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Unclas 17727

ENGINEERING OPERATIONS REPORT

STRUCTURAL EVALUATION OF MARMAN V-BAND COUPLING AND FLANGE WITH CONOSEAL GASKET

Project 127-f

Paragraph 3

JUNE 1972

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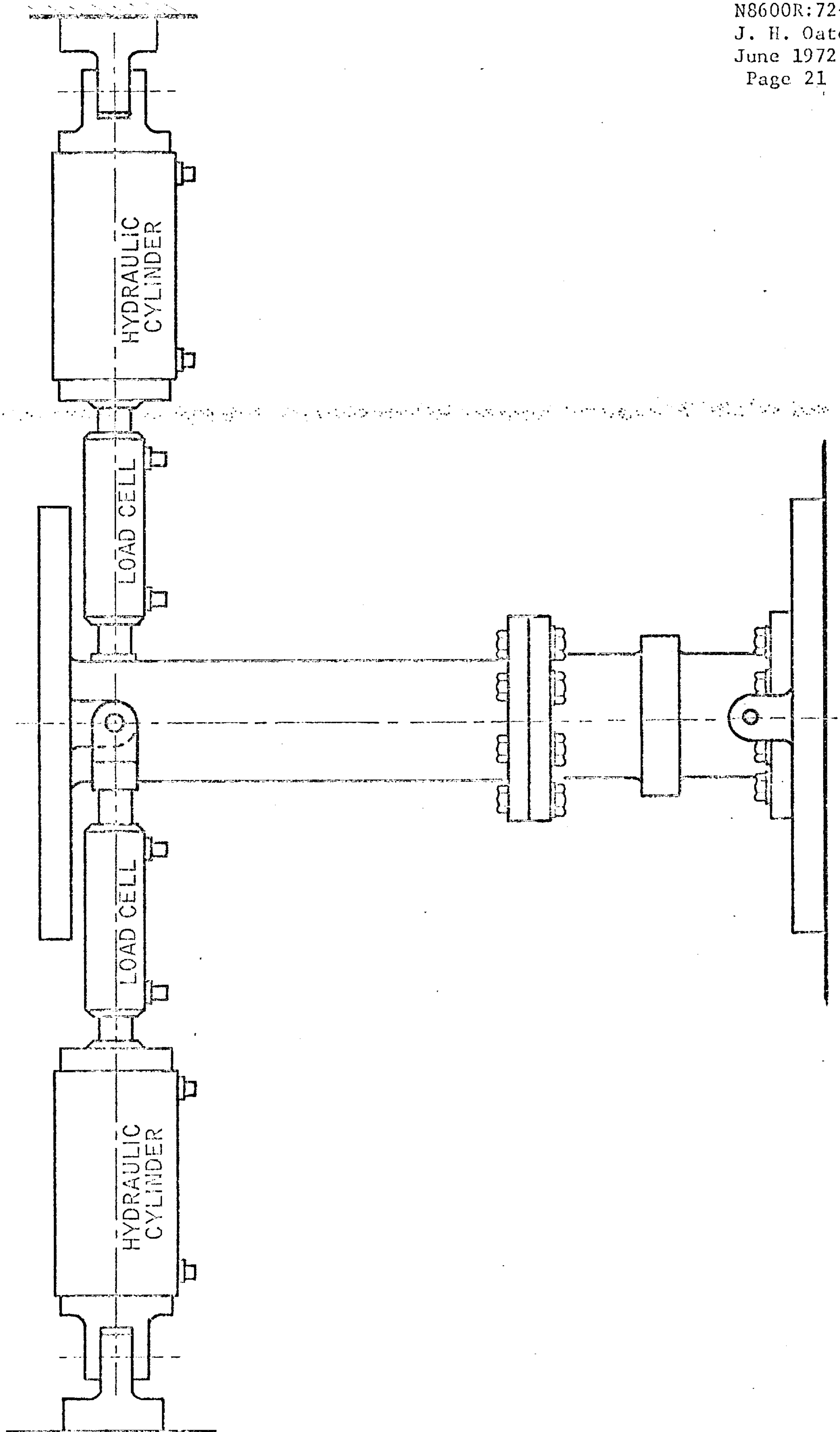


