"Axial/Rotational Restraint" Ref. 3.8.1 · WF IX.11.K · #5

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CALCULATION TITLE PAGE

*SEE INSTRUCTIONS ON REVERSE SIDE

5010.64 (FRONT)

CLIENT & PROJECT: TEXAS UTILITIES GENERATING CO. COMANCHE PEAK SES. - UNIT 1.

CALCULATION TITLE (Indicative of the Objective): JUSTIFICATION OF DESIGN LOAD FOR STRUTS/SNUBBERS AND LUGS USED IN CONJUCTION WITH RISER CLAMP.

QA CATEGORY (✓): ☒ I - NUCLEAR SAFETY RELATED ☐ II ☐ III ☐ ______ OTHER

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15454	NZ(C)-	GENX-042	N/A	N/A

* APPROVALS - SIGNATURE & DATE: FZ [signature] 4/4/86

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC NO.	SUPERSEDES * CALC. NO OR REV. NO.	CONFIRMATION *REQUIRED (✓) YES	NO
Leon ROZINSKY 3-11-86 Kawai R. Ho 3-11-86	C. L. Lin 3/13/86	C. L. Lin 3/13/86	0	N/A		✓

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REVISION STATUS TABLE

REV NO.	PAGE NO.	DESCRIPTION/REASON

REF

OBJECTIVE.

THE OBJECTIVES OF THIS CALCULATION ARE:

1. TO DERMINE THE CRITERION FOR THE DESIGN LOAD DISTRIBUTION BETWEEN TWO PARALLEL STRUTS OR SNUBBERS USED IN CONJUNCTION WITH RISER CLAMPS FOR PIPE SUPPORTS AT CPSES.

2. TO DETERMINE THE DESIGN LOAD FOR LUGS USED IN CONJUNCTION WITH RISER CLAMP AND TWO STRUTS OR SNUBBERS IN PIPE SUPPORTS AT CPSES.

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METHOD / ASSUMPTIONS.

EQUATIONS OF STATIC EQUILIBRIUM AND STABILITY ARE USED IN ORDER TO ESTABLISH CRITERION FOR THE DESIGN LOAD DISTRIBUTION BETWEEN TWO STRUTS OR SNUBBERS USED IN CONJUNCTION WITH RISER CLAMP.

SOURCES OF DATA

1. NPS CATALOG, "CP-PSE NPS CATALOG (REF 2CP1-325)

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CONCLUSIONS

1. IF THE TWO STRUTS/SNUBBER OF THE RISER CLAMP HAVE A STIFFNESS RATIO NOT EXCEEDING β, THEN THE DESIGN OF 75% OF TOTAL PIPE LOAD FOR EACH STRUT/SNUBBER IS CONSERVATIVE.

2. IF THE TWO STRUTS/SNUBBER OF THE RISER CLAMP HAVE A STIFFNESS RATIO EXCEEDING β_{MAX} (TABLES 2, 3), THEN ONE OF THE STRUT/SNUBBER HAD TO BE ELIMINATED AND THE SUPPORT IS DESIGNED AS AN OFF AXIS SUPPORT WITH THE STRUT/SNUBBER DESIGNED FOR 100% TOTAL PIPE LOAD.

3. a) IF TWO STRUTS/SNUBBERS ARE USED IN THE SUPPORT DESIGN, THEN EACH LUG SHALL BE DESIGNED FOR 1/2 OF THE TOTAL LOAD.

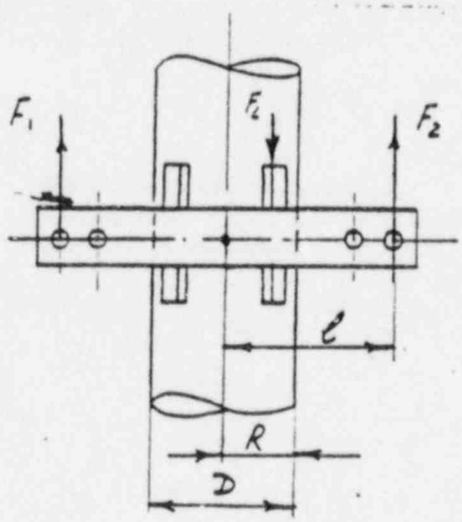
   b) IF ONE STRUT/SNUBBER IS USED IN THE SUPPORT DESIGN THEN EACH LUG SHALL BE DESIGNED FOR THE LOAD PER EQUATION:

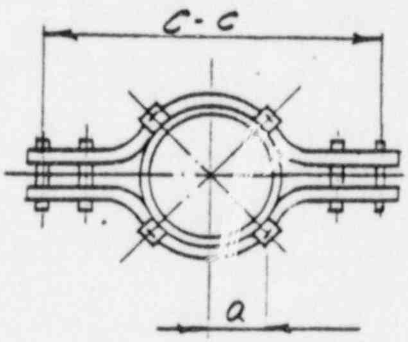
$$F_s = F_a\left(\frac{0.707\,e}{D} + 0.25\right)$$

REF

ANALYSIS

LOAD DISTRIBUTION BETWEEN TWO STRUTS OR SNUBBERS USED IN CONJUNCTION WITH RISER CLAMPS AND LUGS.





