Design of the Spherical Interfaces under the EC Cryostat Stanchions

Engineering Note # 3740.224-EN-282

Issued: February 14, 1991

Originator: Nicole Chlebos/Rick Luther

A handwritten signature in black ink, appearing to read "R. D. Luther", is written over the name "Rick Luther" in the originator line.

Determine the radii of the spherical interfaces between the stanchions and the cradles of the EC cryostats.

- The spherical interfaces are sized to ensure that the vertical centerline of the stanchion does not move laterally as the cradle deflects.

Appendix A contains the set-up and the readings of the deflection survey taken of the two cradles under designated loads. The radii were determined using the displacements contained in these surveys.

Side View of Pad on cradle

$$R \sin \alpha = d$$

$$R = \frac{d}{\sin \alpha}$$

R = radius

h = vertical displacement

d = horizontal displacement

α = angle of deflection

Top View of Pad

The dimensions of the pad are standard as shown in ME-223932-1

Appendix B contains calculations of the radii using 20 as the distance between points B and C on each pad. Data for cradle 2 was used.

$$\sin \alpha = \frac{h_B - h_C}{20}$$

$$R = \frac{d}{\sin \alpha} = \frac{d}{\left(\frac{h_B - h_C}{20} \right)}$$

The radii of pad 1 and pad 3 were averaged as were the radii of pad 2 and pad 4 due to the placement and weight distribution of the EC cryostat.

The Results were a 28" radius for pads 1 and 3 and a 22" radius for pads 2 and 4. These spherical interfaces were ordered at the end of July 1990.

The distances between points B and C for each pad were measured for each cradle.

For Cradle 1, the average distance was 17".
For Cradle 2, the average distance was 19".

Radii were recalculated in Appendix C using these measurements.

The radii for cradle 1 are scattered due to rigid body motion or torsion.

The radii for cradle 2 went down about an inch.

The 28" and 32" spherical interfaces were still ordered based on the previous data so that the process was not delayed.

An analysis of points A & B can not really be made for Pads 1+2 and Pads 3+4 due to the weight displacement of the EC crupstat. Pads 1 and 3 will always deflect more than Pads 2 and 4 because the weight on pads 1 and 3 is three times as much as pads 2 and 4.

Appendix D contains the test procedure ~~that is being~~
and design calculations for the test fixture.

Appendix E contains plots of various deflections of the arms as taken from the survey results in Appendix A.

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D-Ø CRADLE LOAD TEST @ LAB A Appendix A
CRADLE #1JD, RS
900307
BK 95-4

(A.1)

PLAN VIEW OF CRADLE ONLY

FRONT VIEW OF CRADLE WITH LOAD TESTER

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75-1

MARCH 13, 1970

CRADLE LOAD TEST @ LAB A

I guess we can't spell this

CRADLE 1

Appendix A

G. CROCHER

C. BRADFORD

(A2)

OVERHEAD VIEW

HORIZ. OBSERVATIONS - SPREAD

INSTR. #	PAD #	READING	PRESSURE OR LOAD	INSTR. #	PAD #	READING	PRESSURE OR LOAD
#2	4	0.590	0	#1	1	1.512"	0
"	3	0.581	"	#1	2	1.499"	0
"	3	0.563	2300	#1	1	1.482	2300
"	4	0.571	600	#1	2	1.501	600
"	3	0.560	4600	"	1	1.431	4600
"	4	0.530	1200	"	2	1.477	1200
"	3	0.572	7000	"	1	1.368	7000
"	4	0.592	1800	"	2	1.451	1800
"	3	0.610	0	"	1	1.492	0
"	4	0.601	0	"	2	1.493	0
"	3	0.572	7000	"	1	1.365	7000
"	4	0.598	1800	"	2	1.443	1800
"	3	0.611	0	"	1	1.487	0
"	4	0.604	0	"	2	1.491	0

Dr. C. B. BROWN
C. B. BROWN

U.S. OBSERVATIONS

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95-4

MARCH 13-90

DATE	TIME	B.S.	I.I.	F.S.	HEIGHT	CHANGE FROM 0	REMARKS
1	10:15 AM	12.256	112.256				100.000" ASSUMED
2	A	0		1.616	110.640		
	B	"		1.628	110.628	(.640)	
	C	"		1.617	110.639		
4	A	0		1.567	110.689		
	B	"		1.557	110.699		
	C	"		1.561	110.695		
2	A	0		1.525	110.729		
	B	"		1.523	110.733		
	C	"		1.530	110.726		
1	A	0		1.544	110.712		
	B	"		1.558	110.698		
	C	"		1.560	110.696		
1	A	2300		1.589	110.667		
	B	"		1.624	110.632		
	C	"		1.608	110.653		
2	A	600		1.540	110.716		
	B	"		1.514	110.742		
	C	"		1.518	110.738		
3	A	2300		1.686	110.570	.670	
	B	"		1.711	110.545		
	C	"		1.677	110.579		
4	A	600		1.598	110.658		
	B	"		1.581	110.675		
	C	"		1.577	110.679		

✓ DRB
3.13.90

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VERT. OBSERVATIONS CONT

BENCH MARK	PSIG	B.G.	W.I	F.G	HEIGHT	CHANGE FROM Q PSIG	REMARKS
			112.256				
#1 A	4600			1.682	110.574		
B	"			1.731	110.525		
C	"			1.676	110.580		
#2 A	1200			1.571	110.685		
B	"			1.533	110.723		
C	"			1.526	110.730		
#3 A	4600			1.689	110.567	.073	
B	"			1.721	110.535		
C	"			1.684	110.572		
#4 A	1200			1.608	110.648		
B	"			1.586	110.670		
C	"			1.579	110.677		
#1 A	7000			1.791	110.465		
B	"			1.853	110.403		
C	"			1.764	110.492		
#2 A	1800			1.604	110.652		
B	"			1.557	110.699		
C	"			1.536	110.720		
#3 A	7000			1.684	110.572	.068	
B	"			1.722	110.524		
C	"			1.687	110.569		
#4 A	1800			1.602	110.654		
B	"			1.576	110.680		
C	"			1.567	110.687		

✓ DRB
3.13.90

VERT. OBSERVATIONS CONT.