FIGURE 9 - TEST SET-UP TORSION TEST

TORSIONAL LOAD CAPABILITY

MARMAN V-BAND COUPLING AND FLANGE WITH CONOSEAL GASKET

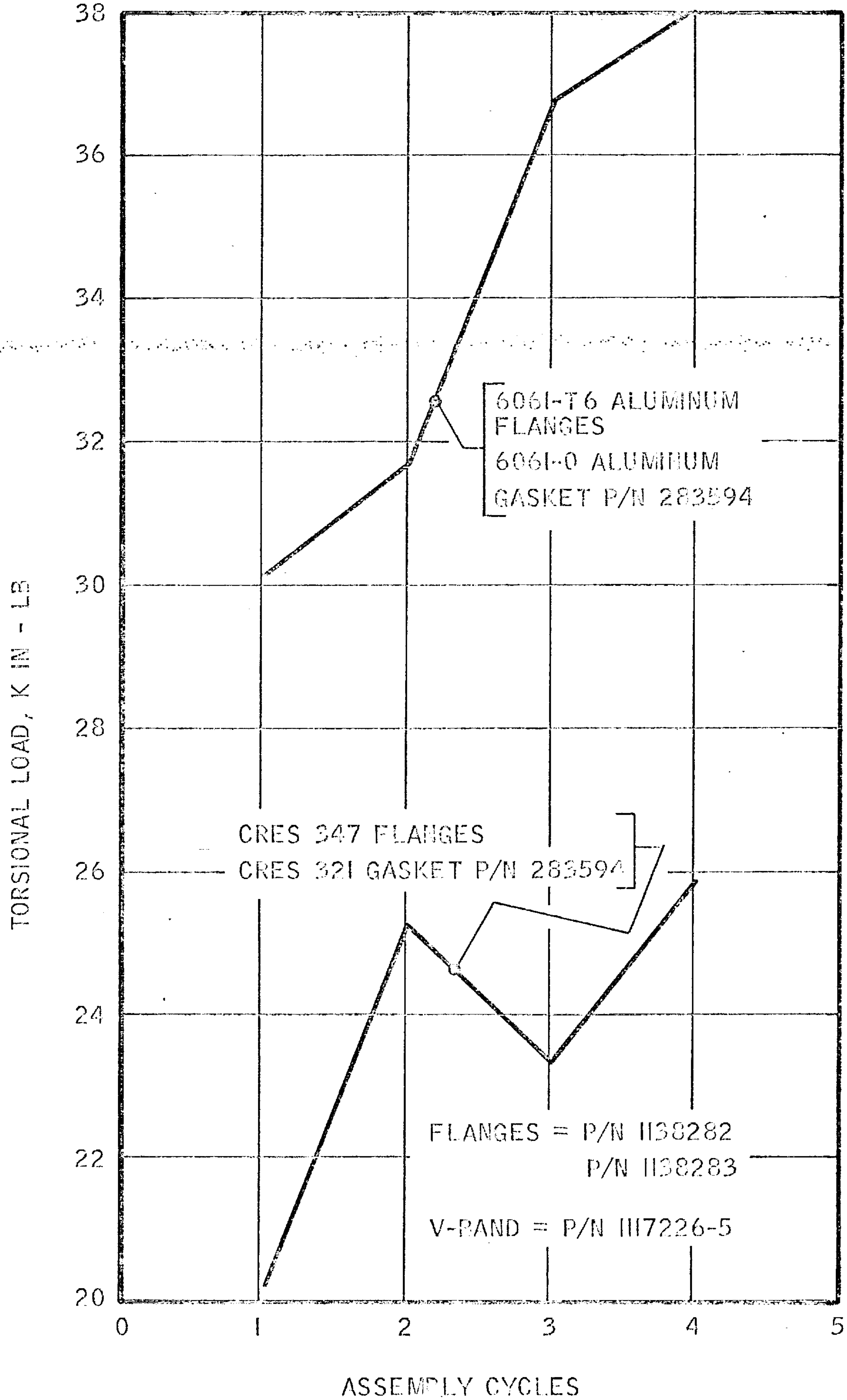


FIGURE 10

CONOSEAL GASKET FORCE - DEFLECTION CHARACTERISTICS

P/N 283549, CRES 321 GASKET

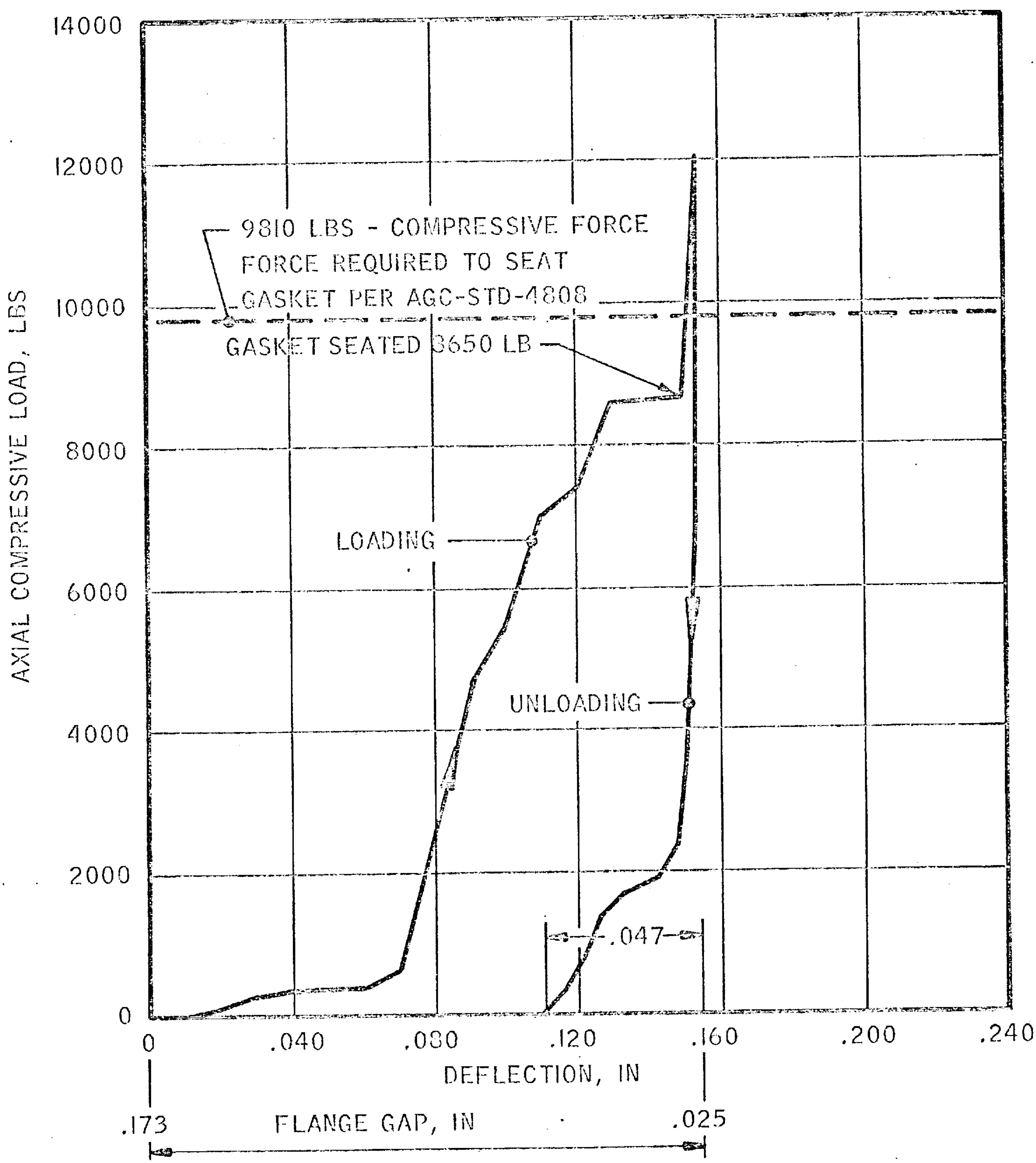


FIGURE 11

CONOSEAL GASKET FORCE - DEFLECTION CHARACTERISTICS

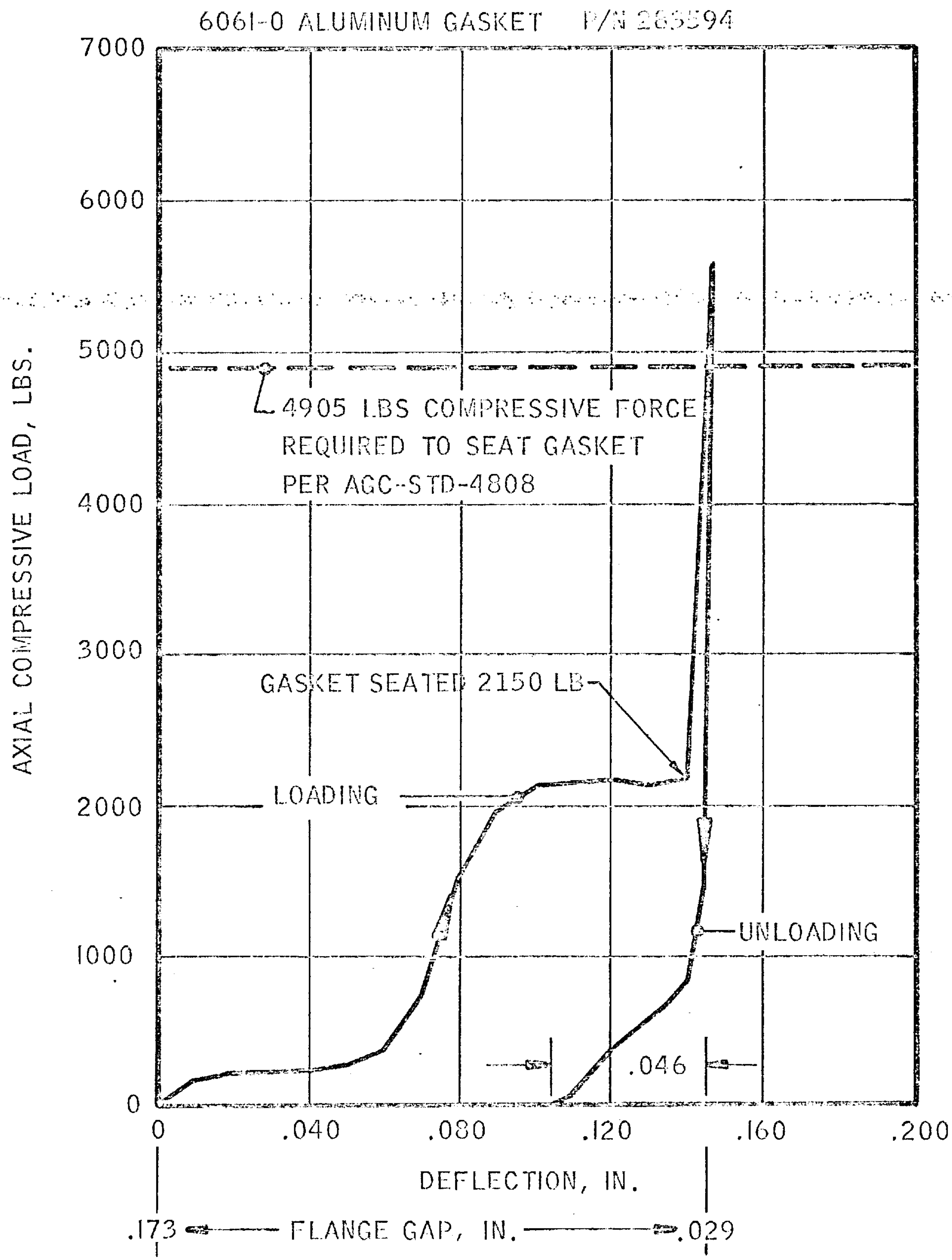


FIGURE 12

FORCE DEVELOPED BY V - BAND COUPLING

P/N 1117226-5

WITH CRES 347 FLANGES

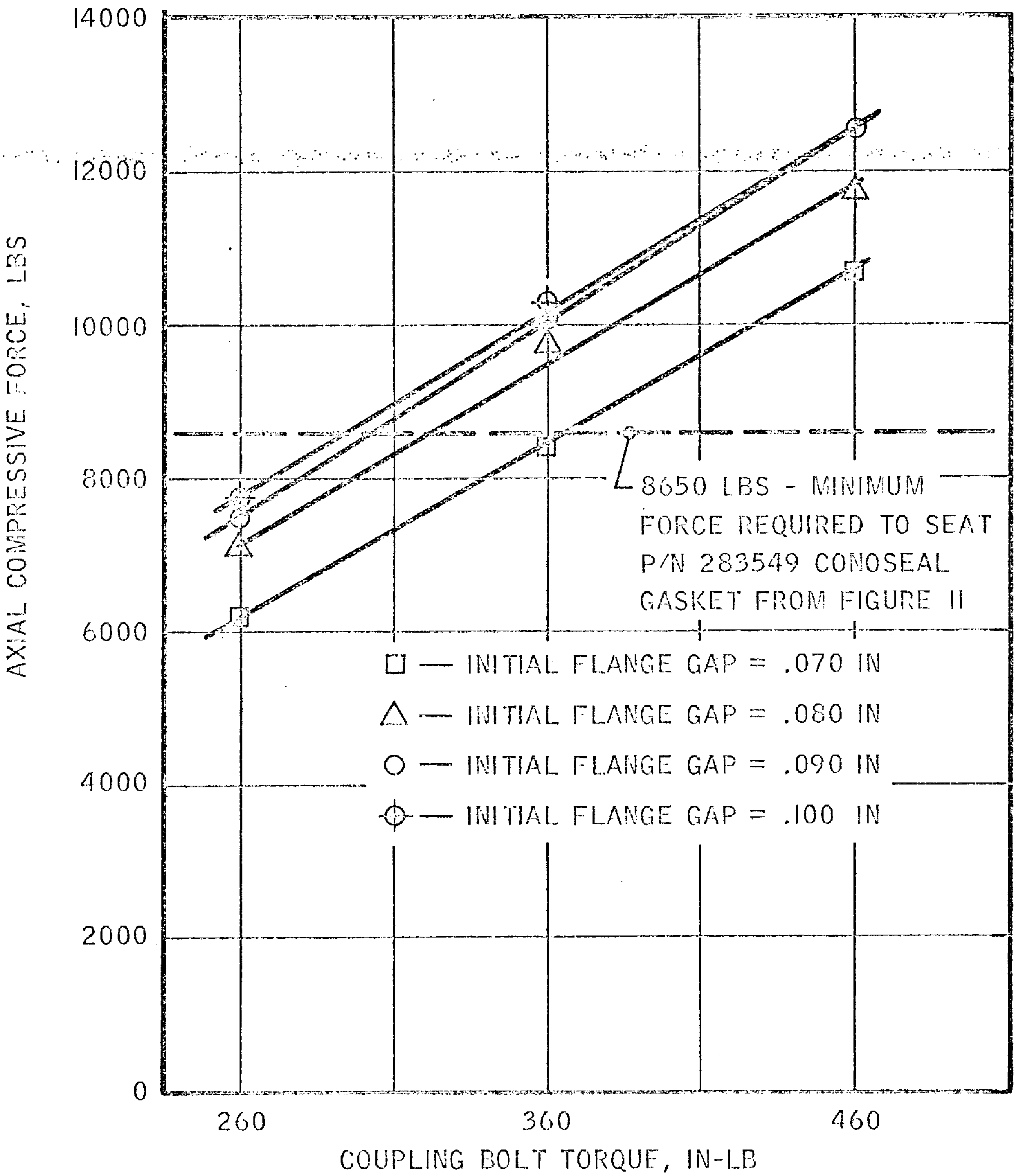


FIGURE 13

FORCE DEVELOPED BY V-BAND COUPLING
P/N 1117226-5
WITH 6061-T6 ALUMINUM FLANGES

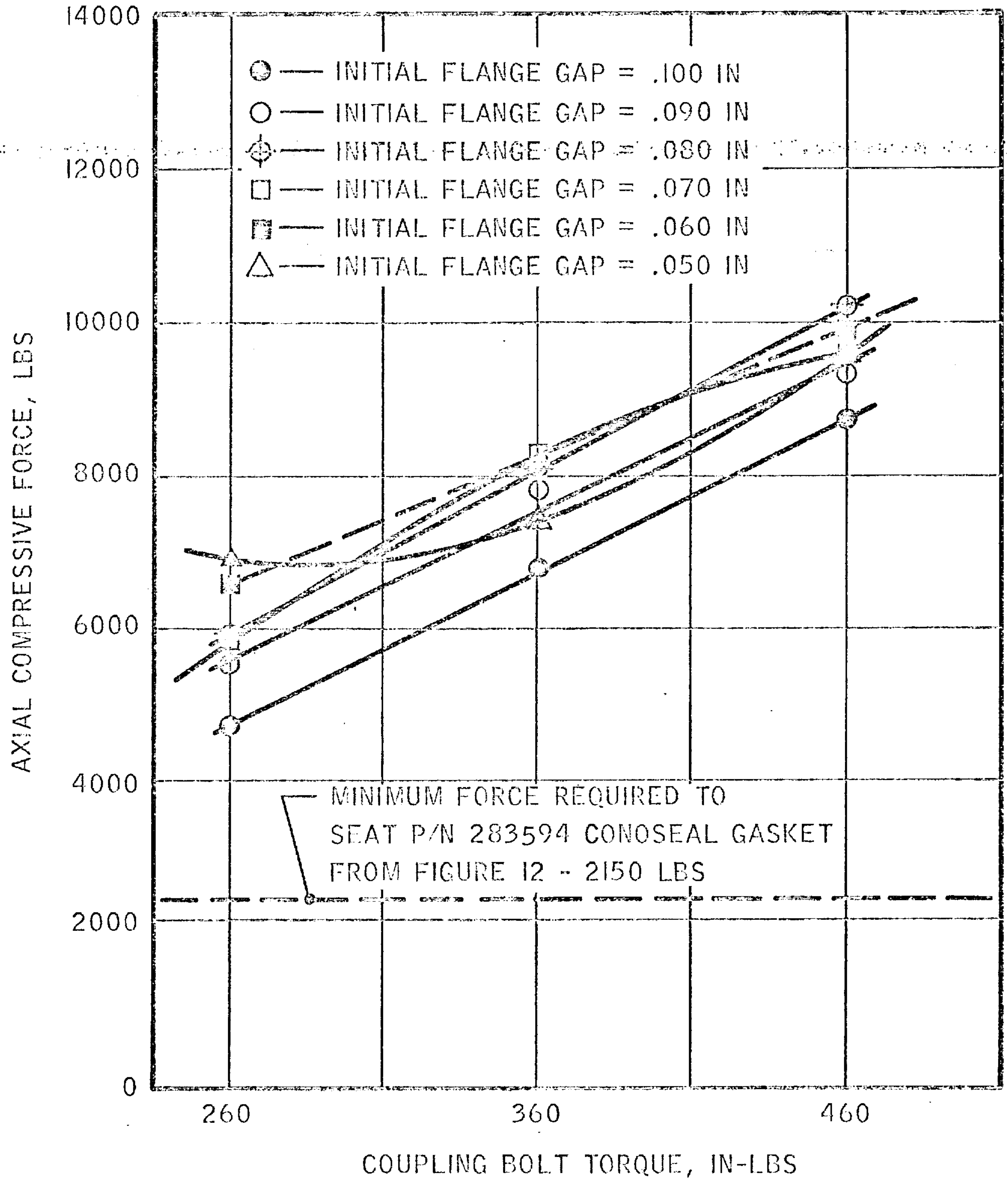
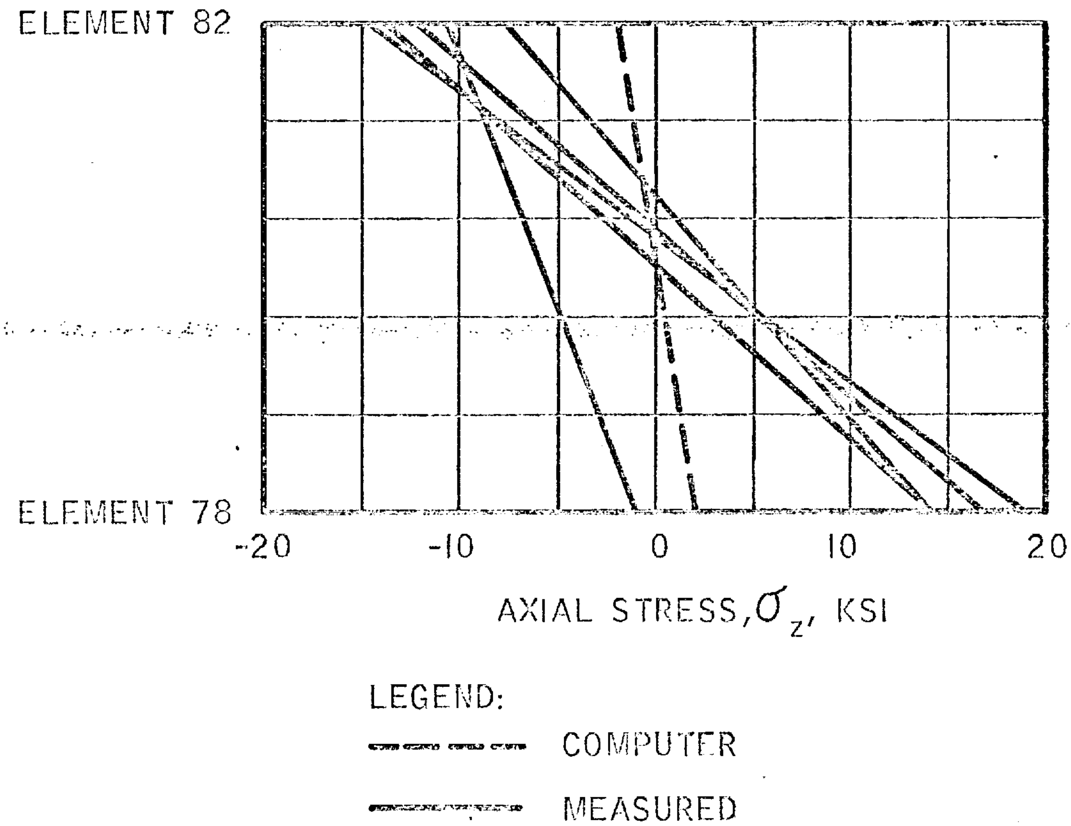


FIGURE 14

STRESS DISTRIBUTION - ELEMENTS 78 - 82

CRES 347 FLANGES, LOADING CONDITION b



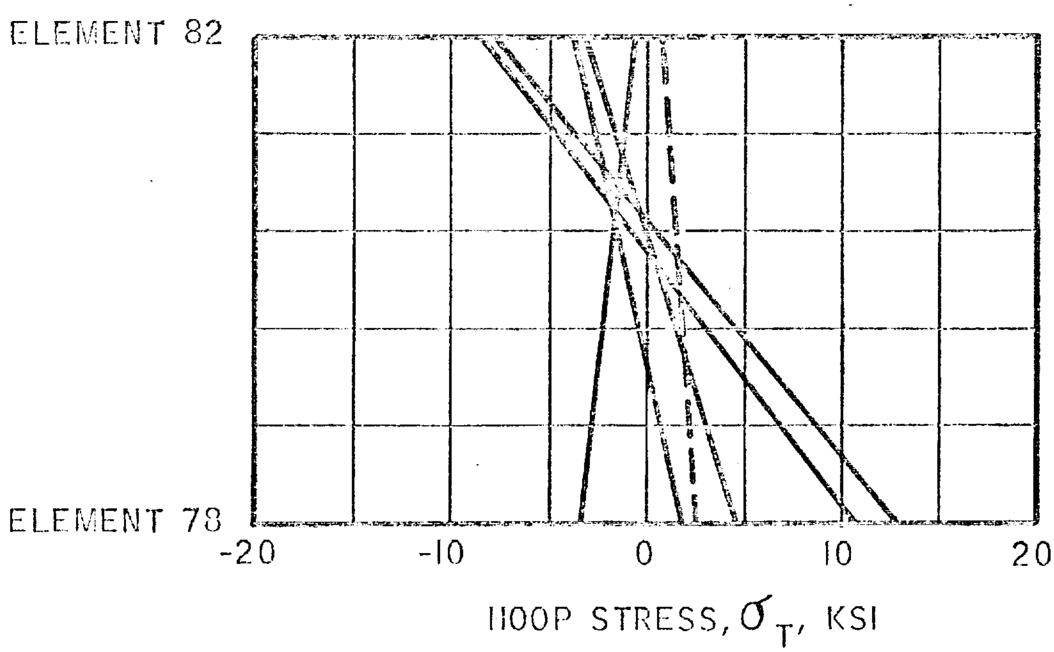
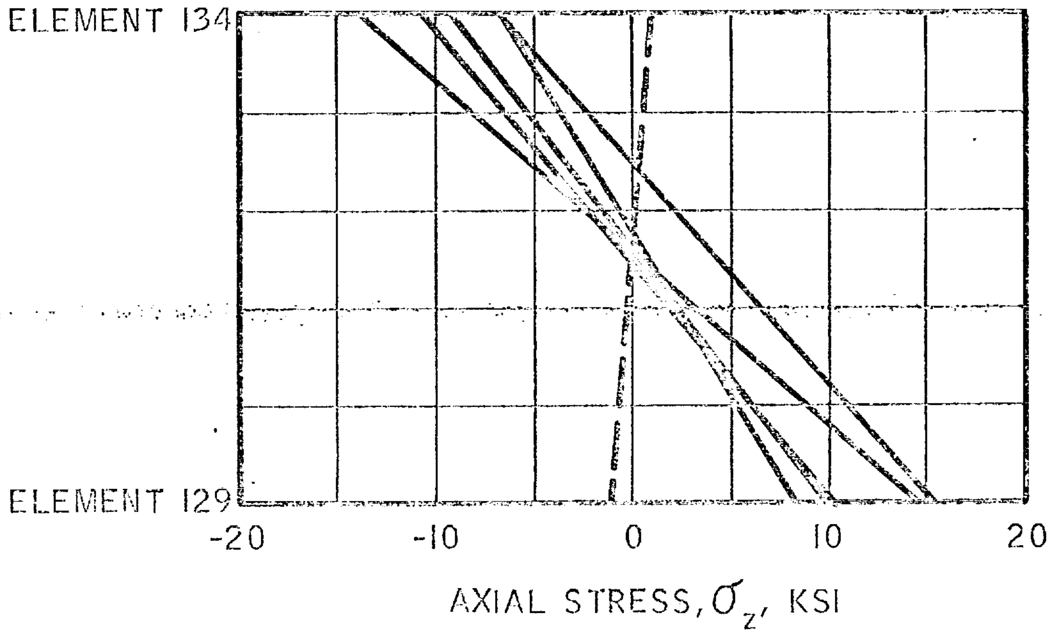


