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Rockwell International

August 31, 1982

In reply refer to 82 ESG-5957

Richard H. Vollmer
Director, Division of Engineering
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Vollmer:

Subject: Significance of Support Modeling Assumptions for Seismic Evaluations of Nuclear Piping

During our involvement over the last 20 years with the design of piping for nuclear power applications, Rockwell has become increasingly aware of significant differences in analytical modeling assumptions being utilized by various design organizations in the nuclear power industry. This, we feel, is largely a result of the lack of a national consensus standard on what constitutes an acceptable piping analysis model. Obviously, there is no perfect piping analysis model, just as there is no perfect piping analysis method. However, national consensus standards have been established which define acceptable analysis methods (e.g., RDT F9-2T, RG 1.92, etc.) and criteria (ASME Section III, RG 1.48). Rockwell strongly recommends that NRC establish similar consensus standards creating minimum requirements for piping modeling assumptions, particularly in the area of stiffness and mass effects of piping supports.

The reasons for this stem from the observation that some organizations are assuming weightless infinitely stiff pipe supports while others are going to the other extreme and modeling in nonlinear effects of clearances/gaps, damping, support offset inertia load coupling, frequency and load-level effects on stiffness, etc. Naturally, the method of analysis will dictate the degree of modeling refinement possible as well as be a major determinant of the accuracy of predicted behavior. However, within each seismic method (e.g., equivalent static, response spectrum, time history) certain modeling assumptions can create significant differences in results. We have observed in a recent Rockwell seismic support modeling sensitivity study that certain modeling simplications can lead to significant underpredictions of stress and loads with respect to more accurate modeling assumptions. We are bringing these observations to the NRC's attention, since there is currently no established minimum modeling requirements, and it is unclear if the less conservative approaches, which have been used in the design of numerous operating plants, will always result in safe designs.

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In particular, the Rockwell sensitivity study addressed the effect of piping support stiffness and weight modeling when using a response spectrum analysis method. The study was initiated because of an apparent change in stiffness values for Pacific Scientific Company mechanical snubbers. Stiffness values provided by the vendor in 1976 were, in some cases, five times the values provided in their most recent company literature (see Enclosures 1 and 2). Since our design activities on the Clinch River Breeder Reactor (CRBR) have evolved to the final stress report stage, such a change in stiffness value could have a significant cost impact on the design effort. It was felt a sensitivity study should be performed to ascertain the magnitude of the change in stiffness on piping response in order to provide meaningful cost estimates. Interestingly enough, discussions with Pacific Scientific technical personnel revealed the value changes were not a change in design but a change in stiffness definition. The earlier values were based on static stiffness tests whereby the snubber was mechanically locked and then loaded. The latter values were based on dynamic frequency dependent tests. In effect, the differences can be attributed to whether or not the free play (dead band plus gaps) is included in the stiffness definition (see Figure 1). NRC should possibly pursue the implications of this redefinition of stiffness by Pacific Scientific since designers may have used the vendor-supplied stiffness data without an awareness of the implicit analytical modeling assumptions. The change in stiffness values also led to reconsideration of the CRBR piping clamp designs which, with a reduced snubber stiffness, no longer were the key flexibility in the support load path. A lighter weight clamp was felt possibly to be more cost effective, thus both support stiffness and mass effects were investigated.

A typical CRBR small diameter auxiliary system piping line (see Figure 2) was evaluated with the old and new snubber stiffness values as well as with revised clamp masses. The result was a moderate (factor of 1.26) change in stress and load at certain locations in the pipeline. The results were inconsistent. Some locations increased in value, others decreased. It was felt this was in large part a frequency shift effect and in order to address the problem in a manner more generic to the total CRBR piping situation, a variable three-leg modeling matrix was established (see Figure 3). The first model evaluated (8-inch line per Figure 4) indicated changing only snubber stiffness (1976 values replaced by 1982 values), increased nozzle loads by a factor as high as 2.3, support loads increased up to 1.9 times, and pipe stresses in some locations more than doubled.

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At this point, it became clear that support stiffness modeling could have a significant effect on predicted loads and stresses, in fact, so much greater than anticipated that the effect of completely ignoring support flexibility (∞-stiff) and mass, a common LWR piping analysis simplification, appeared to have safety implications. Company funds were spent, investigating this extreme modeling assumption. Results for the three-leg model indicated that when support weight and flexibility were included, nozzle loads increased by a factor of up to 30, support load increases of 500 percent were observed, and pipe stresses were, in some places, almost eight times higher. The situation for a particular LWR piping line will, of course, differ from that of the three-leg model just as each leg of the three-leg model responded differently to the boundary condition changes. It is not unreasonable to expect even higher increases for certain piping layouts. This sensitivity of results to layout should be appreciated by NRC and caution exercised in accepting generic conclusions on modeling method conservatisms based on a limited set of sample cases.

It is not known to what extent offsetting conservatisms such as over-prediction of results using response spectrum methods versus time history methods, damping, energy dissipation due to nonlinearities, Code safety factors, etc., will exist to assure design approaches which ignore support stiffness and weight can provide safe designs. However, it <u>is</u> clear that such modeling simplifications significantly alter predicted results and typical FSAR statements such as "support weight and stiffness ignored as insignificant" without extensive backup justification should be disallowed.

On the brighter side, NRC should be aware that the issue of piping support modeling assumptions are par of modeling-methods-criteria studies underway at PVRC and EPRI, which are evaluating the overall piping seismic design approach. Rockwell has begun to interface with these activities and will be providing them with sensitivity results for various modeling and methodology assumptions. Some of these results are included in Enclosure 3 for your information. Enclosure 3 also contains results from additional studies conducted at Rockwell to investigate the impact of the erroneous use of modulus of elasticity values in a commercial nuclear piping program (see Enclosure 4). Therefore, portions of Enclosure 3 may not be directly applicable to this letter's subject, however, most of it is.

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In closing, Rockwell again recommends national consensus standards be established for acceptable piping modeling assumptions, particularly stiffness and weight effects of seismic supports. We would be willing to participate in the preparation of such a document as well as in any NRC-sponsored program to improve the industry's ability to provide safe piping designs.

Please contact Mr. K. Jaquay, Manager of our Piping Analysis Unit, at (213) 700-4042 for any additional details desired on the subject.

Very truly yours,

D. C. Empey, Director
Quality Assurance
Energy Systems Group

cmt:820

Enclosures: (1) 1976 PSA Snubber Stiffness Values
(2) 1982 PSA Snubber Stiffness Values and Comparison to 1976 Values
(3) Selected Sensitivity Study Results
(4) Errors in NUPIPE Program

cc: Robert C. DeYoung
Director, Office of Inspection & Enforcement
Nuclear Regulatory Commission
Washington, D.C. 20555

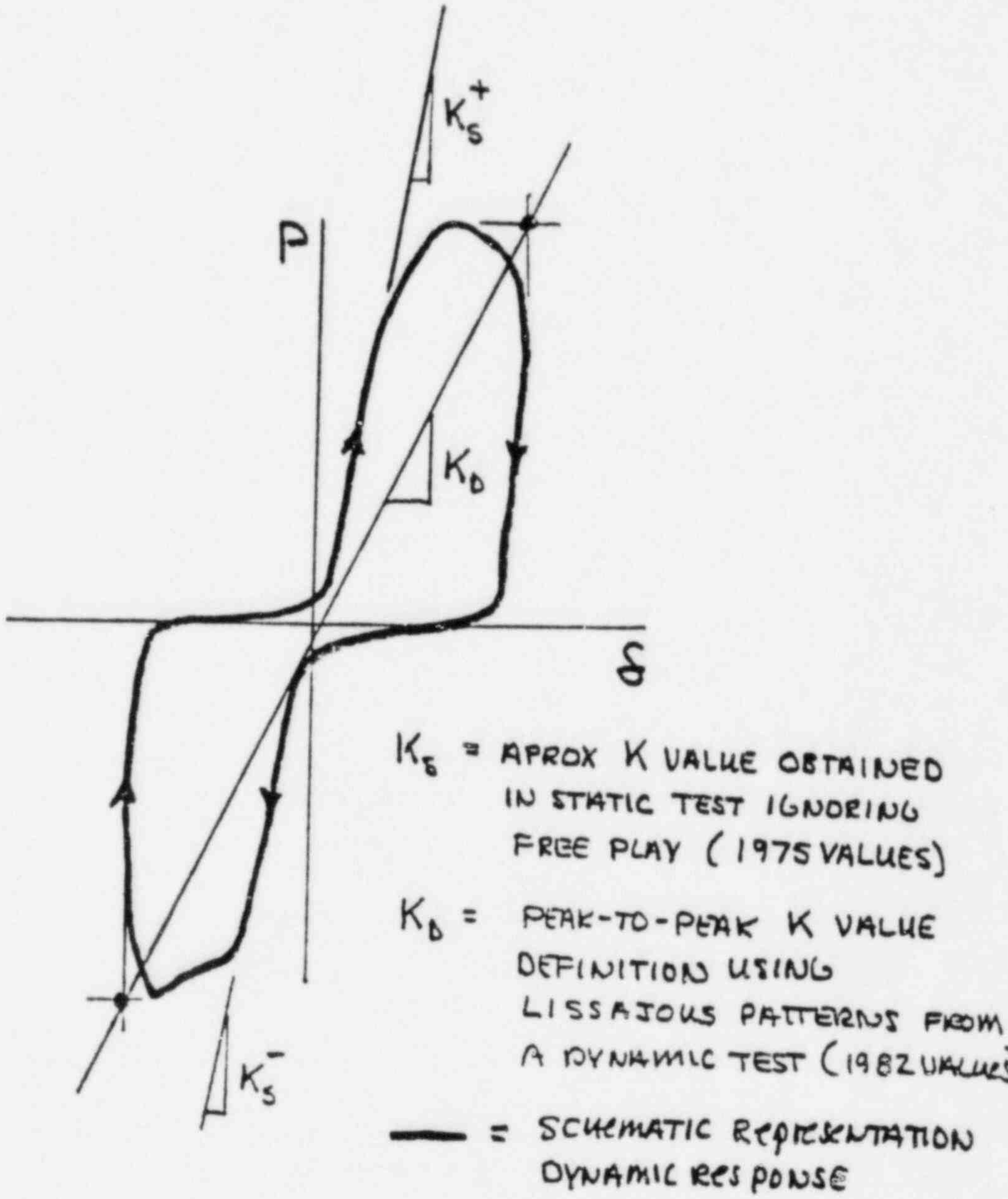


FIGURE 1 : SNUBBER STIFFNESS DEFINITIONS

(A6-1)

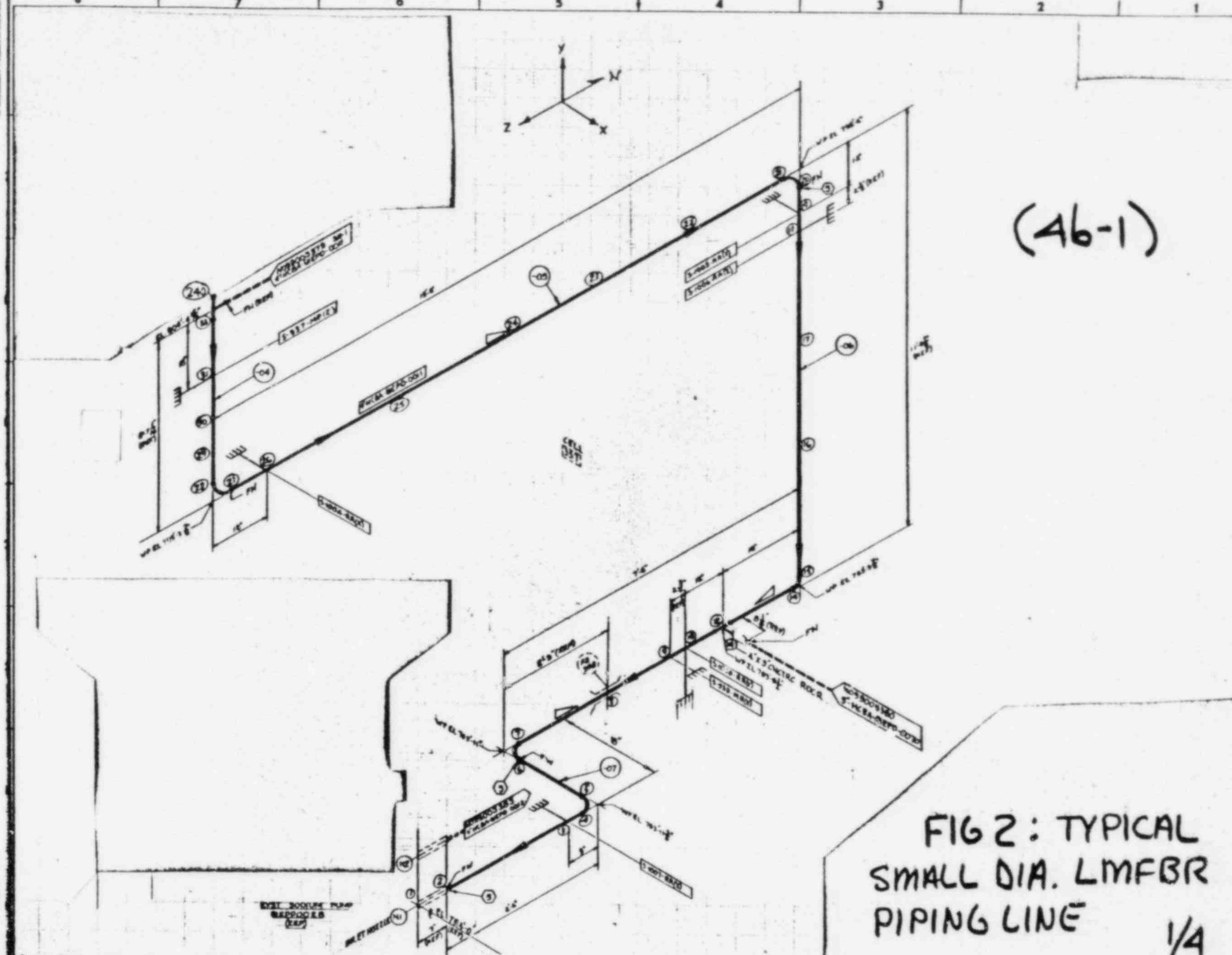


FIG 2: TYPICAL SMALL DIA. LMFBR PIPING LINE

1/4

(4b-1)

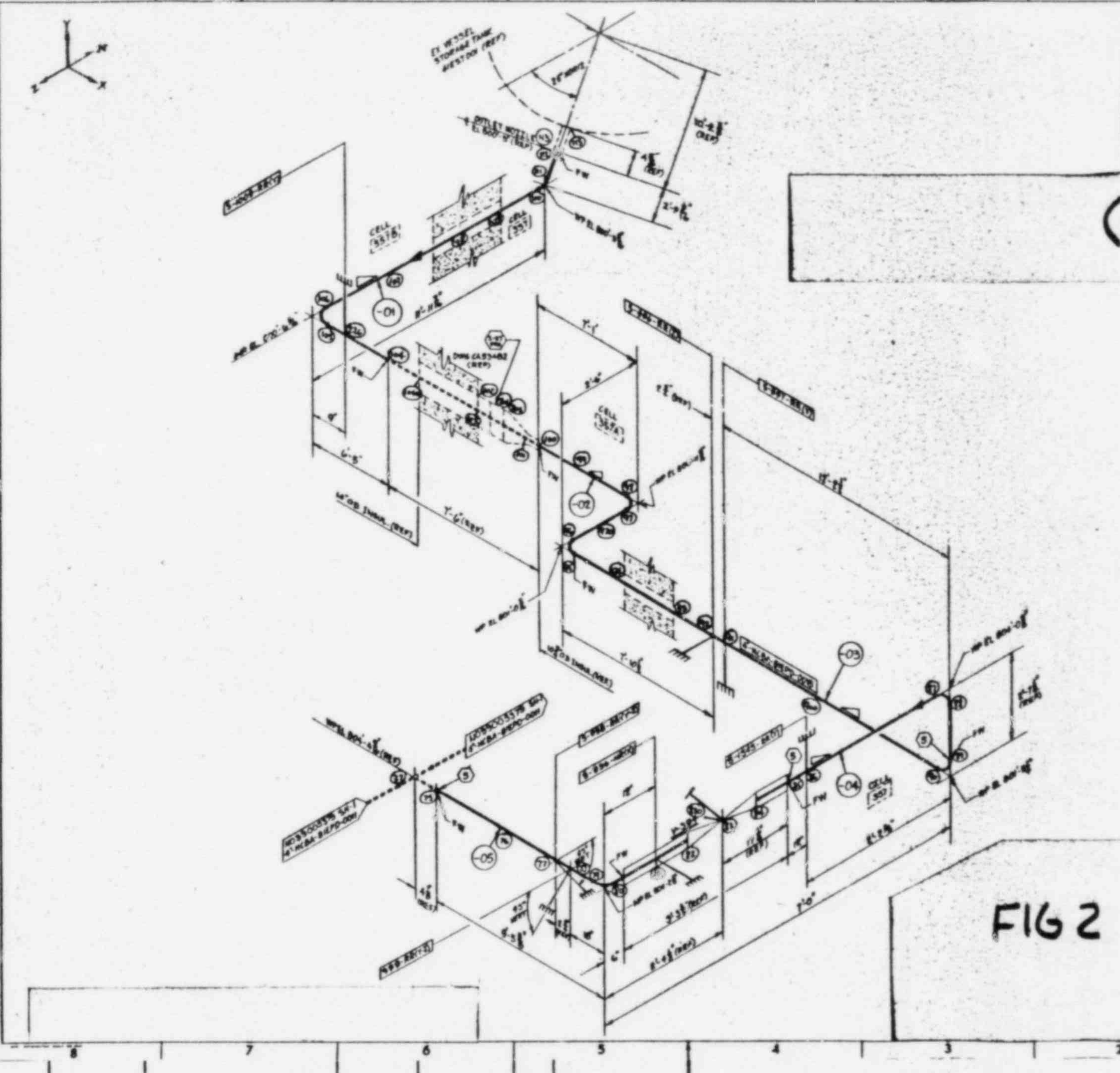


FIG 2 CON'T

2/4

(46-1)

