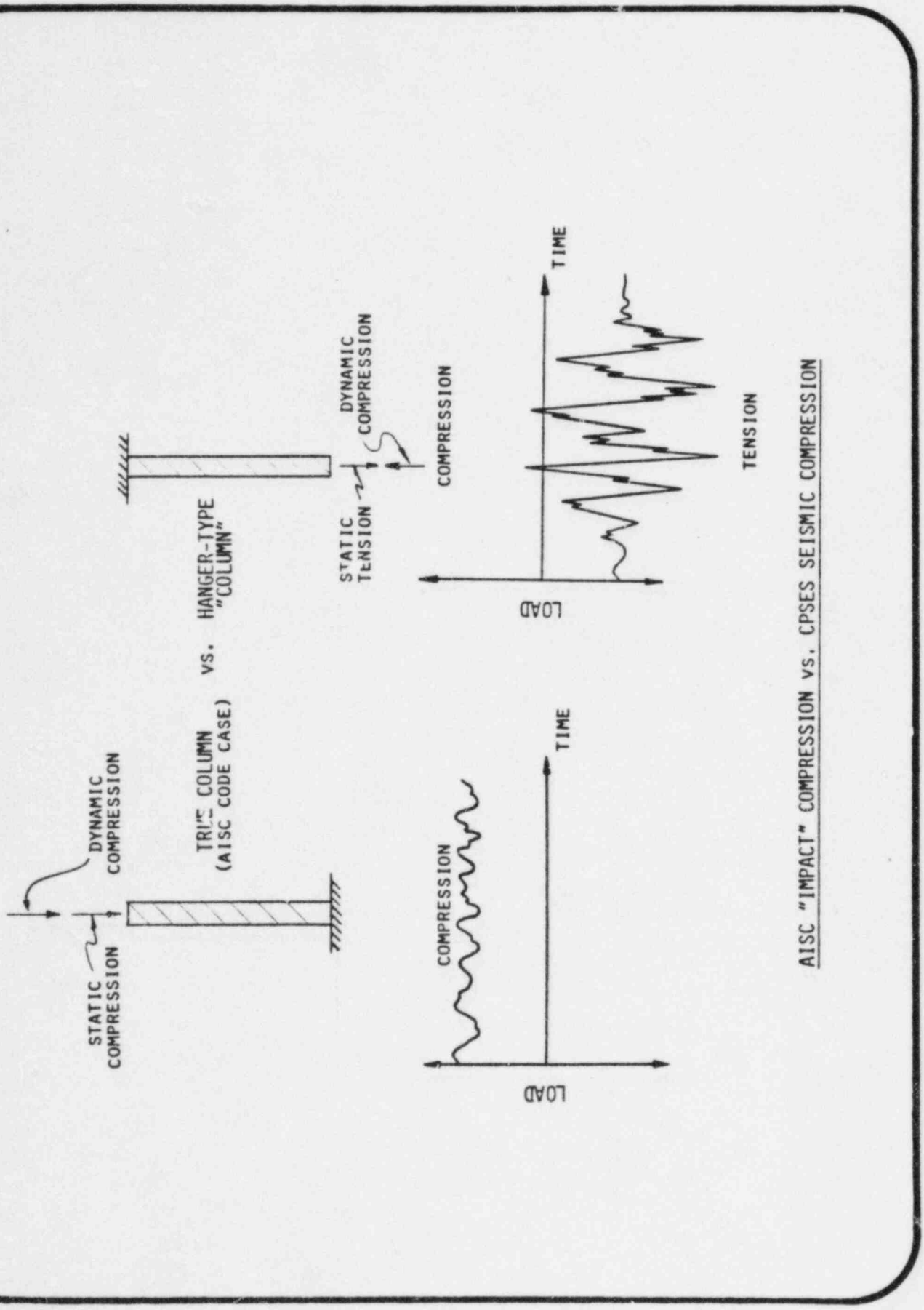
WITHIN THE CONTEXT OF THE AISC CODE, SHORT DURATION COMPRESSIVE LOADS ARE NEGLIGIBLE WITH REGARD TO "COLUMN ACTION" IN HANGER-TYPE SUPPORTS - ONLY STATIC TENSION LOADS REMAIN - KL/R LIMITS NEED NOT BE APPLIED