FIGURE 15

STRESS DISTRIBUTION - ELEMENTS 129 - 134

CRES 347 FLANGES, LOADING CONDITION b



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- - - - COMPUTER
——— MEASURED

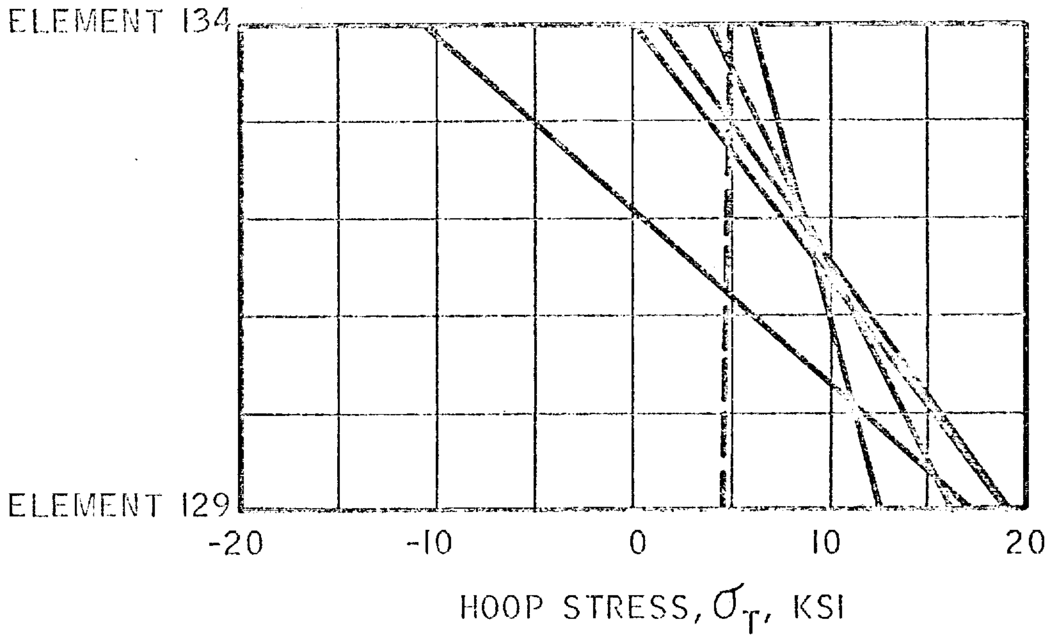


FIGURE 16

STRESS DISTRIBUTIONS - ELEMENTS 291 - 296

CRES 347 FLANGES, LOADING CONDITION b

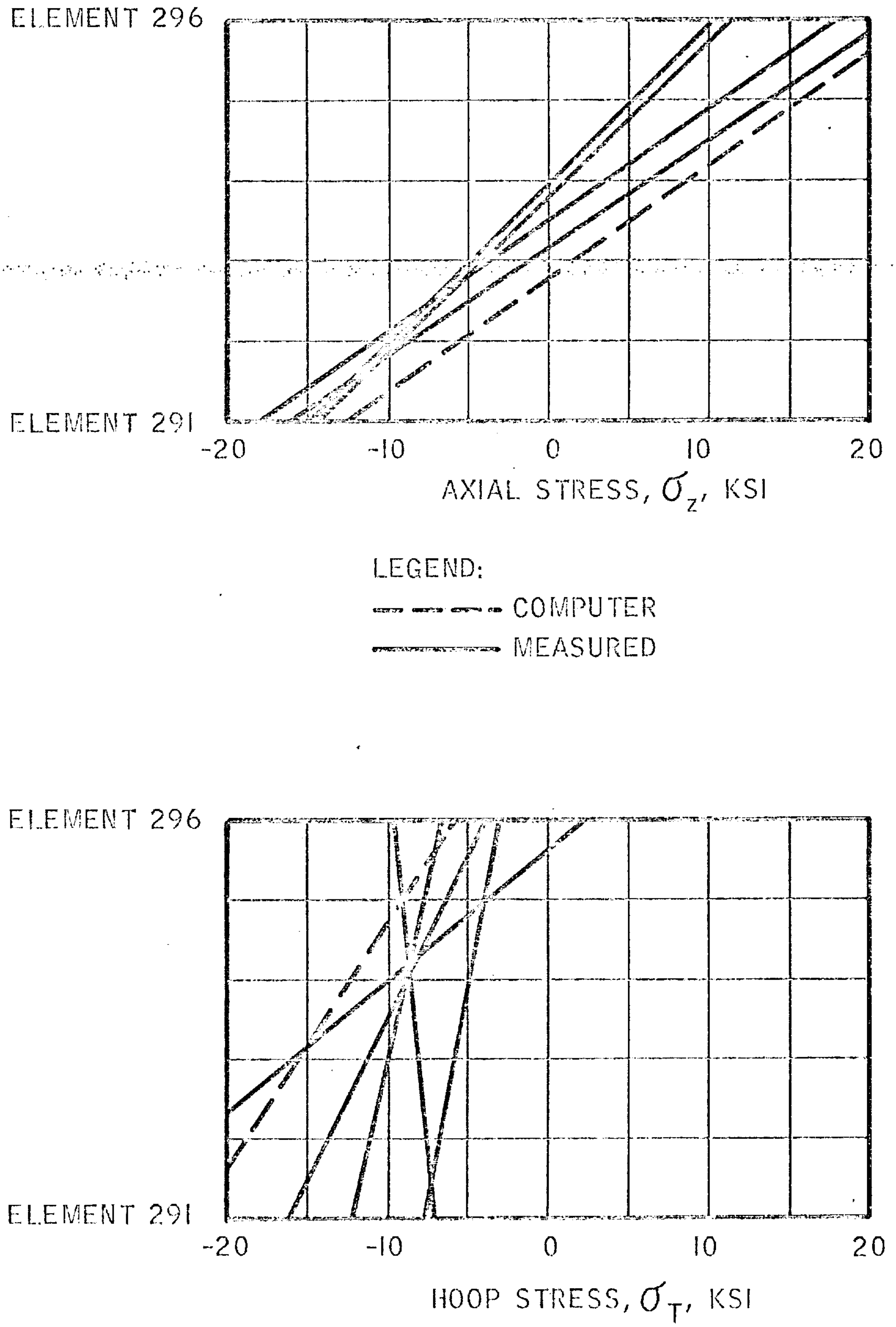
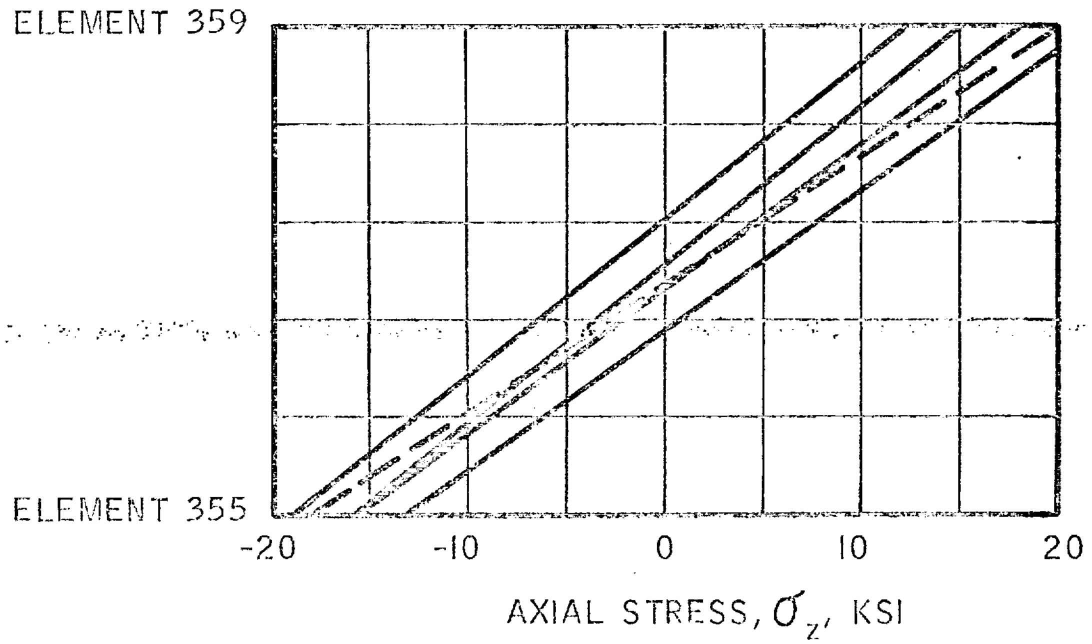


FIGURE 17

STRESS DISTRIBUTIONS - ELEMENTS 355 - 359

CRES 347 FLANGES, LOADING CONDITION b



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COMPUTER
MEASURED

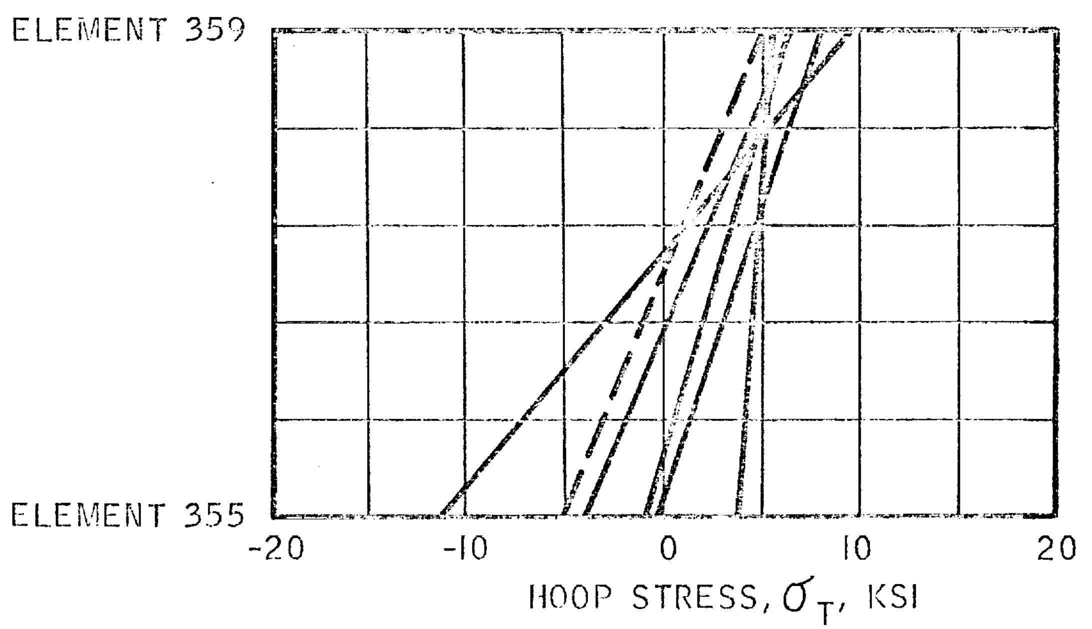
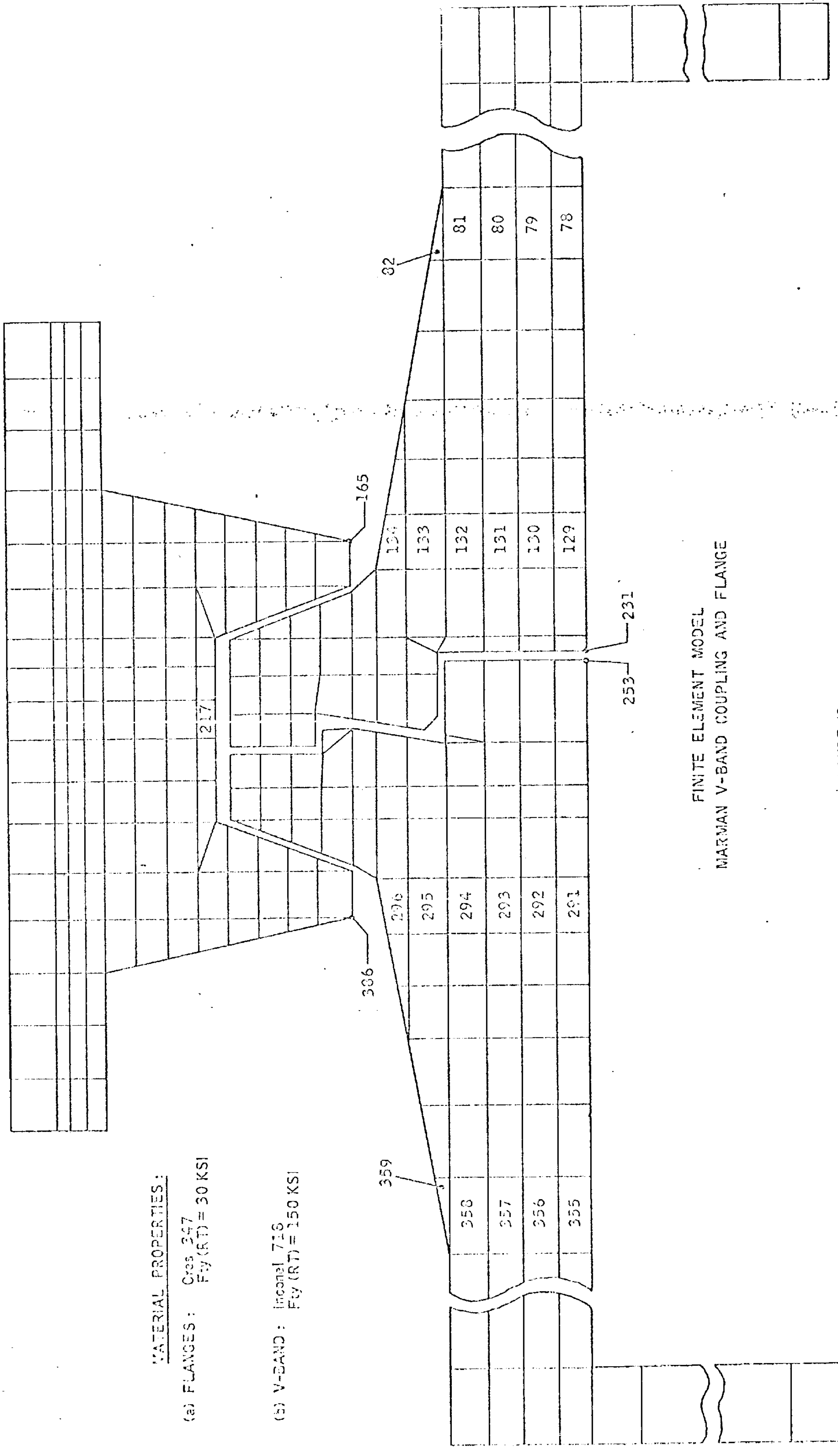