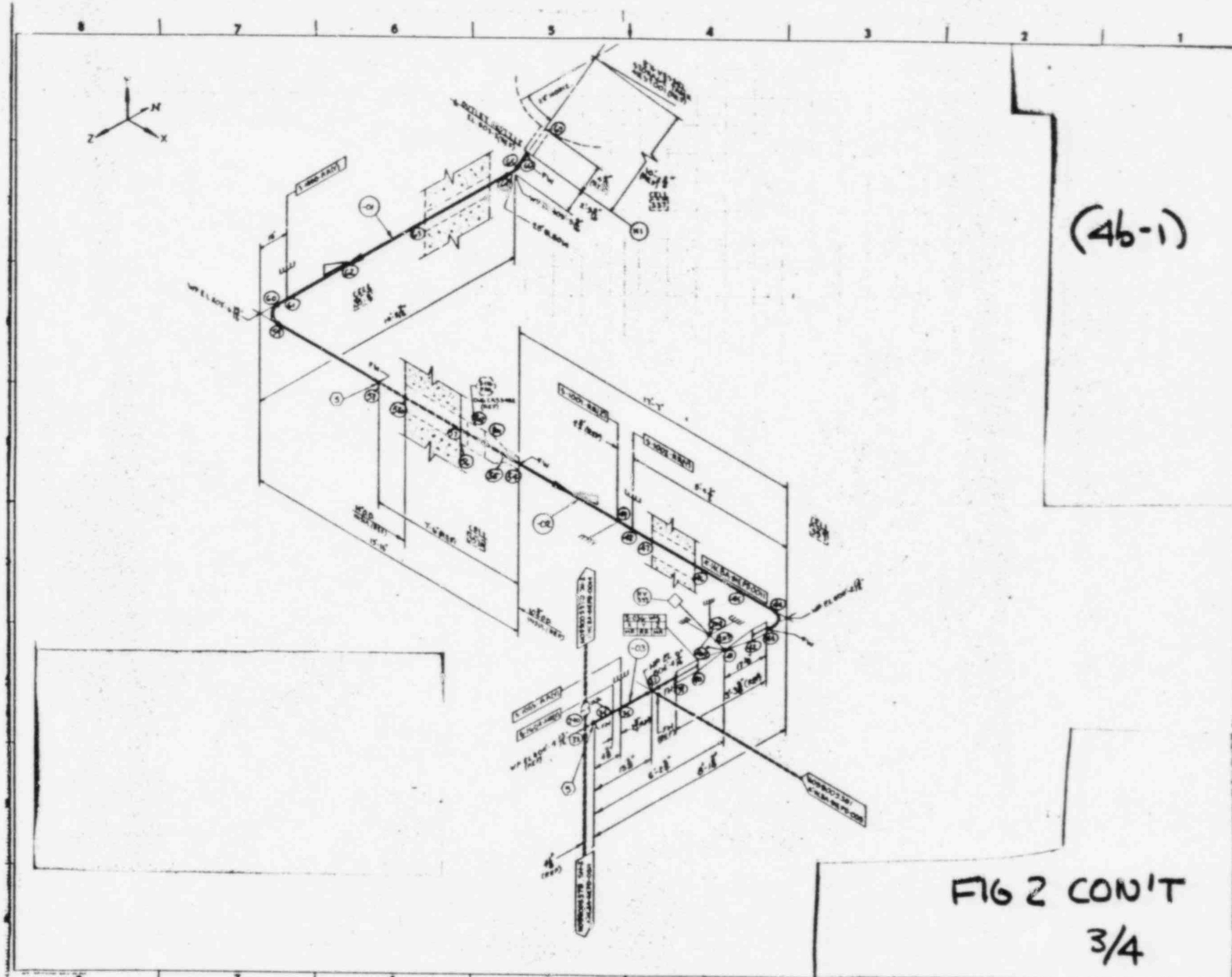
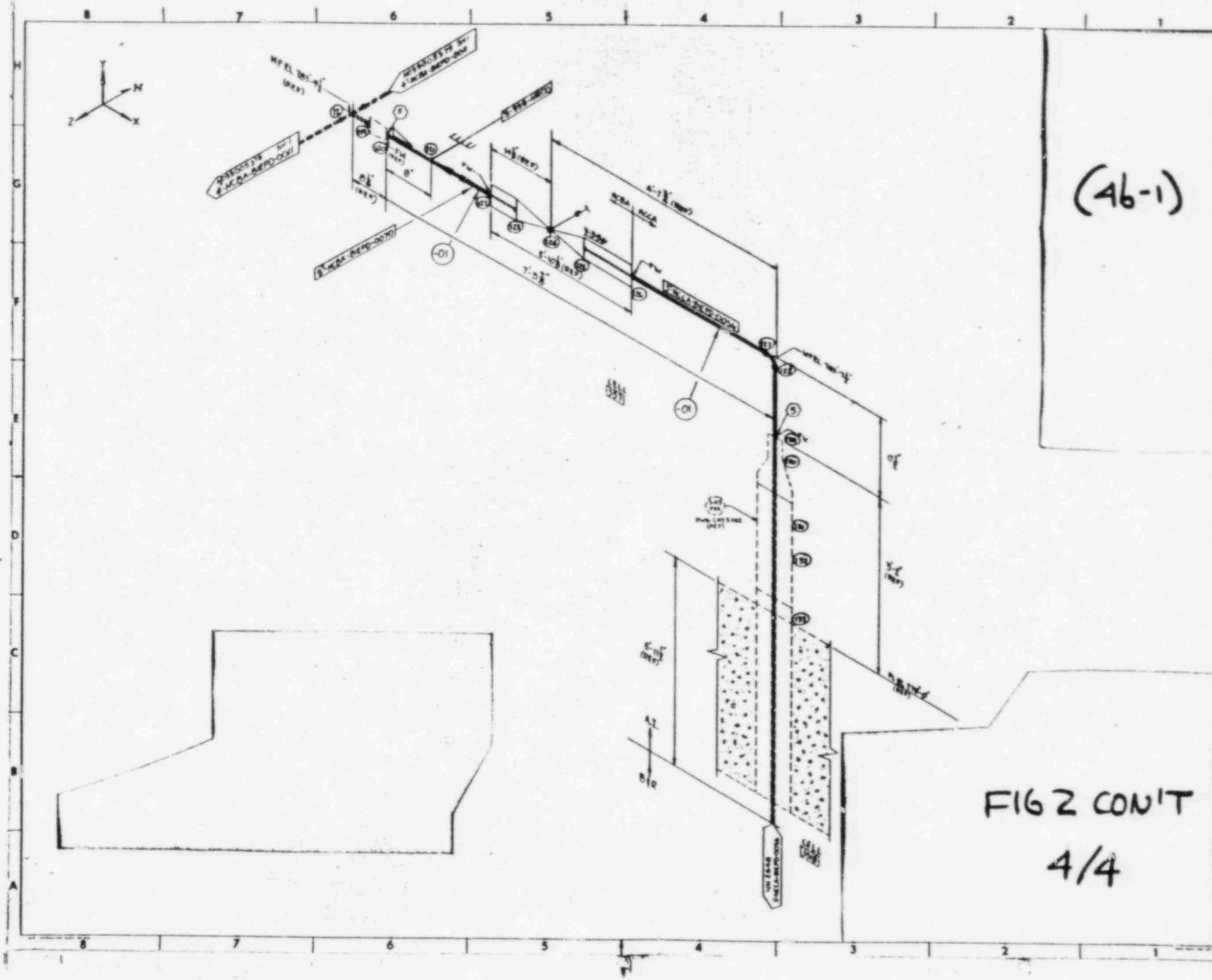


FIG 2 CON'T
3/4



(A6-1)

FIG 2 CON'T
4/4

FIG. 3

VARIABLE THREE LEG MODELING MATRIX

MODELING PARAMETER DESIGNATION:

XXXX-X

- PIPE LOOP LENGTH VARIATION
- PIPE LOOP TEMPERATURE VARIATION
- RESTRAINT STIFFNESS/WEIGHT VARIATION
- PIPE DIAMETER VARIATION
- MODULUS OF ELASTICITY BASIS

XXXX-X • PIPE LOOP LENGTH VARIATION

— PIPE LEG LENGTH (FT.) —

	I	II	III	IV	V	VI
A	15	20	15	10	30	10
B	15	20	15	10	10	10
C	15	20	30	10	30	10
D	15	10	30	10	10	10
E	5	10	15	20	30	10

XXXX-X • PIPE LOOP TEMPERATURE VARIATION

— TEMPERATURE CONDITION (°F) —

	BRANCH "A"	BRANCH "B"	BRANCH "C"
A	1000	1000	1000
B	500	1000	1000
C	1000	500	1000
D	1000	1000	500
E	500	500	500
F	500	500	70

FIG. 3 (cont.)

XX☒X-X • RESTRAINT STIFFNESS/WEIGHT VARIATION

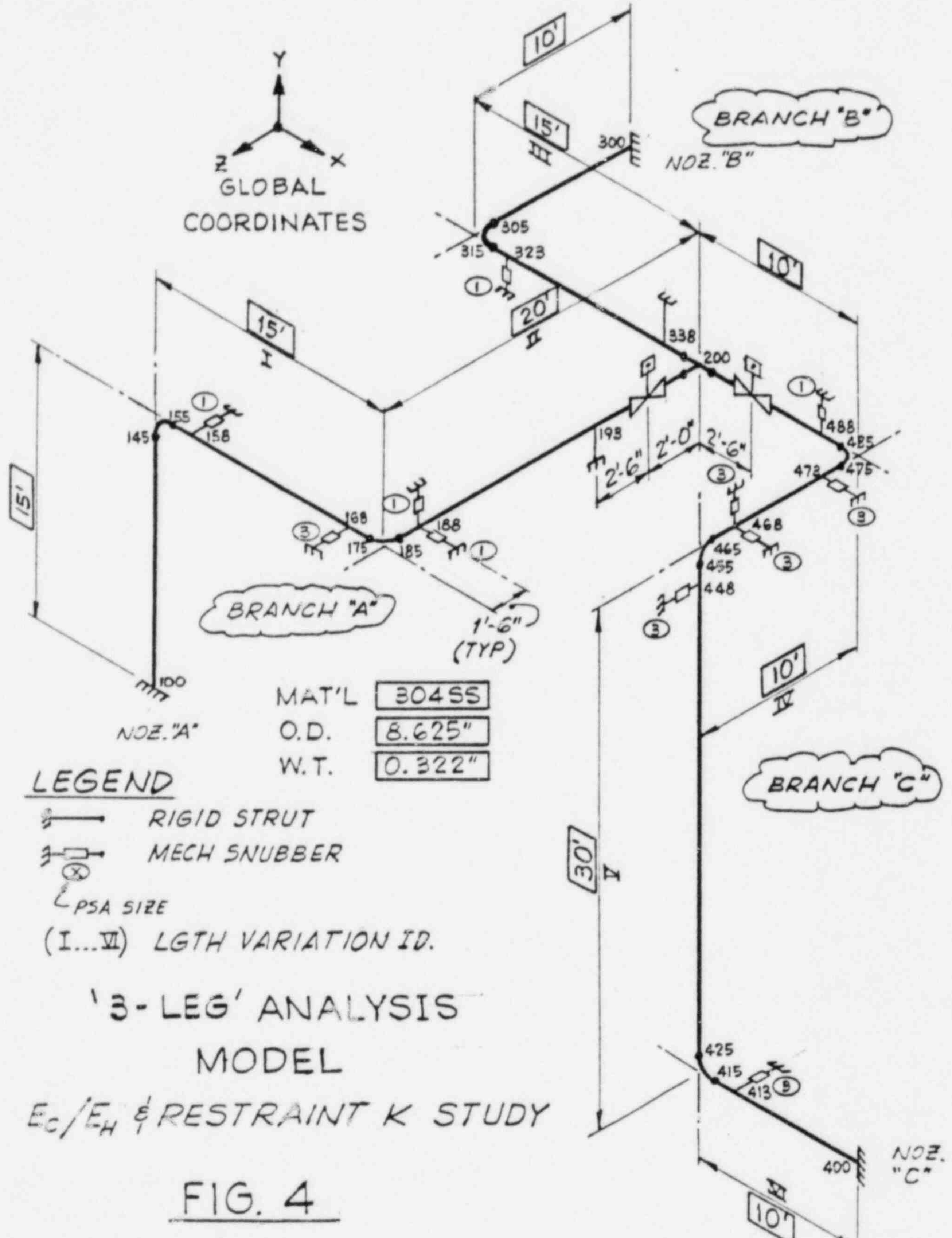
	— STIFFNESS & WEIGHT CONDITIONS —				
	SNUB K	RGD K	CLMP K	BLDG K	RSNT WT.
A	1976	2×10^5	∞	∞	ACTUAL
C	1982	2×10^5	∞	∞	ACTUAL
D	1976	1×10^8	7.5×10^4	5×10^4	ACTUAL
F	1982	1×10^8	5×10^4	1.5×10^5	ACTUAL
H	1×10^8	1×10^8	1×10^8	1×10^8	ACTUAL
I	1×10^8	1×10^8	1×10^8	1×10^8	ZERO
J	1982	1×10^8	7.5×10^4	5×10^4	ZERO
K	1976	1×10^8	1×10^8	1×10^8	ZERO

XXX☒-X • PIPE DIAMETER VARIATION

	— NOMINAL PIPE DIAMETER (IN.) —		
	BRANCH "A"	BRANCH "B"	BRANCH "C"
A	8	8	8
B	4	4	4
C	1	1	1
D	8	4	4
E	4	4	1
F	1	1	1

XXXX-☒ • MODULUS OF ELASTICITY BASIS

- H — E SET @ OPERATING TEMP. VALUE
- C — E SET @ AMBIENT TEMP. VALUE



Y
Z
X
GLOBAL COORDINATES
10'
15'
III
BRANCH "B"
300
NOZ. "B"
305
315
323
1
20'
II
10'
15'
I
338
200
1
488
485
475
472
3
155
145
158
1
198
2'-6"
2'-0"
2'-6"
15'
3
168
175
185
188
1
1
3
468
465
455
448
3
3
3
BRANCH "A"
1'-6" (TYP)
100
NOZ. "A"
MAT'L 304SS
O.D. 8.625"
W.T. 0.322"
10'
IV
BRANCH "C"
LEGEND
RIGID STRUT
MECH SNUBBER
X
PSA SIZE
(I...VI) LGTH VARIATION ID.
30'
V
'3-LEG' ANALYSIS MODEL
Ec/EH & RESTRAINT K STUDY
425
415
413
3
400
NOZ. "C"
VI
10'

FIG. 4

ENCLOSURE 1

1976 PSA SNUBBER STIFFNESS VALUES

PACIFIC SCIENTIFIC COMPANY - SHOCK ARRESTOR

Spring Rate - lbs/inch ⚠1

	Compression Load		Tension Load	
	Unit Retracted	Unit Extended	Unit Retracted	Unit Extended
PSA-1/4	$.586 \times 10^5$	$.383 \times 10^5$	$.259 \times 10^5$	$.302 \times 10^5$
PSA-1/2	$.605 \times 10^5$	$.421 \times 10^5$	$.284 \times 10^5$	$.278 \times 10^5$
PSA-1	1.21×10^5	1.12×10^5	1.04×10^5	1.07×10^5
PSA-3	1.87×10^5	1.87×10^5	1.61×10^5	1.13×10^5
PSA-10	3.95×10^5	3.57×10^5	3.00×10^5	2.68×10^5
PSA-35	— ⚠2	10.6×10^5	13.5×10^5	— ⚠2
PSA-100	— ⚠2	22.7×10^5	22.7×10^5	— ⚠2

⚠1 1/4 inch away from full travel stop in all tests.

⚠2 No test data available.

RFW
7/29/75
Rev 11/16/76

PREPARED BY:	Rockwell International Energy Systems Group	PAGE NO. OF
CHECKED BY:		REPORT NO.
DATE:		MODEL NO.

ENCLOSURE 2

1982 PSA SNUBBER STIFFNESS VALUES
AND COMPARISON TO 1976 VALUES

~~ATTACHMENT 2~~

PACIFIC SCIENTIFIC

Kin-Tech Division

DATA TRANSMITTAL

DATE: 21 April 1982

TO: ENERGY SYSTEMS GROUP
8900 DE SOTO AVE
CANOGA PARK, CA 91304

ATTENTION: MR. GARY DELANO 731-071-LB30
(213) 700-3351

REFERENCE:

SUBJECT :

ENCLOSURE

1 copy ~~design manual~~
1 set ~~price lists~~ } NOT included in enclosure(2)
1 Spring Rate Chart (4/2/82 & 11/77)

REMARKS

BY: Floyd Fredrickson
FLOYD FREDRICKSON
DISTRICT APPLICATION ENGINEER

PACIFIC SCIENTIFIC
KIN-TECH DIVISION
1346 SO. STATE COLLEGE BLVD.
ANAHEIM, CA 92803
714/774-5217

Kin-Tech Division

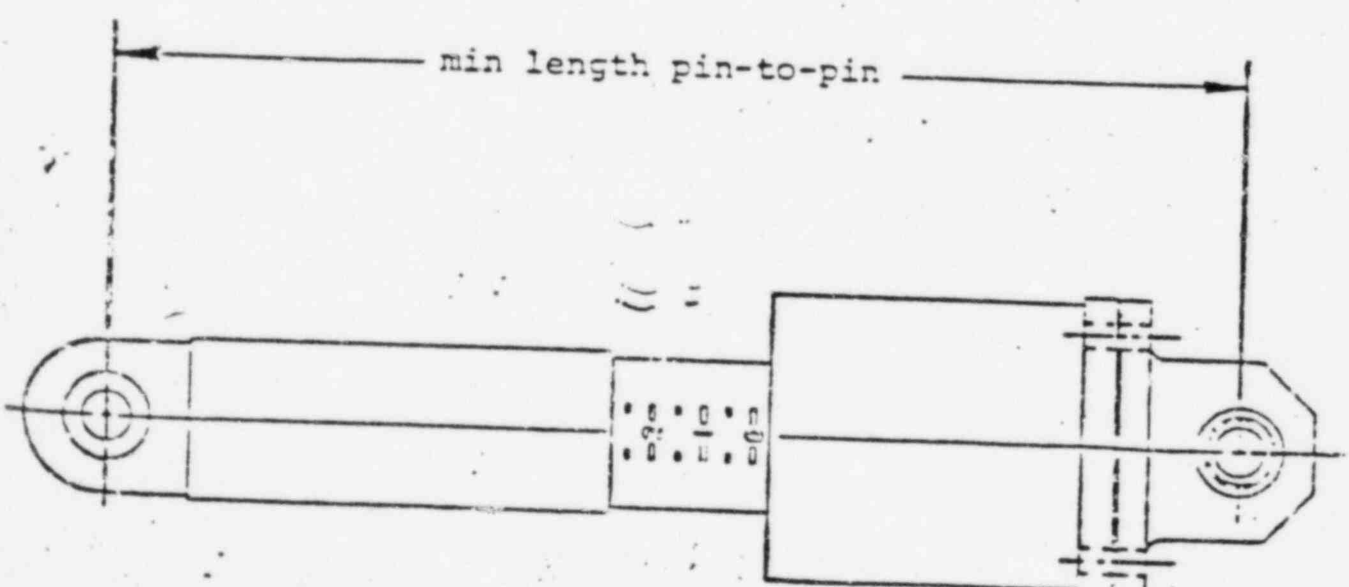
PACIFIC SCIENTIFIC

MECHANICAL SHOCK ARRESTORS

DYNAMIC SPRING RATE

The following dynamic spring rates are for the minimum length arrestor, pin-to-pin. They are minimum values obtained by averaging results at 3 and 9 Hz.

MODEL NUMBER	SPRING RATE - LBS./IN.
PSA-1/4	$.9 \times 10^4$
PSA-1/2	1.5×10^4
PSA-1	$.6 \times 10^5$
PSA-3	$.75 \times 10^5$
PSA-10	2.4×10^5
PSA-35	$.7 \times 10^6$
PSA-100	1.0×10^6



Kin-Tech Division

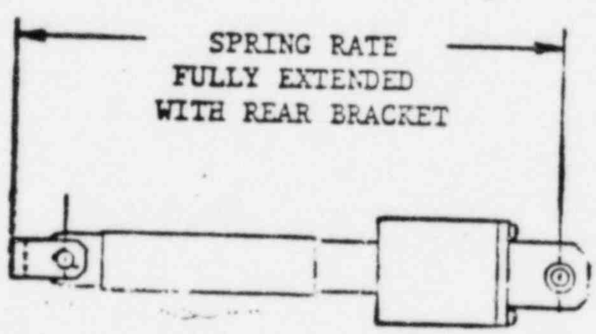
PACIFIC SCIENTIFIC

MECHANICAL SHOCK ARRESTORS

DYNAMIC SPRING RATE

The following spring rates include structural deflection, mechanical gaps and dynamic excursion of the shock arrestor. Data was obtained by averaging tension and compression test results at 3 and 9 Hz plus other calculations. Values are guaranteed minimum at rated load.

