FLEXIBLE FOOT TEST ASSEMBLY

C. H. Kurita

D-Zero Engineering Note: 3740.210-EN-87

April 27, 1987

Rev A

Approved: ______________________

INTRODUCTION

A test model of the flexible foot support was constructed early in the design stages to check its reactions to applied loads. The prototype was made of SS 304 and contained four vertical plates as opposed to the fourteen Inconel 718 plates which comprise the actual structure. Due to the fact that the prototype was built before the design of the support was finalized, the plate dimensions are different from those of the actual proposed design (i.e. model plate thickness is approximately one-half that of the actual plates). See DWG. 3740.210-MC-222376 for assembly details of the test model and DWG. 3740.210-MB-222377 for plate dimensions.

This stanchion will be required to not only support the load of the inner vessel of the cryostat and its contents, but it must also allow for the movement of the vessel due to thermal contraction. Assuming that each vertical plate acts as a column, then the following formula from the Manual of Steel Construction (American Institute of Steel Construction, Inc., Eigth edition, 1980) can be applied to determine whether or not such columns undergoing simultaneous axial compression and transverse loading are considered safe for the given loading. The first term is representative of the axially compressive stress, and the second term, the bending stress. If the actual compressive stress is greater than 15% of the allowable compressive stress, then there are additional considerations which must be accounted for in the bending stress term.

(1) $(f_a/F_a)+(C_m f_b/((1-f_a/F_e)F_b)\leq 1.0$ (when $f_a/F_a>0.15$)

(2) $(f_a/F_a)+(f_b/F_b)\leq 1.0$ (when $f_a/F_a<0.15$)

f_a=P/A=average compressive stress
P=load per support per number of plates in support
A=area of plate
$F_a=(12\pi^2E)/(23(Kl/r)^2)$=allowable axial compressive stress
E=modulus of elasticity
K=effective length factor
l=length of plate
r=radius of gyration
C_m=constraint coefficient

$f_b = P/A + Mc/I$ = maximum bending stress

M = maximum moment

I/c = section modulus

$F_e = (12\pi^2 E)/(23(Kl/r)^2)$ = Euler stress divided by a factor of safety

$F_b = 0.75F_y$ = allowable bending stress

F_y = yield strength

A FORTRAN program written by K. Krempetz was used to determine that the load which could be applied to the above mentioned plates and still be considered safe would be a load of 900 lbs. Figuring in a safety factor of about 4, the plates would then be expected to fail in the vicinity of 3600 lbs.

TEST PROCEDURE

The test procedure for the flexible foot prototype can be found in Appendix 1. The procedure was followed at Fermilab by J. Hoffman, and the results for steps 2-10 were recorded (see Appendix 2). No permanent deformations were observed. However, in step 11, elastic buckling and/or failure could not be achieved at 3600 lbs or at any point thereafter given the available loading capacity of 22,000 lbs.

The flexible foot test assembly was then taken to an outside vendor (Midwest Manufacturing and Engineering Consultants, Inc., Bartlett, Il.) who proceeded to repeat the procedure and document the results (see Appendix 3). Again steps 2-10 were completed with no permanent deformations observed. The assembly was then loaded as requested in step 11, and the load was increased up to the capacity of the press, which was 66,000 lbs, without any apparent signs of failure. However, after being released from this load, there was a permanent deflection noted between the plate ends of 0.034". The assembly was then transferred to a press of larger capacity and re-loaded. Buckling of the plates on one side was observed to have occurred at a load of 107,900 lbs (26,975 lbs/plate).

ANALYSIS OF RESULTS

Upon utilizing the formulas previously mentioned, it was necessary to choose the proper value of K, the effective length factor, which depends upon the end constraints of the column under consideration. It was originally assumed that the column behaves as one which is fixed at one end and guided at the other (case 1). The theoretical K value for this case is 1.0, and the design value is 1.2. If the column behaved as though it were fixed at both ends (case 2), then the theoretical K would be 0.5 and the design K, 0.65. Since the former case (case 1) generates more conservative figures (i.e. lower P_{cr}), its value was used in the design of the flexible foot support.

After measuring the load that caused the plates in the test assembly to buckle, the P_{cr} was calculated using each of the above mentioned values of K. The P_{cr} for case 1 was either 6,066 lbs/plate of 8,735 lbs/ plate, and that for case 2 was either 20,674 lbs/plate or 34,939 lbs/plate. Since the observed value of buckling (26,975 lbs/plate) was between the P_{cr} values of case 2, it is believed that case 2 proves to be a more accurate situation than case 1. Use of the case 1 values brought about a more conservative design, serving to increase the safety factor.

The values of the maximum stress in the plates in the scope of the critical loads were from 24,500 psi to 27,800 psi, lower than the yield strength of SS 304 (35,000 psi). It is therefore believed that the plates will fail due to buckling before they will fail due to the strength of the material.

The AISC code requires that the slenderness ratio, Kl/r, be less than 200. Test model case 2 values satisfy this requirement, but case 1 values do not. The design of the actual support, in both cases, has a slenderness ratio which is less than 200.

The measured values of load for given deflections taken from steps 2-4 were compared to the calculated load values for the same deflections for two beam cases: case 1 being a beam fixed at one end and free at the end being loaded and case 2 being a beam fixed at one end and guided at the loaded end. The plots of the deflection vs. measured load values fell betweeen the two plots of the deflection vs. calculated load values.

In order to understand why the load measured at the point of buckling was so much higher than expected, the FORTRAN program was run taking out all conservatism where possible. The ultimate strength of SS 304 was used, the less conservative design value of K (0.65) was used, and a calculated C_m value of 0.2 was used in place of the standard 0.85 value. Upon revising these constants, the combined stress factor (from formula 1) was found to be greater than or equal to 1.0 at a load of 104,000 lbs, which is in close proximity to the observed value of 107,900 lbs.

CONCLUSION

The results of the buckling test of the flexible foot assembly have helped to provide a more thorough and complete understanding of the behavior of the support when it is loaded. If the actual support made of Inconel 718 (see DWG. 3740.210-MC-222269) behaves in a similar manner to the test model, then there is a considerably large factor of safety present. If the load of the inner vessel of CC and its contents were to be evenly distributed across the fourteen plates of the support, a plate of average width (7.725") would experience a load of 12,185 lbs. Considering the predicted range of 230,564 lbs/plate to 389,653 lbs/plate for P_{cr}, a minimum safety factor of 19 would be present, which demonstrates the conservativeness of the actual design.