FIGURE 18



FINITE ELEMENT MODEL
MARMAN V-BAND COUPLING AND FLANGE

FIGURE 19

5.0 REFERENCES

1. Memo 7733:1275, P. E. Brown to J. R. Lucier, dated 13 July 1970, Subject: Computer Analysis of Marman V-Band Coupling and Flange.
2. SNPO-C-1, NERVA Program Structural Design Requirements, Space Nuclear Propulsion Office, Cleveland Extension, Revised Issue, December 1970, Pages 8 to 14, and Page 19.
3. RN-TP-0106, dated 20 August 1970, Development Test Procedure, Aeroquip Corporation V-Band Coupling, AGC P/N 1117226-5 and Conoseal Gaskets, AGC P/N's 283549 and 283594, R. A. Hartwig.
4. RN-TP-0117, dated 23 November 1970, Development Test Procedure for Obtaining Stress and Deflection Data on Aeroquip Corporation V-Band Couplings and Flanges, R. A. Hartwig.
5. Memo 7770:M:7095, J. H. Oates to K. E. Unmack, dated 14 April 1970, Subject: Allowable Leak Rates for Static Seals
6. Memo 9646:592, R. C. Adrian to R. A. Hartwig, dated 26 June 1970, Subject: Preliminary Design - Seal Tester
7. Memo N4320:M1599, W. R. Thompson to K. E. Unmack, dated 15 December 1970, Subject: Preliminary Analysis of Thermal Transients in the NERVA Cryogenic Seal/Coupling Tester
8. Memo 9680:043, H. J. York, Jr. to R. A. Hartwig, dated 8 June 1970, Subject: ROM Cost for Conducting a NERVA Seal Test Program

9. Memo 7770:M:7346, R. A. Hartwig to K. Sato, dated 23 October 1970, Subject: Thermal Transients in the NERVA Cryogenic Seal/Coupling Tester.

10. Memo 7770:M:7167, R. A. Hartwig to K. E. Unmack, dated 11 June 1970, Subject: Selection of a Laboratory for Performing Development Tests on Marman-Aeroquip Conoseals and V-Band Couplings.

11. Memo 7300:0877, S. A. Komjathy to K. E. Unmack, dated 18 June 1970, Subject: The NERVA Conoseal and V-Band Coupling Test Development Plan

12. Memo 7770:M:7209, R. A. Hartwig to J. G. Schumacher, dated 16 July 1970, Subject: Flange Structural Test Loads.

13. Memo 7770:M:7274, R. A. Hartwig to L. D. Johnson, dated 25 August 1970, Subject: Completion of Milepost for Project 127 Work Statement.

14. Memo 7750:M0726, L. A. Shurley to Distribution, dated 25 November 1969, Subject: Flanges and Couplings for NERVA Propellant Lines

15. Memo 7750:M0673, L. A. Shurley to Distribution, dated 2 October 1969, Subject: Static Seals for NERVA Propellant Lines.

16. Memo 7737:M2660, J. W. Conant to L. D. Johnson, dated 14 October 1969, Subject: Radiation Effects Evaluation of Irradiated Polyimide Seal.

17. Memo 7770:M:6194, L. D. Johnson to L. A. Shurley, dated 17 October 1969, Subject: Static Seals for NERVA Propellant Lines

18. Memo 7770:M6206, A. D. Cornell to Distribution, dated 15 December 1969, Subject: Post Irradiation Test Results of Dynamic Polyimide Seals.

19. Memo 7770:M:7102, R. A. Hartwig to L. D. Johnson, dated 16 April 1970, Subject: Completion of Milestone - Project 127, Suffix g - Development Testing, Paragraph 1a, "Select Candidate Seals and Couplings for an Initial Procurement Package and Place Purchase Order for These Units".

20. Memo 7770:M:7103, R. A. Hartwig to Distribution, dated 20 April 1970, Subject: Design Concept Review of NERVA Line Joints

21. Memo 7770:M:7111, K. E. Unmack to L. D. Johnson, dated 28 April 1970, Subject: Design Concept Review - NERVA Line Joints

22. Memo 7770:M:7096, R. A. Hartwig to J. G. Schumacher, dated 15 April 1970, Subject: Structural Evaluation of Marman V-Band Couplings.

23. Memo 7770:M:7340, R. A. Hartwig to Distribution, dated 14 October 1970, Subject: Test Procedure for Aeroquip Corporation V-Band Couplings and Flanges.

24. Test Report No. 52449, "Development Test to Obtain Stress and Deflection Data on Steel and Aluminum Flange Assemblies for Aerojet Nuclear Systems Company, Wyle Laboratories, El Segundo, California, dated April 30, 1971".

25. Memo, C. K. Leeper to R. A. Hartwig, dated 19 May 1970, Subject: Comments on the Design Concept Review of NERVA Line Joints.

6.0 APPENDIX A, REDUCED DATA

Reduced data enclosed is identified by paragraph numbers of the test procedure, Reference (4).

ATLAS [illegible]
COUPLING BOLT PRE-LOAD TEST
(STEEL FLANGES)
COUPLING BOLT TORQUE=150 FT-LB
TEST PLAN PARAGRAPH 5.1.6, INITIAL TORQUE
PHASE I

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-4451.1	15371.4	9911.25
2	3987.2	15138.2	5602.5
3	-1144.3	-10054.3	-4455
4	2612.4	-5802.6	-4207.5
5	-935.3	5679.7	3307.5
6	2487.3	6469.8	1991.25
7	-1998.5	-6386	-2193.75
8	409.9	-7690.1	-4050
9	-2185.6	12646.4	[illegible]
10	4056.4	11976.4	3960.
11	-7406.7	-10014.7	-1305
12	-1951.4	-6923.9	-2486.25
13	5044.	4976.5	-33.75
14	7060.5	5828.	-616.75
15	-12308.1	-5013.1	3647.5
16	-3935.4	-10982.9	-3523.75
17	-1084.3	12155.2	6628.25
18	4366.4	10643.9	3138.75
19	-6516	-10046.5	-1765.25
20	-2169.7	-8769.7	-3300.
21	1472.5	572.5	-450.
22	-1453.	-1205.5	123.75
23	8453.8	1321.3	-3566.25
24	1368.6	6116.1	2373.75
25	2141.2	-7826.3	-4983.75
26	-1466.7	-6754.2	-2643.75
27	5918.2	4967.2	-475.5
28	-719.9	-179.9	270.
29	-1579.7	-2142.2	-281.25
30	-4346.8	-2974.3	686.25
31	12535.7	4683.2	-3926.25
32	4883.1	8123.1	1620
33	-2395.2	-7052.7	-2328.75
34	-6361.5	-8116.5	-877.5
35	14130.6	8078.1	-3026.25
36	9205.5	9513.	153.75
37	-4898.6	2526.4	3712.5
38	-1875.9	-5363.4	-1743.75
39	8526.9	6074.4	-1226.25
40	3371.8	7016.8	1822.5
41	5606.8	1714.3	-1946.25
42	2773.6	24957.6	11092.
43	5523.	1235.5	-2143.75
44	5577.1	20517.1	7470

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[illegible] 3= 3.71[illegible]E-02
DEFL 4= .00[illegible]704
DEFL 5= 1.5[illegible]49[illegible]E-04
DEFL 6=-6.455[illegible]4E-04

STRAIN DATA REDUCTION
COUPLING BOLT PRE-TORQUE TEST
(STEEL FLANGES)
COUPLING BOLT TORQUE=3560 IN-LB
TEST PLAN PARAGRAPH 5.2.3
PHASE 1

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-9763.[illegible]	21174.3	15468.[illegible]
2	5798.	21710.5	6111.25
3	-7417.2	-16757.7	-4666.75
4	3556.[illegible]	-13815.7	-8692.5
5	-3023.1	11469.4	7256.25
6	8068.8	14993.8	3465.
7	-7758	-14388	-3245
8	-420.6	-15653.1	-7616.25
9	-595[illegible].5	18062.	11015.[illegible]
10	8538.8	15[illegible].6	5525
11	-16113.[illegible]	-17717.[illegible]	-90[illegible]
12	-3911.[illegible]	-15679.[illegible]	-5553.75
13	2254.4	10271.9	3993.75
14	9714.	18505.5	1361.25
15	-24299.8	-14666.7	6306.25
16	-11343.8	-15881.3	-3766.75
17	-5613.3	17906.7	1[illegible]62.5
18	6475.3	18310.2	5917.5
19	-12307.2	-17929.7	-2646.25
20	-1106.3	-15416.3	-7155
21	4037	-5695.5	-5366.25
22	-3257.2	-7682.2	-2182.5
23	17348.4	8197.4	-4522.5
24	14668.7	14136.2	4758.75
25	7064.2	-9063.3	-8066.25
26	-518.3	-10633.3	-5055.
27	12534.1	9579.1	-1387.5
28	-3496.2	-1043.7	1226.25
29	97.3	-10567.7	-5332.5
30	-8483.4	-12043.4	-1777.5
31	14980.6	10335.6	-4297.5
32	10731.5	16671.5	2970.
33	1355.1	-13532.4	-7455.75
34	-7941	-14755.5	-2405.75
35	19172.4	14447.4	-2360.5
36	12930.9	18848.4	2958.75
37	-11635.	6524.5	9079.75
38	-5650.9	-13603.4	-4471.25
39	17137.4	15409.9	-868.75
40	1855.5	14025.5	6120
41	6150.6	1988.3	-2081.25
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43	6547.6	1755.1	-2396.25
44	4213.	19911.	7852.5

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GAP 2= [illegible]E-02
GAP 3= 1.51134E-02
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DEFL 5= 3.3[illegible]E-05
DEFL 6=-5.37754E-04

[illegible] DATA REDUCTION
[illegible] PRE-TORQUE TEST
([illegible] FLANGES)
COUPLING BOLT TORQUE=460 IN-LB
TEST PLAN PARAGRAPH 5.8.6
PHASE 1

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-11701.	26011.5	13956.3
2	6576.6	26061.6	9742.5
3	-11459.1	-21172.1	-4860
4	3176.	-17302.	-2742.5
5	-3709.3	16315.2	10057.5
6	9042.9	19655.4	5006.25
7	-11529.8	-19922.3	-4196.25
8	-403	-13610.5	-9101.25
9	-2615.5	14627.	[illegible]1.25
10	[illegible]7.7	16571.7	4792.5
11	-[illegible]6.3	-21711.[illegible]	-867.5
12	-3860.5	-19062.8	-7571.25
13	1677.5	12355.1	5343.75
14	10415.7	14263.2	8233.75
15	-29975	-17060	6457.5
16	-11394.3	-21169.3	-4747.5
17	-5427.5	19675.	14651.3
18	6351.	20535.5	7143.75
19	-14648.7	-20566.2	-2958.75
20	-1135.2	-17515.2	-3190.
21	3995.2	-7839.6	-5917.5
22	-4682.3	-9645.8	-2504.75
23	13877.2	8962.2	-4457.5
24	5603.3	14405.4	4601.25
25	3101.	-7896.5	-7995.75
26	-170.3	-10935.8	-5382.5
27	11023.8	8976.3	-1023.75
28	-697.4	-209.4	247.5
29	969.8	-12462.7	-6714.25
30	-5637.6	-14820.1	-2981.25
31	15743.4	[illegible]	-4932.75
32	11042.7	14962.7	1937.5
33	-5215.1	-15660.1	-4452.5
34	-3137.3	-13139.5	-3403.75
35	20422.7	14919.7	-2790.
36	11957.1	13377.1	3355
37	-12459.4	8083.1	10271.3
38	-3744.3	-14774.3	-5490
39	16700.6	15733.1	-463.75
40	1419.6	14694.8	6637.5
41	4294.5	4297.5	0
42	2164.2	27743.2	12437.5
43	2447.	3104.	-1372.5
44	3505.5	18560.5	7527.5

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[illegible] 5= [illegible].[illegible]E-05
[illegible] 6=-5.61[illegible]E-04

D

[illegible] COUPLING
AXIAL LOAD TEST
(STEEL FLANGES)
COUPLING BOLT TORQUE=360 IN-LB
TEST PLAN PARAGRAPH 5.3.6
AXIAL LOAD=5000 LB
PHASE 1

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-12014.5	25920.5	18767.5
2	6496.5	25356.3	9945
3	-10596	-21306.	-5355.
4	3873.5	-14961.5	-10417.5
5	-2636.4	13916.6	10777.5
6	11596.3	23425.6	6063.75
7	-12853.3	-19785.3	-3346.25
8	-1465.4	-18452.9	-8493.75
9	-4300.7	17642.3	9495
10	7071.5	17264.	5096.25
11	-13516.8	-21427.3	-1203.75
12	-3176.3	-17846.3	-7335.
13	2524.	12924.5	5051.25
14	10764.5	14998.5	2115
15	-29724.	-17036.5	6378.75
16	-11334.4	-20649.4	-4657.5
17	-7905.3	22874.7	15390.
18	7549.3	24311.3	4381.25
19	-14009.4	-22064.4	-4027.5
20	-477.	-17344.5	-8443.75
21	5074.7	-3606.3	-4342.5
22	-2592.7	-5532.7	-1620.
23	17393.9	6514.9	-5287.5
24	5766.	13866.	4050.
25	7676.2	-4154.8	-5917.5
26	264.5	-6890.4	-3577.5
27	12976.1	9677.6	-1631.25
28	-697.4	-202.4	247.5
29	266.7	-7342.3	-3825
30	-7098.5	-9635.3	-1271.25
31	17464.6	5562.1	-5951.25
32	12651.3	13483.8	416.25
33	1042.	-4813.	-4927.5
34	-6091.5	-11036.5	-2497.5
35	17307.6	10945.1	-3431.25
36	11939.3	15531.8	1796.25
37	-5967.9	8544.6	7256.25
38	-1102.4	-8999.9	-3948.75
39	12900.1	10740.1	-1080
40	608.2	11498.2	5445
41	4565.6	3328.1	-618.75
42	2771.5	22957.3	10091.3
43	4740.4	3930.4	-405
44	5639.9	25734.9	10047.5