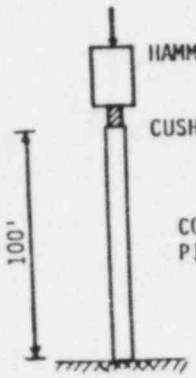
REFERENCE: BIGGS, J.M., INTRODUCTION TO STRUCTURAL DYNAMICS



TYPICAL DYNAMIC EFFECTS DUE TO "IMPACT" LOADS

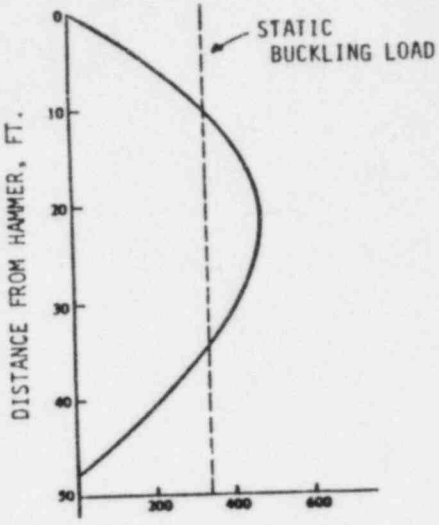


AISC "IMPACT" COMPRESSION vs. CPSES SEISMIC COMPRESSION



CONCRETE
PILE: $E = 3 \times 10^3$ KSI
$I = 1.33 \times 10^4$ IN^4

$$P_e = \frac{\pi^2 EI}{L^2} = 273.5 \text{ KIPS}$$



AXIAL COMPRESSION, KIPS

REFERENCE: CLOUGH & PENZIEN,
DYNAMICS OF STRUCTURES

DYNAMIC PILE-DRIVING COMPRESSION FORCES

2. AISC CODE COMPLIANCE (CONT.)

- o CODE RECOMMENDATION FOR TENSION MEMBERS:
  - L/R < 240 FOR MAIN MEMBERS
  - L/R < 300 FOR BRACING AND OTHER SECONDARY MEMBERS
- o CODE COMMENTARY DISCUSSES ABOVE RECOMMENDATION:

  "THE SLENDERNESS LIMITATIONS RECOMMENDED FOR TENSION MEMBERS ARE NOT ESSENTIAL TO THE STRUCTURAL INTEGRITY OF SUCH MEMBERS. THEY MERELY AFFORD A DEGREE OF STIFFNESS SUCH THAT UNDESIRABLE LATERAL MOVEMENT WILL BE AVOIDED. THESE LIMITS ARE NOT MANDATORY."

- o BOTH TEST AND ANALYSIS DEMONSTRATE THAT HANGER-SUPPORT TRANSVERSE DISPLACEMENTS ARE NEGLIGIBLE.
- o LONGITUDINAL DISPLACEMENTS ARE PROBABLY SMALL AS WELL AND ARE NOT A CONCERN IN ANY CASE

CONCLUSION:

L/R RECOMMENDATIONS FOR TENSION MEMBERS ARE NOT APPLICABLE.

3. ENGINEERING EVALUATION

- o FSAR COMMITMENTS AND CODE REQUIREMENTS ASIDE, REAL ISSUE IS STRUCTURAL INTEGRITY AND DEFLECTIONS OF HANGER-TYPE SUPPORTS