Appendix 1

3/2/87

Flexible Foot Test Procedure

1) Assemble Flexible Foot and Flexible Foot test base as shown on Drawing 3740.210-MC-222376.
2) Load the Enerpacs and measure the force (pressure on the cylinder) that is needed to move the plate ends apart from one another. Record at total distances of .125, .25, .375. and .5 inches.
3) Unload the Enerpacs and measure the plate ends to see if the plate ends returned to their original position.
4) Repeat steps (2) and (3) 3 times.
5) With the plates vertical (Enerpacs unloaded), apply a vertical force of 900 lbs with the large press.
6) Release the vertical load and examine the fixture for permanent deformations.
7) Repeat steps (5) and (6) 3 times.
8) Load the support with a vertical force of 900 lbs and then slowly load the Enerpacs to move the plate ends apart until .5 inches is between the plate ends.
9) Release the loads and examine the fixture for permanent deformations.
10) Repeat steps (8) and (9) 3 times.
11) Load the Enerpacs to achieve a deflection between the plate ends of .5 inches and load the vertical load until elastic buckling and/or failure of the support occurs. Record the results.

Note: The model has previously been loaded to 22,000 lbs with no visible damage noted. It is constructed of SS 304.

APPENDIX 2

Student's Name

Date 6-

Subject FLEXIBLE FOOT

Instructor's Name

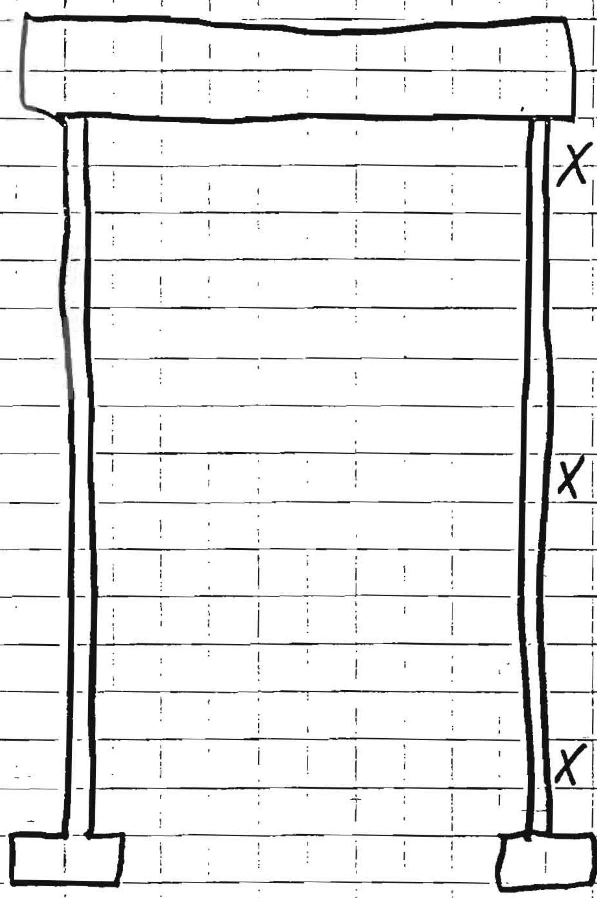
STEPS
2 + 3 + 4

	REQESTED	ACT.	LOAD ON CYLINDER
(A)	.125"	.124"	150 lbs
	.250"	.251"	275 lbs
	.375"	.377"	375 lbs
	.500"	.498"	475 lbs
(B)	.125"	.128"	150 lbs
	.250"	.256"	275 lbs
	.375"	.372"	350 lbs
	.500"	.498"	500 lbs
(C)	.125"	.126	150 lbs
	.250"	.257	275 lbs
	.375"	.376	400 lbs
	.500"	.501	475 lbs

Student's Name		Date	6-10-86
Subject	FLEXIBLE FOOT	Instructor's Name	

STEPS
5 + 6 + 7

all measurements made ~ 1" in



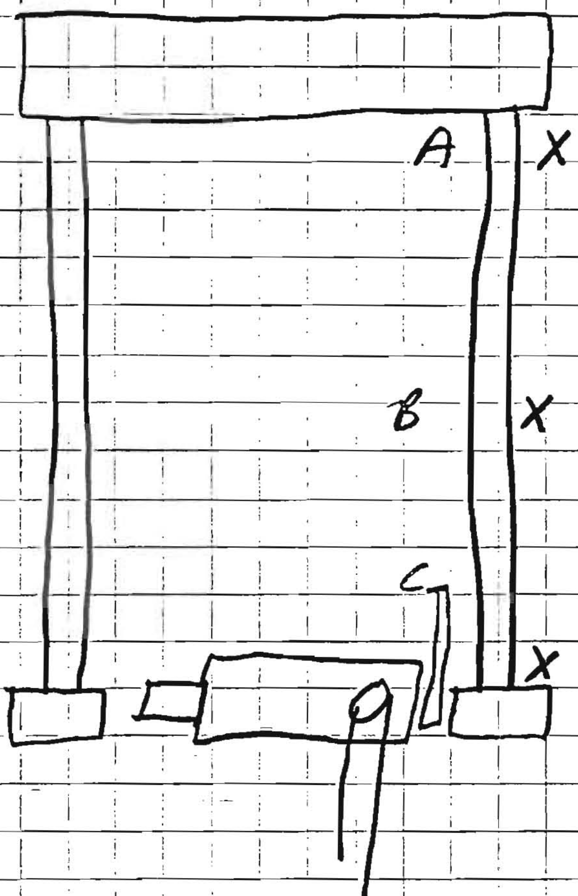
	①	②	③
INITIAL	5.794	5.773	5.77
AFTER LOADED	5.773	5.774	5.77
INITIAL	5.759	5.761	5.7
AFTER LOADED	5.761	5.757	5.7
INITIAL	5.736	5.735	5.73
AFTER LOADED	5.735	5.737	5.73