GAP 1= 7.13[illegible]E-02
GAP 2= 9.51473E-02
GAP 3= 1.11136E-03
DEFL 4= .00[illegible]105
DEFL 5= 1.1[illegible]77[illegible]E-04
DEFL 6=-3.1[illegible]E-04

[illegible] DATA REDUCTION
[illegible] BENDING MOMENT TEST
([illegible] FLANGED)
COUPLING BOLT TORQUE=360 IN-LB
TEST PLAN PARAGRAPH 5.4.4
BENDING MOMENT=5464 IN-LB
PHASE 1

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-4663.1	17224.4	10946.3
2	8917.4	21514.6	6300.
3	-7120.5	-13373	-3341.25
4	1534.9	-10350.1	-6157.5
5	-3105.1	12596.9	7352.5
6	5300.9	12163.4	3431.25
7	-6610.1	13762.6	-3475.25
8	-743.1	-12263.1	-5760
9	-5394.4	10906.5	7607.5
10	4333.2	18695.7	4866.25
11	-9560.9	-14643.9	-2542.5
12	51.2	-10726.2	-5333.75
13	1944.3	10460.3	4252.5
14	702.3	12105.3	1961.25
15	-20597.1	-12654.6	3971.25
16	-6854	-14414.	-3730.
17	-5151.6	17548.4	10550
18	7176.6	17526.8	5175.
19	-11434.9	-15177.4	-1976.25
20	-2560.9	-12738.4	-5088.75
21	4136.1	-7074.9	-5608.5
22	-2650.8	-7533.3	-2741.25
23	12554.5	7252.	-2646.25
24	2630.1	9762.6	3566.25
25	6154.3	-6400.2	-6277.5
26	-1749.6	-10029.6	-4140.
27	5444.3	5557.3	56.25
28	-2019.6	-557.1	731.25
29	974.5	-8745.5	-4860
30	-3097.6	-5278.6	-2567.5
31	10422.	4302.	-3060.
32	5996.2	7459.3	731.25
33	2394.3	-7752.7	-5073.75
34	-3412.4	-4334.9	-2261.25
35	11026.3	8705.3	-1172.5
36	4917.[illegible]	6749.3	1912.5
37	-4374.4	5115.6	4747.5
38	-1653.5	-6701.	-2508.75
39	10223.4	7235.9	-1496.25
40	1593.4	5703.4	3555.
41	4630.2	1750.2	-1440.
42	3161.7	20326.7	8617.5
43	7138.4	4196.2	-1473.75
44	5330.3	23667.6	9165.75

CAP 1= 7.61743E-02
CAP 2= 3.19975E-02
CAP 3= 4.76361E-03
DEFL 4= .001464
DEFL 5= 1.34444E-03
DEFL 6=-1.10013E-04

[illegible]

PAGE A-6

[illegible] TEST DATA REDUCTION
EXTERNAL BENDING MOMENT TEST
(STEEL FLANGE)
COUPLING BOLT TORQUE=360 IN-LB
TEST PLAN PARAGRAPH 5.4.4
BENDING MOMENT=11025 IN-LB
PHASE 1

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-4771.4	17368.6	11070
2	5959.6	21469.6	6855.
3	-7800.7	-14108.2	-3453.75
4	1637.5	-10890.	-6263.75
5	-3379.9	10660.1	7020.
6	4544.4	10056.9	2756.25
7	-6646.3	-13343.8	-3341.25
8	-975.2	-12562.7	-5793.75
9	13882.6	16177.3	1473.75
10	4416.3	13416.2	4500
11	-9351.3	-14613.2	-2633.5
12	143.3	-10612.7	-5377.5
13	2273.	11633.	4680
14	8823.3	13216.3	2193.75
15	-21021.4	-13416.4	3802.5
16	-6651.5	-14616.5	-3982.5
17	-2672.2	19400.3	11036.3
18	7936.4	19343.9	5703.75
19	-11832.9	-16265.4	-2216.25
20	-2523.5	-13017.5	-5242.5
21	4100.4	-6677.1	-5388.75
22	-2613	-7203.	-2295.
23	12717.5	7117.	-2801.25
24	2469.4	9636.9	3468.75
25	5797.1	-8332.9	-7065
26	-2256.6	-11976.6	-4860
27	5513.4	5810.9	146.25
28	-2103.	-530.5	798.75
29	367.1	-8515.4	-4491.25
30	-3114	-7929.	-2407.5
31	10489.5	4234.5	-3127.5
32	5907.6	7497.6	720
33	2514.3	-6440.7	-4477.5
34	-3404.5	-7229.5	-1912.5
35	10765.2	7355.2	-1440.
36	5010.9	8363.4	1676.25
37	-2111.3	5628.7	3870.
38	-974.	-4956.5	-1991.25
39	9344.	5789.	-1777.5
40	1636.3	4133.3	3251.25
41	4647.6	1610.1	-1512.75
42	3027.6	19835.3	8403.75
43	7240.5	5643.	-798.75
44	6177.6	27687.6	10755.

GAP 1= .074327
GAP 2= 5.04633E-02
GAP 3= 5.44587E-03
DEFL 4= .001588
DEFL 5= 1.77774E-04
DEFL 6=-1.52340E-04

[illegible] 0122[illegible]

[illegible]
EXTERNAL BENDING MOMENT TEST
(STEEL FLANGES)
COUPLING BOLT TORQUE=360 IN-LB
TEST PLAN PARAGRAPH 5.4.4
BENDING MOMENT=1[illegible] IN-LB
PHASE 1

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-4675.3	17599.7	11137.5
2	9078.4	21674.4	6300.
3	-7029.9	-14319.9	-3645.
4	2067.9	-10779.6	-6423.75
5	-3621.	8529.	6075
6	3945.4	7792.9	1923.75
7	-6730.4	-13187.2	-3228.75
8	-1183.3	-12681.3	-5748.75
9	-5129.7	11632.3	8381.25
10	4646.2	14205.7	4751.25
11	-9058.4	-14510.9	-2711.25
12	401	-10421.5	-5411.25
13	2696.8	13091.2	5197.5
14	9541.4	14671.4	2565
15	-11892.3	-14349.5	3521.25
16	-6467.4	-14382.4	-4207.5
17	-2240.9	21536.6	11913.5
18	9170.4	21995.4	6412.5
19	-12299.1	-17271.6	-2486.25
20	-2649.5	-13397.	-5523.75
21	4071.7	-6075.8	-5073.75
22	-2646.8	-6719.3	-2036.25
23	12716.5	6913.5	-2902.5
24	3158.3	9643.5	3262.5
25	5714.5	-10418.	-8066.25
26	-2592.2	-14132.2	-5625
27	5610.4	6127.9	253.75
28	-1200.6	-530.6	310.
29	946.8	-7929.7	-4443.75
30	-2655.6	-7255.1	-2243.75
31	10547.8	4135.3	-3206.25
32	5929.3	7526.8	791.75
33	2761.6	-4033.4	-3325
34	-2755.3	-5792.3	-1518.75
35	10457.5	6925.	-1766.25
36	5158.2	7970.7	1406.25
37	563.9	6261.4	2846.25
38	244.7	-2657.3	-1451.25
39	8273.5	4461.	-2036.25
40	1704.9	7374.9	2835
41	4765.2	1615.2	-1575.
42	2665.4	19317.9	8326.25
43	7395.3	7485.3	45
44	7167.	32097.	12465.

CAL 1= 7.4[illegible]E-03
CAL 2= [illegible]E-03
CAL 3= 6.1[illegible]E-03
ACEL 4= .00[illegible]
ACEL 5= [illegible]E-04
ACEL 6=-1.1[illegible]E-04

[illegible]
[illegible] PRESSURE TEST
(STEEL FLANGES)
COUPLING BOLT TORQUE=360 IN-LB
TEST PLAN PARAGRAPH 5.5.5
INTERNAL PRESSURE=250 PSIG
PHASE I

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-1827.7	21009.3	11418.5
2	13669.5	25594.5	5962.5
3	-7624.3	-16669.3	-4522.5
4	4041.7	-12130.8	-3111.25
5	-1833.3	17639.2	9438.75
6	10056.3	19146.3	4545.
7	-4610.	13785.	-4022.5
8	-160.1	-12262.4	-7811.25
9	-3644.	13051.	3347.5
10	7636.2	15303.7	3836.25
11	-3970.7	-15405.7	-3217.5
12	[illegible]	-11456.7	-7143.75
13	4459.	14764.	5152.5
14	12471.	16563.5	1946.25
15	-20107	-15067	2520
16	-7940.5	-16123	-5591.25
17	-2198.9	22152.1	12172.5
18	11944.5	24252.	6153.75
19	-10483.6	-17511.1	-3543.75
20	353.4	-14586.6	-7470
21	6649.4	-3295.6	-4972.5
22	2443.6	-4165.4	-3307.5
23	12573.6	5131.1	-3723.75
24	5024.5	7644.5	1305.
25	10154.9	6082.4	-2036.25
26	3187.9	-3719.6	-3453.75
27	6565.2	5650.2	-507.5
28	294.5	114.5	-90.
29	3905.2	-4846.6	-4376.25
30	467.0	-5089.6	-2778.75
31	10063.3	3163.3	-3448.5
32	6323.3	5973.3	-675
33	4409.4	-4038.7	-4421.25
34	55.5	-5209.5	-2632.5
35	11744.1	3270.6	-9684.75
36	8748.6	7338.6	-405
37	723.4	7583.4	3397.5
38	4782.5	-2519.	-2621.25
39	15991.6	4264.1	-3363.75
40	4130.6	6830.6	1350
41	5085.7	4013.2	-536.25
42	3956.1	23963.6	10001.3
43	3333.4	3103.4	-115.0
44	7105.8	30665.8	11790

GAP 1= 7.[illegible]E-03
GAP 2= [illegible]E-03
GAP 3A 4.06572E-03
DEFL 4= .001966
DEFL 5= 2.39163E-04
DEFL 6= 3.14350E-04

[illegible]
COUPLING BOLT PRE-TORQUE TEST
(STEEL FLANGES)
COUPLING BOLT TORQUE=260 IN-LB
TEST PLAN PARAGRAPH 6.2.1
PAGE 11

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-3160.7	25519.3	14490
2	14216.	21776.	3780.
3	-21[illegible].1	-33912.6	-6243.75
4	1003.	-25958.	-13477.5
5	-3516.6	26093.4	14805
6	-12214.7	24137.2	5905.25
7	-13149.9	-26604.9	-6727.5
8	-3126.7	-18693.5	-10172.
9	-8541.2	21383.6	14962.5
10	11197.4	20467.4	4640.
11	-17460.7	-31455.7	-6997.5
12	5310.	-23715.	-14512.5
13	-4667.4	29330.1	16998.3
14	15734.2	26536.2	5400.
15	-23209.2	-34071.7	-5411.25
16	-14452.7	-32163.7	-8932.5
17	-1532.1	28754.4	15018.8
18	14498.5	27224.5	6165.
19	-15010	-30047.5	-6915.75
20	223.4	-22636.6	-11430
21	4559.2	-8895.2	-6727.5
22	-5257.1	-10612.1	-2677.5
23	13110.	8362.5	-2373.75
24	8309.8	6479.2	2835.
25	4332.2	-2705.3	-3543.75
26	-4703.9	-6191.4	-731.25
27	13634.7	8472.2	-2581.25
28	-126.3	-36.8	45
29	2845.	-10062.5	-6453.75
30	-6164.1	-11136.6	-2486.25
31	14566.1	9274.6	-2643.75
32	1341.4	8024.3	3341.25
33	7147.	-3733.	-7265
34	-3402.2	-9522.2	-3060.
35	10906.	10771.	-67.5
36	-746.6	10030.9	5388.75
37	-10925.2	4956.3	7942.5
38	-6344.1	-10956.6	-2305.25
39	12417.2	12777.2	180
40	1093.	11785.5	5345.75
41	3699.2	9434.2	2767.5
42	1519.5	8305.5	3397.5
43	1776.	11721.	4972.5
44	3612.7	10947.7	3667.5

CAP 1= 5.77125E-02
CAP 2= .052103
CAP 3= 5.45553E-02
DEFL 4= .023352
DEFL 5= 2.1295E-0[illegible]
DEFL 6= 2.53174E-02

[illegible] SECTION
[illegible] PRESSURE TEST
([illegible] FLANGES)
COUPLING NUT TORQUE=360 IN-LB
TEST PLAN PARAGRAPH 4.3.3
INTERNAL PRESSURE=[illegible] PSIG
PAGE II

GAGE NO.	HOOP STRESS	LONG. STRESS	MAX SHEAR
1	-19.4	28561.6	14267.5
2	20142.5	26892.5	3375.
3	-13405.5	-32310.5	-6952.5
4	44773.6	-13771.4	-29272.5
5	-16716.3	24323.7	20520
6	18399.7	29039.7	5745
7	-10113.8	-26048.8	-7965
8	7659.4	-18620.6	-13140
9	-5436.4	23678.8	14557.5
10	17285.6	24350.6	3532.5
11	-15707	-30714.5	-7503.75
12	9599.8	-23660.2	-16260
13	-1651.9	34115.6	17398.8
14	28917.	34758.	5917.5
15	-23612.3	-35447.3	-5917.5
16	1837.6	-29744.9	-15421.3
17	1799.2	32803.2	15502.5
18	21430.2	33130.3	5850.
19	-15813.1	-31530.6	-8156.25
20	13978.4	-21054.1	-17516.3
21	7416.6	-5453.4	-6435
22	291.1	-6096.9	-3195
23	14564.2	7971.7	-3296.25
24	7141.	6401.	630
25	6502.4	238.4	-3265
26	332.6	-2254.9	-1293.75
27	15917.1	7521.6	-4196.25
28	5153.4	1553.8	-1800.
29	5773.5	-7614.	-6693.75
30	-887.[illegible]	-7660.3	-3386.25
31	15605.1	9057.6	-3273.75
32	10805.5	4211.	-3043.75
33	9535.2	-4054.7	-6795.
34	2553.5	-4571.4	-3712.5
35	16046.6	7299.1	-2373.75
36	5984.	9076.5	1991.25
37	-4307.8	8765.3	6536.25
38	707.2	-4755.3	-2733.75
39	13553.9	8605.9	-2475
40	5736.8	9764.3	2013.75
41	4421.7	11036.7	3307.5
42	1580.5	10340.5	4410.
43	2791.2	14015.7	5613.75
44	5955.4	21120.7	7582.5

GAP 1= 6.03621E-03
GAP 2= 5.47941E-03
GAP 3= .056356
DEFL 4= .023344
DEFL 5= 2.13166E-02
DEFL 6= 2.46548E-02

1.0 INTRODUCTION

This report describes the results of a development test program directed at evaluating the structural capabilities of the Marman V-Band Coupling and Flange with Conoseal gasket as shown in Figure 1. The intended end use was for the 75K NERVA flight engine propellant lines. The list of references at the end of this report describes the method of selecting this configuration for testing and outlines a complete development program which would assess capabilities for all NERVA operational modes.