$2\ell = kD$

$\frac{\ell}{R} = \frac{2\ell}{D} = K$

CASE (1) : BOTH LUGS ARE IN CONTACT WITH CLAMP ON THE SAME SIDE

1. CONSERVATIVELY ASSUME THAT THE TOTAL LOAD IS TRANSFERRED THROUGH ONE LUG PAIR.
APPLYING FORCE AND MOMENT EQUILIBRIUM

$$\begin{cases} F_L a + F_1 \ell - F_2 \ell = 0 \\ F_L - F_1 - F_2 = 0 \qquad F_L = F_1 + F_2 \end{cases}$$

$a \approx 0.707R$

IF $\ell = 2R$, THEN

$$(F_1 + F_2)0.707R + F_1 2R - F_2 2R = 0$$

$$0.707F_1 + 0.707F_2 + 2F_1 - 2F_2 = 0$$

$$2.707F_1 = 1.293F_2$$

$$F_2 = 2.09F_1$$

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$$F_L = F_1 + 2.09 F_1$$

$$F_1 = \frac{F_L}{3.09} = 0.323 F_L$$

$$F_2 = 2.09 F_1 = 2.09 \times 0.323 F_L$$

$$F_2 = 0.68 F_L$$

FOR $\ell = 2.5R$

$$(F_1 + F_2) 0.707 R + F_1 2.5 R - F_2 2.5 R = 0$$

$$0.707 F_1 + 0.707 F_2 + 2.5 F_1 - 2.5 F_2 = 0$$

$$3.207 F_1 = 1.793 F_2$$

$$1.789 F_1 = F_2$$

$$F_L = F_1 + 1.789 F_1$$

$$F = 0.358 F_L$$

$$F_2 = 1.789 F_1 = 1.789 \times 0.358 F_L = 0.641 F_L$$

FROM THE ABOVE CALCULATION IT IS CLEAR THAT WITH THE INCREASE OF ℓ DISTANCE THE FORCE F_1 INCREASES AND THE FORCE F_2 decREASES.

BY COMPARING ACTUAL (C-C) DIMENSIONS WITH THE PIPE RADIUS IT IS CLEAR THAT $\frac{C-C}{2} > 1.44 R$

REF

HOWEVER IT WAS DECIDED FOR SIMPLIFICATION OF DESIGN TO QUALIFY EACH STRUT OR SNUBBER TO CARRY 75% OF THE TOTAL LOAD.

2. FIND THE e DISTANCE IN ORDER TO HAVE $F_2 = 0.75 F_L$

$$F_L = F_1 + F_2$$

$$F_1 = F_L - F_2 = F_L - 0.75 F_L = 0.25 F_L$$

$$F_L \cdot 0.707 R + 0.25 F_L e - 0.75 F_L e = 0$$

$$0.707 R F_L = 0.5 F_L e$$

$$e = \frac{0.707 R F_L}{0.5 F_L} = 1.414 R$$

e IS ALWAYS BIGGER THAN $1.414R$ (SEE TABLE 1)

THEREFORE TO USE $F_2 = 0.75 F_L$ IS CONSERVATIVE.

3. LUG DESIGN LOAD.

IT IS ASSUMED THAT EACH PART OF THE CLAMP CAN CARRY 1/2 OF THE TOTAL LOAD, AND THEREFORE IT IS CONSERVATIVE TO ASSUME THAT EACH LUG SHALL BE DESIGNED FOR 1/2 OF TOTAL LOAD.

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TABLE 1. COMPARISION OF PIPE RADIUS AND RISER CLAMP C-C (MIN) DISTANCE.