Student's Name | Date 6-10-87

Subject ELEXIBLE FOOT | Instructor's Name

Kurt 4657
P-509
6-10-86 N.A
3:00

steps 8+9+10 900 lb + .5" flex



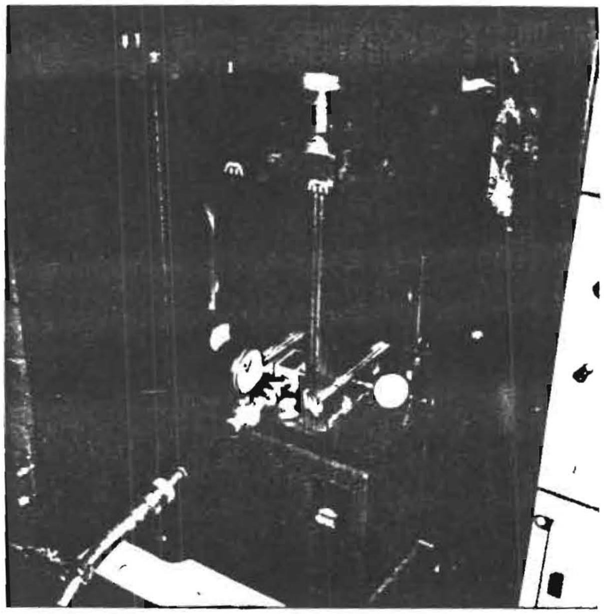
A	INITAL	5.772"	5.773"	5.773"
	AFTER	5.773"	5.773"	5.775"
B	INITAL	5.759"	5.763"	5.761"
	AFTER	5.763"	5.761"	5.766"
C	INITAL	5.731"		
	AFTER	5.743"	5.737"	
		5.729"	5.736"	5.734"

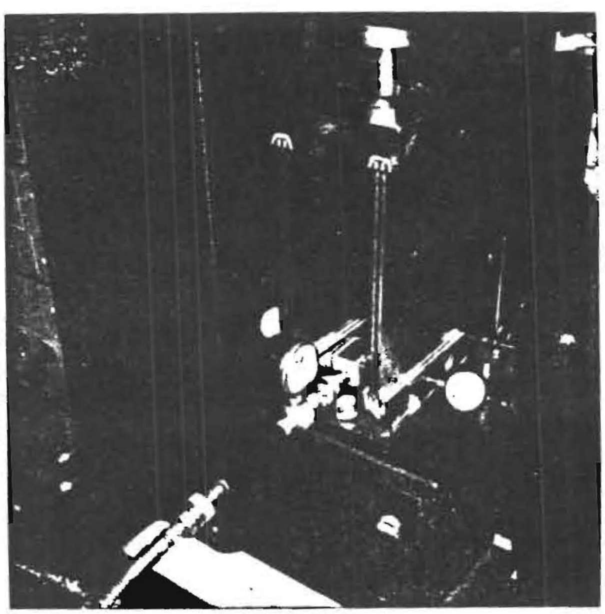
step 11

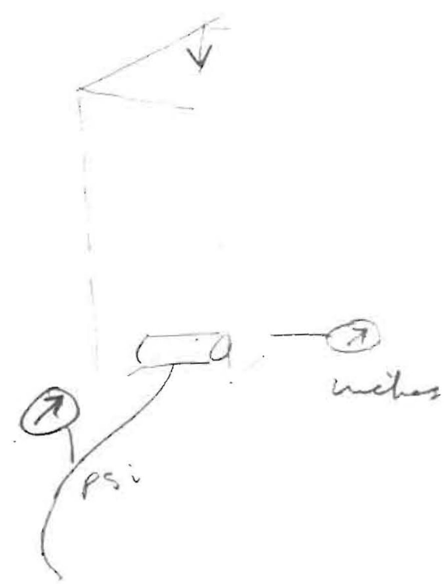
A 5.774"

B 5.769"

C 5.736"






inches
psi

APPENDIX 3

MIDWEST MATERIALS & ENGINEERING CONSULTANTS, INC.

Box 5
Wayne, IL 60184
312/741-1983

864 W. Stearns
Bartlett, IL
312/830-4979

BUCKLING TEST

CALORIMETER FLEXIBLE FOOT PROTOTYPE

Signed : Ralph C. Daehn
Ralph C. Daehn, P.E.
President

Beran Tari Black
Beran Tari Black
Metallurgical Engineer
Associate

Date: April 2, 1987

Buckling Test Report
on
Calorimeter Flexible Foot Prototype

Ref: Purchase Order # 928640

INTRODUCTION:

Midwest Materials Engineering & Consultants, INC., was requested by Mr. Kurt Krempetz and Ms. Caroline Kurita to perform a buckling test on a calorimeter flexible foot prototype. The subject flexible foot per drawing # 3740.210-MC-222376, was to be tested in accordance to the procedure provided by Fermi-Lab (See Appendix A).

OBJECTIVE:

To determine the structural strength of the prototype assembly.

PROCEDURE:

The test was conducted in accordance with the procedure outlined in Appendix A. This procedure involves four different testing sequences as follows:

Sequence 1 (steps 2-4) - loading of Enerpac and measuring force required to spread feet .125, .25, .375, and .5 inches apart.

Sequence 2 (steps 5-7) - applying vertical force of 900 lbs., using 60kip max. press, to assembly without Enerpac load.

Sequence 3 (steps 8-10) - applying vertical force of 900 lbs., using 60kip max. press, to assembly and then slowly applying load to Enerpac to spread feet .5 inches.

Sequence 4 (step 11) - loading the Enerpac to spread feet .5 inches and then increase vertical load until elastic buckling and/or failure of support occurs.

Each sequence was repeated four times, except for the fourth sequence requiring permanent, destructive results. In sequences 1 - 3, measurements were obtained before and after to determine if permanent deformation occurred. The return distance value is defined as the difference in feet spread before load and after release of load.

A 60kip hydraulic tension/compression tester was used in all four sequences of the test procedure. The final sequence was repeated with a 400kip machine in order to obtain desired results. The Enerpac and hydraulic pump were provided by Fermi-Lab. Linear measurements were made with a Mitutoyo Digimatic Caliper.

RESULTS:

Sequence 1 - The pressure, spread and return distances are listed in Table 1. Before and after measurements indicate that no permanent deformation occurred. The gage (6000psi scale) provided by Fermi-Lab was not sensitive enough to record the pressures required to spread the feet of the assembly. All readings did not even register above 0. Therefore, the measurements had to be taken using a more sensitive gage (2000psi scale).