Of major importance in the structural evaluation is the ability to predict stresses throughout the assembly for a variety of loading conditions. Computer finite element analysis (1)[1] is used to predict these stresses but, for the subject configuration, large uncertainties are introduced in modeling the complex geometry and boundary conditions. The purpose of the structural tests was to obtain actual stresses and deflections for correlation with, and updating of the finite element model. Accurate representation would allow the application of probabilistic design techniques to determine the suitability for use on the NERVA engine.

2.0 SUMMARY/CONCLUSIONS

Results of the incomplete test program are inconclusive with respect to determining suitability for use on the NERVA engine. However, test data indicates yielding will occur at various points in the flange assembly at loading conditions considerably below those anticipated on the engine. Further study of the test data is required to make the proper evaluation which must

1 Numbers in parentheses refer to references at the end of this report.

include the strain hardening characteristics of the flange material. Significant contributions to the stress levels are of a self limiting nature; i.e., due to bolt clamping torque, and as such can be classified as secondary stresses (2). Inelastic analysis techniques are applicable under these conditions, and the yielding condition is not necessarily cause for rejection of the design. In addition, consideration must be given to the possibility of geometry changes which may improve the capabilities of the preliminary design which was tested.

Tests were performed to determine the spring rates of Conoseal gaskets and the ability of the V-Band Coupling to generate sufficient force to properly seat the gasket (3). This information was used as input for a finite element computer analysis model of the subject assembly. Structural tests were then performed to verify and update the finite element model. Correlation of test data with the computer analysis, for a relatively simple loading condition, was made and indicated unsatisfactory modeling.

It is concluded that considerable refinement of the finite element model is required. Perhaps of greatest significance is the lack of axisymmetry shown in the test data which was assumed in the finite element analysis. If the finite element model can be updated to accurately represent the test used for correlation, several computer runs must be made corresponding with all loading conditions used in testing. Only after satisfactory correlation is obtained for all loading conditions, can sufficient confidence be placed in the analysis to permit probabalistic design to proceed.

At this time no assessment has been made concerning the degree of correlation between the test data and the computer analysis that is necessary. If this program were to be carried to completion, it would necessarily be required and would include a comprehensive examination of the accuracy of the test data. This would be factored into the entire program along with the accuracy of the computer analysis to establish the uncertainty involved. For the purpose of this report, it is assumed that the test data is exact. This is a reasonable assumption until the finite element model has been updated to model basic behavior.

3.0 TECHNICAL DISCUSSION

3.1 Test Article

Details of the male flange, female flange, and V-Band Coupling are shown in Figures 2, 3, and 4. Strain gages were located as shown at points where the computer analysis indicated the largest stresses would exist. Deflection gages were installed as shown to measure relative flange separation and the deflection of the V-Band. The assembled test article with the Conoseal gasket installed is shown in Figure 7.

3.2 Test Program

The test program planned to evaluate the Marman V-Band Coupling and Flange with Conoseal Gasket for use on NERVA propellant lines consisted of three distinct areas of investigation as described below:

PART I - The purpose of this activity was to determine the spring rates of Conoseal gaskets made of aluminum and of stainless steel and the ability of the V-Band Coupling to provide the necessary clamping force to properly seat the gasket. The test setup used to determine the Conoseal spring rates is shown in Figure 5. With the Conoseal installed, axial compressive loads were applied by the tensile testing machine with the flange gap and deflection measured directly. A similar setup was used to measure the force developed by the V-Band Coupling and is shown in Figure 6. With the Conoseal removed, the force developed by the V-Band Coupling as a function of bolt torque and flange gap was measured directly using the tensile testing machine. The detailed test procedure for Part I is described in Reference (3).

PART II - The purpose of this activity was to perform structural tests on the assembled Marman V-Band Coupling and Flange with the Conoseal Gasket installed and correlate the stresses and deflections with those obtained from a finite element computer analysis. The test article was instrumented and assembled as shown in Figures 2, 3, 4, and 7. Stresses and deflections were measured for loading conditions listed below. The test setup used for each test is shown in the indicated figures.

a.* V-Band Coupling Bolt Torque, Figure 7.

b. V-Band Coupling Bolt Torque plus Axial Tensile Load, Figure 8.

c. V-Band Coupling Bolt Torque plus External Bending Moment, Figure 8.

d.* V-Band Coupling Bolt Torque plus Internal Pressure, Figure 7.

For each of the loading conditions above, the test procedure required that stresses and deflections be measured over a range of loading conditions to establish functional relationships if possible. Thus, for each loading condition, loads were applied in increments with several strain

* These tests were performed for two nominal tube wall thicknesses.

Heavy wall tests, thickness = .258 inches

Thin wall tests, thickness = .150 inches gages being monitored as test control. In the interest of maintaining the test article free of previous test history, yielding could not be tolerated. To prevent the occurrence of yielding in each test, the loading was terminated when the maximum shear stress reached test control limits (10,000 psi for the CRES 347 flanges and 40,000 psi for the Inconel 718 V-Band).

Two additional tests were performed. One was to determine the torsional load carrying capability of the test article as a function of assembly cycles. The only data recorded for this test was the load at which the flanges slipped. The test setup was as shown in Figure 9 with the test results shown in Figure 10. The other test was to determine the failure mode of the thin wall version of the test article when subjected to internal hydrostatic pressure. For this test, all stresses and deflections were recorded continuously until fluid containment capability was lost. The test setup was as shown in Figure 7. The detailed test procedure for Part II is described in Reference (4).

PART III - The purpose of this activity was to determine the behavior of the test article of Part II when subjected to pressure-temperature cycling. Of greatest importance were the effects on fluid containment and load carrying capabilities throughout the life of the NERVA engine. Also of interest was the desire to correlate ambient helium leakage with hydrogen leakage at engine operating conditions to establish leak test acceptance criteria.

3.3 Tests Completed

Parts I and II of the test program were completed and the results are described in Sections 3.4 and 3.5 of this report. Part III of the test program was cancelled due to the NERVA Program phasedown of February 1971. Material representing the effort expended on Part III may be found in References 5 through 9.

3.4 Correlation With Analysis

Part I of the aforementioned test program was directed at determining actual Conoseal spring rate and V-Band Coupling clamping force characteristics. Force-deflection curves for steel and aluminum Conoseal gaskets are shown in Figures 11 and 12 and are in accordance with ACC-STD 4808B, Conoseal Grooves and Flanges, Part I, Engineering Design Criteria. Of interest is the rapid reduction in axial force with flange separation which indicates a possible leakage mechanism if preload is significantly reduced. Clamping force characteristics are shown in Figures 13 and 14 for steel and aluminum flanges and are seen to be sufficient to properly seat the gaskets; however, there is an effect of initial flange gap. These results were used by the Applied Mechanics Section in modeling the assembly for finite element analysis. While several loading conditions were analyzed by computer, none are significant unless actual behavior is modeled. Thus, the first consideration is a very basic one of obtaining a good correlation for rather simple loading conditions. The case chosen for the first step in correlating the results was that of simply clamping the assembly together with a torque of 360 in-lb applied to the bolts of the V-Band Coupling with the Conoseal installed. This corresponds with loading condition (b) of Reference 1 and test plan paragraph 5.2.3 of Reference 4.

The correlation is shown in Figures 15 through 18, where the broken lines are computer results, assumed axisymmetric, and the solid lines are measured values at various locations around the circumference of the test item. Finite elements are identified in Figure 19. It can be seen that variations in stresses around the circumference of the flange are large and in general do not agree with the finite element analysis. Also, most of the measured flange stresses are larger than those predicted by analysis. The maximum shear stress predicted for the coupling (element 217) was approximately 31 ksi. Measured values range from 2 to 11 ksi, indicating the modeled stiffness for the V-Band was too small. Comparison of predicted and measured deflections of the V-Band is inconclusive due to the lack of axisymmetry of the test article and the accuracy of the measured deflections. The predicted deflection was .0004256 inches, while measured values range from -.0005 to +.002 inches.

The conclusion is that the general behavior of the assembly is not adequately modeled. The finite element model must be examined and changes introduced to produce the basic behavior indicated by the test results. Until this is accomplished, further correlation efforts are not warranted.

3.5 Test Results

The finite element model used for computer analysis is shown in Figure 19. This simplified representation shows only those locations where stresses and deflections were actually measured during the test program.

Examination of this model and the strain gage locations shown in Figures 2, 3, and 4 yields the following correspondence:

Finite Element Number	Strain Gage Numbers	Location
78	24, 28, 32, 36, 40	Female Flange
82	22, 26, 30, 34, 38	Female Flange
129	23, 27, 31, 35, 39	Female Flange
134	21, 25, 29, 33, 37	Female Flange
291	3, 7, 11, 15, 19	Male Flange
296	1, 5, 9, 13, 17	Male Flange
355	4, 8, 12, 16, 20	Male Flange
359	2, 6, 10, 14, 18	Male Flange
217	41, 42, 43, 44	Coupling

The fact that there are several strain gages listed above for each finite element is due to the gages being located around the circumference of the test item. Stresses are listed by these strain gage numbers in the reduced data in psi (see Appendix A). Internal deflection gages, designated B-1, B-2, and B-3 correspond with relative displacements of nodes 231 and 253 of the finite element model and are listed in the reduced data as GAP 1, GAP 2, and GAP 3, respectively. Similarly, external deflection gages B-4, B-5, and B-6 correspond with relative displacements of nodes 165 and 386 of the finite element model and are listed in the reduced data as DEFL 4, DEFL 5, and DEFL 6, respectively. All deflections are inches.

The above information allows the identification of stresses in the various elements of the test article by referring to the finite element model (Figure 19) and the reduced data for test conditions listed in Appendix A. No effort will be made to examine each element for all loading conditions, but some general observations are made as follows:

Efforts to insure that no yielding would occur during the test program were not entirely successful. Using the maximum shear stress theory to predict the onset of yielding, shear stresses must be limited to one-half the tensile yield strength of the material. For the CRES 347 flanges tested, shear stresses should have been limited to 15,000 psi. That this value was exceeded for several loading cases was due to either or both of the following:

a. Incorrect stress calculations during testing.

b. Yield stresses were encountered at the initial load increment specified in the test procedure.

The end result is that the accuracy of the test data is compromised due to local yielding and the accompanying redistribution of stresses. No attempt was made to quantify this inaccuracy.

Referring to the reduced data, Appendix A, Pages A-1, A-2, and A-3, maximum shear stresses are seen to increase with coupling bolt torque. From Page A-4, further increases exist due to the application of an axial tensile load. Application of an external bending moment to the test article produces a reduction in maximum shear stresses initially, Page A-5. Subsequent increases in the magnitude of the bending moment increases maximum shear stresses, but the rate of increase is small compared with the increase in bending moment, Pages A-6 and A-7. This indicates that the effects of bolt clamping torque remained dominant for the range of bending moments applied. Similar behavior was experienced when the test article was subjected to internal pressure, Page A-8. Initially, maximum shear stresses decreased; however, further increases in pressure were not made as test control limits were exceeded at the initial pressure increment. The coupling bolt torque test and internal pressure test for the thin wall version of the test article, Pages A-9 and A-10, show increased stresses where the condition of localized yielding may no longer be valid. This does not preclude the possibility of the test article performing satisfactorily at load levels anticipated on the NERVA engine if the flange material has sufficient strain hardening capability. This is evidenced by the test to determine the failure mode, Reference (24), Page 39, where fluid containment capability was maintained to approximately 2350 psig. This is considerably above the nominal pump discharge pressure for NERVA (1431 psia).

In order to assess the capabilities of the test article for the various loading conditions mentioned above, and combinations thereof, detailed analysis of the test data is required in accordance with SNPO-C-1(2). This would define the load carrying capabilities within allowable stress and strain limits. Comparison with anticipated service conditions would then be required to determine suitability of this configuration for use on the NERVA engine. The performance of this analysis is beyond the scope of this report.