PIPE SIZE	PIPE RADIUS	$\frac{C-C}{2}$ (MIN)	e/R = K
—	R	e	K(MIN)
3	1.75	6	3.4
4	2.25	6	2.7
6	3.31	7.5	2.3
8	4.31	9.0	2.1
10	5.38	10.25	1.9
12	6.38	11.5	1.8
14	7.0	13.0	1.9
16	8.0	14.0	1.8
18	9.0	15.0	1.7
20	10.0	16.0	1.6
24	12.0	18.0	1.5
26 *	13.0	20.0	1.5
28 *	14.0	21.0	1.5
30 *	15.0	22.0	1.5
32 *	16.0	23.0	1.44
34 *	17.0	25.0	1.47
36 *	18.0	26.0	1.44
22	11.0	17.0	1.55

See p. 11

(*) (C-C) DIMENSIONS ARE FROM THE TAKE-OUT, TO_2, OF SWAY-STRUT PIPE CLAMP (SPC)

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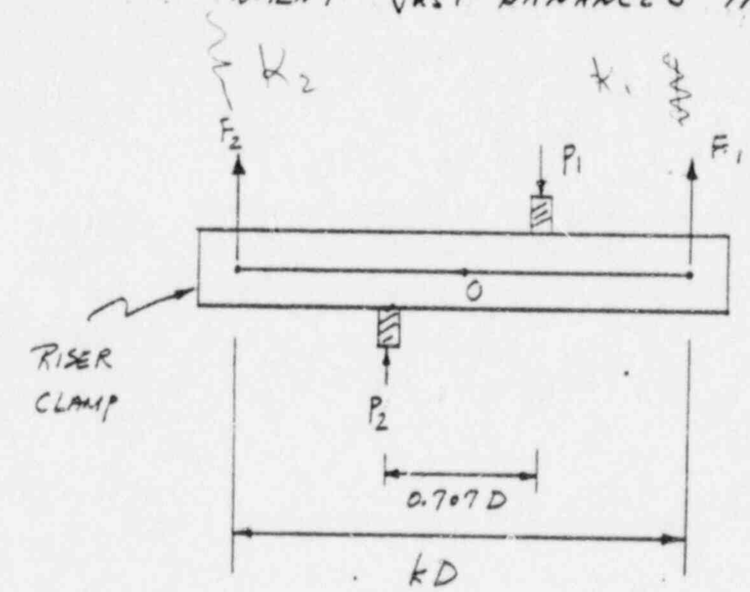
CASE (2): WHEN TWO ALTERNATE LUGS ARE IN CONTACT WITH RISER CLAMP, AND THE RESISTING MOMENT JUST BANANCES THE APPLIED MOM



ASSUME BOTH STRUT OR SNUBBER HAVE THE SAME DEFORMATION DUE TO THE RIGID RISER CLAMP.

THEREFORE,

$F_1 = K_1 \Delta$

$F_2 = K_2 \Delta$

$\frac{F_1}{F_2} = \frac{K_1}{K_2} = \beta$

DEFINE β AS THE STIFFNESS RATIO BETWEEN THE THE TWO STRUTS OR SNUBBERS.

$F_1 = \beta F_2$

Ref

LET P BE PIPE LOAD TRANSMITTED FROM PIPE

$\therefore \quad P = P_1 - P_2$

VERTICAL FORCE EQUILIBRIUM:

$$F_1 + F_2 = P_1 - P_2 = P$$

$$\Rightarrow \beta F_2 + F_2 = P$$

$$\Rightarrow F_2 = \frac{P}{\beta + 1}$$

$$F_1 = \left(\frac{\beta}{\beta + 1}\right) P$$

FOR ROTATIONAL STABILITY ABOUT POINT O : $\Sigma M = 0$

$$(F_1 - F_2)\frac{kD}{2} = (P_1 + P_2)\frac{0.707D}{2}$$

$$\Rightarrow P_1 + P_2 = \frac{k}{0.707}(F_1 - F_2)$$

$$\Rightarrow P_1 + P_2 = \frac{k}{0.707}\left(\frac{\beta - 1}{\beta + 1}\right) P$$

BUT $P_1 - P_2 = P$

$$\therefore \quad 2P_1 = \left[\frac{k}{0.707}\left(\frac{\beta - 1}{\beta + 1}\right) + 1\right] P$$

$$P_1 = \frac{1}{2}\left[\frac{k}{0.707}\left(\frac{\beta - 1}{\beta + 1}\right) + 1\right] P$$

$$P_2 = \frac{1}{2}\left[\frac{k}{0.707}\left(\frac{\beta - 1}{\beta + 1}\right) - 1\right] P$$