MODEL NUMBER	SHOCK ARRESTOR KIT NUMBER	SPRING RATE LBS./IN.
PSA-1/4	1801159-01	$.7 \times 10^4$
PSA-1/2	1801162-01	1.2×10^4
PSA-1	1801165-01	3.9×10^4
PSA-3	1801168-01	6.6×10^4
PSA-10	1801171-01	20.7×10^4
PSA-35	1801174-01	52.4×10^4
PSA-100	1801177-01	84.2×10^4

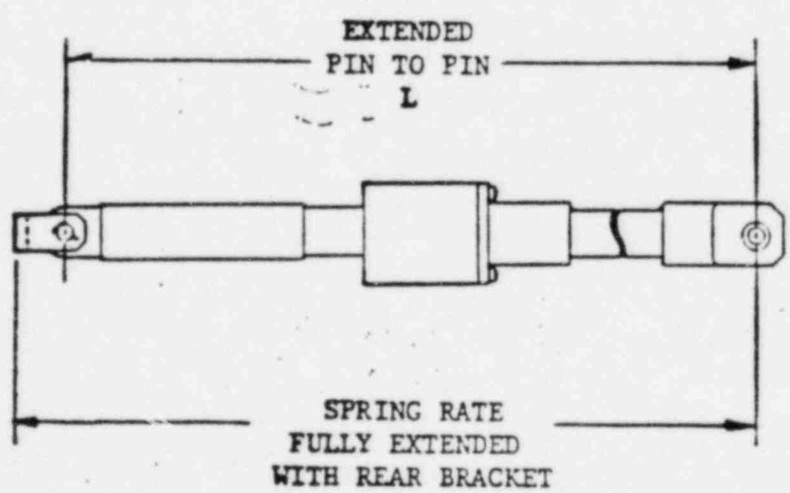


MECHANICAL SHOCK ARRESTORS

DYNAMIC SPRING RATE

The following spring rate formulas include structural deflection, mechanical gaps and dynamic excursion of the shock arrestor with an extension. Data was obtained by averaging tension and compression test results at 3 and 9 Hz plus other calculations. The values calculated are guaranteed minimum at rated load.

MODEL NUMBER	SPRING RATE - LBS./IN.
PSA-1/4	$S.R. = \dfrac{700}{.096 + .0000725\ (L - 14.1)}$
PSA-1/2	$S.R. = \dfrac{1300}{.107 + .000135\ (L - 11.1)}$
PSA-1	$S.R. = \dfrac{3000}{.077 + .000162\ (L - 16.5)}$
PSA-3	$S.R. = \dfrac{12000}{.183 + .000406\ (L - 21.5)}$
PSA-10	$S.R. = \dfrac{30000}{.145 + .00055\ (L - 25.5)}$
PSA-35	$S.R. = \dfrac{100000}{.191 + .000426\ (L - 33.1)}$
PSA-100	$S.R. = \dfrac{240000}{.285 + .00073\ (L - 38.8)}$



Kin-Tech Division

PACIFIC SCIENTIFIC

COMPARISON

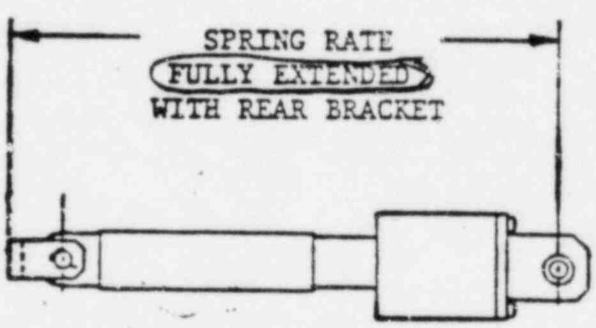
MECHANICAL SHOCK ARRESTORS

DYNAMIC SPRING RATE

The following spring rates include structural deflection, mechanical gaps and dynamic excursion of the shock arrestor. Data was obtained by averaging tension and compression test results at 3 and 9 Hz plus other calculations. Values are guaranteed minimum at rated load.

MODEL NUMBER	SHOCK ARRESTOR KIT NUMBER	ENCLOSURE VALUES (1)	SPRING RATE LBS./IN.	RATIO
PSA-1/4	1801159-01	$.34 \times 10^5$	$.7 \times 10^4$	4.9
PSA-1/2	1801162-01	$.44 \times 10^5$	1.2×10^4	3.7
PSA-1	1801165-01	1.1×10^5	3.9×10^4	2.8
PSA-3	1801168-01	1.5×10^5	6.6×10^4	2.3
PSA-10	1801171-01	3.13×10^5	20.7×10^4	1.5
PSA-35	1801174-01	(2) 10.6×10^5	52.4×10^4	2.0
PSA-100	1801177-01	(2) 22.7×10^5	84.2×10^4	2.7

NOTES: (1) AVERAGE OF TENSION AND COMPRESSION
(2) COMPRESSION LOAD ONLY



Kin-Tech Division

PACIFIC SCIENTIFIC

COMPARISON

MECHANICAL SHOCK ARRESTORS

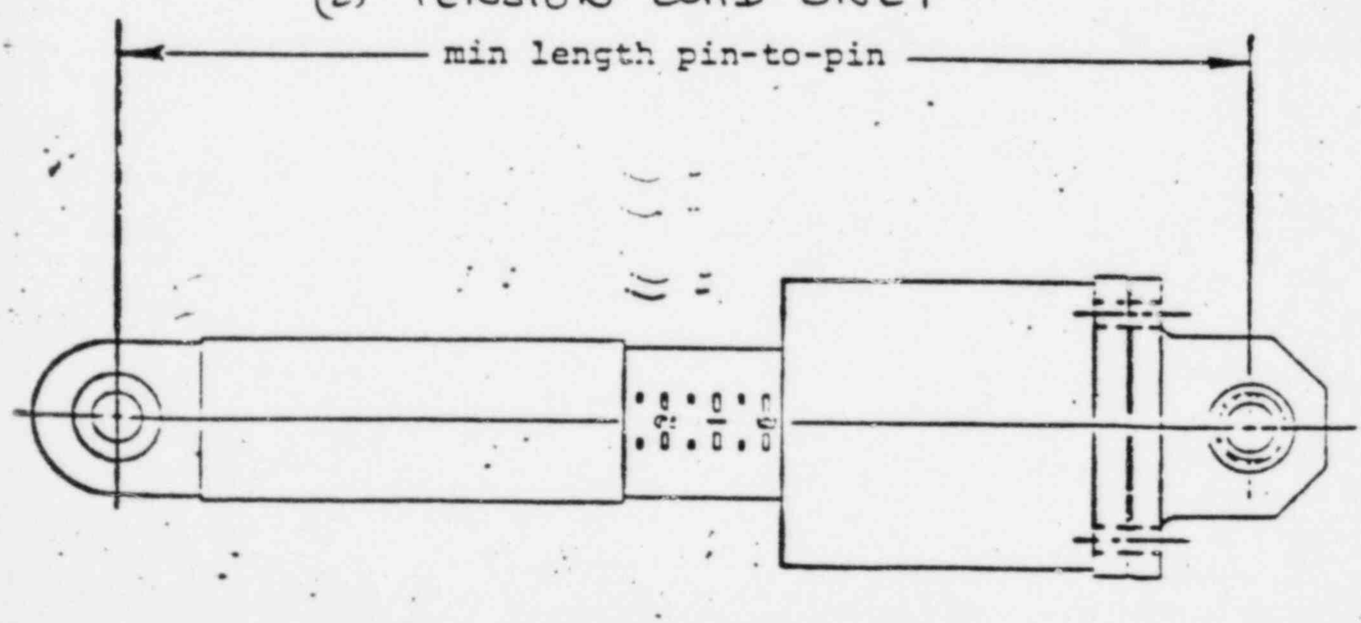
DYNAMIC SPRING RATE

The following dynamic spring rates are for the minimum length arrestor, pin-to-pin. They are minimum values obtained by averaging results at 3 and 9 Hz.

MODEL NUMBER	ENCLOSURE VALUES(1)	SPRING RATE - LBS./IN.	RATIO
PSA-1/4	$.42 \times 10^5$	$.9 \times 10^4$	4.7
PSA-1/2	$.44 \times 10^5$	1.5×10^4	3.0
PSA-1	1.1×10^5	$.6 \times 10^5$	1.9
PSA-3	1.74×10^5	$.75 \times 10^5$	2.3
PSA-10	3.48×10^5	2.4×10^5	1.4
PSA-35	(2) 13.5×10^5	$.7 \times 10^6$	1.9
PSA-100	(2) 22.7×10^5	1.0×10^6	2.3

NOTES: (1) AVERAGE OF TENSION AND COMPRESSION

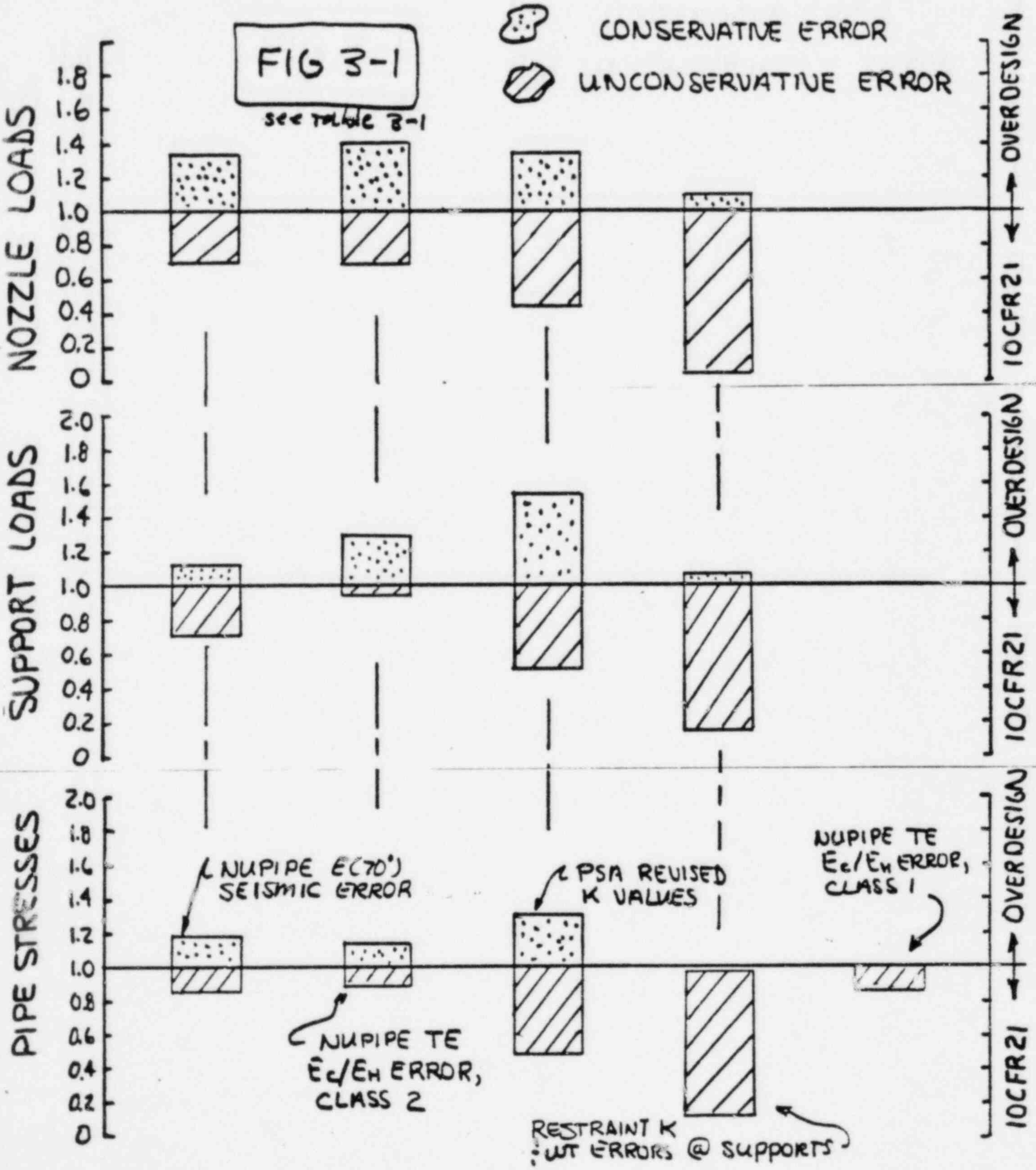
(2) TENSION LOAD ONLY



ENCLOSURE 3

SELECTED SENSITIVITY STUDY RESULTS

RANGE OF RATIO : (PREDICTED VALUE ÷ CORRECT VALUE) FOR VARIOUS ERRORS IN PIPING SOLUTIONS OF SELECTED PIPELINES



FN-156 (8-50) (E) 180x250 1mm Divisions

FIG 3-2

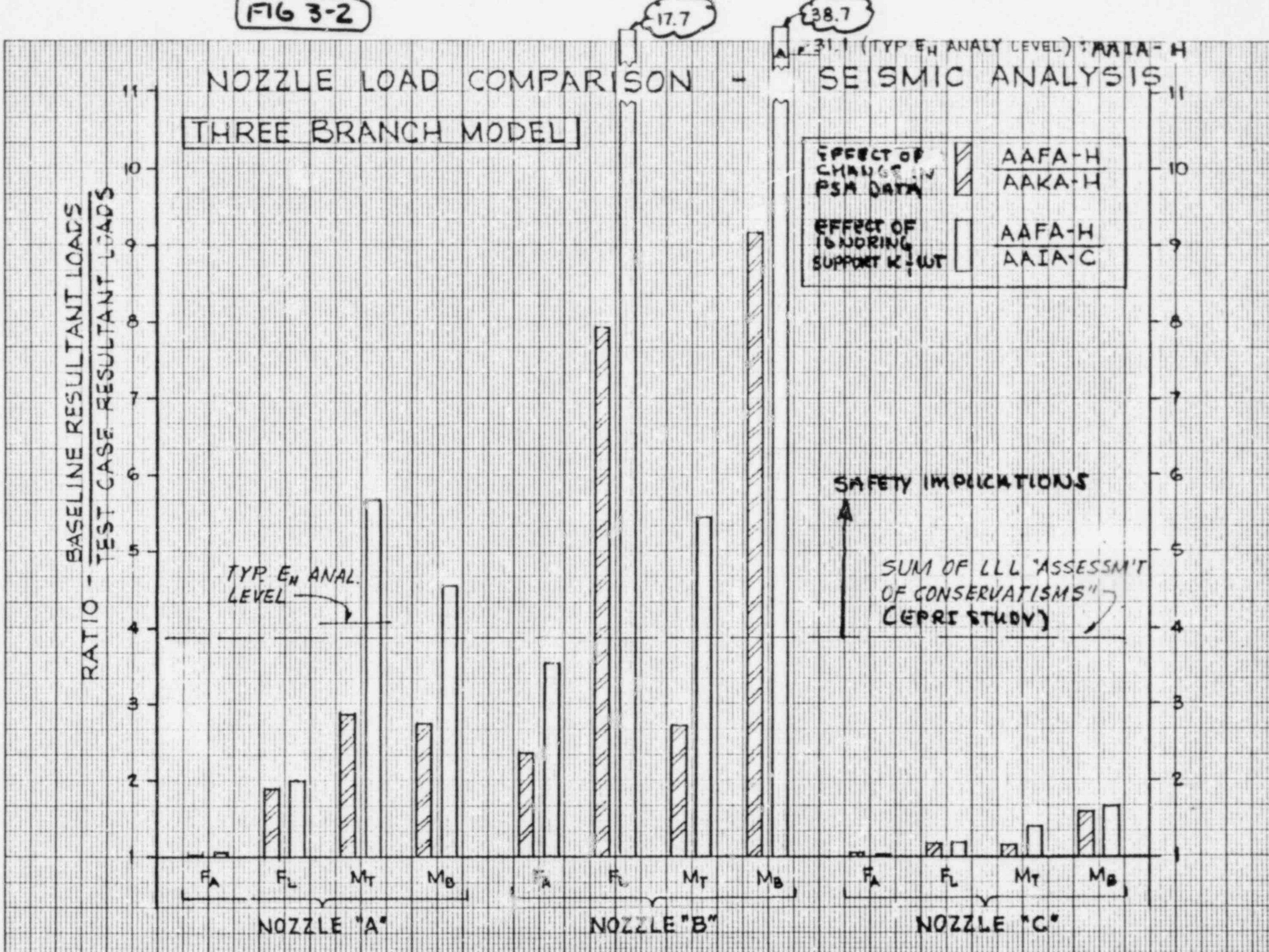


FIG 3-3

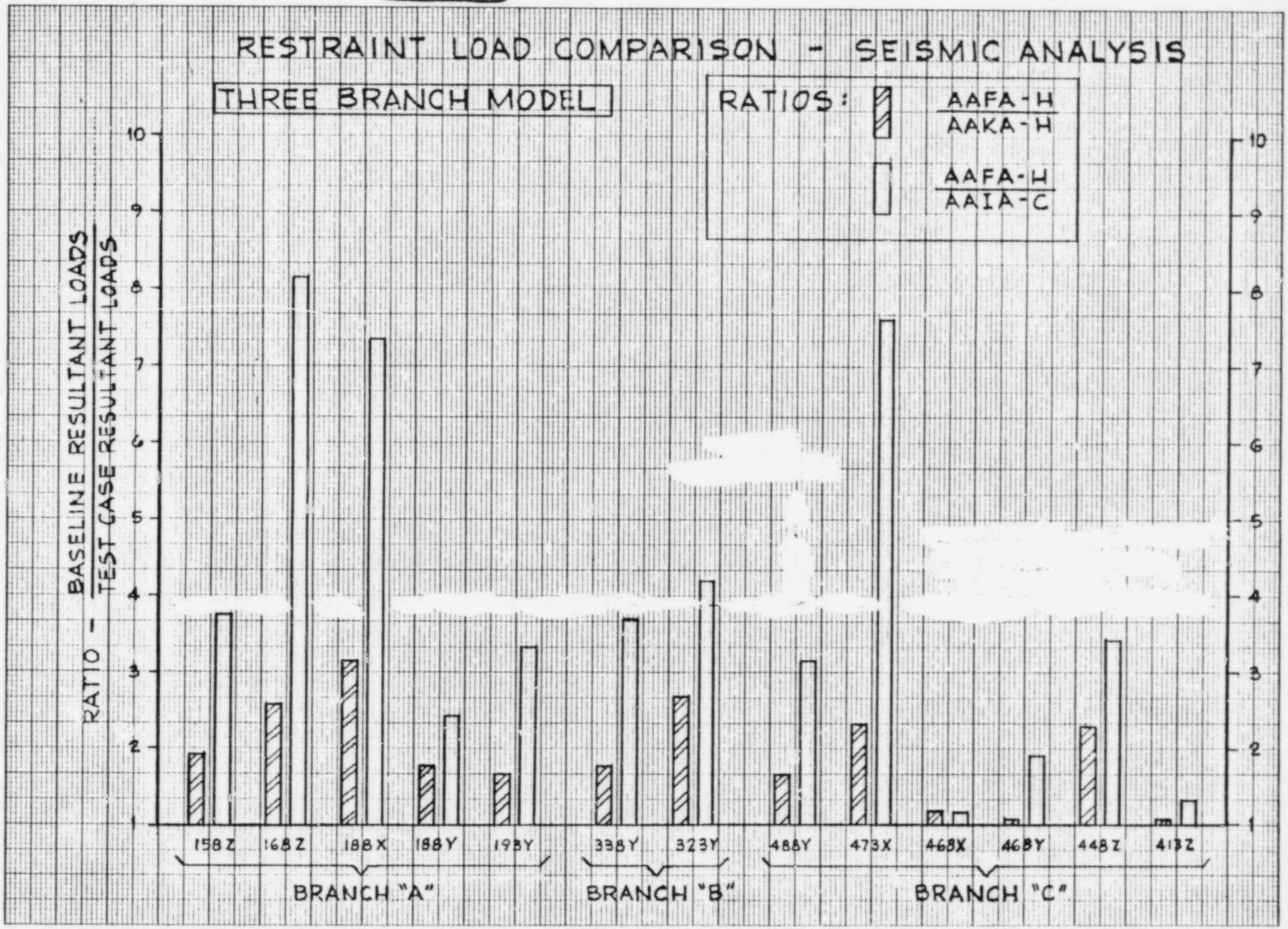

RESTRAINT LOAD COMPARISON - SEISMIC ANALYSIS
THREE BRANCH MODEL
RATIOS:
AAFA-H / AAKA-H
AAFA-H / AAIA-C
RATIO - BASELINE RESULTANT LOADS / TEST CASE RESULTANT LOADS
1
2
3
4
5
6
7
8
9
10
158Z
168Z
188X
188Y
193Y
338Y
323Y
488Y
473X
468X
468Y
448Z
413Z
BRANCH "A"
BRANCH "B"
BRANCH "C"