Sequence 2 - No permanent deformation occurred shown by the identical before and after measurements (3.397 inch and 3.397 inch, respectively). Also, no visible deformation of the fixture was observed.

Sequence 3 - No permanent deformation occurred as the before and after measurements were the same. Again, no visible deformation of the fixture was observed.

Sequence 4 - Elastic buckling and/or failure could not be initially obtained using the 60kip press. However, a .034 inch permanent deformation of the feet spread was measured upon removal of the maximum 60kip load. Using the 400kip press, elastic buckling of the left side of the support occurred at 107,900 lbs, as shown by Photograph 1.

CONCLUSIONS:

It appears that under the first three testing sequences, no permanent deformation will occur.

Permanent deformation was not observed until a force of 60kip was applied to the assembly. This deformation was minimal, only .034 inches.

The assembly did not buckle until a force of 107,900 lbs (108 kips) was applied. Only one side of the fixture buckled. Both parallel plates of that side buckled inward, approximately .6 inches.

TABLE 1

Sequence 1 Test Results

	Spread (in.)	Return (in.)	Pressure (psi)*	(LBS)
SET 1	.128	.003	80	80.48
	.256	.0005	160	160.97
	.375	.0045	270	271.63
	.500	.004	370	372.63
SET 2	.130	-.0005	80	80.48
	.255	.0035	160	160.97
	.375	-.0005	260	261.57
	.501	.004	360	362.17
SET 3	.129	.0045	80	80.48
	.255	.0045	180	181.09
	.375	-.0055	270	271.63
	.500	.0045	360	362.17
SET 4	.126	.006	80	80.48
	.252	.004	180	181.09
	.375	.0045	270	271.63
	.501	.0045	370	372.23

Initial Reading: front - 3.397"
back - 3.417"
Final Reading : front - 3.397"
back - 3.417"

NOTE: The slight differences in return distances in SETS 1-4 are due to the friction experienced between the feet and the plate on which the assembly was resting. When the feet are nudged slightly there appears to be no deformation as indicated by the initial and final readings.

* HYDRAULIC JACK USED HAD A: 5TON CAPACITY
5/8" STROKE
.994 IN² EFFECTIVE AREA

PHOTOGRAPH 1

PHOTOGRAPH 1

Flexible foot assembly after 108kip vertical load and a feet spread of .5 inches. Only the left side of the support has buckled. Both plates of that side buckled inward, approximately .6 inches.

APPENDIX A

Flexible Foot Test Procedure

1) Assemble Flexible Foot and Flexible test base as shown on Drawing 3740.210-MC-222376.

2) Load the Enerpacs and measure the force (pressure on the cylinder) that is needed to move the plate ends apart from one another. Record at total distances of .125, .25, .375, and .5 inches.

3) Unload the Enerpacs and measure the plate ends returned to their original position.

4) Repeat steps (2) and (3) 3 times.

5) With the plates vertical (Enerpacs unloaded), apply a vertical force of 900 lbs with the large press.

6) Release the vertical load and examine the fixture for permanent deformations.

7) Repeat steps (5) and (6) 3 times.

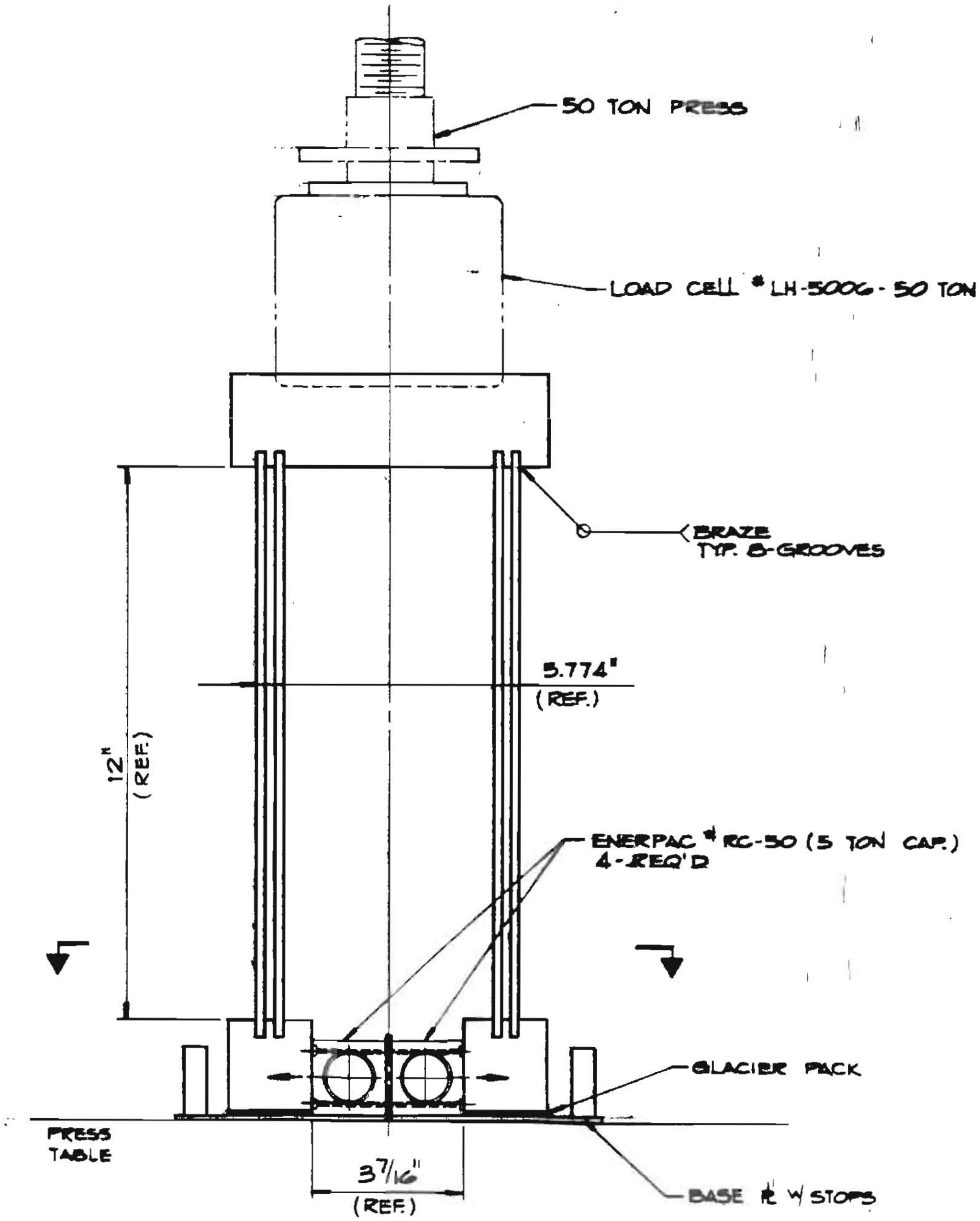
8) Load the support with a vertical force of 900 lbs and then slowly load the Enerpacs to move the plate ends apart until .5 inches is between the plate ends.