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BUT $P_1 - P_2 = P$

OR $P_1 \geq P$

$P_1 \overset{<}{\geq} P$ WILL GOVERN ONLY IF

$$\frac{1}{2}\left[\frac{k}{0.707}\left(\frac{\beta-1}{\beta+1}\right)+1\right] \leq 1 \iff P_1 \leq P$$

$$\Rightarrow \frac{k}{0.707}\left(\frac{\beta-1}{\beta+1}\right) \leq 1$$

$$\Rightarrow \frac{\beta-1}{\beta+1} \leq \frac{0.707}{k}$$

$$\Rightarrow \beta - 1 \leq \frac{0.707}{k}(\beta+1)$$

$$\Rightarrow \beta \leq \frac{1+\frac{0.707}{k}}{1-\frac{0.707}{k}} = \beta_{MAX}$$

criterion curves 2 legs at contact

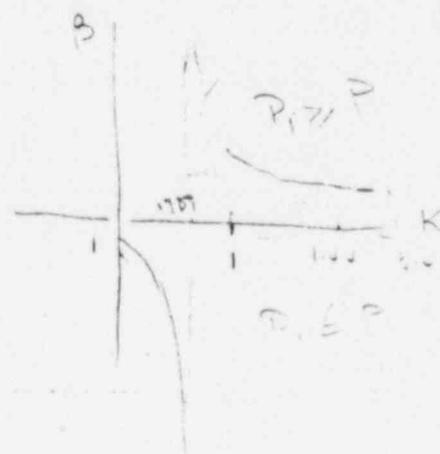
$K = 3.4$ GIVES $\beta_{MAX} = 1.53$ (See p.10)

$K = 1.44$ GIVES $\beta_{MAX} = 2.93$

FOR $\beta_{MAX} = 1.53$,

$$F_1 = \frac{1.53}{1.53+1}P = 0.605\,P$$

$$F_2 = \frac{1}{1.53+1}P = 0.395\,P$$



FOR $\beta_{MAX} = 2.93$,

$$F_1 = \frac{2.93}{2.93+1}P = 0.746\,P$$

$$F_2 = \frac{1}{2.93+1}P = 0.254\,P$$

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Ref 1

FOR $k = 3.4$, $\beta_{MAX} = 1.53$

$$P_1 = \frac{1}{2}\left[\frac{3.4}{0.707}\left(\frac{1.53-1}{1.53+1}\right)+1\right]P = 1.004P \approx P$$

$$P_2 = \frac{1}{2}\left[\frac{3.4}{0.707}\left(\frac{1.53-1}{1.53+1}\right)-1\right]P = 0.004P \approx 0$$

FOR $k = 1.44$, $\beta_{MAX} = 2.93$

$$P_1 = \frac{1}{2}\left[\frac{1.44}{0.707}\left(\frac{2.93-1}{2.93+1}\right)+1\right]P = 1.0001P \approx P$$

$$P_2 = \frac{1}{2}\left[\frac{1.44}{0.707}\left(\frac{2.93-1}{2.93+1}\right)-1\right]P = 0.0001P \approx 0$$

$$\beta_{MAX} = \frac{1+\frac{0.707}{k}}{1-\frac{0.707}{k}}$$

SUBSTITUTING β_{MAX} INTO P_1 & P_2 EQUATIONS,

$$P_1 = \frac{1}{2}\left\{\frac{k}{0.707}\left[\frac{1+\frac{0.707}{k}-\left(1-\frac{0.707}{k}\right)}{1+\frac{0.707}{k}+\left(1-\frac{0.707}{k}\right)}\right]+1\right\}P$$

$$= \frac{1}{2}\left\{\frac{k}{0.707}\left[\frac{0.707}{k}\right]+1\right\}P$$

$\Rightarrow P_1 = P$, $P_2 = 0$

THE MAXIMUM STIFFNESS RATIOS β_{MAX} ALLOWED FOR ALL PIPE SIZES (STANDARD AND HEAVY DUTY) ARE SHOWN IN TABLES 2 AND 3.