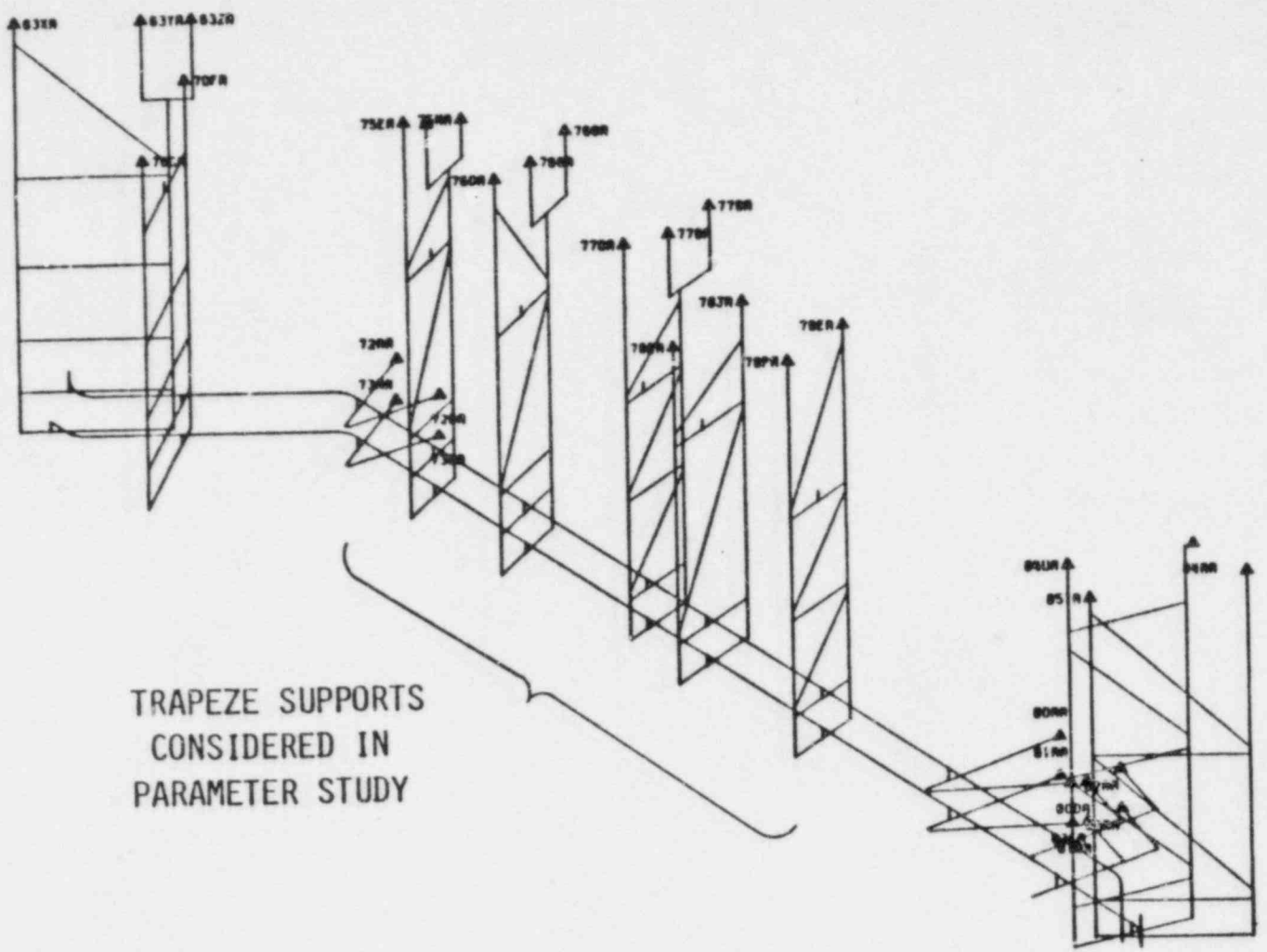
- o EXPLICIT DYNAMIC ANALYSES PERFORMED TO EVALUATE WORST CASE BEHAVIOR

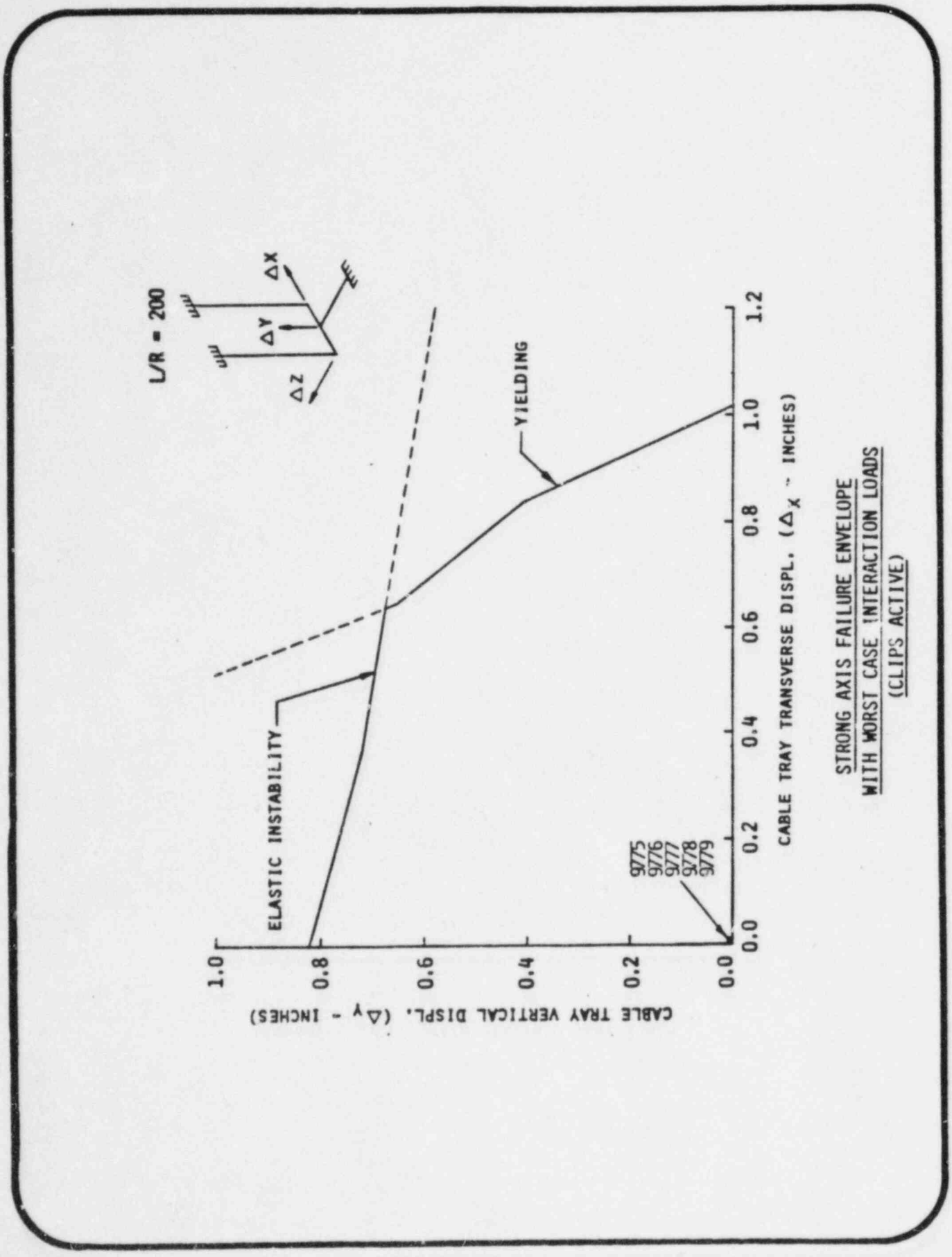
  - KL/R ASSUMED AS HIGH AS 394
  - MAXIMUM INPUT SPECTRA FROM TOP OF REACTOR BLDG.
  - FIVE TRAPEZE HANGERS IN A ROW (REAL SYSTEM)
  - RESULTS WITH AND WITHOUT ACTIVE CLIPS
  - RIGOROUS FAILURE ENVELOPES