FIG 3-4

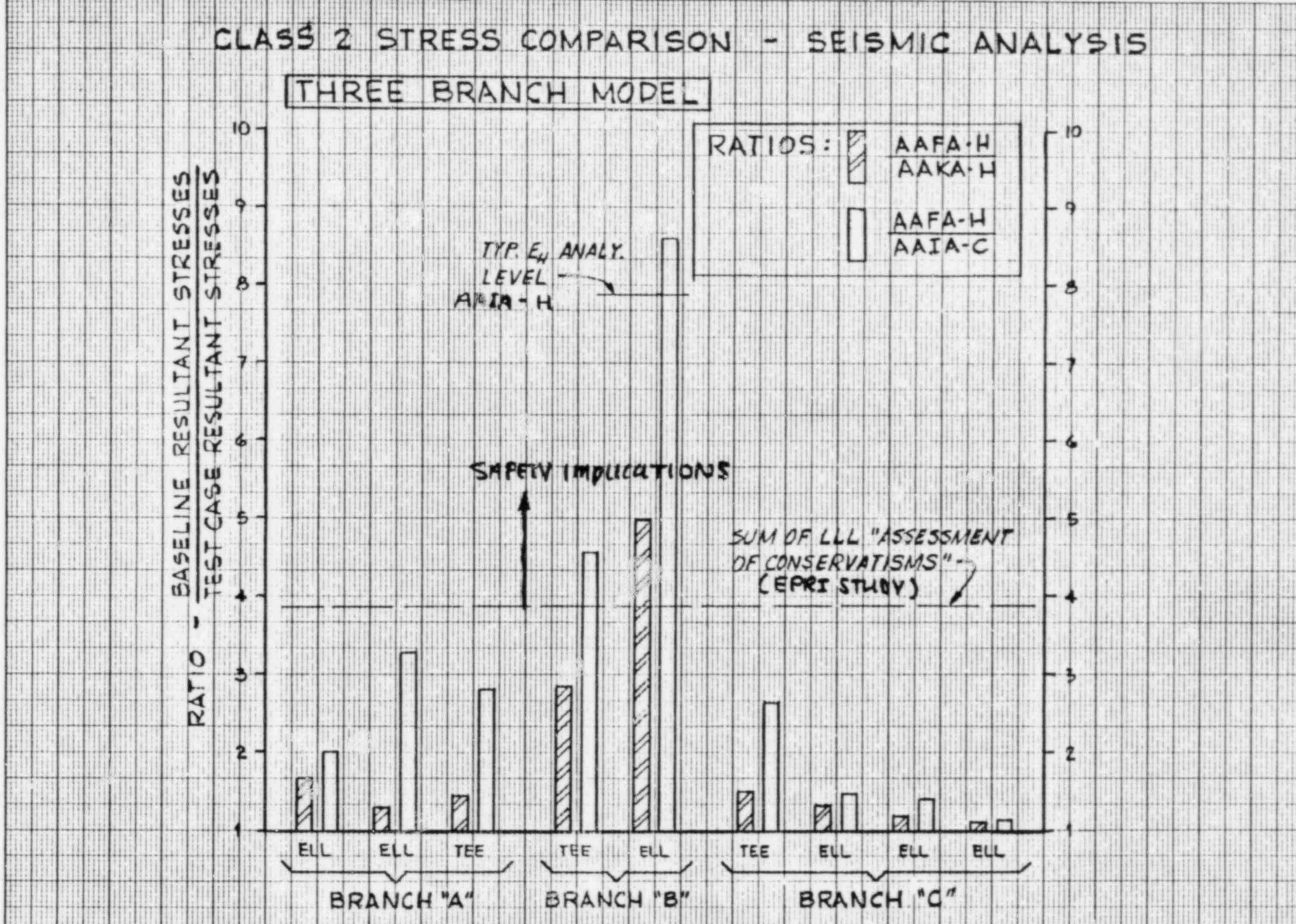

CLASS 2 STRESS COMPARISON - SEISMIC ANALYSIS
THREE BRANCH MODEL
RATIO - BASELINE RESULTANT STRESSES / TEST CASE RESULTANT STRESSES
RATIOS:
AAFA-H / AAKA-H
AAFA-H / AAIA-C
TYP. E_H ANALY. LEVEL - AAIA-H
SAFETY IMPLICATIONS
SUM OF LLL "ASSESSMENT OF CONSERVATISMS" - (EPRI STUDY)
ELL
ELL
TEE
TEE
ELL
TEE
ELL
ELL
ELL
BRANCH "A"
BRANCH "B"
BRANCH "C"
1
2
3
4
5
6
7
8
9
10

FIG 3-5 1/3

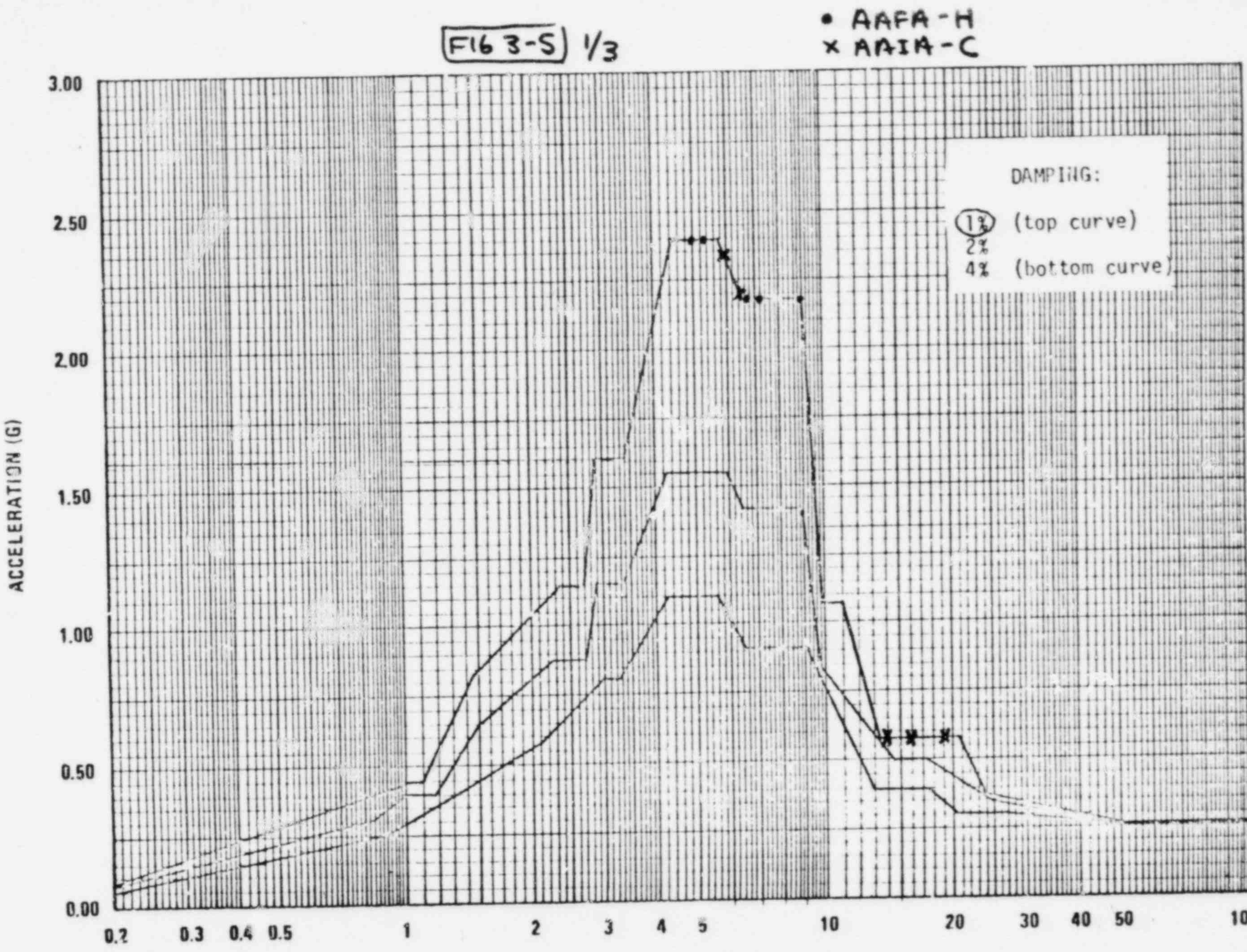


FIG. RSB-0816EH CRBRP OBE HORIZONTAL E-W DESIGN RESPONSE SPECTRA FOR REACTOR SERVICE BUILDING AT EL. 816', NODE 27 (x = 15.39'; y = -160.41')

7860-3

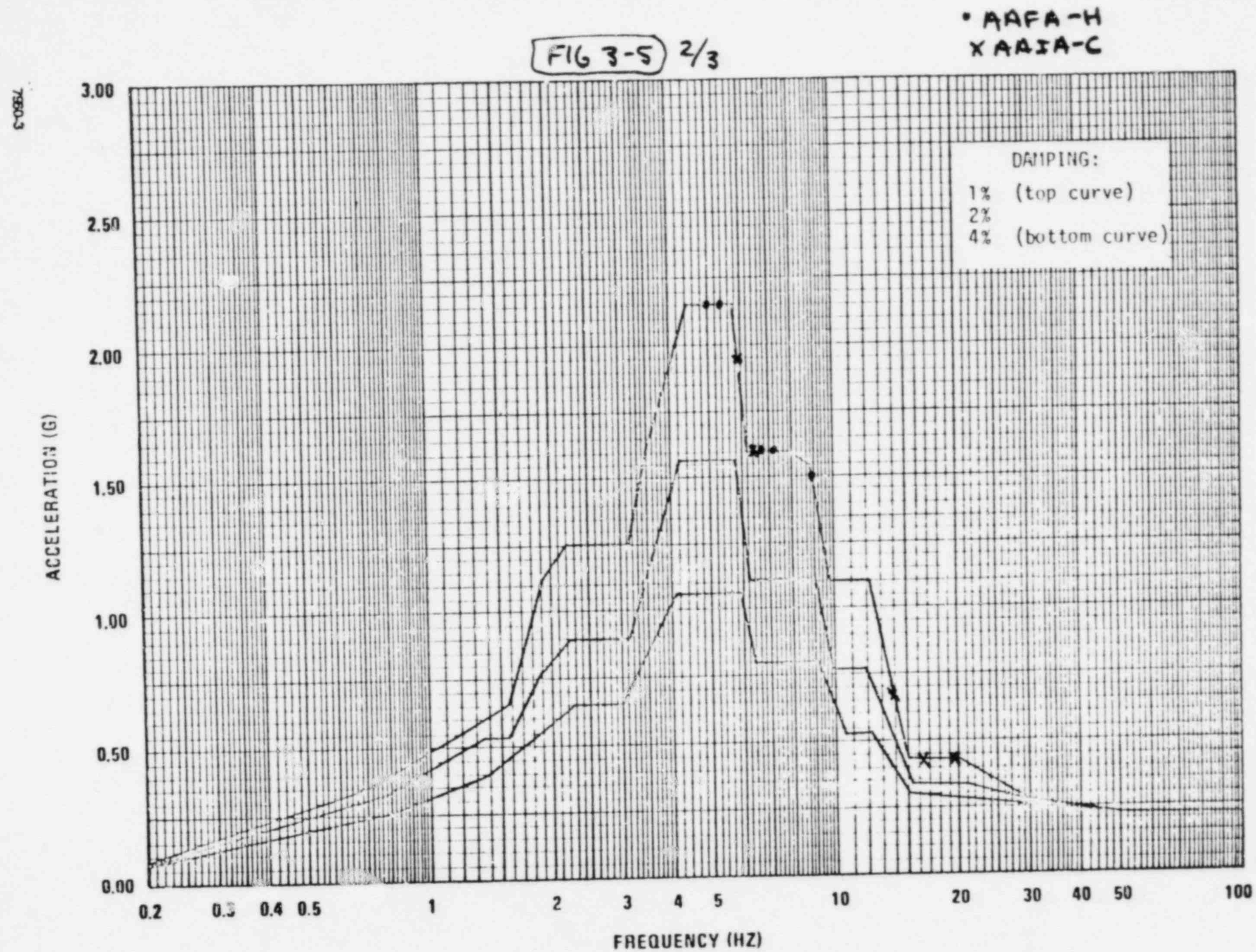


FIG. RSB-0816NH CRBRP OBE HORIZONTAL N-S DESIGN RESPONSE SPECTRA FOR REACTOR SERVICE BUILDING AT EL. 816', NODE 27 (x = 15.39'; y = -160.41')

FIG 3-5 3/3

FIG. RSB-0816V CRBRP OBE VERTICAL DESIGN RESPONSE SPECTRA FOR REACTOR SERVICE BUILDING AT EL. 816', NODE 28 (x = 15.39'; y = -160.41')

7960-3

TABLE 3-1

SUMMARY OF ERROR IMPACT : RANGE

* : PLOTTED ON FIG 3-1

RATIO OF PREDICTED VALUES ; ERRONEOUS/CORRECT

ERROR ID	MODEL ID	BRIEF MODEL DESCRIPTION	NOZZLE LOADS MIN	NOZZLE LOADS MAX	SUPPORT LOADS MIN	SUPPORT LOADS MAX	PIPE STRESS MIN	PIPE STRESS MAX
NUPIPE - CLASS 2	4b-1	ACTUAL LINE, E(70°) USED INSTEAD E(1000°)	0.80	1.26	0.90	1.11	0.84*	1.18
USE OF E(70°) FOR	AACA	3 LEG LINE, SNBR K ONLY, E(70°) INSTEAD E(1000°)	0.71*	1.04	0.87	1.12*	0.87	1.01
SIESMIC	AAFA	3 LEG LINE, TOTAL SUPPORT K, E(70°) INSTEAD E(1000°)	0.90	1.33*	0.71*	1.12	0.92	1.19*
		H vs C						
NUPIPE - CLASS 2	AAAA	3 LEG LINE, LEG A = 1000°, LEG B = 1000°, LEG C = 1000°	1.26	1.28	1.23	1.30*	1.0	1.0
USE E(70°) FOR TE	ABAA	3 LEG LINE, LEG A = 500°, LEG B = 1000°, LEG C = 1000°	0.96	1.40*	0.95*	1.26	0.97	1.0
CASES INSTEAD OF	ACAA	3 LEG LINE, LEG A = 1000°, LEG B = 500°, LEG C = 1000°	0.70*	1.25	1.11	1.30	0.98	1.07
E(HOT) w/ E(COLD)	AEAA	3 LEG LINE, LEG A = 500°, LEG B = 500°, LEG C = 1000°	0.93	1.36	1.08	1.24	0.89*	1.14*
÷ E(HOT) CORRECTION	AFAA	3 LEG LINE, LEG A = 500°, LEG B = 1000°, LEG C = 500°	1.04	1.24	1.06	1.19	0.89	1.14
		- H w/ E_C/E_H vs - C w/o E_C/E_H						
	(CASE)							
NUPIPE - CLASS 1	D	FICTICIOUS LINE, SIDE 1 = 70°, SIDE 2 = 1000° INITIALLY, CYCLE TO 70°, 500° RESPECTIVELY					0.88	1.0*
CORRECTION E(COLD)	E	FICTICIOUS LINE, SIDE 1 = 70°, SIDE 2 = 1000° INITIALLY, CYCLE TO 500°, 1000° RESPECTIVELY					0.86	1.0
÷ E(HOT) ON TE σ	F	FICTICIOUS LINE, SIDE 1 = 70°, SIDE 2 = 500° INITIALLY, CYCLED TO 500°, 1000° RESPECTIVELY					0.94	0.96
RANGES, NOT AMPLITUDE.	G	FICTICIOUS LINE, SIDE 1 = 70°, SIDE 2 = 1000° INITIALLY, CYCLED TO 1000°, 1000° RESPECTIVELY					0.83*	1.0
'CORRECT" = CODE METHOD	(CASE)							
'CORRECT" = EXACT $d\sigma/dE$	D						0.95	1.0
CONTINUUM CORRECTION	E	SAME AS ABOVE					0.86	1.26*
	F						0.96	1.01
PSA - 1976 STATIC K	G						0.83*	1.26
VALUES USED INSTEAD OF	— VS AACA-H							
1982 DYNAMIC K VALUES	4b-1	ACTUAL LINE, TOTAL SUPPORT K IN K_{eff} VALUE	0.85	1.11	0.79	1.56*	0.81	1.31*
(VENDOR DATA LISTS)	AAAA-H	3 LEG LINE @ 1000°, SNBR ONLY K AT SUPPORTS	0.43*	1.37*	0.53*	1.06	0.49*	1.04
	AADA-H	3 LEG LINE @ 1000°, TOTAL SUPPORT K USED	0.68	1.01	0.64	1.15	0.88	1.01
	VS AAFA-H							
MODELING ERRORS:								
STIFFNESS & MASS	AAJA-H	3 LEG LINE @ 1000°, WT OF SUPPORTS = 0.0	0.66	1.04	0.57	1.06*	0.84	0.99*
OF SUPPORTS	AAHA-H	3 LEG LINE @ 1000°, K OF SUPPORTS = ∞	0.03*	1.09*	0.18	0.90	0.12*	0.88
IGNORED	AAIA-H	3 LEG LINE @ 1000°, WT = 0.0, K = ∞	0.03	0.99	0.14*	0.88	0.12	0.88
	VS AAFA-H							

TABLE 3-2

MAGNITUDE OF ERRORS IN PREDICTION OF SIESMIC RESPONSE

'RATIO' = VALUE USING REFERENCE CASE (REF) / VALUE USING ERRONEOUS CASE (ERROR)

CASE ID	SNUB K	SNUB WT	OTHER K	MODULUS	PRINCIPLE ERROR STUDIED	CRBR 4" LINE N	CRBR 4" LINE R	CRBR 4" LINE σ	3-LEG 8" LINE N	3-LEG 8" LINE R	3-LEG 8" LINE σ
REF	'82	ACT	REP	HOT	DIFFERENCE IN '76 VS '82 SNUBBER K VALUES	1.18	1.26	1.23	1.47	1.56	1.14
ERROR	'76	ACT	REP	HOT							
REF	'82	ACT	∞	HOT	DIFFERENCE IN '76 VS '82 SNUBBER K VALUES	–	–	–	2.32	1.89	2.04
ERROR	'76	ACT	∞	HOT							
REF	'82	ACT	REP	HOT	EFFECT OF USING ∞ K SUPPORTS	–	–	–	33.3	5.55	8.33
ERROR	∞	ACT	∞	HOT							
REF	'82	ACT	REP	HOT	EFFECT OF USING ZERO WT. SUPPORTS	–	–	–	1.52	1.75	1.19
ERROR	'82	0	REP	HOT							
REF	'82	ACT	REP	HOT	EFFECT OF USING ∞ K BLDG AND ZERO WT. W/ 76→82 ΔK	–	–	–	9.05	3.12	4.98
ERROR	'76	0	∞	HOT							
REF	'82	ACT	REP	HOT	EFFECT OF ∞ K, WTLESS SUPPORT MODELING	–	–	–	31.08	6.50	7.84
ERROR	∞	0	∞	HOT							
REF	'82	ACT	REP	HOT	EFFECT OF USING 70°E IN SIESMIC RUNS	1.25	1.11	1.19	1.11	1.41	1.09
ERROR	'82	ACT	REP	70°							
REF	'82	ACT	∞	HOT	EFFECT OF USING 70°E IN SIESMIC RUNS	–	–	–	1.41	1.15	1.15
ERROR	'82	ACT	∞	70°							

TABLE 3-3

MAGNITUDE OF ERRORS IN PREDICTING THERMAL RESPONSE

$$\text{'RATIO'} = \frac{\text{VALUE USING REFERENCE CASE (REF)}}{\text{VALUE USING ERRONEOUS CASE (ERROR)}}$$

	DESCRIPTION OF COMPARISON EVALUATED	2 SEGMENT LINE σ	3-LEG 8" LINE N	3-LEG 8" LINE R	3-LEG 8" LINE σ
REF: ERROR:	E (HOT) USED FOR 500° (A), 1000° (B), 1000° (C) LEGS; E_c/E_H ADJUSTED E_c USED ALL LINES, NO CORRECTION (ABAA)		1.04	1.05	1.03
REF: ERROR:	E (HOT) USED FOR 1000°, 500°, 1000° LEGS; E_c/E_H ADJUSTED E_c USED ALL LINES, NO CORRECTION (ACAA)		1.43	0.90	1.02
REF: ERROR:	E (HOT) USED FOR 500°, 500°, 1000° LEGS; E_c/E_H ADJUSTED E_c USED ALL LINES, NO CORRECTION (AEAA)		1.08	0.93	1.12
REF: ERROR:	E_c/E_H CORRECTION ON σ AT EXTREMES OF ΔT : CODE CORRECTION E_c/E_H CORRECTION ON Δσ USING MAX E_c/E_H OVER ΔT (NUPIPE)	1.20	—	—	—

TABLE 3-4

06/22/82 NUPIPE-IIM - NUCLEAR SERVICES CORPORATION PIPING ANALYSIS PROGRAM - VERSION 1.