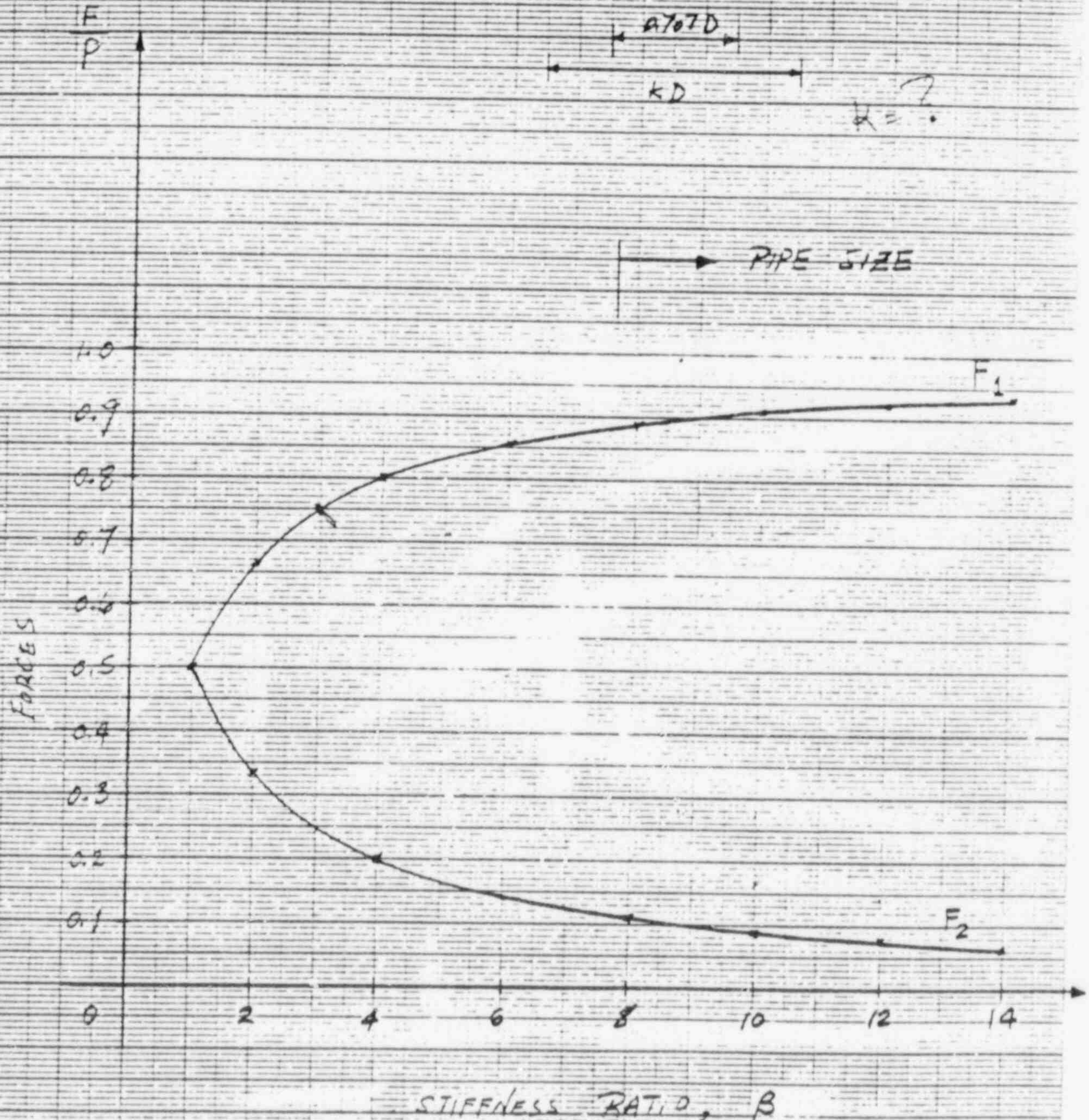

FIG. 1 VARIATION OF FORCES WITH STIFFNESS RATIO FOR ALL PIPE SIZES

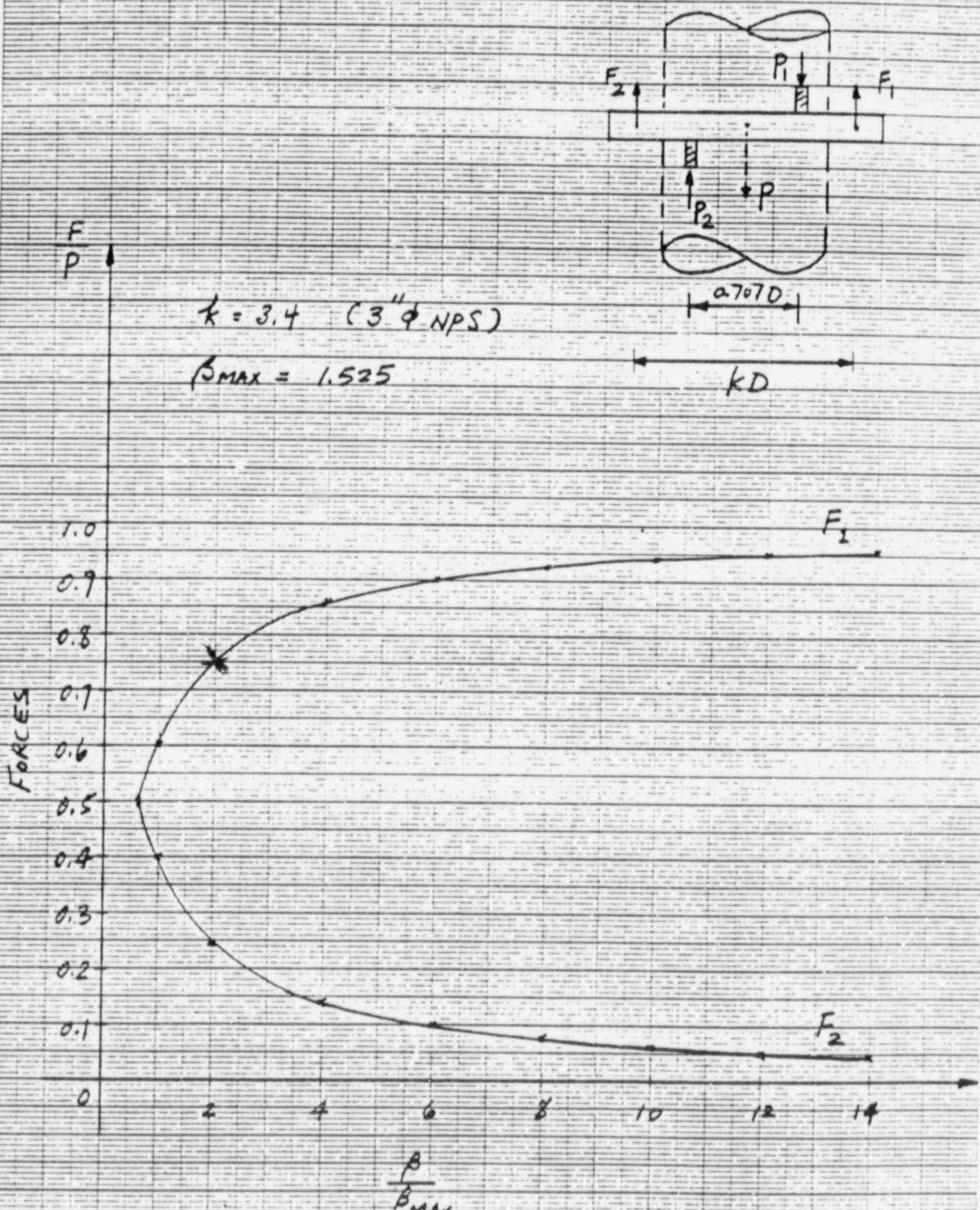

FIG. 2 VARIATION OF FORCES WITH RELATIVE STIFFNESS RATIOS FOR 3" ϕ PIPE

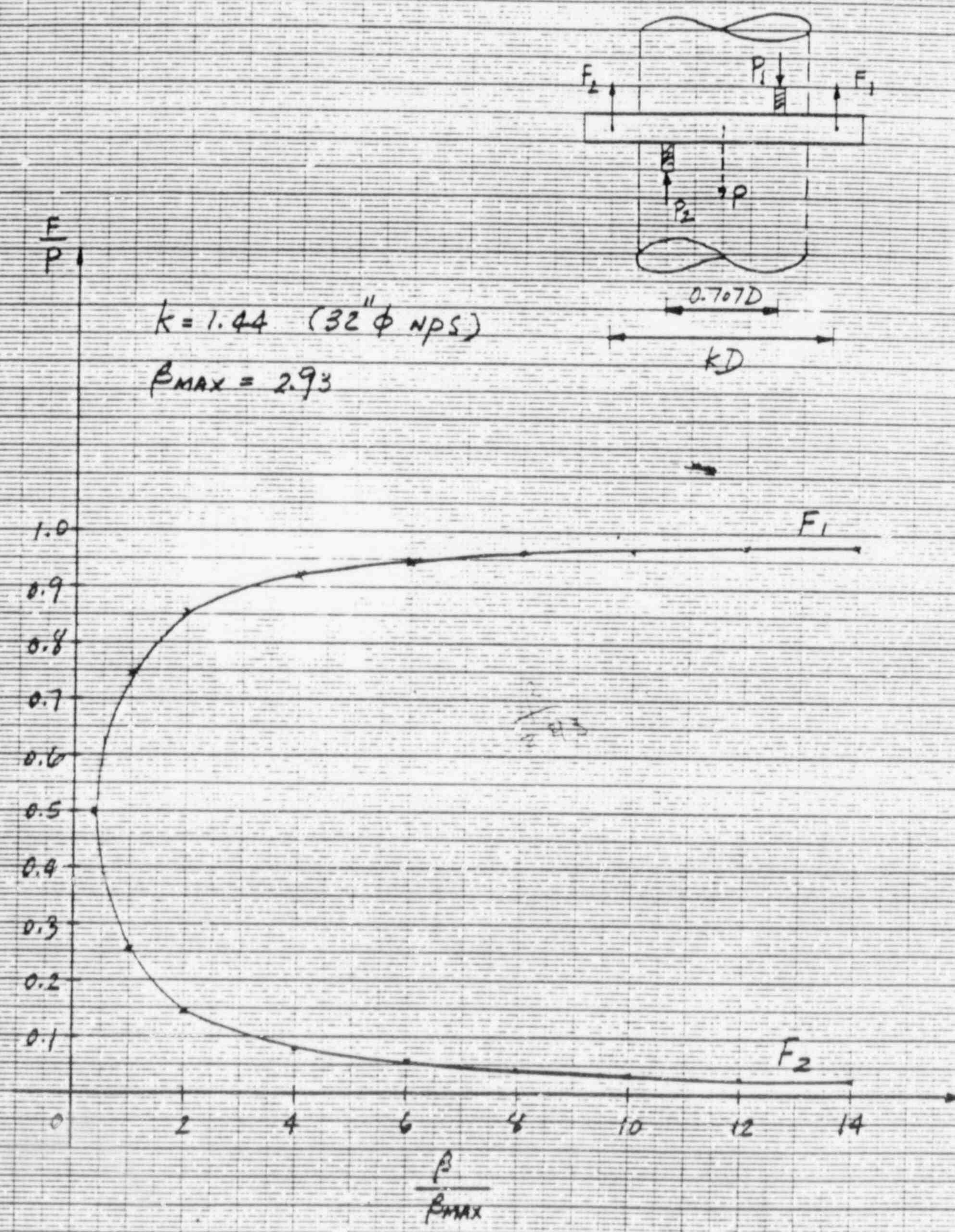

FIG. 3 VARIATION OF FORCES WITH RELATIVE STIFFNESS RATIOS FOR 32" φ PIPE

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TABLE 2 MAXIMUM STIFFNESS RATIO BETWEEN STRUTS USED IN RISER CLAMP WITH LUGS (PIPE SIZES 3" TO 24")

MAXIMUM STIFFNESS RATIO BETWEEN STRUTS, β_{MAX}

PIPE SIZE	C-C DIMENSION (IN.) 12	18	24	30	36	42	48	54	60	66	72	78	84	MIN.	MAX