- o RESULTS SHOW STRUCTURAL INTEGRITY IS INSENSITIVE TO KL/R ISSUE

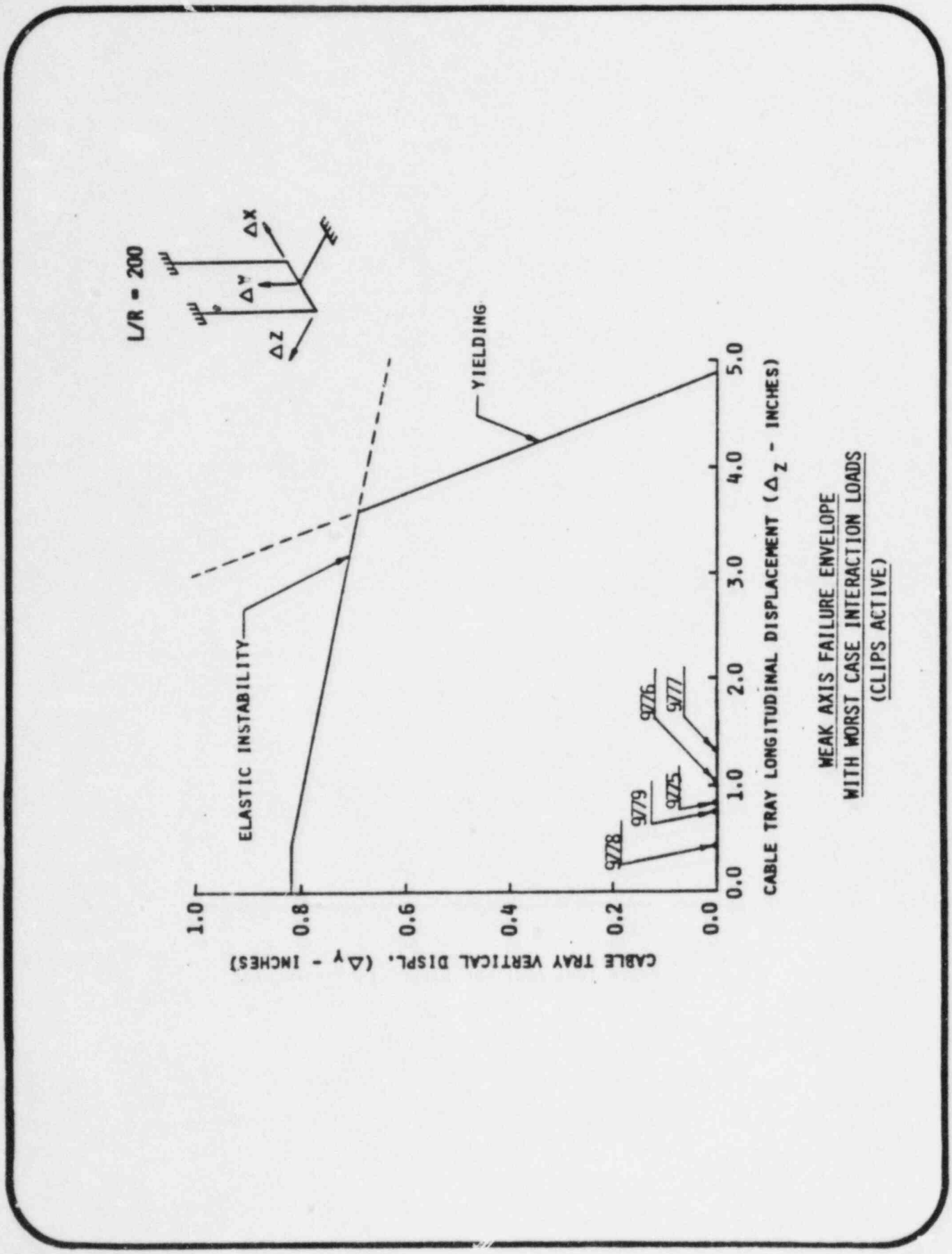
  - WORST CASE RESULTS WELL WITHIN WORST CASE FAILURE ENVELOPES
  - INTERACTION CHECK UNAFFECTED BY COMPRESSIVE LOADS
  - CAPACITY OF SUPPORTS DEPENDENT UPON CANTILEVER ACTION - NOT COLUMN ACTION