EC/EH STUDY SEISMIC OBE EC=28.3 CASE AAFA-B (H) SEIS

INTERPOLATED SPECTRAL ACCELERATION VALUES FOR SPECTRUM 5

MODE	FREQ.	PERIOD	X(G)	Y(G)	Z(G)
1	5.0263	0.198955	0.0492	0.0	0.0
2	5.3794	0.185893	0.1932	0.0	0.0
3	6.7326	0.148530	0.5617	0.0	0.0
4	7.2408	0.138105	0.5617	0.0	0.0
5	9.0071	0.111023	0.4798	0.0	0.0
6	9.3790	0.106621	0.4323	0.0	0.0
7	11.2390	0.088976	0.2451	0.0	0.0
8	11.9913	0.083394	0.2451	0.0	0.0
9	13.1324	0.076148	0.2369	0.0	0.0
10	14.1142	0.070851	0.1785	0.0	0.0
11	14.2071	0.070388	0.1732	0.0	0.0
12	14.7755	0.067680	0.1428	0.0	0.0
13	15.7634	0.063438	0.1428	0.0	0.0
14	15.9285	0.062780	0.1428	0.0	0.0
15	16.6333	0.060120	0.1428	0.0	0.0
16	18.4667	0.054152	0.0943	0.0	0.0
17	19.4295	0.051468	0.0646	0.0	0.0
18	20.2454	0.049394	0.0476	0.0	0.0
19	21.9248	0.045610	0.0476	0.0	0.0
20	22.4500	0.044543	0.0476	0.0	0.0
21	24.5184	0.040786	0.0476	0.0	0.0
22	24.6901	0.040502	0.0476	0.0	0.0
23	26.4653	0.037785	0.0476	0.0	0.0
24	28.6364	0.034921	0.0444	0.0	0.0
25	29.7918	0.033566	0.0422	0.0	0.0
26	32.6502	0.030628	0.0371	0.0	0.0
27	33.3956	0.029944	0.0359	0.0	0.0

FREQUENCIES

82 SNUBBER K
ACTUAL CLAMP K
SUPPORT WTS
HOT MODULUS
ACTUAL BLDG K

(SEE FIG 3-5)

TABLE 3-5 EC/EH STUDY SEISMIC OBE EC=28.3 CASE AXIA-C-SEIS

INTERPOLATED SPECTRAL ACCELERATION VALUES FOR SPECTRUM 5

∞ SNUBBER K
∞ CLAMP K
∞ BLDG K
WEIGHTLESS SUPPORTS
COLD MODULUS

(see Fig 3-5)

MODE	FREQ.	PERIOD	X(G)	Y(G)	Z(G)
1	5.9432	0.168260	0.4046	0.0	0.0
2	6.4140	0.155909	0.5617	0.0	0.0
3	13.9399	0.071737	0.1886	0.0	0.0
4	15.6765	0.063790	0.1428	0.0	0.0
5	19.0125	0.052597	0.0773	0.0	0.0
6	19.6472	0.050898	0.0580	0.0	0.0
7	20.2177	0.049462	0.0476	0.0	0.0
8	20.5294	0.048711	0.0476	0.0	0.0
9	23.2873	0.042942	0.0476	0.0	0.0
10	26.6313	0.037550	0.0476	0.0	0.0
11	26.9234	0.037142	0.0476	0.0	0.0
12	27.7317	0.036060	0.0461	0.0	0.0
13	28.6285	0.034930	0.0444	0.0	0.0
14	29.0753	0.034393	0.0435	0.0	0.0
15	30.3803	0.032916	0.0411	0.0	0.0
16	31.5129	0.031733	0.0391	0.0	0.0
17	37.1107	0.026946	0.0333	0.0	0.0

FREQUENCIES

DEFINITION OF '3 LEG' MODELS FOR SEISMIC CASES

	SNUB K	CLMP K	BLDG K	WEIGHT	"E" TEMP
AAFA-H*	1982	ACTUAL	ACTUAL	ACTUAL	HOT
AAKA-H	1976	∞	∞	ZERO	HOT
AAIA-H	∞	∞	∞	ZERO	HOT
AAIA-C	∞	∞	∞	ZERO	AMB.
AACA-C	1982	∞	∞	ACTUAL	AMB.
AAFA-C	1982	ACTUAL	ACTUAL	ACTUAL	AMB.
AACA-H	1982	∞	∞	ACTUAL	HOT
AAAA-H	1976	∞	∞	ACTUAL	HOT
AADA-H	1976	ACTUAL	ACTUAL	ACTUAL	HOT
AAJA-H	1982	ACTUAL	ACTUAL	ZERO	HOT
AAHA-H	∞	∞	∞	ACTUAL	HOT

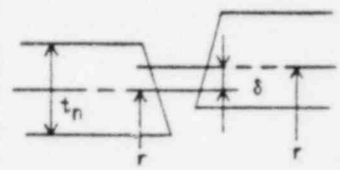
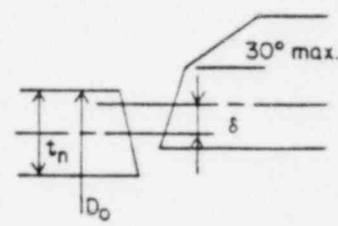
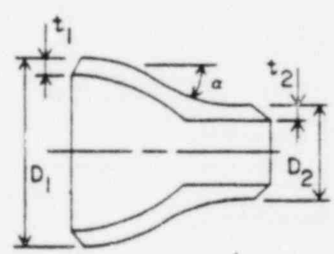
* BASELINE ANALYSIS

PARAMETER VALUES FOR '3 LEG MODELS (8" LINE)

		1982	1976	∞
SNUB K	PSA 1	3.9×10^4	1.0×10^5	1.0×10^8
	PSA 3	6.6×10^4	1.5×10^5	
		ACTUAL	∞	
CLMP K		5.0×10^4	1.0×10^8	
BLDG K		1.5×10^5		
WEIGHT	RIGID	98	0	
	PSA 1	94	0	
	PSA 3	106	0	

	HOT	AMBIENT
MODULUS	22.5 @ 1000°F	28.3 @ 70°F

TABLE 3-6 3 LEG MODEL DEFINITION

Description	Flexibility Factor, k	Stress Intensification Factor, i	Sketch
Branch connection (6)	1	$1.5\left(\frac{R_m}{T_r}\right)^{2/3}\left(\frac{r'_m}{R_m}\right)^{1/2}\left(\frac{T'_b}{T_r}\right)\left(\frac{r'_m}{r_p}\right)$	Fig. NC-3673.2(b)-2
Butt weld (1) $t_n > 3/16$ and $\frac{\delta}{t_n} \leq 0.1$	1	1.0	
Butt weld (1) $t_n \leq 3/16$ or $\frac{\delta}{t_n} > 0.1$	1	1.0 for flush weld 1.8 for as-welded	
Fillet welded joint, socket welded flange, or single welded slip on flange	1	2.1	Fig. NC-3673.2(b)-3, sketches (a), (b), (c), (e) and (f)
Full fillet weld	1	1.3	Fig. NC-3673.2(b)-3, sketch (d)
30° tapered transition (ANSI B16.25)(1)	1	1.9 max. or $1.3 + 0.0036\frac{D_o}{t_n} + 3.6\frac{\delta}{t_n}$	
Concentric reducer (ANSI B16.9 or MSS SP48) (7)	1	2.0 max. or $0.5 + 0.01\alpha\left(\frac{D_2}{t_2}\right)^{1/2}$	
Threaded pipe joint or threaded flange	1	2.3	
Corrugated straight pipe or corrugated or creased bend (8)	5	2.5	

(See notes on next page)

FIG. NC-3673.2(b)-1 FLEXIBILITY AND STRESS INTENSIFICATION FACTORS (Cont'd)

S75
S76

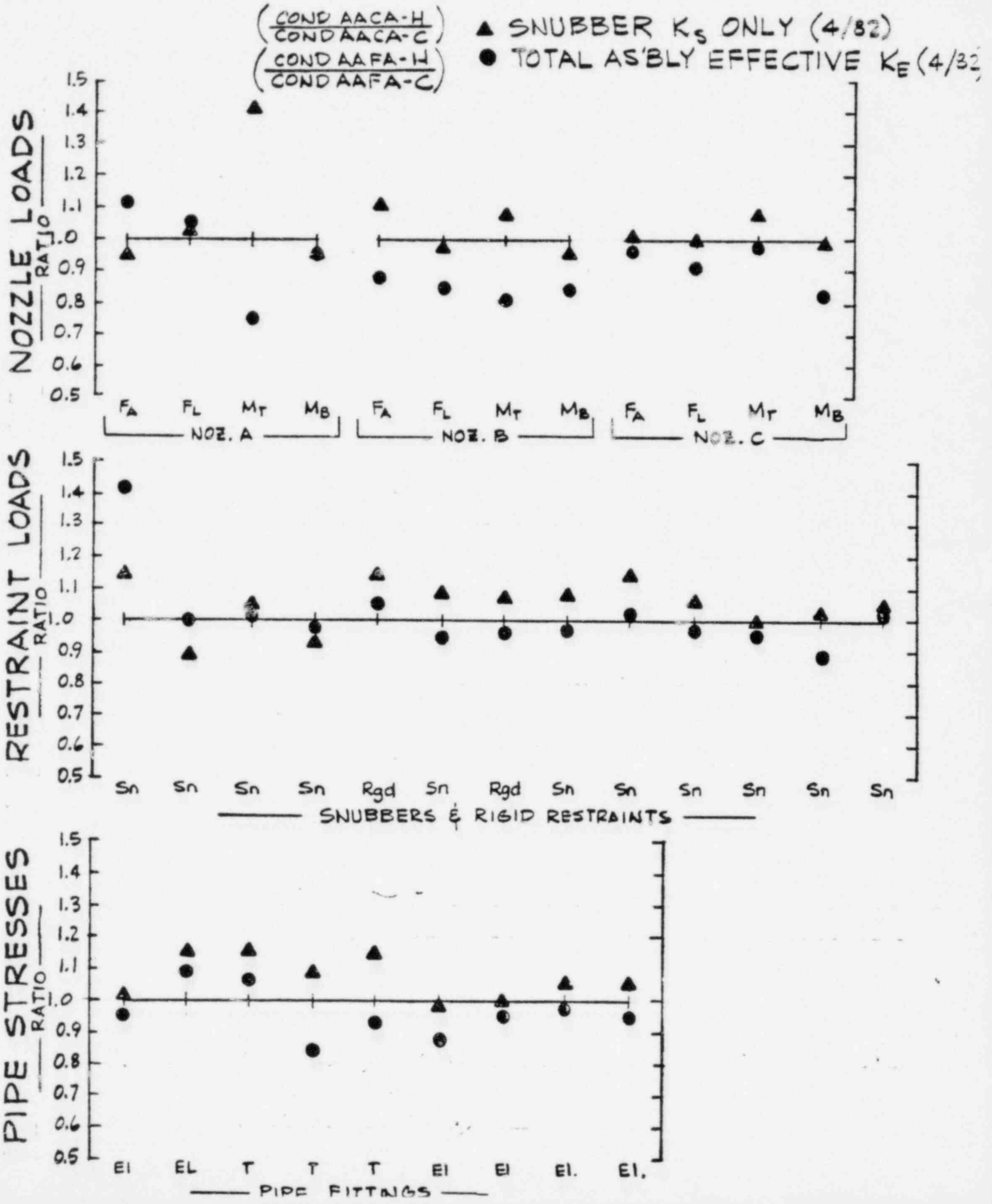
PREPARED BY:	Rockwell International Energy Systems Group	PAGE NO. OF
CHECKED BY:		REPORT NO.
DATE:		MODEL NO.

DETAILED RESULTS/CALCS

D-1

SEISMIC R.S. ANALYSIS -

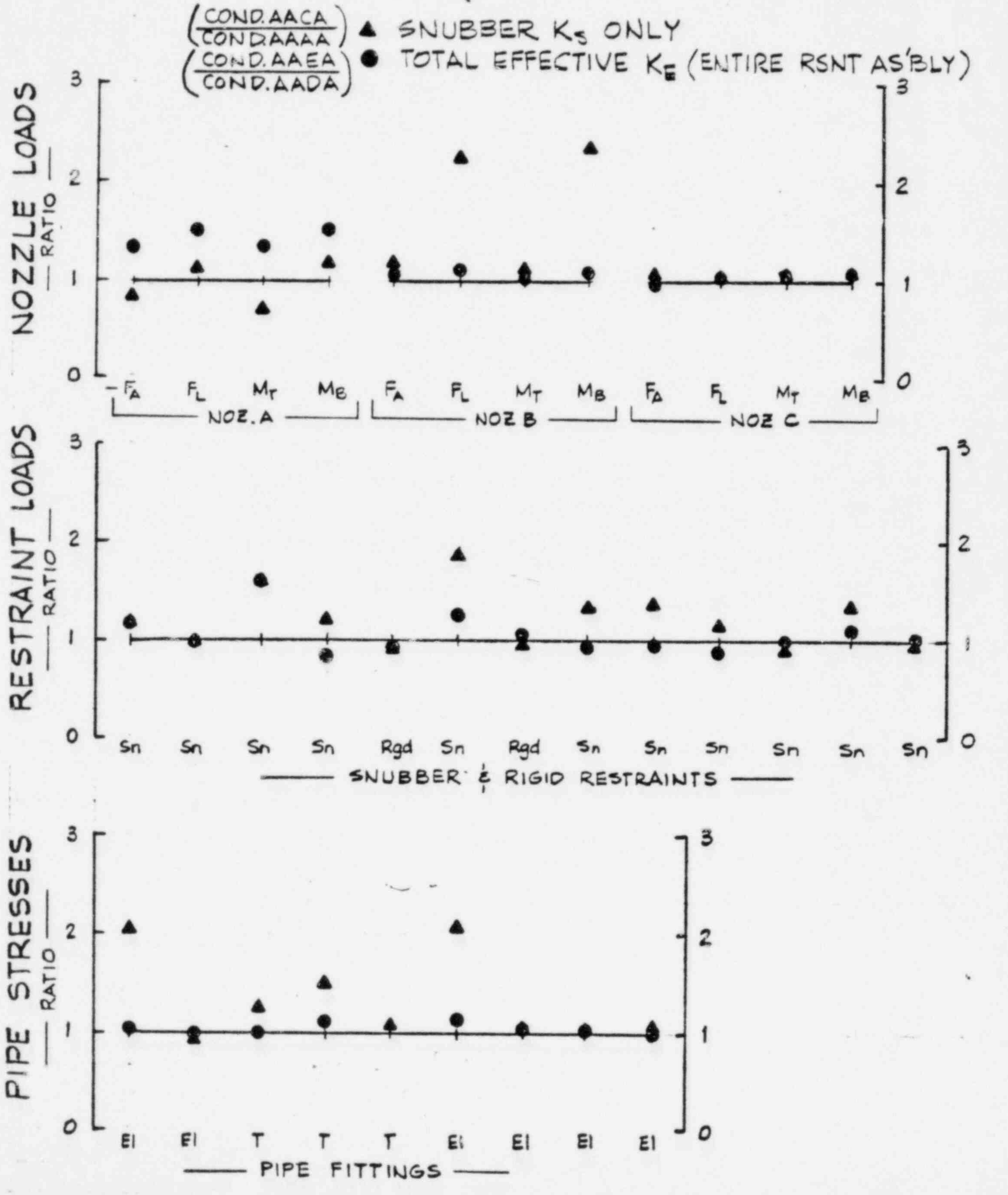
EFFECT OF USING E_C vs E_H AS STRUCTURAL MODEL BASIS FOR:



D-2

SEISMIC R.S. ANALYSIS

EFFECT OF USING NEW (4/82) VS ORIGINAL (11/76) SNUBBER K. VALUES



D-3

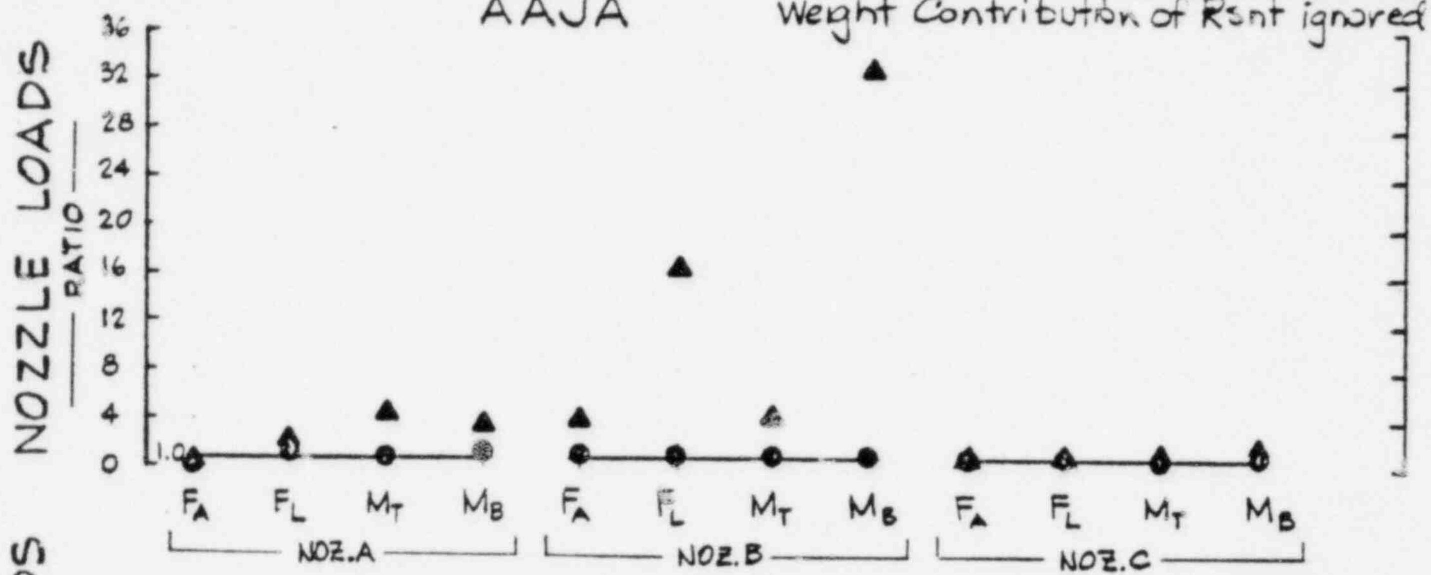
SEISMIC R.S. ANALYSIS

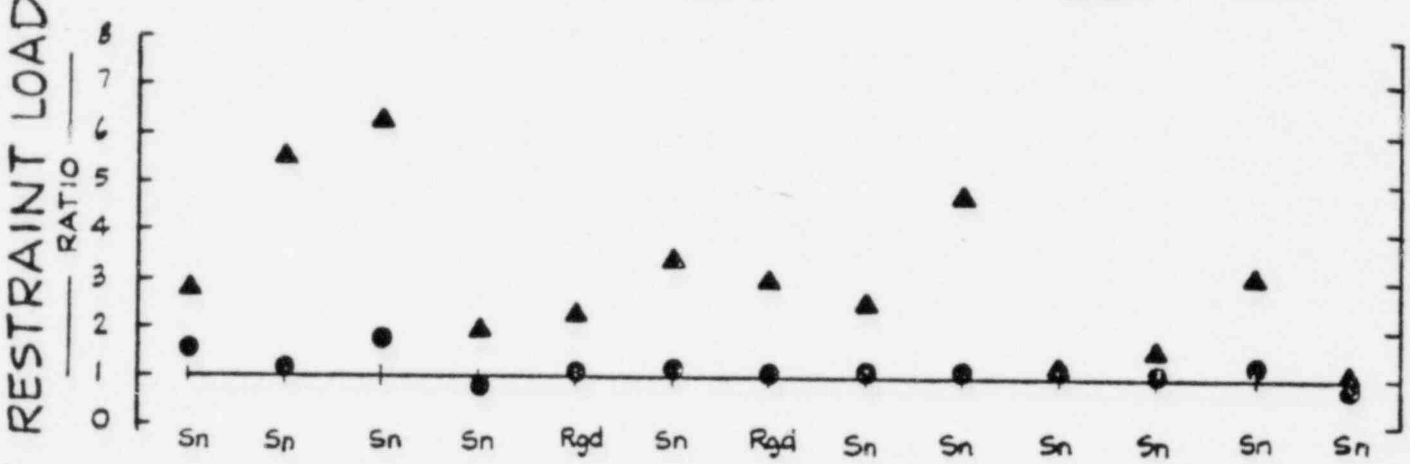
▲ EFFECT OF IGNORING SUPPORT K

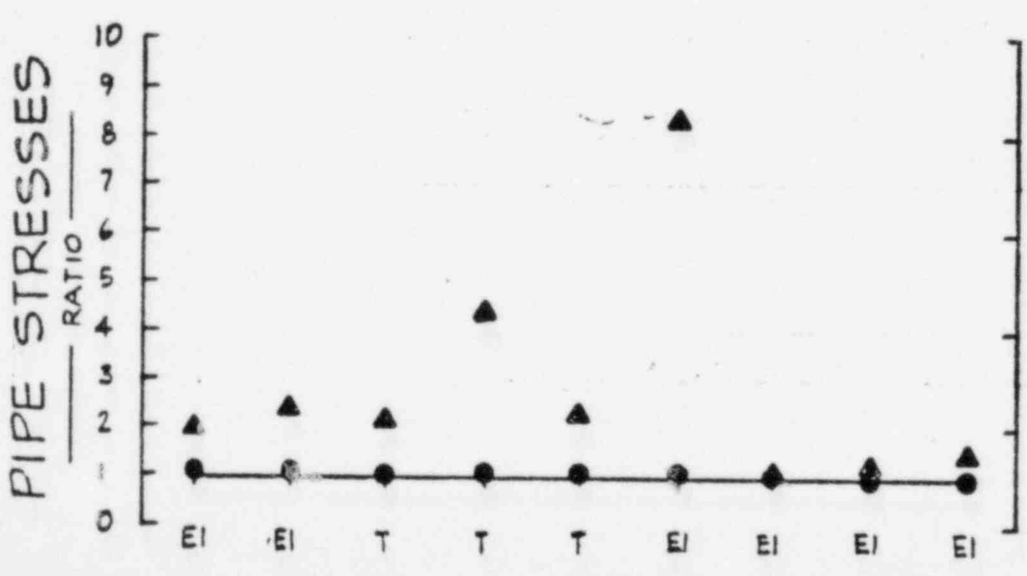
● EFFECT OF IGNORING SUPPORT WT

RATIOS: $\frac{AAEA}{AAHA} = \frac{\text{Effective Combined K w/ 4/82 Snbr K}}{K = 1 \times 10^{8} \text{ (Effective Rigid Rsnt)}}$

$\frac{AAEA}{AAJA} = \frac{\text{Weight of Rsnt Assbly included}}{\text{Weight Contribution of Rsnt ignored}}$





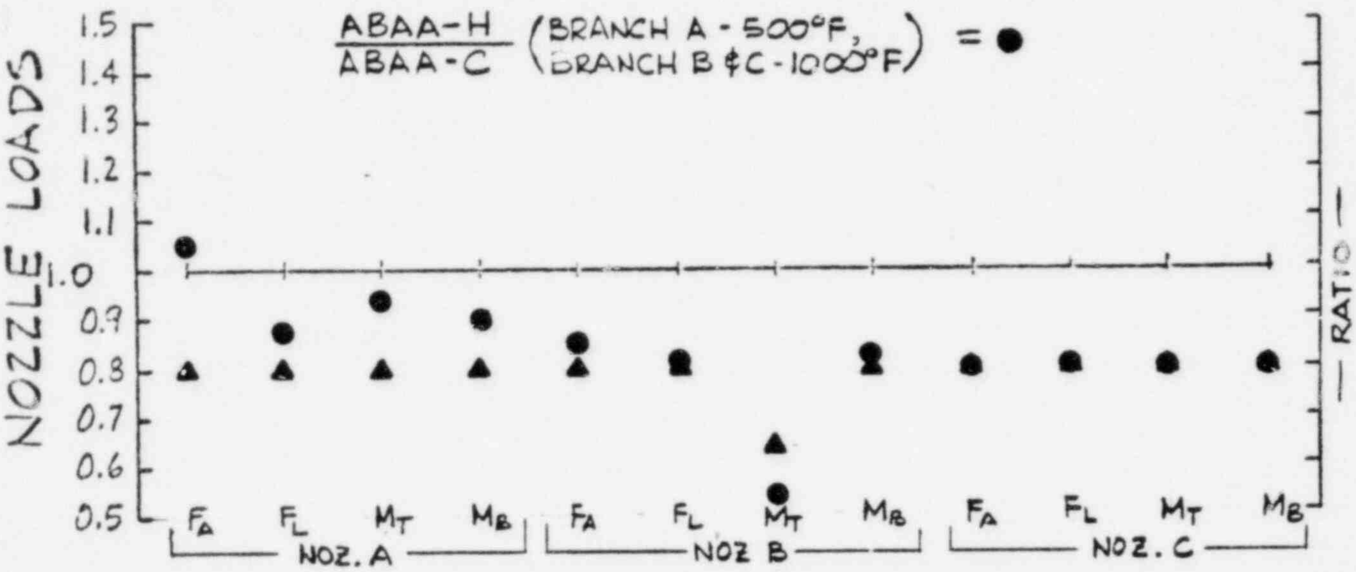


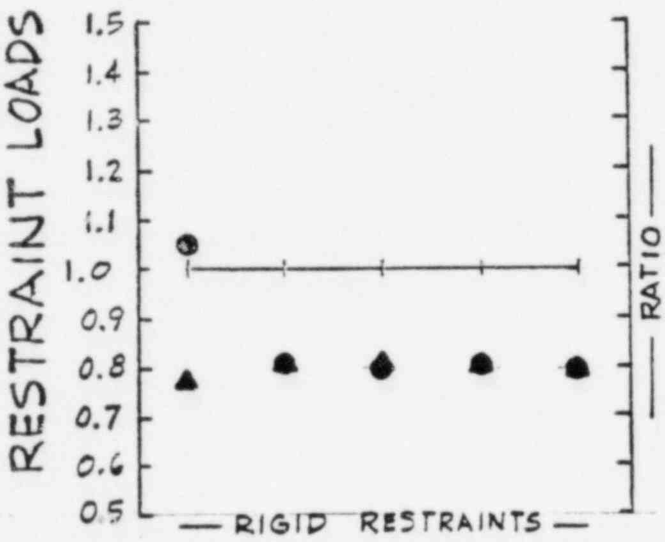
THERMAL EXPAN. ANALYSIS

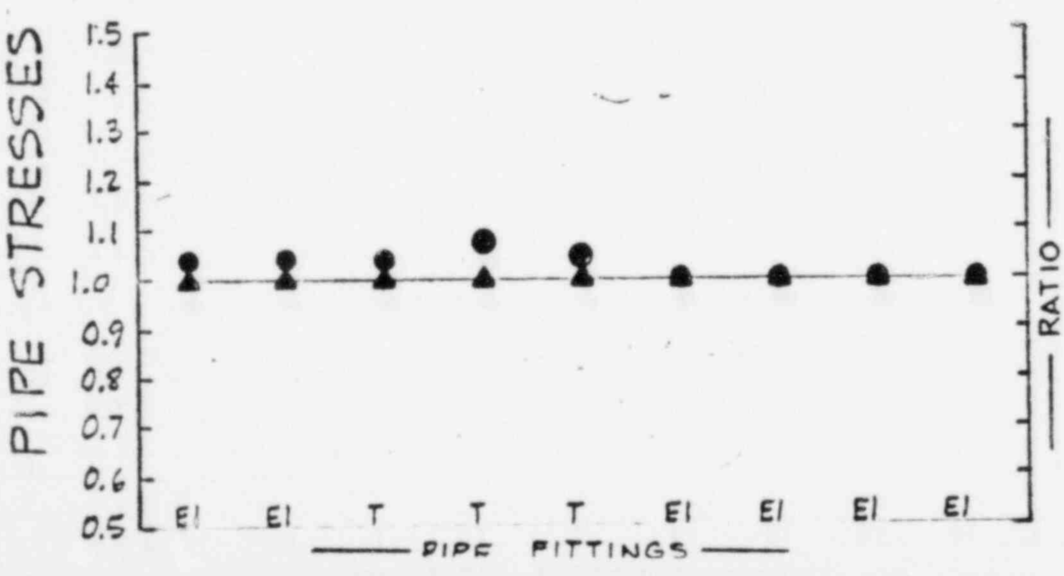
Δ-4 USE OF E_H VS E_C AS STRUCTURAL MODEL BASIS

RATIO: $\frac{\text{AAAA-H}}{\text{AAAA-C}}$ (ALL BRANCHES-1000°F) = ▲

$\frac{\text{ABAA-H}}{\text{ABAA-C}}$ (BRANCH A - 500°F, BRANCH B & C - 1000°F) = ●





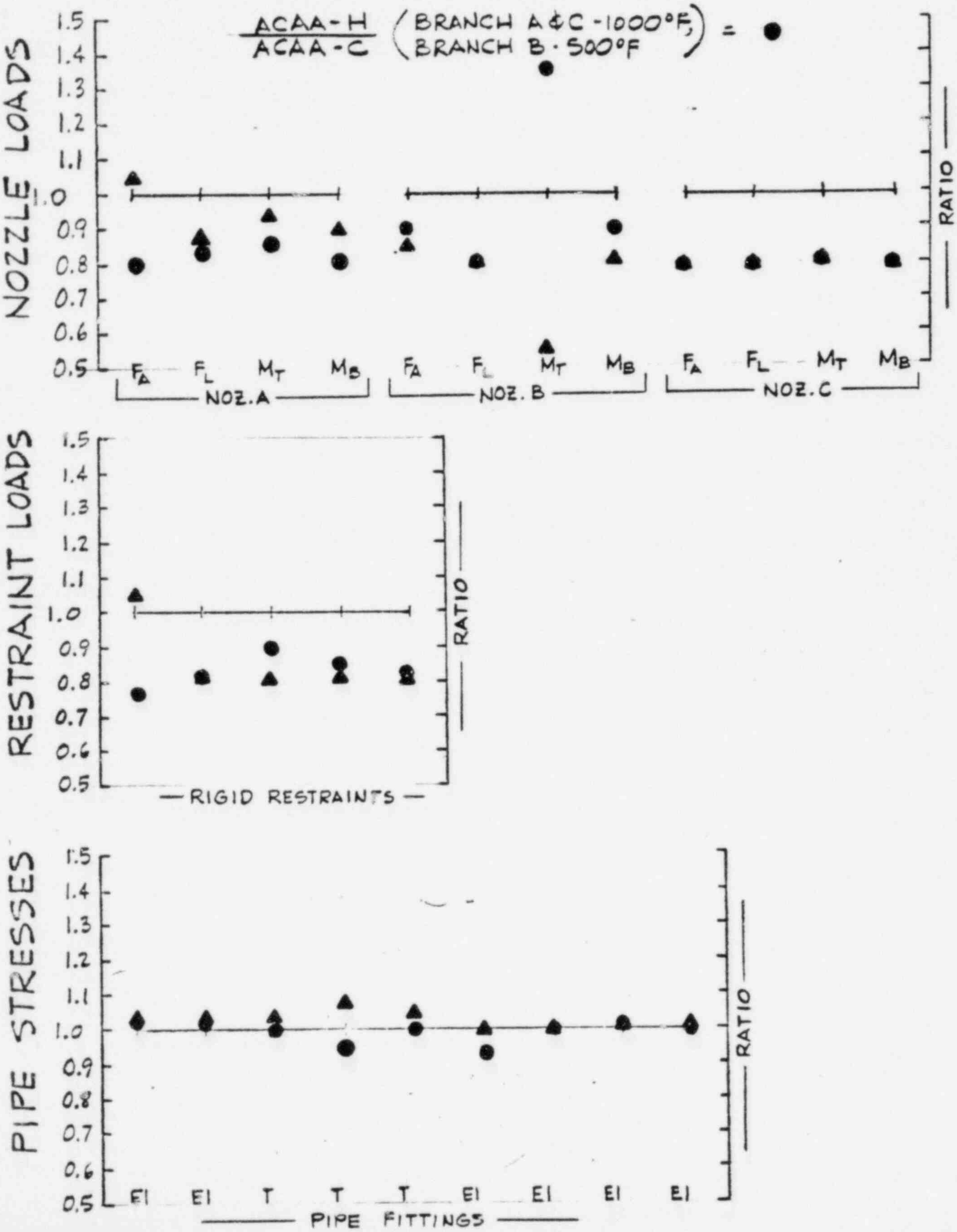


THERMAL EXPAN. ANALYSIS

D-5 USE OF E_H VS E_C AS STRUCTURAL MODEL BASIS

RATIO: $\frac{ABAA-H}{ABAA-C}$ (BRANCH A - 500°F, BRANCH B & C - 1000°F) = ▲

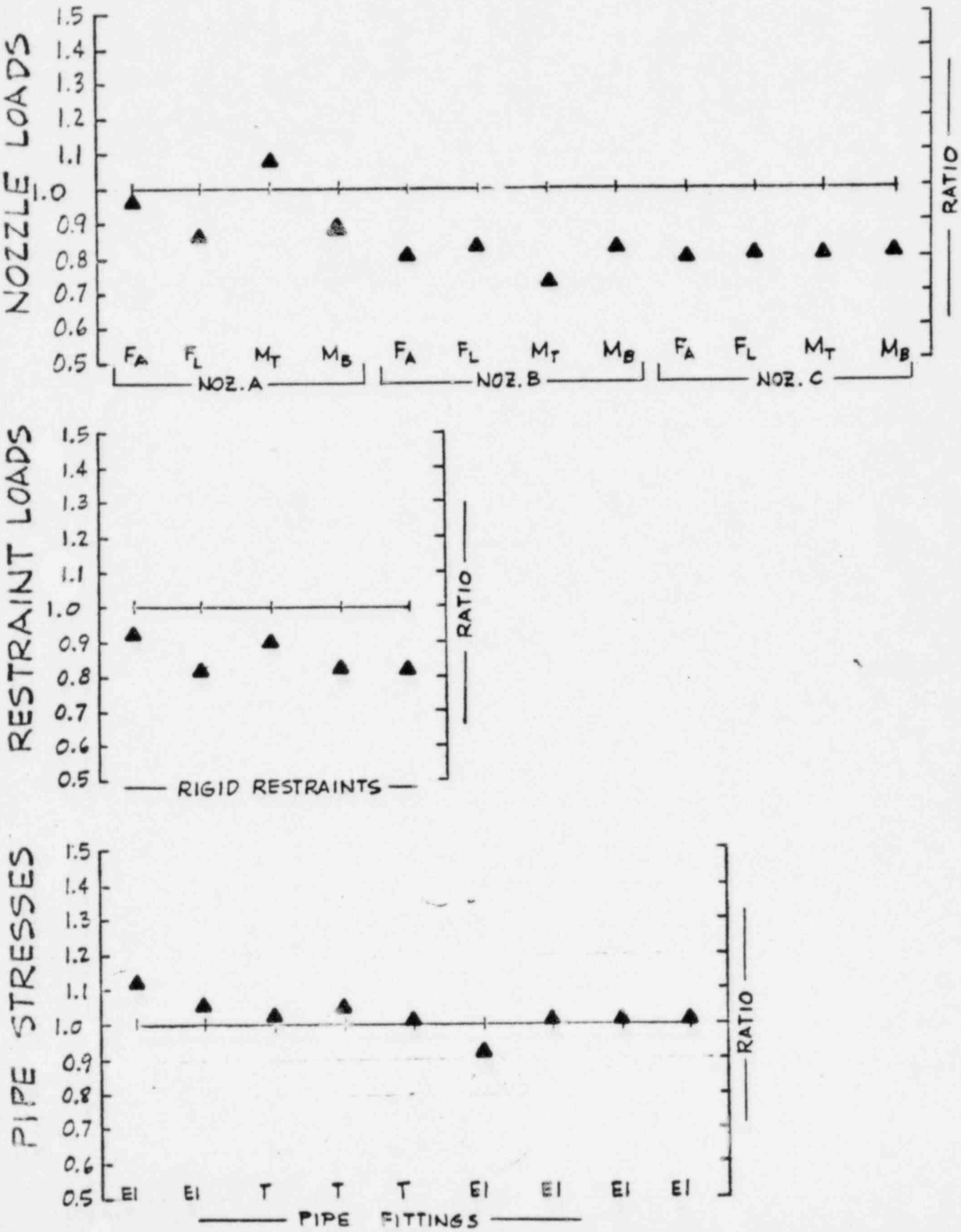
$\frac{ACAA-H}{ACAA-C}$ (BRANCH A & C - 1000°F, BRANCH B - 500°F) = ●



THERMAL EXPAN. ANALYSIS

D-6 USE OF E_H vs E_C AS STRUCTURAL MODEL BASIS

RATIO: $\frac{\text{AEAA-H}}{\text{AEAA-C}}$ (BRANCH A&B - 500°F, BRANCH C - 1000°F) = ▲



D-7

E_C - E_H / RESTRAINT K STUDY

SEISMIC R.S. ANALYSIS – TEST vs BASE CASE COMPARISON TABLES

(NO. > 1.0 is conservative w/ respect to base case)

RATIO: FORCE/STRESS CMPT - TEST CASE (COLD E) / " " " BASE " (HOT E)