3	1.5	1.3	1.2	—	—	—	—	—	—	—	—	—	—	1.5	1.2
4	1.7	1.4	1.3	—	—	—	—	—	—	—	—	—	—	1.7	1.3
6	—	1.7	1.5	1.4	—	—	—	—	—	—	—	—	—	1.9	1.4
8	—	2.0	1.7	1.5	1.4	1.3	1.3	1.3	1.2	1.2	—	—	—	2.0	1.2
10	—	—	1.9	1.7	1.5	1.4	1.4	1.3	1.3	1.3	—	—	—	2.2	1.2
12	—	—	2.2	1.9	1.7	1.5	1.5	1.4	1.4	1.3	1.3	—	—	2.3	1.3
14	—	—	—	2.0	1.8	1.6	1.5	1.4	1.4	1.4	1.3	—	—	2.2	1.3
16	—	—	—	2.2	1.9	1.7	1.6	1.5	1.5	1.4	1.4	—	—	2.4	1.3
18	—	—	—	2.5	2.1	1.9	1.7	1.6	1.5	1.5	1.4	1.4	—	2.5	1.4
20	—	—	—	—	2.3	2.0	1.8	1.7	1.6	1.5	1.5	1.4	—	2.6	1.4
22	—	—	—	—	2.5	2.2	2.0	1.8	1.7	1.6	1.6	1.5	—	2.7	1.5
24	—	—	—	—	2.8	2.4	2.1	1.9	1.8	1.7	1.6	1.6	1.5	2.8	1.5

TABLE 3 MAXIMUM STIFFNESS RATIO BETWEEN STRUTS USED IN RISER CLAMP WITH LUGS (PIPE SIZES 26" TO 36")

PIPE SIZE	MAXIMUM STIFFNESS RATIO BETWEEN STRUTS, β_{MAX}											
	C-C DIMENSION (IN)											
	42	48	54	60	66	72	78	84	90	96	MIN	MAX.
26	2.6	2.2	2.0	1.9	1.8	1.7	1.6	1.6	—	—	2.7	1.5
28	2.8	2.4	2.2	2.0	1.9	1.8	1.7	1.6	—	—	2.8	1.6
30	—	2.6	2.3	2.1	2.0	1.8	1.8	1.7	1.6	—	2.9	1.6
32	—	2.8	2.4	2.2	2.0	1.9	1.8	1.7	1.7	—	2.9	1.7
34	—	—	2.6	2.3	2.2	2.0	1.9	1.8	1.7	—	2.9	1.7
36	—	—	2.8	2.5	2.3	2.1	2.0	1.9	1.8	1.7	2.9	1.7