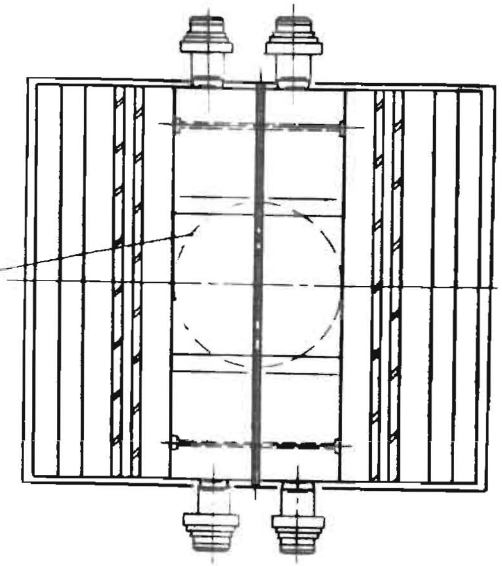
9) Release the loads and examine the fixture for permanent deformations.

10) Repeat steps (8) and (9) 3 times.

11) Load the Enerpacs to achieve a deflection between the plate ends of .5 inches and load the vertical load until elastic buckling and/or failure of the support occurs. Record the results.

Note: The model has previously been loaded to 22,000 lbs with no visible damage noted. It is constructed of SS 304.





SECTION

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
3	3740.210-MC-222378	HEADER - BOTTOM	2
2	3740.210-MC-222378	HEADER - TOP	1
1	3740.210-MB-222377	PLATE	4

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
FRACTIONS ± ~	DECIMALS ± ~	ANGLES ± ~	ORIGINATOR	K. Krempetz	11-5-85
			DRAWN	C. Reid	11-5-85
			CHECKED	[signature]	11-6-85
			APPROVED	[signature]	11-6-85

1. BREAK ALL SHARP EDGES 1/64 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD'S.
MAX. ALL MACHINED SURFACES

USED ON

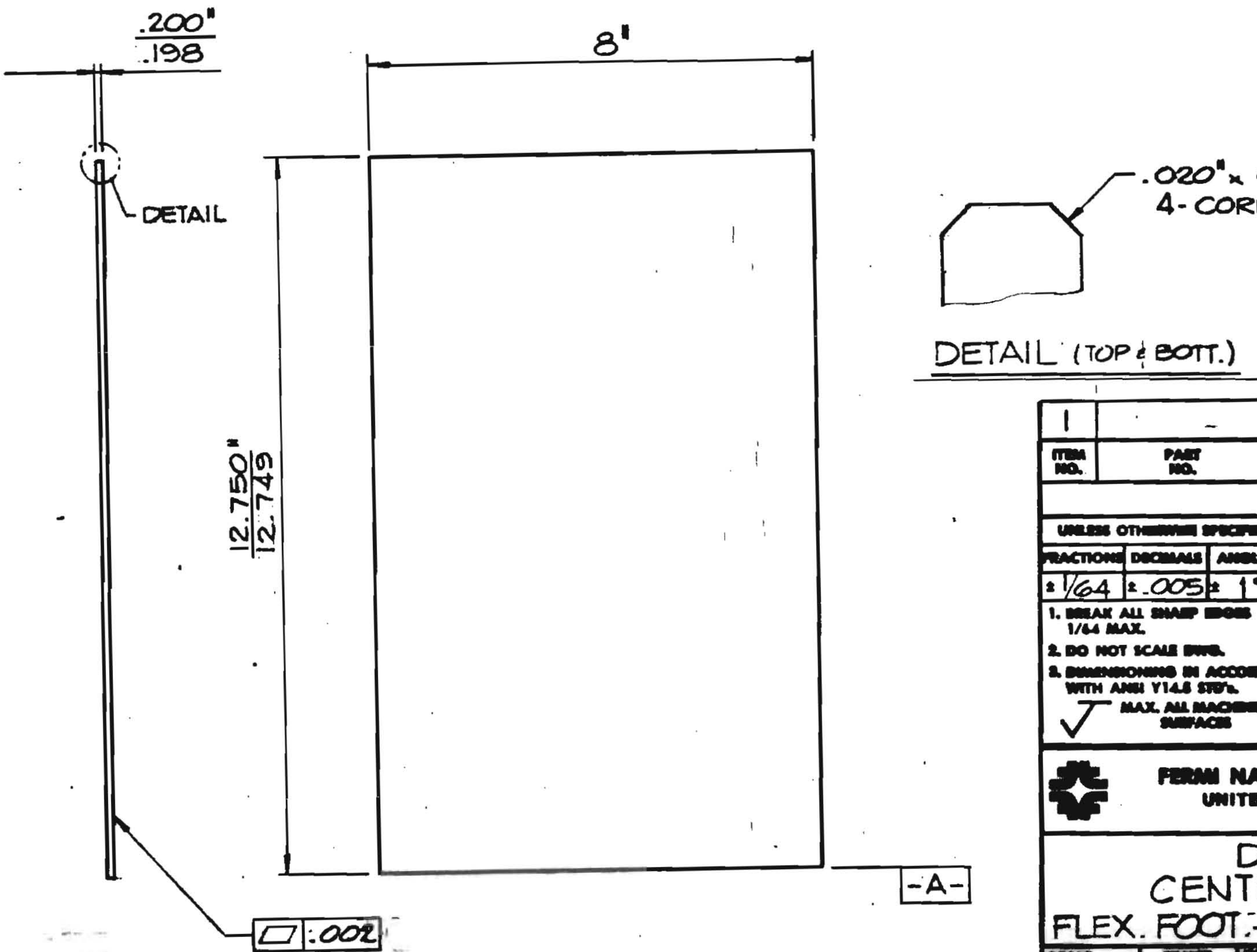
MATERIAL

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DØ DETECTOR
CENTRAL CALORIMETER
FLEX. FOOT - BUCKLING TEST - ASS'Y.