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4.0 FIGURES

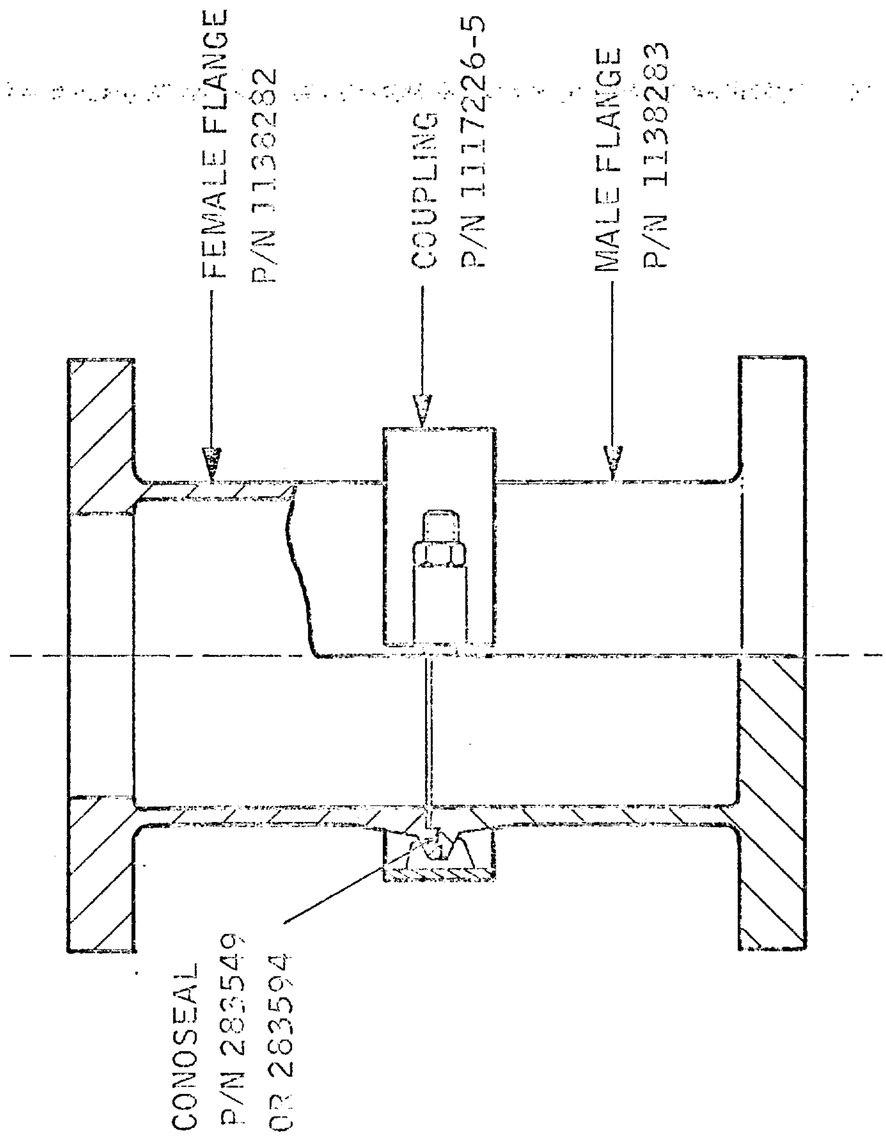


FIGURE 1 - ASSEMBLED TEST ARTICLE

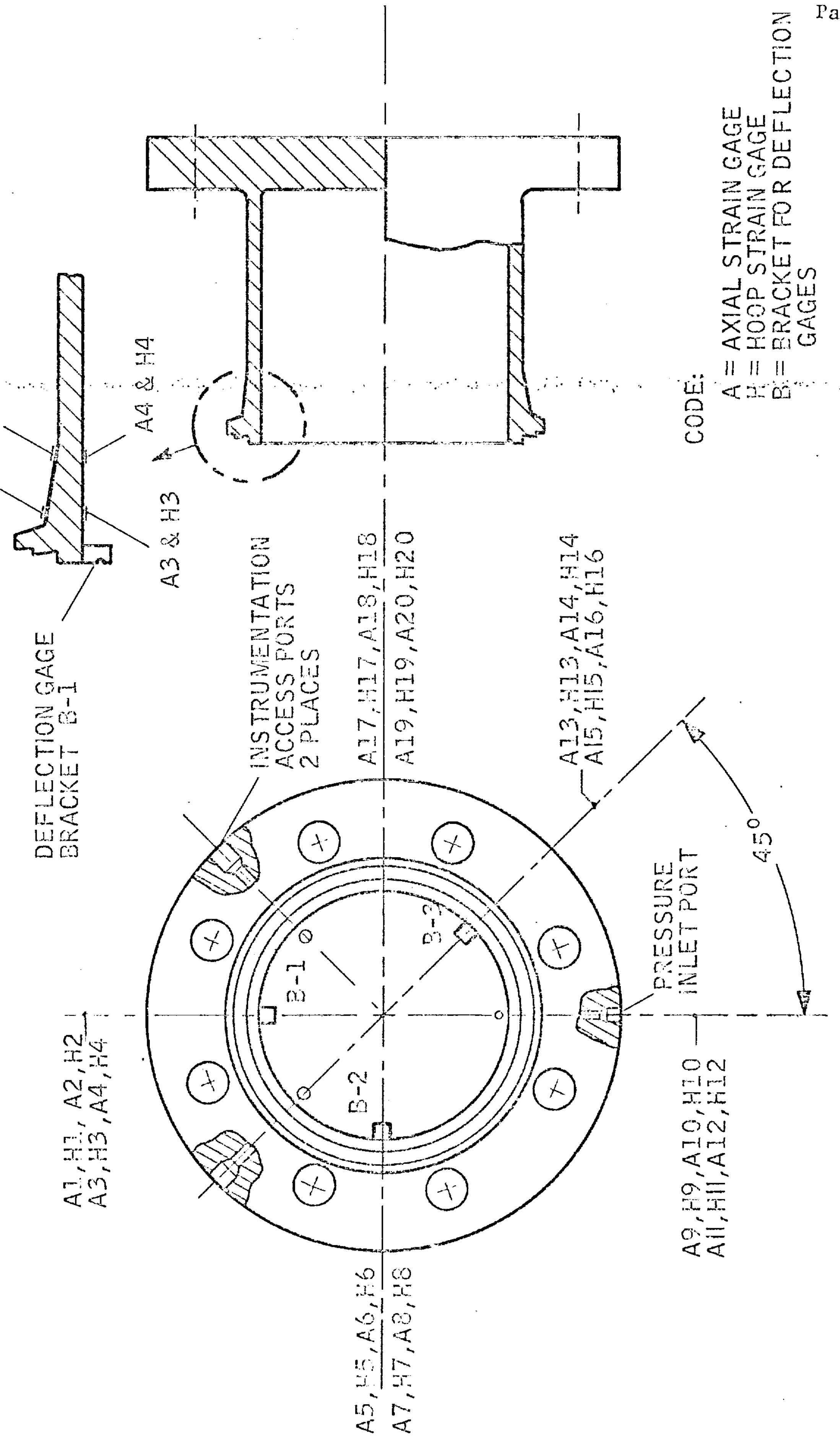


FIGURE 2 - MALE FLANGE
STRAIN GAGE & DEFLECTION GAGE LOCATIONS
P/N 1138282

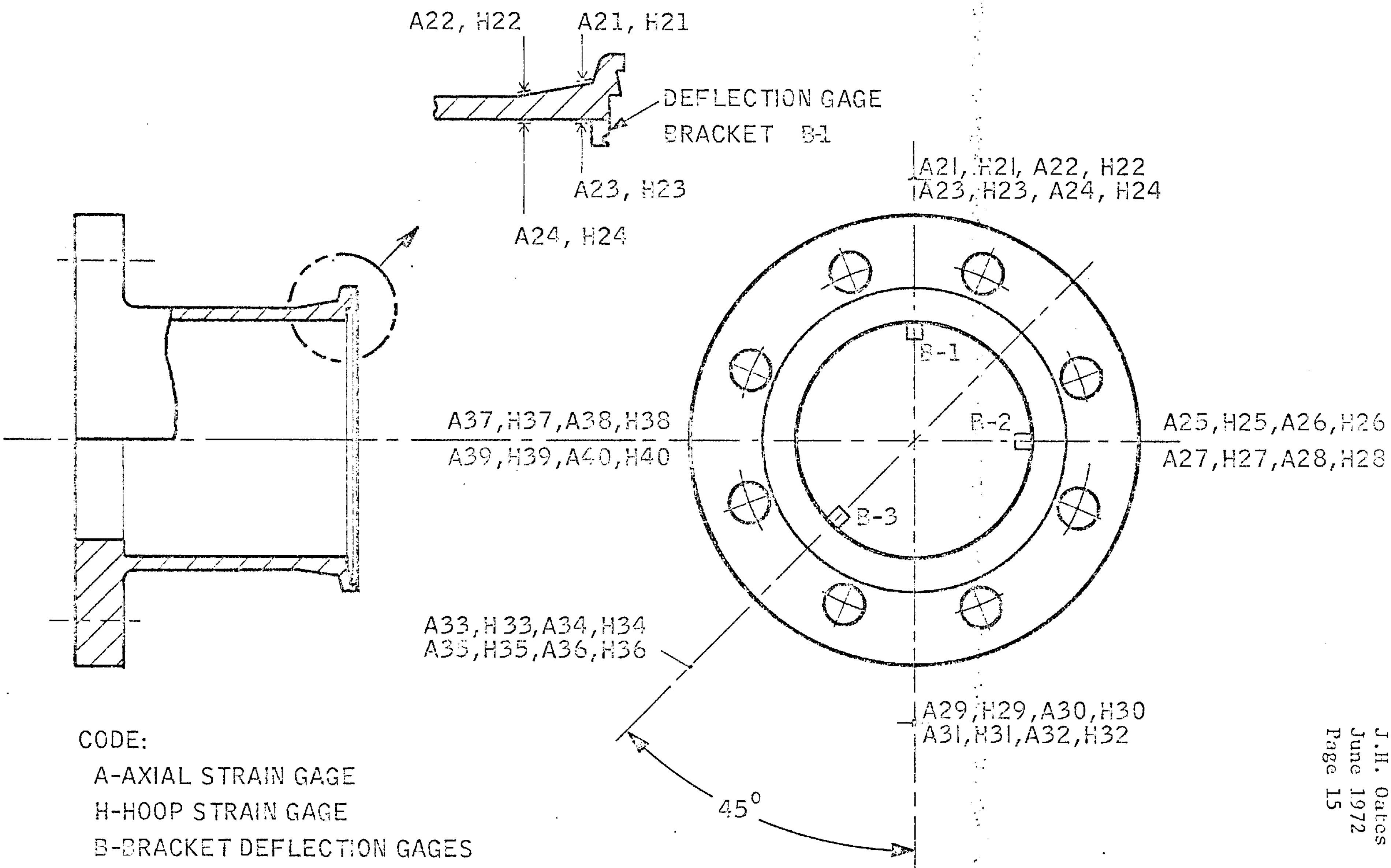


FIGURE 3 - FEMALE FLANGE STRAIN GAGE & DEFLECTION GAGE LOCATIONS P/N 1138283

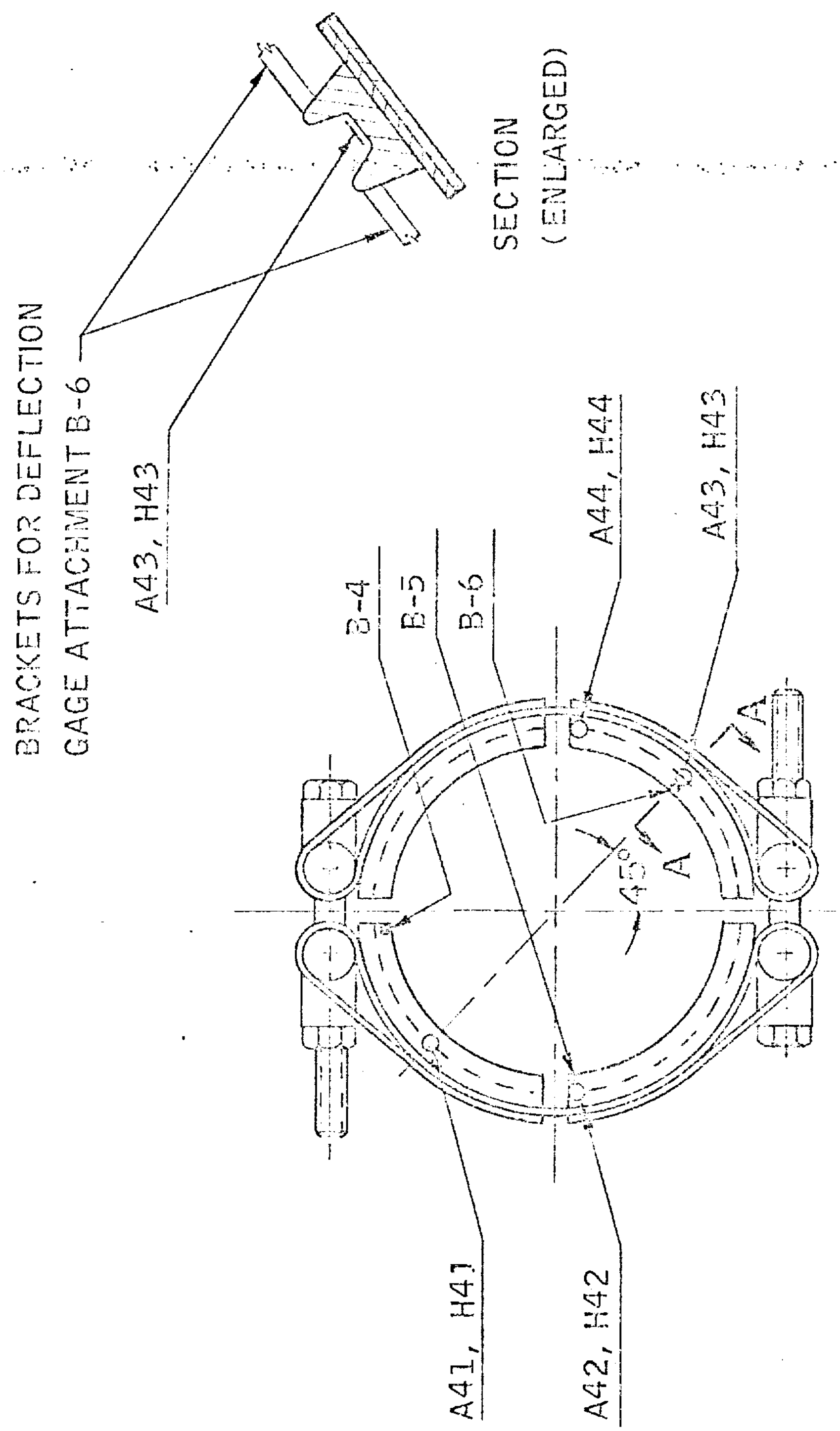


FIGURE 4 - V-BAND COUPLING STRAIN AND DEFLECTION GAGE LOCATIONS P/N 1117226-5