- o TRANSVERSE DISPLACEMENTS ARE NEGLIGIBLE FOR ALL KL/R

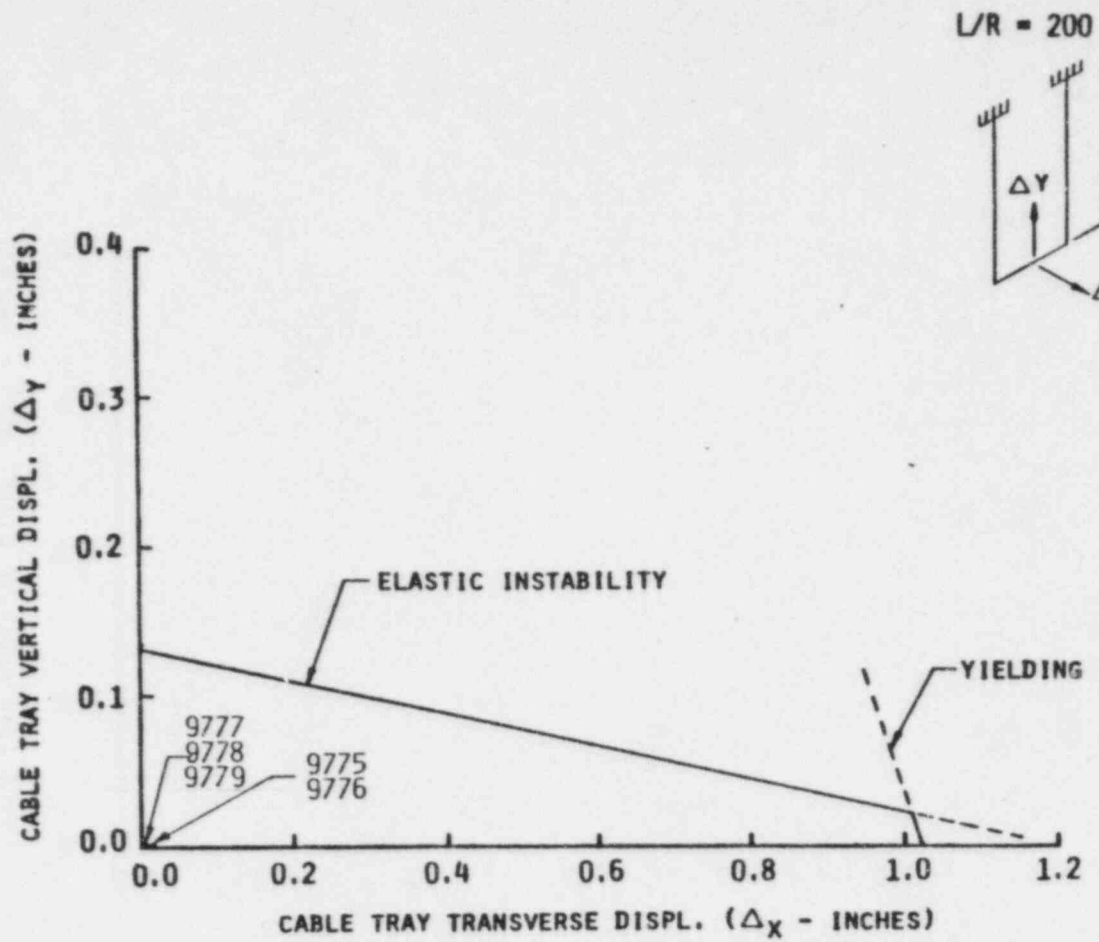

TRAPEZE SUPPORTS
CONSIDERED IN
PARAMETER STUDY
N
X
Z
GEOMETRY PLOT 1