SCALE	FILMED	DRAWING NUMBER	REV.
1/2		3740.210-MC-222376	

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE



ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
1	-	PLATE	5

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
FRACTIONS	DECIMALS	ANGLES	ORIGINATOR	K. Krempetz	10-4-85
± 1/64	± .005	± 1°	DRAWN	C. Reid	10-4-85
			CHECKED	[illegible]	11-6-85
			APPROVED	[illegible]	11-6-85

1. BREAK ALL SHARP EDGES 1/64 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD'S.

√ MAX. ALL MACHINED SURFACES

USED ON 3740.210-MC-222376

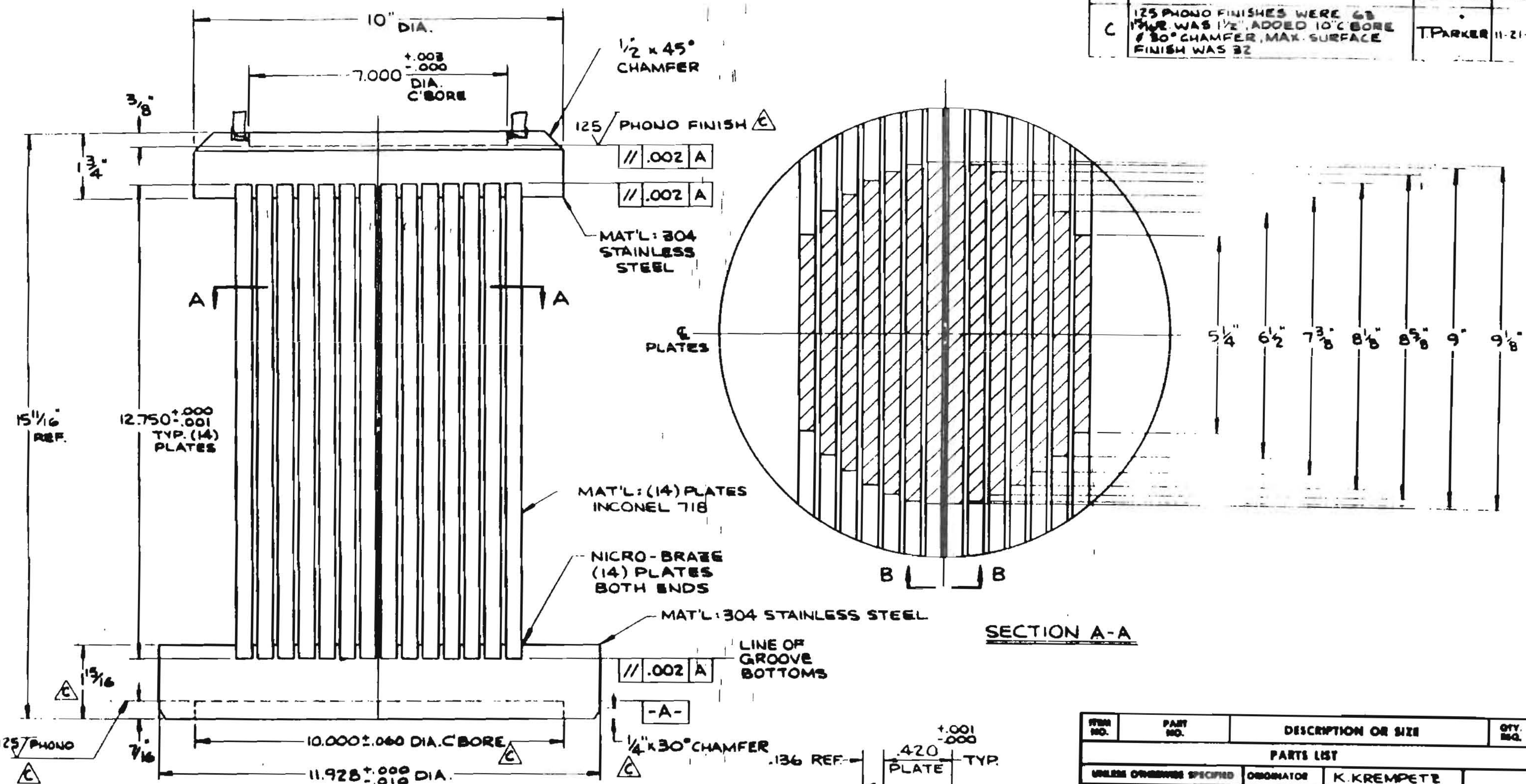
MATERIAL 304 ST. STEEL

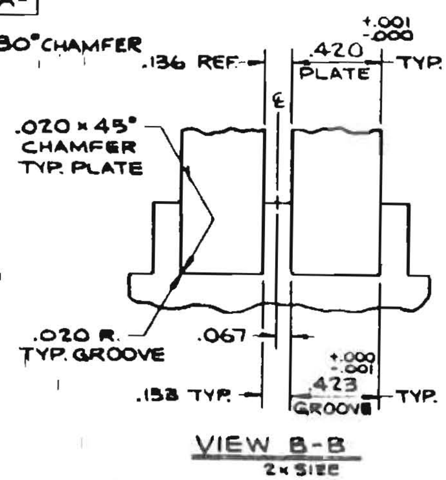
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DØ DETECTOR
CENTRAL CALORIMETER
FLEX. FOOT - BUCKLING TEST - PL DET.