$(C-C)_{MAX} = 60 + D_o$

$(C-C)_{MIN}$, REFER TO NPS CATALOG

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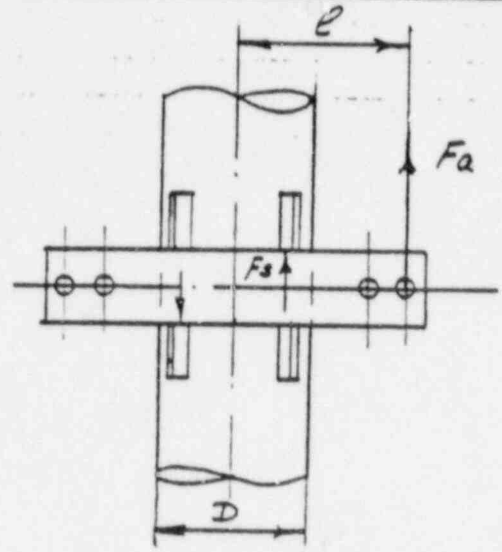
(CASE 2) DESIGN LOAD FOR SHEAR LUG



$$a/2 = R\cos 45^\circ$$

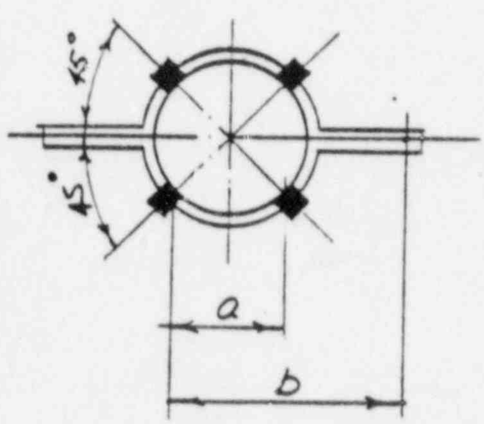
$$a = 2R\cos 45^\circ$$

$$a = 0.707D$$

$$b = \ell + a = \ell + 0.707D/2$$

$$\Sigma M = 0$$

$$F_s' a = F_a b$$



$$F_s' = \frac{F_a b}{a} =$$

$$= F_a \frac{\ell + \frac{0.707D}{2}}{0.707D}$$

$$= F_a \frac{2\ell + 0.707D}{1.414D} =$$

$$= F_a\left(\frac{2\ell}{1.414D} + \frac{0.707D}{1.414}\right)$$

FORCE PER PAIR OF LUG $F_s' = F_a\left(\frac{1.414\ell}{D} + 0.5\right)$

IT IS ASSUMED THAT EACH PART OF CLAMP TAKES 1/2 OF TOTAL LOAD. THEREFORE LOAD PER LUG

$$F_s = \frac{F_s'}{2} = F_a\left(\frac{1.414\ell}{D} + 0.5\right)/2$$

$$F_s = F_a\left(\frac{0.707\ell}{D} + 0.25\right)$$

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DISCUSSION.

1. AS IT IS SHOWN IN THE CALCULATION WHEN THE STIFFNESS RATIO (β) BETWEEN THE TWO STRUTS OR SNUBBERS IS SMALLER THAN THE MAXIMUM STIFFNESS RATIO DETERMINED (β_{MAX}), THE RISER CLAMP WILL MAINTAIN ROTATIONAL STABILITY, AND THE PIPE LOAD IS CONSIDERED BEING TRANSMITTED TO THE RISER CLAMP THROUGH ONE LUG PAIR, THIS IS SHOWN ON PG. 13 & 14 WHEN β_{MAX} WAS SUBSTITUTED IN EQUATION OF ROTATIONAL STABILITY AND THE RESULT SHOWS THAT THE TOTAL LOAD IS TRANSMITTED THROUGH ONE LUG PAIR.
AND THEREFORE AS SHOWN ON PG. 9 IT IS CONSERVATIVE TO DESIGN EACH STRUT OR SNUBBER FOR 75% OF THE TOTAL LOAD.

2. AS IT IS SHOWN ON PG. 15, 16, 17 FIG. 1, 2, 3 WHEN THE STIFFNESS RATIO BETWEEN THE TWO STRUTS OR SNUBBERS EXCEEDS THE MAXIMUM STIFFNESS RATIO (β_{MAX}) DETERMINED FOR ROTATIONAL STABILITY, THE RISER CLAMP TENDS TO ROTATE ABOUT PIPE AXIS.

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BUT IT WILL START MAKING CONTACT WITH THE SECOND LUG WHICH WILL PREVENT ROTATION. PIPE LOAD IS TRANSMITTED THROUGH BOTH LUG PAIRS TO THE RISER CLAMP, BUT THE PIPE LOAD WILL BE RESISTED MAINLY BY ONE STRUT OR SNUBBER.

AND THEREFORE ONE STRUT OR SNUBBER SHALL BE REMOVED, SUPPORT SHALL BE MODELED AS OFF-AXIS CLAMP, STRUT SHALL BE DESIGNED FOR TOTAL PIPE LOAD AND LUG SHALL BE DESIGNED USING FORMULA AS SHOWN ON PG. 18.