	TYPE	NODE	CMPT	AACA-C	E_C/E_H	AACA-H	AAFA-C	E_C/E_H	AAFA-H
ANCHOR LOADS/ RATIOS		100	F_A	.97	1.04	.93	.73	.90	.81
			F_L	.65	.98	.66	.94	.95	.99
			M_T	2.74	.71	3.84	18.61	1.33	14.01
			M_B	44.69	1.04	43.01	87.90	1.04	84.74
		300	F_A	.91	.90	1.01	2.10	1.13	1.86
			F_L	1.26	1.02	1.24	4.07	1.17	3.48
			M_T	2.76	.93	2.96	8.81	1.23	7.14
			M_B	99.14	1.04	95.30	353.42	1.19	300.05
		400	F_A	2.21	.99	2.23	2.28	1.03	2.21
			F_L	1.51	1.00	1.51	1.82	1.09	1.67
			M_T	51.51	.92	56.22	65.75	1.02	64.33
			M_B	74.21	1.01	73.31	127.40	1.21	105.33
	TYPE	NODE	DIR.						
RESTRAINT AXIAL FORCES/RATIOS	SNB	158	Z	.90	.87	1.04	1.05	.71	1.48
	SNB	168	Z	6.97	1.12	6.22	13.16	1.00	13.21
	SNB	188	X	2.68	.95	2.81	4.36	.99	4.41
	SNB	183	Y	1.72	1.06	1.62	1.60	1.02	1.57
	RGD	193	Y	1.93	.87	2.23	2.94	.95	3.10
	SNB	323	Y	.67	.92	.73	1.11	1.05	1.06
	RGD	338	Y	1.93	.93	2.08	3.41	1.03	3.32
	SNB	488	Y	2.07	.92	2.25	2.70	1.02	2.65
	SNB	473	X	8.13	.88	9.19	13.10	.98	13.33
	SNB	468	X	2.76	.94	2.93	2.84	1.02	2.79
	SNB	468	Y	4.06	1.00	4.06	4.32	1.04	4.16
	SNB	448	Z	3.04	.98	3.11	5.86	1.12	5.23
	SNB	413	Z	2.03	.95	2.13	2.35	.99	2.38
	TYPE	NODE	LOOP						
ASME SEC III CLASS 2 eq. 9 σ/RATIOS	ELL	145	A	2.68	.99	2.70	3.88	1.04	3.76
	"	175	A	4.85	.87	5.57	6.45	.92	7.01
	TEE	200	A	9.98	.87	11.48	12.19	.94	12.98
	"	200	B	6.19	.92	6.72	13.44	1.19	11.26
	"	200	C	7.26	.87	8.32	12.58	1.08	11.70
	ELL	315	B	3.92	1.01	3.86	10.52	1.14	9.26
	"	425	C	9.47	1.00	9.44	10.65	1.04	10.20
	"	455	C	7.32	.94	7.77	9.30	1.02	9.08
	"	475	C	7.50	.95	7.87	9.62	1.04	9.25

D-8

E_c - E_H /RESTRAINT K STUDY

SEISMIC R.S. ANALYSIS – TEST vs BASE CASE COMPARISON TABLES

(NO. > 1.0 is conservative w/ respect to base case)

RATIO: FORCE/STRESS CMPT – TEST CASE / " " " BASE CASE

BASE CASE – AADA

		NODE	CMPT	AADA	AAEA	AAGA	AAFA
ANCHOR LOAD RATIOS		100	F_A	1.0	.67	.63	.74
			F_L		1.31	1.33	1.22
			M_T		1.33	1.55	1.10
			M_B		1.46	1.54	1.29
		300	F_A		1.09	1.16	1.01
			F_L		1.13	1.22	1.04
			M_T		1.03	1.15	.84
			M_B		1.16	1.26	1.04
		400	F_A		.99	1.00	.98
			F_L		1.05	1.11	1.01
			M_T		1.03	1.05	1.00
			M_B	↓	1.14	1.29	1.03
	TYPE	NODE	DIR				
RESTRAINT AXIAL FORCE RATIOS	SNB	158	Z	1.0	1.20	1.14	1.28
	SNB	168	Z		.99	0.99	1.00
	SNB	188	X		1.56	1.59	1.34
	SNB	182	Y		.87	.89	.84
	RGD	193	Y		.98	.89	1.04
	SNB	323	Y		1.27	1.11	1.31
	RGD	338	Y		1.04	.98	1.06
	SNB	488	Y		.96	.97	.95
	SNB	473	X		.98	.97	1.00
	SNB	468	X		.94	.95	.95
	SNB	468	Y		1.00	1.01	1.00
	SNB	448	Z		1.11	1.18	1.03
	SNB	413	Z	↓	1.01	1.00	1.01
	TYPE	NODE	LOOP				
ASME SEC III CLASS 2 eq. 9 σ RATIOS	ELL	145	A	1.0	1.03	1.09	.96
	"	175	A		.99	.96	1.01
	TEE	200	A		1.00	.97	1.04
	"	200	B		1.14	1.24	1.01
	"	200	C		1.08	1.14	1.04
	ELL	315	B		1.10	1.17	1.02
	"	425	C		1.02	1.04	1.00
	"	455	C		1.03	1.05	1.00
	"	475	C	↓	1.00	1.02	.99

D-9

$E_C - E_H$ / RESTRAINT K STUDY

SEISMIC R.S. ANALYSIS – TEST vs BASE CASE COMPARISON TABLES

(NO. > 1.0 is conservative w/ respect to base case)

RATIO: FORCE/STRESS CMPT – TEST CASE / " " " BASE CASE

		NODE	CMPT	BASE CASE - AACA: AAAA	AABA	AACA		BASE CASE - AAEA: AAAA	AAEA
ANCHOR LOAD RATIOS		100	F_A	1.14	0.94	1.0		1.44	1.0
			F_L	0.89	0.98			0.55	
			M_T	1.37	1.07			0.31	
			M_B	0.84	0.95			0.37	
		300	F_A	0.82	1.02			0.41	
			F_L	0.44	0.71			0.14	
			M_T	0.88	0.86			0.30	
			M_B	0.43	0.67			0.12	
		400	F_A	0.95	0.95			0.96	
			F_L	0.93	0.98			0.84	
			M_T	0.96	0.99			0.82	
			M_B	0.94	0.97			0.59	
	TYPE	NODE	DIR						
RESTRAINT AXIAL FORCE RATIOS	SNB	158	Z	0.86	0.84	1.0		0.64	1.0
	SNB	168	Z	1.01	0.92			0.48	
	SNB	188	X	0.63	0.87			0.35	
	SNB	188	Y	0.86	0.87			0.86	
	RGD	193	Y	1.06	0.98			0.82	
	SNB	323	Y	0.53	0.68			0.33	
	RGD	338	Y	1.03	1.02			0.66	
	SNB	488	Y	0.76	0.81			0.64	
	SNB	473	X	0.73	0.79			0.52	
	SNB	468	X	0.88	0.89			0.93	
	SNB	468	Y	1.06	0.97			1.03	
	SNB	443	Z	0.74	0.97			0.41	
	SNB	413	Z	1.03	1.00			0.92	
	TYPE	NODE	LOOP						
ASME SEC III CLASS 2 eq. 9 σ RATIOS	ELL	145	A	0.49	0.43	1.0		0.68	1.0
	"	175	A	1.04	1.09			0.85	
	TEE	200	A	0.82	0.86			0.75	
	"	200	B	0.66	0.57			0.35	
	"	200	C	0.93	0.90			0.63	
	ELL	315	B	0.49	0.83			0.19	
	"	425	C	0.98	0.99			0.89	
	"	455	C	0.98	0.99			0.82	
	"	475	C	0.95	0.95			0.80	

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THERMAL EXPAN. CONDITIONS

E_C/E_H STUDY

ASME SEC III, CLASS 2

* LOAD E_C / LOAD E_H & $\sigma_C/\sigma_H(E_C/E_H)-1$

	NODE	LD CMPT	AAAA	ABAA (A@500)	ACAA (B@500)	ADAA (C@500)	AEAA (AB@500)	AFAA (AC@500)	AGAA (BC@500)
NOZZLE LOADS	100	F_A	.26	-.04	.25	.26	.03	.09	.24
		F_L	.26	.15	.21	.26	.16	.11	.21
		M_T	.26	.07	.17	.27	-.07	.12	.21
		M_B	.26	.14	.24	.26	.14	.10	.24
	300	F_A	.28	.40	.12	.15	.23	.24	.02
		F_L	.26	.21	.24	.19	.21	.10	.17
		M_T	.26	.21	-.30	.80	.36	.04	.16
		M_B	.26	.38	.12	.16	.22	.23	.03
	400	F_A	.26	.25	.25	.09	.25	.09	.08
		F_L	.26	.25	.25	.09	.24	.09	.08
		M_T	.26	.26	.24	.09	.24	.10	.05
		M_B	.26	.24	.25	.09	.24	.09	.08
RESTRAINT AXIAL FORCES	188	F_A	.30	-.05	.30	.28	.08	.06	.27
	193		.24	.23	.24	.08	.24	.08	.08
	323		.23	.26	.11	.24	.14	.19	.11
	333		.23	.23	.22	.06	.23	.08	.04
	413		—	—	—	—	—	—	—
	488		.25	.25	.23	.04	.24	.09	-.01
$\frac{\sigma_C}{\sigma_H(E_C/E_H)}$ @ ELBOWS & TEE	145	$\sqrt{M_x^2+M_y^2+M_z^2}$	.00	-.03	-.02	.00	-.11	.03	-.02
	175		.00	-.03	-.02	.00	-.05	.03	-.02
	200		.00	-.03	.17	-.08	.14	-.13	.06
	315		.00	.00	.07	-.04	.09	-.10	.03
	425		.00	.00	.00	.00	-.01	.01	.00
	455		.00	-.01	-.01	.01	-.01	.01	-.01
	475		.00	-.01	.00	.01	-.01	.00	.01

* POSITIVE VALUES INDICATE THERMAL EXPAN. E_H BASE MODEL LOADS < E_C BASE MODEL.

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DATE:	3LEG MODEL	MODEL NO.

		II AAFA-H / AAIA-H	I AAFA-H / AAKA-H	III AAFA-H / AAIA-C
NOZ LOADS				
100	F_2	1.11	1.00	1.04
	F_1	1.89	1.88	2.00
	M_t	4.03	2.83	5.60
	M_B	3.28	2.71	3.50
300	F_2	4.27	2.34	4.78
	F_1	15.55	7.81	17.68
	M_t	4.16	2.71	4.40
	M_B	31.08	9.05	38.66
400	F_2	1.02	1.04	1.02
	F_1	1.18	1.17	1.18
	M_t	1.22	1.16	1.41
	M_B	1.65	1.59	1.66
RSNT LOADS				
158		3.19	1.92	3.72
168		6.50	2.57	8.06
188		6.34	3.12	7.25
188		2.33	1.77	2.39
193		2.74	1.67	3.33
338		3.16	1.77	3.70
323		3.92	2.68	4.19
488		2.73	1.66	3.17
473		6.08	2.34	7.59
468		1.18	1.15	1.15
468		1.83	1.05	1.87
448		2.98	2.31	3.43
413		1.14	1.05	1.32

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3 LEG MODEL

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MODEL NO.

	$\frac{AAFA-H}{AAIA-H}$		" / AAKA-H	" / AAIA-C
	Cl: 2 Stress			
BR. "A"	195	1.95	1.67	2.00
	175	2.72	1.38	3.27
	200	2.40	1.43	2.79
BR. "B"	200	4.06	2.86	4.55
	315	7.84	4.98	8.59
BR C	200	2.32	1.48	2.64
	475	1.44	1.31	1.45
	~~455~~	1.25	1.18	1.40
	425	1.12	1.11	1.13

NEW SNUB K, B.L. CLMP K & WT

VS.

× NEW SNUB K, NEW CLMP K & WT

Maximum % change in stress

NODE	B.L.	NEW	% CHG. $\left(\frac{\lvert B.L. - NEW \rvert}{B.L.}\right)100$
106 (ELB)	2438	1480	39%
106 (GRUN)	1815	1161	36%
105 (ELB)	2133	1589	26%
9012 (GRUN)	3507	2625	25%
101 (GRUN)	5199	3911	25%

24% of all stress locations had a percent change of 10% or greater

Maximum stress % change and location

NODE	B.L.	NEW	% CHG $\left(\frac{\lvert B.L. - NEW \rvert}{B.L.}\right)100$
101 (GRUN)	8763	10166	-16%
100 (GRUN)	7348	8496	-16%
95 (ELB)	6941	7700	-11%

The maximum stress locations occur at the same locations in both cases.

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NEW SNUB K, B.L. CLMP K & WT.

VS.

NEW SNUB K, NEW CLMP K & WT.

Maximum Anchor Component % Differences

NODE	COMPONENT	B.L.	NEW	% CHG. $\left(\frac{\lvert B.L.-NEW\rvert}{B.L.}\right)100$
113	F_x	331	164	50%
113	F_z	268	173	35%
113	M_y	9102	6586	28%
102	M_y	34620	41580	20%
1	M_y	1480	1777	20%

Support Load Differences

NODE	B.L.	NEW	% CHG
3	98	88	10%
10	939	968	3%
18	735	846	15%
19	339	358	6%
26	278	286	3%
35	687	733	7%
48	191	200	5%
49	117	118	1%
61	385	398	3%
77	1022	1155	13%
78	868	974	12%
86	566	621	10%

NODE	B.L.	NEW	% CHG.
91	464	550	19%
92	626	749	20%
220	322	291	10%
208	668	711	6%
208	1479	1545	4%
208	607	648	7%
9	337	347	3%
31	558	522	6%
34	512	481	6%
81	528	515	2%
121	365	349	4%

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B.L. SNUB K, CLMP K & WT.

VS.

NEW SNUB K, NEW CLMP K & WT.

AT SPECIFIED NODES

STRESSES

NODE	B.L.	NEW	% CHG	$\left(\frac{\lvert B.L. - NEW\rvert}{B.L.}\right)100$
106 (ELB)	2432	1480	39%	
106 (GRUN)	1811	1161	36%	
105 (ELB)	2129	1589	25%	
9012 (GRUN)	3501	2625	28%	
101 (GRUN)	5184	3911	25%	

MAXIMUM STRESSES

NODE	B.L.	NEW	% CHG.	$\left(\frac{\lvert B.L. - NEW\rvert}{B.L.}\right)100$
101 (GRUN)	8577	10166	19%	
100 (GRUN)	7190	8496	18%	
95 (ELB)	6772	7700	14%	

MAXIMUM ANCHOR COMPONENTS

NODE	COMPONENT	B.L.	NEW	% CHG.	$\left(\frac{\lvert B.L. - NEW\rvert}{B.L.}\right)100$
113	F_x	330	164	50%	
113	F_z	267	173	35%	
113	M_y	9078	6586	27%	
102	M_y	33540	41580	24%	
1	M_y	1455	1777	22%	

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DATE: 7/21/82			MODEL NO.

B.L. SNUB K, CLMP K & WT.
VS.
NEW SNUB K, NEW CLMP K & WT.
AT SPECIFIED NODES

SUPPORT LOADS

$\left(\frac{|B.L. - NEW|}{B.L.}\right)100$

NODE	B.L.	NEW	% CHG
3	77	88	14%
10	942	968	3%
18	938	846	10%
19	329	358	9%
26	262	286	9%
35	786	733	7%
48	178	200	12%
49	131	118	10%
61	387	398	3%
77	935	1155	24%
78	859	974	13%
86	670	621	7%
91	545	550	1%
92	596	749	26%
220	322	291	10%
208 (x)	579	711	23%
208 (y)	1347	1545	15%
208 (z)	944	648	31%
9	459	347	24%
31	636	522	18%
34	536	481	10%
81	640	515	20%
121	388	349	10%

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B.L. SNUB K, CLMP K & WT.

VS.

NEW SNUB K, B.L. CLMP K & WT.

Maximum % change in stress

NODE	B.L.	NEW	% CHG. $\left(\frac{\lvert B.L.-NEW \rvert}{B.L.}\right)100$
21 (ELB)	3134	2396	24%
21 (GRUN)	2290	1787	22%
43 (RUN)	898	1103	23%
43 (ELB)	1596	2003	26%
44 (ELB)	1794	2128	19%

9.4% of all stress locations had a percent change of 10% or greater.

Maximum stress % change and location

NODE	B.L.	NEW	% CHG $\left(\frac{\lvert B.L.-NEW \rvert}{B.L.}\right)100$
101	8577	8763	2%
100	7190	7348	2%
119	7270	7306	.4%

The maximum stress locations occur at the same locations in both cases.

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B.L. SNUB K, CLMP K & WT.

VS.

NEW SNUB K, B.L. CLMP K & WT.

Maximum Anchor Component % difference

NODE	COMPONENT	B.L.	NEW	% CHG $\left(\frac{\lvert B.L - NEW \rvert}{B.L.}\right)100$
133	F_x	267	313	17%
133	M_x	1513	1671	10%
56	M_y	3867	3485	10%
102	M_x	3977	3694	7%

~~Support Load differences~~

NODE	B.L.	NEW	% CHG
3	77	98	27% *
10	942	939	—
18	938	735	22% *
19	329	339	3%
26	262	278	6%
35	786	687	11%
48	178	191	7%
49	131	117	11%
61	387	385	—
77	935	1022	9%
78	859	868	1%
86	670	566	16%
91	545	464	15%
92	596	626	5%
220	322	322	—
208 (x)	579	668	15%
208 (y)	1347	1479	10%

NODE	B.L.	NEW	% CHG
208 (z)	944	607	36% *
9	459	337	27% *
31	636	558	12%
34	536	512	4%
81	640	528	18%
121	388	365	6%

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NEW SNUB K, B.L. CLMP K & WT., E_H

VS.

NEW SNUB K, B.L. CLMP K & WT., E_C

Maximum Anchor Component % differences

NODE	COMPONENT	E_H	E_C	% CHG $\left(\frac{\|E_C - E_H\|}{E_H}\right)100$
113	F_Y	2129	2677	26%
113	M_Z	9425	11830	26%
133	F_Z	2863	3488	22%
133	M_X	1671	2042	22%

17% of all nozzle components vary by more than 10%

~~Support Load differences~~

NODE	E_H	E_C	% CHG
3	98	105	7%
10	939	940	—
18	735	802	9%
19	339	347	2%
26	278	251	10%
35	687	760	11%
48	191	203	6%
49	117	112	4%
61	385	396	3%
77	1022	930	9%
78	868	783	10%
86	566	538	5%
91	464	455	2%
92	626	649	4%
220	322	345	7%
208 (X)	668	658	1%
208 (Y)	1479	1478	—

NODE	E_C	E_H	% CHG
208 (Z)	607	647	7%
9	337	337	—
31	558	537	4%
34	512	483	6%
81	528	489	7%
121	365	404	11%

(2

NEW SNUB K, B.L. CLMP K & WT., E_H

VS.

NEW SNUB K, B.L. CLMP K & WT., E_C

Maximum % change in stress

NODE	E_H	E_C	% CHG $\left(\frac{\lvert E_C - E_H \rvert}{E_H}\right)100$
106 (ELB)	2438	2059	18%
106 (GRUN)	1815	1556	17%
101 (GRUN)	5199	4456	17%
121 (GRUN)	4657	5472	15%
120 (RED)	6981	8146	14%
130 (GRUN)	9060	7814	14%

13.5% of all stress locations had a percent change of 10% or greater.