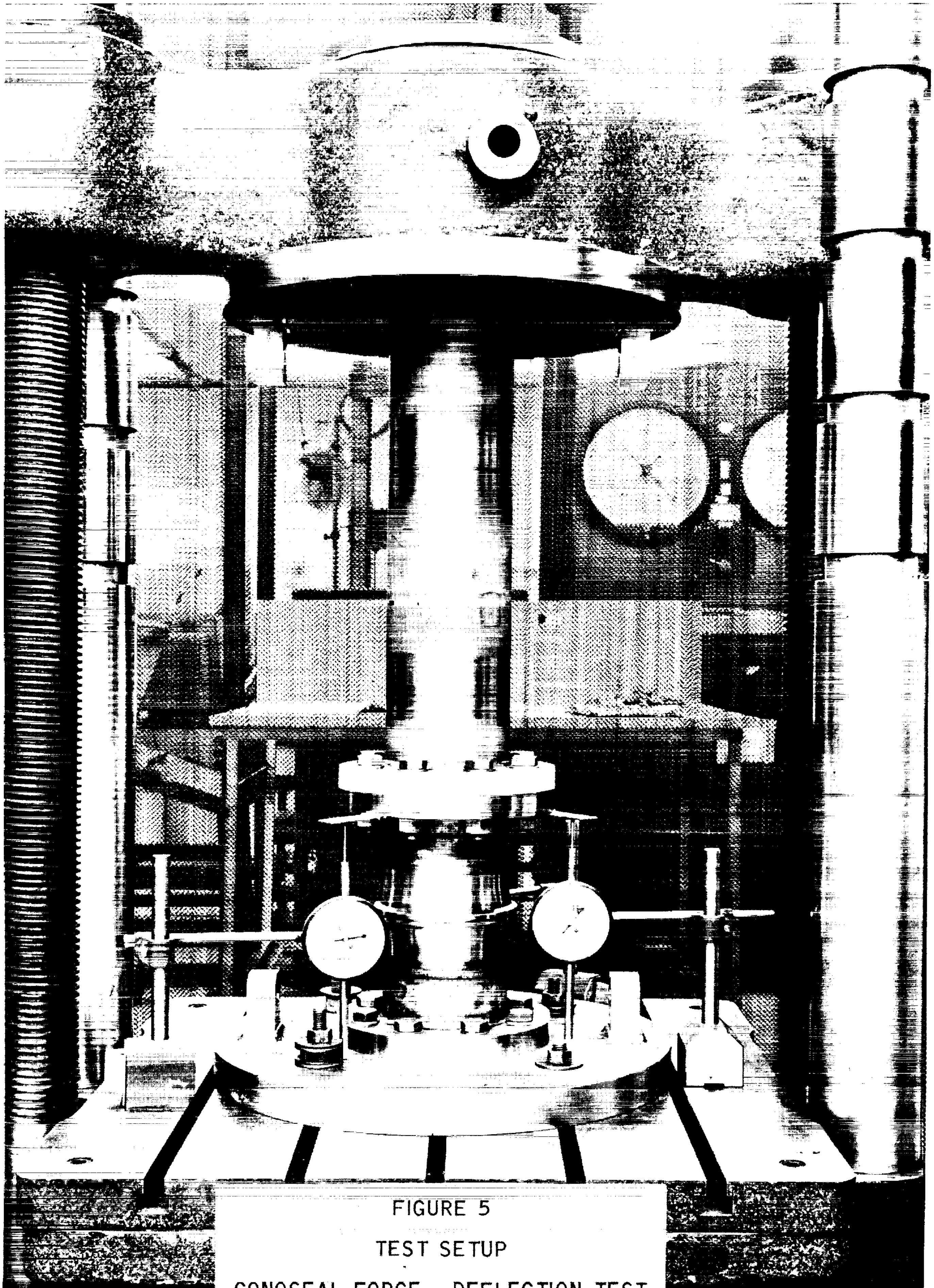


FIGURE 5

TEST SETUP

CONOSEAL FORCE - DEFLECTION TEST

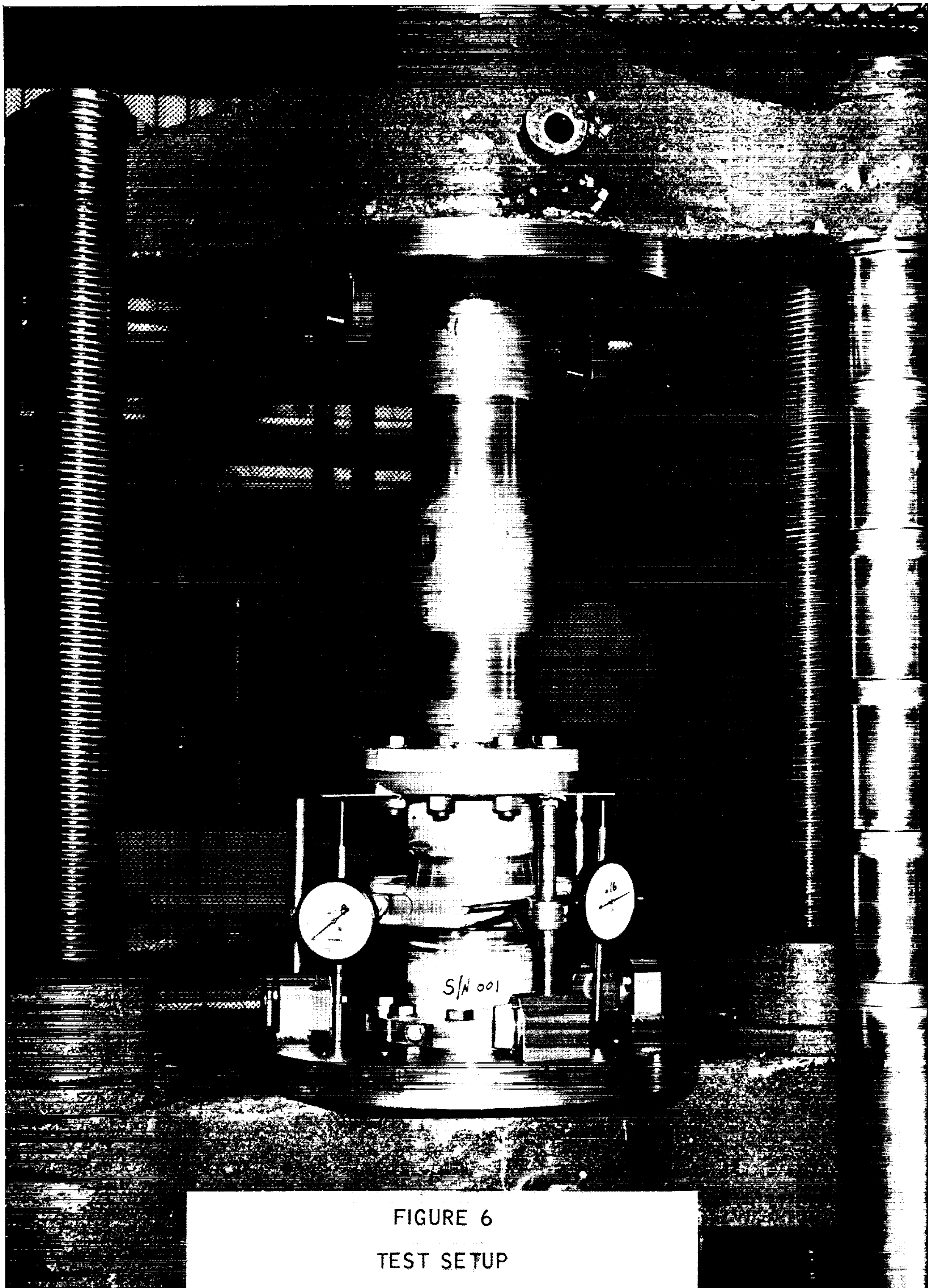


FIGURE 6

TEST SETUP

V-BAND COUPLING FORCE CAPABILITY TEST

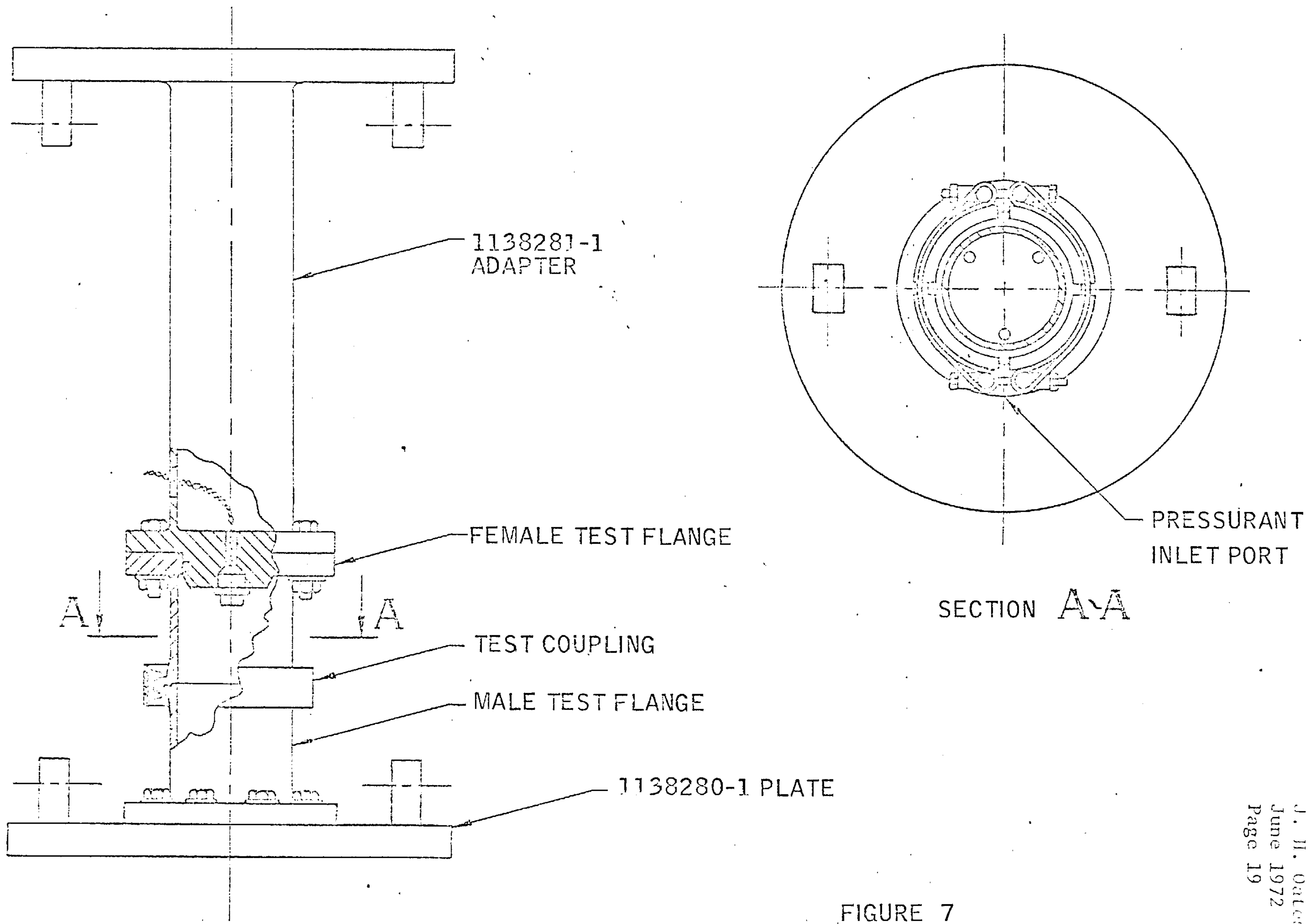
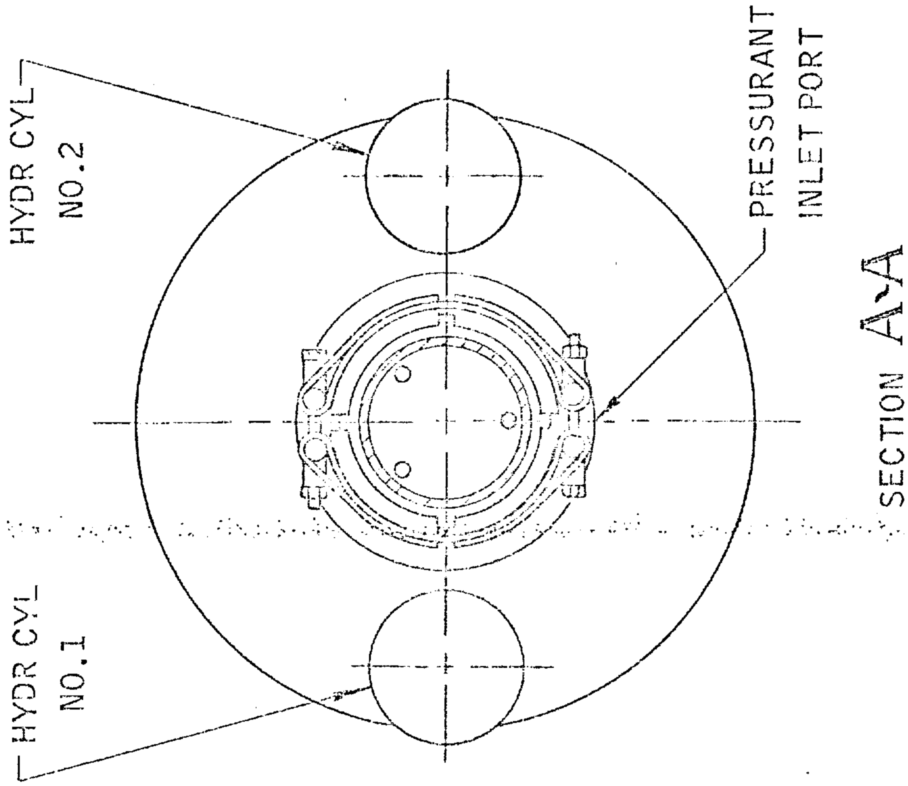


FIGURE 7
TEST SET UP
V-BAND COUPLING BOLT PRETORQUE
AND INTERNAL PRESSURE TESTS



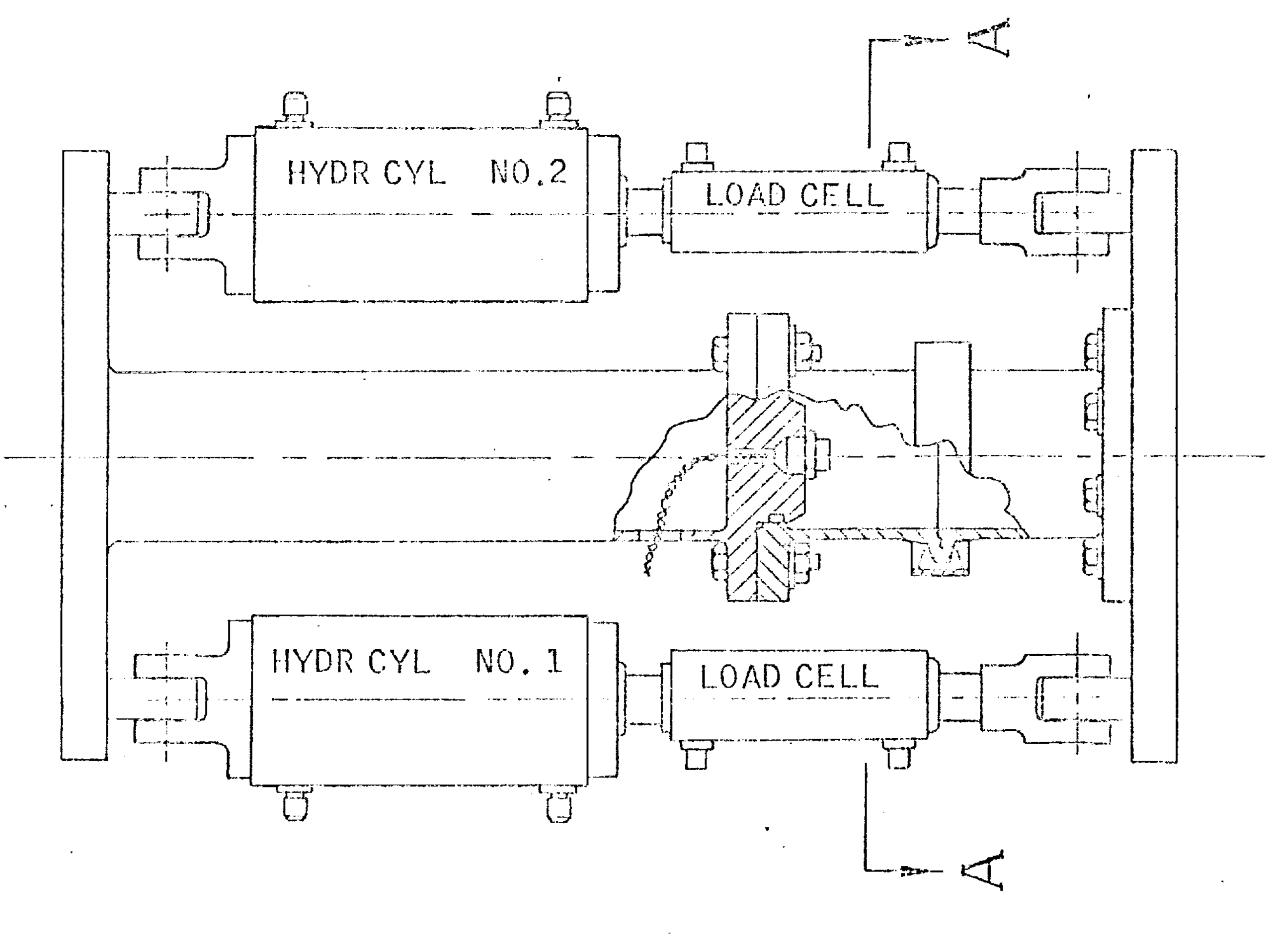


FIGURE 8
TEST SET UP
AXIAL TENSILE LOAD AND EXTERNAL
BENDING MOMENT TESTS