TEXAS UTILITIES - CPSES
CABLE TRAY SYSTEM 2



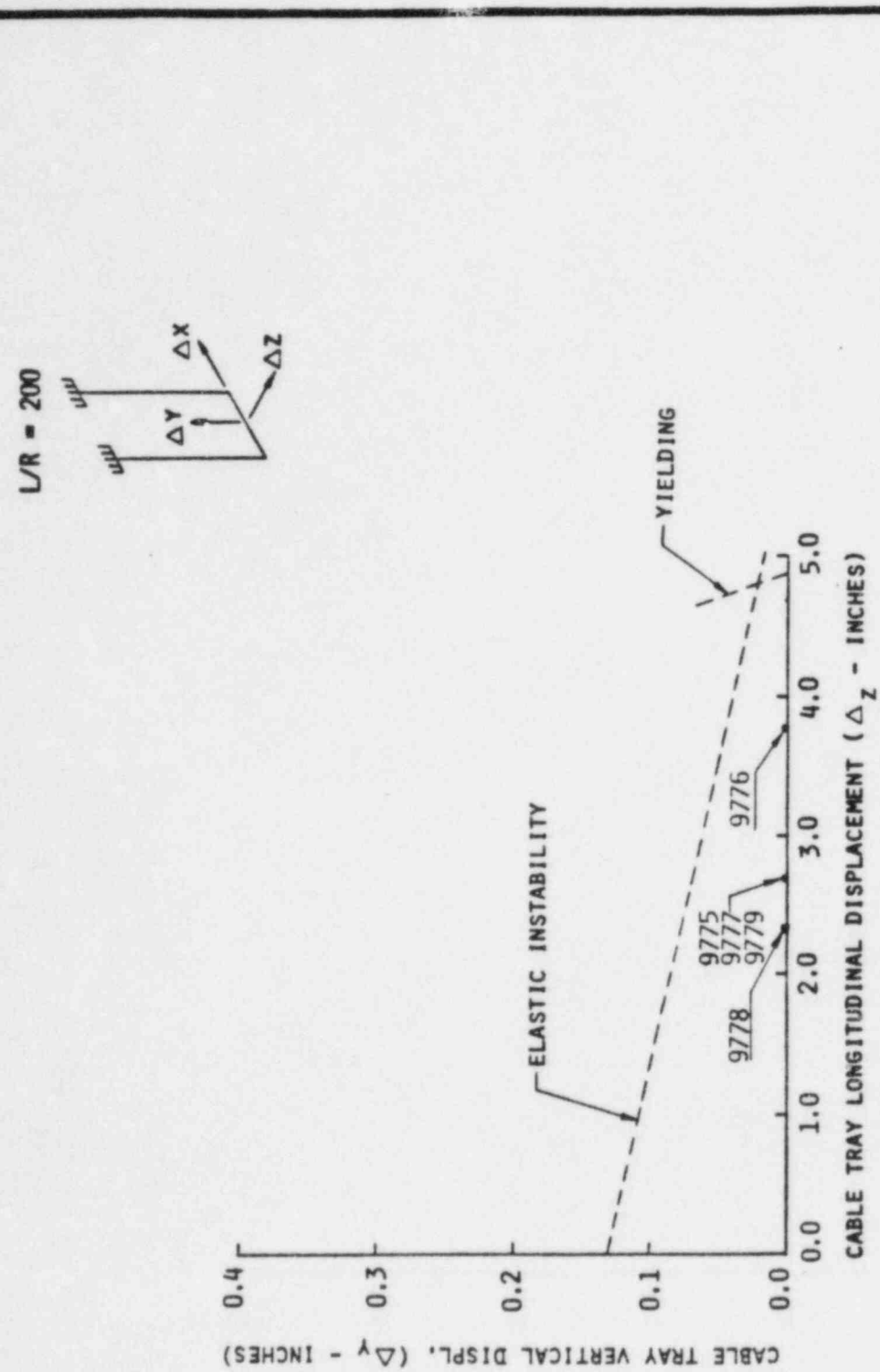
STRONG AXIS FAILURE ENVELOPE
WITH WORST CASE INTERACTION LOADS
(CLIPS ACTIVE)