Maximum stress % change and location

NODE	E_H	E_C	% CHG $\left(\frac{\lvert E_C - E_H \rvert}{E_H}\right)100$
101 (GRUN)	8763	9539	8%
130 (GRUN)	7814	9060	14%
119 (RED)	7306	8367	13%

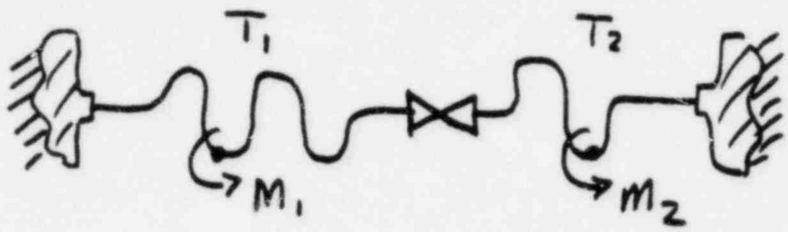
The maximum stress locations occur at the same locations in both cases.

D-21

NUPIPE vs CODE E_c/E_H CORRECTION STUDY

I. Temperature, moment values

(FICTICIOUS LINE)



COND. ~~CASE~~	T_1	T_2	$M_1 = M_2$
REF	70	70	0
1	70	1000	20,000
2	70	500	10,000
3	500	1000	30,000
4	1000	1000	40,000

New case 4:

1000 1000 40,000

II. MODULUS VALUES (304SS) – CC N47 values

T	E
70	28.3×10^{-6}
500	26.1×10^{-6}
1000	22.5×10^{-6}

TABLE I-14.7
CODE 1592
p. 379

III. LOAD PAIRS

PAIR	COND i	COND J
A	REF	1
B	REF	2
C	REF	3
D	1	2
E	1	3
F	2	3
G	1	4
H	REF	4

New load pair G:

G 1 4

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III COMPUTATIONS

NUPIPE CORRECTION

$$M_1^{i\to j} = \left(E_c/E_1^i ,\ E_c/E_1^j \right)_{max} * \left(M_1^i - M_1^j \right)$$

$$M_2^{i\to j} = \left(E_c/E_2^i ,\ E_c/E_2^j \right)_{max} * \left(M_2^i - M_2^j \right)$$

CODE CORRECTION (REF)

$$\bar{M}_1^{i\to j} = \frac{E_c}{E_1^i}\left(M_1^i\right) - \frac{E_c}{E_1^j}\left(M_1^j\right)$$

$$\bar{M}_2^{i\to j} = \frac{E_c}{E_2^i}\left(M_2^i\right) - \frac{E_c}{E_2^j}\left(M_2^j\right)$$

TABLE 1. RESULTS

PAIR	M_1^{i-j} ✓	M_2^{i-j} ✓	$\bar{M}_1^{i-j}$ ✗	$\bar{M}_2^{i-j}$ ✗	$\frac{M_1^{i-j}}{\bar{M}_1^{i-j}}$	$\frac{M_2^{i-j}}{\bar{M}_2^{i-j}}$		
A	-20000	-25155.5	-20000	-25155.5	1	1		
B	-10000	-10842.9	-10000	-10842.9	1	1		
C	-32528.7	-37733.3	-32528.7	-37733.3	1	1		
D	10000	12577.8	10000	14312.6	1	.879		
E	-10842.9	-12577.8	-12528.7	-12577.8	(.865)	1		
F	-21685.8	-25155.5	-22528.7	-26890.4	.963	.935		
G	-25155.5	-25155.5	-30311.1	-25155.6	.83	1		
					$1/.865 =$ **1.16** D.F. $1/.83 = 1.2$			
H	-50311.1	-50311.1	-50311.1	-50311.1	1	1		

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TABLE I RESULTS

✓ 2 ✓

PAIR	$M_1^{i\to j}$	$M_2^{i\to j}$	$\bar{M}_1^{i\to j}$	$\bar{M}_2^{i\to j}$	$\frac{M_1^{i\to j}}{\bar{M}_1^{i\to j}}$	$\frac{M_2^{i\to j}}{\bar{M}_2^{i\to j}}$	$M_1'^{\,i\to j}$	$M_2'^{\,i\to j}$	$\frac{M_1'^{\,i\to j}}{\bar{M}_1^{i\to j}}$	$\frac{M_2'^{\,i\to j}}{\bar{M}_2^{i\to j}}$
A	-20000	-25156	-20000	-25156	1	1	-20000	-25156	1	1
B	-10000	-10843	-10000	-10843	1	1	-10,000	-10843	1	1
C	-32529	-37733	-32529	-37733	1	1	-32529	-37733	1	1
D	10000	12578	10000	14313	1	·879	10000	13200	1	·922
E	-10843	-12578	-12529	-12578	·865	1	12529	10,000	1	·795
F	-21686	-25156	-22529	-26890	·963	·935	-22529	-24800	1	·922
G	-25156	-25156	-30311	-25156	·83	1	-30311	-20000	1	·795
H	-50311	-50311	-50311	-50311	1	1	-50311	-50311	1	1

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COMPUTATIONS: NUPIPE CORRECTION M_1^{i-j}

PAIR A

$$M_1^{i-j} = (1, 1)_{MAX} * (0 - 20000) = -20000$$

PAIR B

$$M_1^{i-j} = (1, 1)_{MAX} * (0 - 10000) = -10000$$

PAIR C

$$M_1^{i-j} = \left(1, \frac{28.3}{26.1}\right)_{MAX} * (0 - 30000) = -32528.7$$

PAIR D

$$M_1^{i-j} = (1, 1)_{MAX} * (20000 - 10000) = 10000$$

PAIR E

$$M_1^{i-j} = \left(1, \frac{28.3}{26.1}\right)_{MAX} * (20000 - 30000) = -10842.9$$

PAIR F

$$M_1^{i-j} = \left(1, \frac{28.3}{26.1}\right)_{MAX} * (10000 - 30000) = -21685.8$$

PAIR G

$$M_1^{i-j} = \left(1, \frac{28.3}{22.5}\right)_{MAX} * (20,000 - 40000) = -25155.5$$

PAIR H

$$M_1^{i-j} = \left(1, \frac{28.3}{22.5}\right)_{MAX} * (0 - 40000) = -50311.1$$

D-26

COMPUTIONS: NUPIPE CORRECTION M_2^{i-j}

PAIR A

$$M_2^{i-j} = \left(1, \frac{28.3}{22.5}\right)_{max} * (0 - 20000) = -25155.5$$

PAIR B

$$M_2^{i-j} = \left(1, \frac{28.3}{26.1}\right)_{max} * (0 - 10000) = -10842.9$$

PAIR C

$$M_2^{i-j} = \left(1, \frac{28.3}{22.5}\right)_{MAX} * (0 - 30000) = -37733.3$$

PAIR D

$$M_2^{i-j} = \left(\frac{28.3}{22.5}, \frac{28.3}{26.1}\right)_{max} * (20000 - 10000) = 12577.8$$

PAIR E

$$M_2^{i-j} = \left(\frac{28.3}{22.5}, \frac{28.3}{22.5}\right)_{max} * (20000 - 30000) = -12577.8$$

PAIR F

$$M_2^{i-j} = \left(\frac{28.3}{26.1}, \frac{28.3}{22.5}\right)_{max} * (10000 - 30000) = -25155.5$$

PAIR G

$$M_2^{i-j} = \left(\frac{28.3}{22.5}, \frac{28.3}{22.5}\right)_{max} * (20000 - 40000) = -25155.5$$

PAIR H

$$M_2^{i-j} = \left(1, \frac{28.3}{22.5}\right)_{max} * (0 - 40000) = -50311.1$$

COMPUTATIONS: CODE CORRECTION $\bar{M}_1^{i-j}$

PAIR A

$$\bar{M}_1^{i-j} = \frac{1}{1}(0) - \frac{1}{1}(20000) = -20000$$

PAIR B

$$\bar{M}_1^{i-j} = \frac{1}{1}(0) - \frac{1}{1}(10000) = -10000$$

PAIR C

$$\bar{M}_1^{i-j} = \frac{1}{1}(0) - \frac{28.3}{26.1}(30000) = -32528.7$$

PAIR D

$$\bar{M}_1^{i-j} = \frac{1}{1}(20000) - \frac{1}{1}(10000) = 10000$$

PAIR E

$$\bar{M}_1^{i-j} = \frac{1}{1}(20000) - \frac{28.3}{26.1}(30000) = -12528.7$$

PAIR F

$$\bar{M}_1^{i-j} = \frac{1}{1}(10000) - \frac{28.3}{26.1}(30000) = -22528.7$$

PAIR G

$$\bar{M}_1^{i-j} = 1(20000) - \frac{28.3}{22.5}(40000) = -30311.1$$

PAIR H

$$\bar{M}_1^{i-j} = 1(0) - \frac{28.3}{22.5}(40000) = -50311.1$$

(D-28)

COMPUTATIONS: CODE CORRECTION $\overline{M}_2^{\,i-7}$

PAIR A

$$\overline{M}_2^{\,i-7} = \frac{1}{1}(0) - \frac{28.3}{22.5}(20000) = -25155.5$$

PAIR B

$$\overline{M}_2^{\,i-7} = \frac{1}{1}(0) - \frac{28.3}{26.1}(10000) = -10842.9$$

PAIR C

$$\overline{M}_2^{\,i-7} = \frac{1}{1}(0) - \frac{28.3}{22.5}(30000) = -37733.3$$

PAIR D

$$\overline{M}_2^{\,i-7} = \frac{28.3}{22.5}(20000) - \frac{28.3}{26.1}(10000) = 14312.6$$

PAIR E

$$\overline{M}_2^{\,i-7} = \frac{28.3}{22.5}(20000) - \frac{28.3}{22.5}(30000) = -12577.8$$

PAIR F

$$\overline{M}_2^{\,i-7} = \frac{28.3}{26.1}(10000) - \frac{28.3}{22.5}(30000) = -26890.4$$

PAIR G

$$\overline{M}_2^{\,i-7} = \left(\frac{28.3}{22.5}\right)20000 - \frac{28.3}{22.5}(40000) = -25155.6$$

PAIR H

$$\overline{M}_2^{\,i-7} = 1(0) - \frac{28.3}{22.5}(40000) = -50311.1$$

PREPARED BY:	Rockwell International Energy Systems Group	PAGE NO. OF
CHECKED BY:		REPORT NO.
DATE:		MODEL NO.

ENCLOSURE 4

ERRORS IN NUPIPE program

Energy Systems Group
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Canoga Park, California 91304

Telephone (213) 341-1000
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Rockwell
International

August 27, 1982 In reply refer to 82SG-5728

Mr. Tom Vinson
Quadrex Corporation
1700 Dell Avenue
Campbell, California 95008

Dear Mr. Vinson:

Subject: Errors in NUPIPE Program

The results of a methods validation effort for in-house production analyses have identified seven areas in the version of the NUPIPE program we purchased from Quadrex that can result in solutions which are not in conformance with the ASME B&PV Code and can result in underprediction of loads and stresses. We have already made the corrections to our NUPIPE program and are not requesting any action on your part per warranty clauses or otherwise. However, we believe these corrections should be made to all NUPIPE codes currently being used by the nuclear industry, and the past use of the program with these errors, in the design of operating nuclear power plants, requires your filing a deviation report to NRC per the requirements of 10 CFR 21. Related errors have also been discovered that result in overprediction of stresses and loads which, although not requiring 10 CFR 21 action, are brought to your attention in the hope of evolving more accurate programs for the nuclear industry. The seven potential 10 CFR 21 areas are as follows:

(1) For Class 2 and Class 3 analyses, specification of an as-welded girth butt weld in straight pipe (GRUN) results in a stress intensification factor of:

$i = 1.0$ for thickness $\geq 3/16$ inch

$i = 1.8$ for thickness $< 3/16$ inch

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The Code intensification factor for thickness >3/16 inch is 1.0 only if the construction offset ratio δ/t is less than 0.1. NUPIPE does not accept any user input information on δ/t ratios. This can lead to a 44 percent underprediction of stress at locations failing to meet the offset ratio limit. This error carries over into the multiple weld indices LGRUN and FLGRUN (longitudinal-plus-girth welds).

(2) A similar error as (1) above exists in the Class 1 post-processor. In this case it is the C_2 and K_2 indices for as-welded girth butt welds. The C_2 value in NUPIPE of 1.0 should be 1.4 for those cases $\delta/t > 0.1$; the K_2 values similarly could be erroneously set at 1.8 when they should be 2.5. With respect to equation (11) fatigue evaluations using the product C_2 K_2, the ratio (1.0) (1.8)/(1.4) (2.5) = 0.51 indicates only half the actual moment stress range could be predicted which, based on the ASME Code Appendix I fatigue curves, translates to an erroneous ten to twenty times underprediction of fatigue usage fractions for moment-controlled load cycles.

(3) For Class 2, Class 3, and B31.1 analyses established by defining CODE = 2.0, the modulus of elasticity specified on the XSECTN cards is used in the seismic analysis. The NUPIPE manual states this should be the value at room temperature. The change in stiffness resulting from use of a room temperature modulus of elasticity versus the correct use of actual operating temperature modulus of elasticity can shift the piping frequencies away from response spectrum peaks, resulting in a reduction in predicted seismic loads and stresses. (The opposite trend is also possible, but overdesign is not a potential 10 CFR 21 concern.) Results from studies run on representative piping lines at Rockwell with operating temperatures of 500°F resulted in 30 percent underprediction of loads and 15 percent underprediction of stresses when a 70°F modulus of elasticity was used.

It is recognized that the Winter 1975 Code Addenda for Class 2 and Class 3 replaced earlier wording that required thermal expansion and flexibility moment calculations be based on E_h and stress calculations be based on E_c/E_h times these moments. The new wording states more simply

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that stresses be based on E_c, which makes possible the simpler approach moments can be computed using E_c and no modulus adjustment used to compute stresses. However, these rules are for thermal expansion loadings only. The Code does not specify a selection of modulus values or use of modulus-based stress adjustments for seismic loadings. Intuitively, this makes sense because the seismic events are usually over before any significant change in temperature occurs. Furthermore, nuclear piping at room temperature is usually empty so the seismic case being run in NUPIPE (room temperature with fluid mass) is not even a real operating mode.

As you know, the NUPIPE option for Class 2 and Class 3 analyses with portions of the problem containing Class 1 piping (Code = 17.0) provides for Class 1, Class 2, and Class 3 stress post-processing. In this case the hot modulus of elasticity is used in the seismic analysis, resulting in completely different results for the Class 2 and Class 3 sections than if the Code = 2.0 option is used. The NUPIPE sample problem statement (Page 102) that the Class 2 and Class 3 "output" is the same for Code = 2.0 and Code = 17.0 evaluations is misleading. The same tables will appear but values may differ.

(4) For Class 2 and Class 3 analyses established by defining Code = 2.0, the "cold" modulus of elasticity specified on the XSECTN cards is used in the thermal expansion analyses and no E_c/E_h type adjustment on thermal expansion stresses is used. This approach, as discussed in (3) above, is valid per the Code after the Winter 1975 Code Addenda replaced earlier requirements that E_h be used in the moment calculation and an E_c/E_h adjustment be used on thermal expansion stresses. For Class 2 and Class 3 analyses to a Code of Record prior to the Winter 1975 Addenda, specifying Code = 2.0 will not give a valid analysis. Sample cases run at Rockwell for multibranch problems at different temperatures resulted in situations where locations experienced over 10 percent increase in thermal expansion stresses and over 40 percent increase in nozzle loads when the earlier treatment of modulus values was used. This is due to a difference in load distribution created by the difference in individual branch stiffnesses with changes in modulus of elasticity values.

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This issue is complicated by the fact that Class 2 and Class 3 analyses established by defining Code = 17.0 use the Class 1 E_h moment, E_c/E_h stress adjustment approach which conceptually at least (see Item (5)) is identical to the pre-Winter 1975 Addenda Class 2 and Class 3 approach. This can create different Class 2 and Class 3 thermal expansion stress range results, depending on whether Code = 2.0 or Code = 17.0 is specified. This, however, is consistent with the Code requirement of NC/ND-3672.1(b).

Related to the code-of-record problem with modulus of elasticity used in the moment calculations is the NUPIPE treatment of support and nozzle loads when the cold modulus approach (Code = 2.0) is used. No E_h/E_c adjustment on reaction loads is made per the Code rules (NC/ND-3673.5a) so the loads calculated do not represent actual hot condition loads. This can result in overly conservative nozzle and support load predictions.

(5) For Class 1 analyses established by defining Code = 7.0 or 17.0, the method for adjusting thermal expansion stresses in the Class 1 piping by an E_c/E_h factor is incorrect. The Code adjustment is on moment (stress) amplitude whereas the NUPIPE correction is based on moment (stress) range. More precisely, the differences expressed algebraically are:

Code Adjustment

$$\Delta M_{1-2}^{TE} = \frac{E_c}{E_{H2}} M_2^{TE} - \frac{E_c}{E_{H1}} M_1^{TE}$$

NUPIPE Adjustment

$$\Delta M_{1-2}^{TE} = \text{Maximum of} \left(\frac{E_c}{E_{H1}}, \frac{E_c}{E_{H2}}\right) * \left(M_2^{TE} - M_1^{TE}\right)$$

Situations can exist where the NUPIPE adjustment is unconservative with respect to the Code adjustment. Sample cases computed by Rockwell had differences as high as 20 percent for 1000°F thermal ranges.

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Interestingly, the Class 2 and Class 3 sections of piping evaluated using the Code = 17.0 option use the Code E_c/E_h adjustment on moment (stress) amplitudes. Only the Class 1 sections employ the questionable moment range-based correction.

A related non 10 CFR 21 issue is the unnecessary conservative NUPIPE E_c/E_h stress adjustments on loadings other than restrained thermal expansion. Examples include but may not be limited to seismic anchor motions and external loads.

(6) An observation requiring consideration is that conventional modeling procedures could result in underprediction of stresses in tees and branch connections. NB-3687.4, from the Winter 1975 Addenda onward, requires modeling tees and branch connections with a rigid member for the branch from the run centerline to the run surface. This is to provide the correct flexibility for these components. If the user creates this rigid member in the conventional manner using a very stiff geometry section, the section modulus used in the tee branch stress calculation will be incorrect, resulting in an underprediction of stresses. The user can avoid this problem if a ficticiously high modulus of elasticity is used while maintaining the nominal geometry. On the other hand, the NB-3687.4 requirement is commonly overlooked by piping analysts (the rule is somewhat obscure) resulting in incorrect flexibility being used. It would be a good idea if NUPIPE was modified to automatically provide correct flexiblity and stress reduction without the current risk for analytical pitfalls.

A minor comment on tees is NUPIPE's erroneous use of the term $D_o/2I$ instead of Z in the Class 1 moment stress equation. The Code definitions of each lead to slight differences in results.

(7) A final area with potential 10 CFR 21 implications is in the cycle bookkeeping for the Class 1 fatigue evaluation. NUPIPE has no provision for specifying dynamic subcycles for response spectrum earthquake loadings. The analyst must input the total number of dynamic cycles (number of events times number of cycles per event (subcycles)) to define the

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cyclic character of the earthquake loading during life. Two loading combinations are evaluated each time an earthquake load cycle is eliminated:

(a) Range of nonseismic loading (such as thermal expansion) - plus earthquake amplitude; i.e., the seismic event lead cycle in combination with other loads.

(b) Earthquake range only; i.e., the dynamic subcycles.

The maximum moment range value of the two combinations is used in the fatigue evaluation. Regardless of which governs one cycle of loadings in (a) is eliminated. This is unconservative if (b) governs since the nonseismic load cycles in (a) acting independent of seismic loading will contribute to fatigue damage. However, they are effectively eliminated without contribution, one for one, each time an earthquake subcycle occurs.

On the other hand, if the (a) moment range governs, an unnecessarily conservative fatigue evaluation will result because the nonseismic loadings are in fact too slow to combine additively with the earthquake subcycles. They can only combine with the earthquake lead cycles, and the combination should be limited to the total number of seismic events, not cycles.

Any questions on this letter should be addressed to Key Jaquay, Manager of our Piping Stress Unit, at (213) 700-4042.

D. C. Empey, Director
Quality Assurance
Energy Systems Group

cc: J. R. Sutton, U.S. Nuclear Regulatory Commission
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