SCALE	FILMED	DRAWING NUMBER	REV.
1/2		3740.210-MB-222377	

REV.	DESCRIPTION	DRAWN / APPD.	DATE
A	REDRAWN	C.REID	2-21-86
B	REDRAWN	J.BRANDT	9-16-86
C	125 PHONO FINISHES WERE 63. 1¾R. WAS 1½", ADDED 10" C'BORE & 30° CHAMFER, MAX. SURFACE FINISH WAS 32	T.PARKER	11-21-86





THE FOLLOWING TESTS SHALL BE PERFORMED AND DOCUMENTED FOR EACH FLEXIBLE SUPPORT ASSEMBLY:

1) WITH NO AXIAL LOAD ON THE ASSEMBLY AND WITH THE BOTTOM OF THE ASSEMBLY FIXED, THE TOP PLATE SHALL BE DEFLECTED .25"±.01" HORIZONTALLY IN A DIRECTION NORMAL TO THE VERTICAL PLATES. THE FORCE REQUIRED TO EFFECT THIS DEFLECTION SHALL BE RECORDED.
2) THE ASSEMBLY SHALL THEN BE LOADED AXIALLY WITH A MINIMUM FORCE OF 200,000 LB. AND THE TOP PLATE SHALL AGAIN BE DEFLECTED .25"±.01" AND THE REQUIRED FORCE RECORDED.
3) THE ASSEMBLY SHALL THEN BE VISUALLY EXAMINED FOR CRACKS, PERMANENT DISTORTIONS, AND BROKEN BRAZE JOINTS.

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
		PARTS LIST	

UNLESS OTHERWISE SPECIFIED: FRACTIONS ± 1/64; DECIMALS ± .005; ANGLES ± 1°
1. BREAK ALL SHARP EDGES 1/64 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD'S.
(C) 125 MAX. ALL MACHINED SURFACES

ORIGINATOR	K.KREMPETZ	
DRAWN	C.REID	2-21-86
CHECKED	R.O. [signature]	2-25-86
APPROVED	[signature]	11/25/86

USED ON: 3740.214-ME-223235

MATERIAL: AS NOTED

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DØ DETECTOR
CENTRAL CALORIMETER CRYOSTAT
FLEXIBLE SUPPORT ASSEMBLY

SCALE: ½ SIZE | DRAWING NUMBER: 3740.210-MC-222269 | REV. C

SS 304 PROTOTYPE
(VARYING LOADS)

XGAL =LGO

Note	LOAD	FORCE	MOMENT	COMPR	TOTAL
	1	215.887	27636.185	.667	27636.852
	1001	190.852	27098.375	667.333	27765.708
	2001	165.745	26551.390	1334.000	27885.390
	3001	140.564	25994.860	2000.667	27995.526
	4001	115.305	25428.392	2667.333	28095.725
	5001	89.965	24851.571	3334.000	28185.571
	6001	64.541	24263.955	4000.667	28264.621
	7001	39.029	23665.074	4667.333	28332.407
	8001	13.425	23054.430	5334.000	28388.430
	9001	-12.275	22431.492	6000.667	28432.159
	10001	-38.075	21795.696	6667.333	28463.029
	11001	-63.981	21146.437	7334.000	28480.437
	12001	-89.997	20483.071	8000.667	28483.738
	13001	-116.128	19804.911	8667.333	28472.245
	14001	-142.381	19111.220	9334.000	28445.220
	15001	-168.761	18401.206	10000.667	28401.873
	16001	-195.276	17674.024	10667.333	28341.358
	17001	-221.932	16928.763	11334.000	28262.763
	18001	-248.736	16164.442	12000.667	28165.109
K=0.65	19001	-275.698	15380.006	12667.333	28047.339
P_{cr}=20,674	20001	-302.826	14574.314	13334.000	27908.314
	21001	-330.129	13746.136	14000.667	27746.802
	22001	-357.619	12894.136	14667.333	27561.470
	23001	-385.306	12016.870	15334.000	27350.870
	24001	-413.202	11112.766	16000.667	27113.432
	25001	-441.322	10180.113	16667.333	26847.446
	26001	-469.679	9217.046	17334.000	26551.046
	27001	-498.290	8221.527	18000.667	26222.194
	28001	-527.172	7191.326	18667.333	25858.659
	29001	-556.344	6123.994	19334.000	25457.994
	30001	-585.827	5016.837	20000.667	25017.504
	31001	-615.644	3866.888	20667.333	24534.222
	32001	-645.821	2670.866	21334.000	24004.866
K=0.5	33001	-676.387	1425.134	22000.667	23425.801
P_{cr}=34,939	34001	-707.373	125.653	22667.333	22792.986
	35001	-738.813	1232.081	23334.000	24566.081
	36001	-770.748	2653.100	24000.667	26653.767
	37001	-803.222	4143.050	24667.333	28810.383
	38001	-836.283	5708.284	25334.000	31042.284
	39001	-869.989	7355.980	26000.667	33356.647
	40001	-904.403	9094.275	26667.333	35761.608
	41001	-939.597	10932.436	27334.000	38266.436
	42001	-975.654	12881.062	28000.667	40881.729
	43001	-1012.669	14952.332	28667.333	43619.665
	44001	-1050.752	17160.312	29334.000	46494.312
	45001	-1090.031	19521.339	30000.667	49522.005
	46001	-1130.655	22054.492	30667.333	52721.825
	47001	-1172.798	24782.204	31334.000	56116.204
	48001	-1216.669	27731.024	32000.667	59731.690
	49001	-1262.515	30932.614	32667.333	63599.947
	50001	-1310.633	34425.041	33334.000	67759.041
	51001	-1361.384	38254.487	34000.667	72255.154
	52001	-1415.210	42477.531	34667.333	77144.865
	53001	-1472.658	47164.257	35334.000	82498.257
	[illegible]	-1534.416	52403.535	36000.667	88403.202