WEAK AXIS FAILURE ENVELOPE
WITH WORST CASE INTERACTION LOADS
(CLIPS ACTIVE)



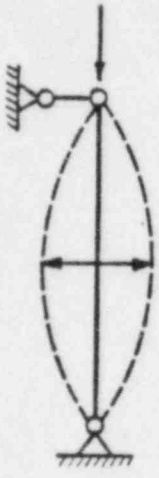
STRONG AXIS FAILURE ENVELOPE
WITH WORST CASE INTERACTION LOADS
(CLIPS NOT ACTIVE)



WEAK AXIS FAILURE ENVELOPE
WITH WORST CASE INTERACTION LOADS
(CLIPS NOT ACTIVE)

3.0 ENGINEERING EVALUATION (CONT.)

DYNAMIC INSTABILITY



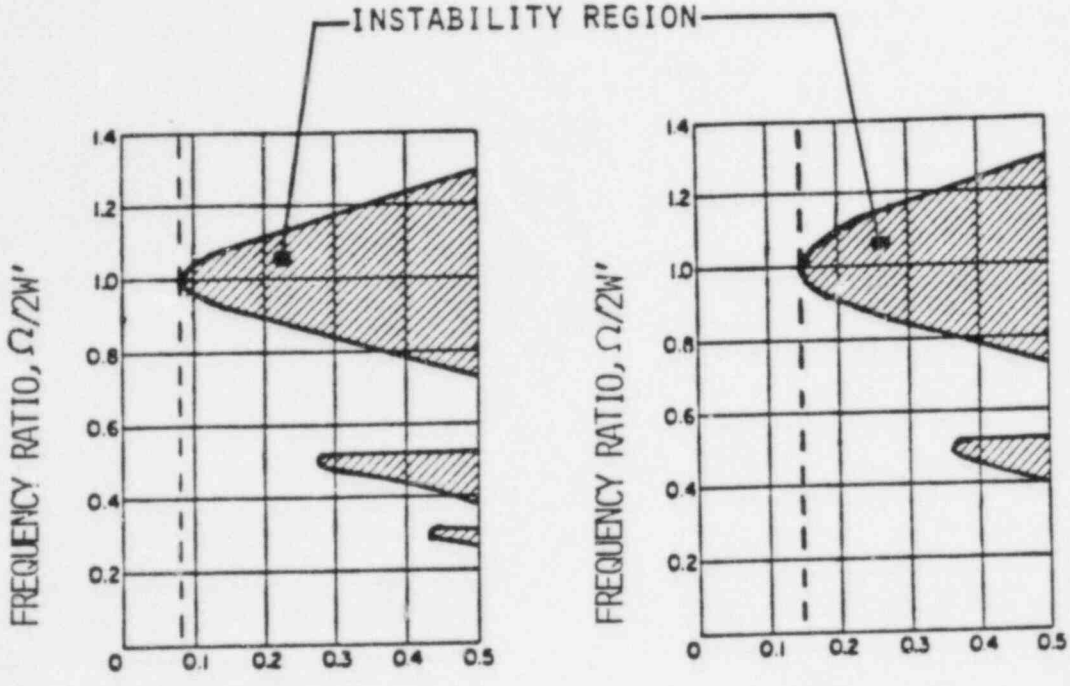
$P = P_o + P_t \cos \Omega t$

P_o = STATIC LOAD (TENSION OR COMPRESSION)
P_t = HARMONIC AXIAL LOAD
Ω = LOAD FREQUENCY
β = DAMPING RATIO
P_e = EULER BUCKLING LOAD

- UNSTABLE GROWTH OF TRANSVERSE MODAL DISPLACEMENTS POSSIBLE IF:
  - $P_t \geq 4\beta (P_o + P_e)$
  - Ω WITHIN CRITICAL RANGE

- DYNAMIC INSTABILITY ISSUE NOT REALLY APPLICABLE TO HANGER-TYPE SUPPORTS:
  - LOAD AMPLITUDE TOO SMALL
  - LOAD IS RANDOM NOT HARMONIC
  - LOAD DURATION TOO SHORT
  - STRUCTURE TOO COMPLEX

DYNAMIC INSTABILITY



FOR HANGER-TYPE SUPPORTS, DYNAMIC INSTABILITY WILL NOT OCCUR UNLESS $P_t \geq 2\mu(P_o + P_e)$:

OBE LOAD CASE

$P_t \geq 0.16\ (P_o + P_e)$

SSE LOAD CASE

$P_t \geq 0.28\ (P_o + P_e)$

EXPLICIT ANALYSIS SHOWS THAT WORST CASE LOADS LESS THAN CRITICAL VALUE OF P_t

3.0 ENGINEERING EVALUATION (CONT.)

- o UNLIKE TRUE COLUMNS, THE PRACTICAL CONSEQUENCES OF "BUCKLING" IN HANGER-TYPE SUPPORTS ARE NEGLIGIBLE
  - 30% DROP IN STIFFNESS
  - 30% DROP IN FREQUENCY
  - SMALL INCREASE IN DISPLACEMENTS
  - NO LOSS OF LATERAL/TENSILE STRENGTH
- o FLEXIBLE STEEL STRUCTURES, SUCH AS HANGER-TYPE SUPPORTS, ARE THE LEAST VULNERABLE TO EARTHQUAKES OF ANY TYPE OF STRUCTURE - WITH OR WITHOUT KL/R LIMITS

CONCLUSION:

KL/R LIMITS ARE IRRELEVANT TO THE STRUCTURAL INTEGRITY OF HANGER-TYPE SUPPORTS

SUMMARY OF TUGCO POSITION

- o AISC CODE REQUIREMENTS NOT EXPLICIT BUT SUGGEST THAT KL/R ISSUE NOT APPLICABLE TO HANGER-TYPE SUPPORTS
  - SUPPORTS SHOULD BE CLASSIFIED AS TENSION MEMBERS
  - SHORT DURATION COMPRESSION NEGLIGIBLE IN COLUMN BUCKLING PROBLEMS
  - ONLY STATIC LOAD IS TENSION - KL/R LIMITS NOT REQUIRED
- o ENGINEERING EVALUATION VERIFIES THAT KL/R LIMITS NOT IMPORTANT
  - NEGLIGIBLE COMPRESSIVE LOADS
  - NO DYNAMIC INSTABILITY
  - STRUCTURAL BEHAVIOR IS CANTILEVER ACTION - NOT COLUMN ACTION
  - STRUCTURAL INTEGRITY NOT DEPENDENT UPON KL/R LIMIT
  - DEFLECTIONS NEGLIGIBLE FOR ALL KL/R

CONCLUSION:

KL/R LIMITATIONS SHOULD NOT BE APPLIED TO STRUCTURAL ME 'BERS WHICH DO NOT EXPERIENCE STATIC COMPRESSION LOADS

KL/R LIMITATIONS WILL BE APPLIED TO MEMBERS WHICH EXPERIENCE STATIC AXIAL COMPRESSION