57001	-1755.636	72718.746	38000.667	110719.413
58001	-1846.441	81675.150	38667.333	120342.484
59001	-1949.738	92230.504	39334.000	131564.504
60001	-2069.364	104875.972	40000.667	144876.639
61001	-2210.911	120327.241	40667.333	160994.575
62001	-2382.854	139669.371	41334.000	181003.371
63001	-2598.696	164630.418	42000.667	206631.085
64001	-2881.328	198140.597	42667.333	240807.931
65001	-3272.920	245597.785	43334.000	288931.785
66001	-3860.630	318158.017	44000.667	362158.684
67001	-4858.401	443206.057	44667.333	487873.390
68001	-6969.277	710731.512	45334.000	756065.512
69001	-14647.438	1690869.366	46000.667	1736870.033
70001	38830.350	5156954.091	46667.333	5203621.424
71001	6726.626	1050344.181	47334.000	1097678.181
72001	3134.103	593167.901	48000.667	641168.567
73001	1737.267	417039.459	48667.333	465706.792
74001	986.313	323584.094	49334.000	372918.094
75001	512.171	265560.615	50000.667	315561.281
76001	181.963	225960.620	50667.333	276627.954
77001	-63.881	197159.202	51334.000	248493.202
78001	-256.051	175228.194	52000.667	227228.861
79001	-411.964	157937.999	52667.333	210605.332
80001	-542.242	143929.042	53334.000	197263.042
81001	-653.731	132325.106	54000.667	186325.772
82001	-751.041	122536.043	54667.333	177203.376
83001	-837.392	114149.829	55334.000	169483.829
84001	-915.098	106870.060	56000.667	162870.726
85001	-985.869	100478.047	56667.333	157145.380
86001	-1050.993	94808.901	57334.000	152142.901
87001	-1111.459	89735.940	58000.667	147736.607
88001	-1168.040	85160.217	58667.333	143827.551
89001	-1221.349	81003.320	59334.000	140337.320
90001	-1271.878	77202.294	60000.667	137202.961
91001	-1320.026	73706.011	60667.333	134373.344
92001	-1366.121	70472.503	61334.000	131806.503
93001	-1410.435	67466.997	62000.667	129467.664
94001	-1453.195	64660.429	62667.333	127327.762
95001	-1494.591	62028.309	63334.000	125362.309
96001	-1534.788	59549.854	64000.667	123550.521
97001	-1573.922	57207.303	64667.333	121874.636
98001	-1612.114	54985.381	65334.000	120319.381
99001	-1649.467	52870.874	66000.667	118871.540

```
   STOP

    0.074 CP SECONDS EXECUTION TIME.
/ICE,LEGO
ICE 2.6.3
?? PW
      PROGRAM LEG(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7)
      INTEGER S
      REAL T,L,Y,E,K,K1,K2,S1,T1,S2,ST,W,M,S0
      T=.1875
      L=12.
      Y=.25
      B=8
      E=28300000.0
      WRITE(6,9)
      DO 1 S=1,100000,1000
      K=(12*S/(E*B*T**3))**.5
      K1=.5*K*L
      K2=TAN(K1)
```

```
      SO=6*M/(B*T**2)
      S1=ABS(SO)
      S2=S/(B*T)
      ST=S1+S2
 9    FORMAT(' LOAD         FORCE          MOMENT         COMPR         TOTAL')
      WRITE(6,10) S,W,S1,S2,ST
 10   FORMAT(I7,4F14.3)
  1   CONTINUE

      STOP
      END
?? ER
FILE: LEGO
REPLACED
/BYE
UN=93679     LOG OFF   12.13.00.
JSN=ACVA      SRU-S=        3.006
CHARACTERS=    33.173KCHS
IAF      CONNECT TIME 00.25.59.
LOGGED OUT.

XGAL =
```

SS 304 prototype

SS 304 PROTOTYPE (TO FIND FAILURE)

LENGHT=	LGO ~~SLENDERNESS RATIO=~~ LOAD =	COMBINE STRESS FACTOR=
12	1.000	.068
12	1001.000	.076
12	2001.000	.084
12	3001.000	.091
12	4001.000	.099
12	5001.000	.106
12	6001.000	.114
12	7001.000	.122
12	8001.000	.129
12	9001.000	.137
12	10001.000	.145
12	11001.000	.152
12	12001.000	.160
12	13001.000	.168
12	14001.000	.175
12	15001.000	.183
12	16001.000	.191
12	17001.000	.199
12	18001.000	.206
12	19001.000	.214
12	20001.000	.222
12	21001.000	.230
12	22001.000	.237
12	23001.000	.245
12	24001.000	.253
12	25001.000	.261
12	26001.000	.269
12	27001.000	.277
12	28001.000	.284
12	29001.000	.292
12	30001.000	.300
12	31001.000	.308
12	32001.000	.316
12	33001.000	.324
12	34001.000	.332
12	35001.000	.340
12	36001.000	.348
12	37001.000	.356
12	38001.000	.364
12	39001.000	.372
12	40001.000	.380
12	41001.000	.388
12	42001.000	.396
12	43001.000	.404
12	44001.000	.412
12	45001.000	.420
12	46001.000	.429
12	47001.000	.437
12	48001.000	.445
12	49001.000	.453
12	50001.000	.461
12	51001.000	.470
12	52001.000	.478
12	53001.000	.486
12	54001.000	.495
12	55001.000	.503
12	56001.000	.512
12	57001.000	.520

12	59001.000	[illegible]
12	60001.000	.546
12	61001.000	.554
12	62001.000	.563
12	63001.000	.572
12	64001.000	.580
12	65001.000	.589
12	66001.000	.598
12	67001.000	.607
12	68001.000	.616
12	69001.000	.625
12	70001.000	.634
12	71001.000	.643
12	72001.000	.652
12	73001.000	.661
12	74001.000	.670
12	75001.000	.680
12	76001.000	.689
12	77001.000	.698
12	78001.000	.708
12	79001.000	.717
12	80001.000	.727
12	81001.000	.737
12	82001.000	.747
12	83001.000	.757
12	84001.000	.767
12	85001.000	.777
12	86001.000	.787
12	87001.000	.798
12	88001.000	.808
12	89001.000	.819
12	90001.000	.829
12	91001.000	.840
12	92001.000	.852
12	93001.000	.863
12	94001.000	.874
12	95001.000	.886
12	96001.000	.898
12	97001.000	.910
12	98001.000	.922
12	99001.000	.934
12	100001.000	.947
12	101001.000	.960
12	102001.000	.974
12	103001.000	.987
12	104001.000	1.001
12	105001.000	1.016
12	106001.000	1.031
12	107001.000	1.046
12	108001.000	1.062
12	109001.000	1.078
12	110001.000	1.095
12	111001.000	1.113
12	112001.000	1.131
12	113001.000	1.151
12	114001.000	1.171
12	115001.000	1.192
12	116001.000	1.214
12	117001.000	1.238
12	118001.000	1.263
12	119001.000	1.289

STOP