AS

BLK MARK	BIE	B.S	H.I	F.S.	HEIGHT	CHANGE FROM 0	REMARKS
			112.256				
#1 A	0			1.574	110.682		
B	"			1.592	110.664		
C	"			1.583	110.673		
#2 A	0			1.550	110.706		
B	"			1.536	110.720		
C	"			1.538	110.718		
#3 A	0			1.605	110.651		
B	"			1.616	110.640		
C	"			1.610	110.646		
#4 A	0			1.556	110.700		
B	"			1.547	110.709		
C	"			1.555	110.701		
#1 A	7000			1.795	110.461		
B	"			1.860	110.396		
C	"			1.769	110.487		
#2 A	1800			1.603	110.653		
B	"			1.554	110.702		
C	"			1.534	110.722		
#3 A	7006			1.690	110.566		
B	"			1.730	110.526		
C	"			1.692	110.564		
#4 A	1800			1.599	110.657		
B	"			1.576	110.680		
C	"			1.570	110.686		

✓DRB
3-13-90

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VEET. OBSERVATIONS CONT.

G. CATCHER

J. BRADFORD

BENCH MARK	PSIG	B.S.	HEIGHT I. 112.256.	F.S.	HEIGHT	CHANGE FROM 0	REMARKS
#1 A				1.580	110.676		
B				1.598	110.658		
C				1.590	110.666		
#2 A				1.548	110.708		
B				1.535	110.721		
C				1.538	110.718		
#3 A				1.604	110.652		
B				1.614	110.642		
C				1.608	110.648		
#4 A				1.554	110.702		
B				1.546	110.710		
C				1.555	110.701		
CLOSED				12.253	100.003		(100.000)

✓DRB
3-13-90

CONTINUE D-D CRADLE LOAD TEST

JN, KS

90030761

BK 95-4

A7

OVERLOAD TEST W/ PINNED EXT.

LOCATION	BS	HI	FS	HEIGHT	LOAD	DIFF FROM 0#
TBM	16.778					
NW			1.056"		0 #	
NE			1.020"		11	
SW			1.044"		11	
SE			1.031"		11	
NW			1.105"		2600 #	-.049"
NE			1.078"		2600 #	-.058"
SW			1.047"		670 #	-.003"
SE			1.031"		670 #	-.010"
NW			1.138"		5300 #	-.082"
NE			1.164"		5300 #	-.144"
SW			1.050"		1300 #	-.006"
SE			1.051"		1300 #	-.030"
NW			1.120"		8000 #	-.064"
NE			1.258"		8000 #	-.238"
SW			1.055"		2000 #	-.011"
SE			1.087"		2000 #	-.066"
NW			1.067"		0 #	-.011"
NE			1.065"		0 #	-.045"
SW			1.040"		0 #	+.004"
SE			1.027"		0 #	-.006"
NW			1.120"		8000 #	-.064"
NE			1.260"		8000 #	-.240"
SW			1.057"		2000 #	-.013"
SE			1.089"		2000 #	-.068"

✓ DRB
3-8-90

112 95-4
MAY 9 - 1990

DEFLECTION SURVEY OF CRADLE @ LAB "A" CRADLE 2

CRUTCHER
BRADFORD

(A)

HORIZ. DEFLECTION OBSERVATIONS

INSTR. #	PAD #	READING	LOAD P.S.I.	INSTR. #2	PAD #	READING	LOAD P.S.I.
#1	1	0.877	0	#2	3	0.566	0
#1	2	0.908	0	#2	4	0.555	0
"	1	0.830	2300	"	3	0.538	2300
"	2	0.875	600	"	4	0.542	600
"	1	0.825	2300	2	3	0.526	2300
"	2	0.870	600	2	4	0.541	600
1	1	0.798	4600	2	3	0.503	4600
1	2	0.862	1200	2	4	0.535	1200
1	1	0.774	7000	2	3	0.462	7000
1	2	0.848	1800	2	4	0.529	1800
1	1	0.874	Ø	2	3	0.547	Ø
1	2	0.899	Ø	2	4	0.553	Ø
1	1	0.782	7000	2	3	0.453	7000
1	2	0.849	1800	2	4	0.524	1800
1	1	0.871	Ø	2	3	0.547	Ø
1	2	0.902	Ø	2	4	0.556	Ø

CRESTONER
BRADFORD

95-4 113 (49)
MAY 9-1990

STA	+			H.I.	-			Corr	ELEV.	DES. ELEV.	REMARKS P.S.I.
	Stic	Set	Mic		Stic	Set	Mic				
T.B.M.	Ø	8.2	86	108.826						100.00 ASSUMED	
PAD #1 A					3	1.6	33	-	103.653		Ø
B					3	1.4	47		103.639		Ø
C					3	1.6	22		103.664		Ø
PAD #2 A					3	1.5	43		103.743		Ø
B					3	1.5	41		103.745		Ø
C					3	1.5	33		103.753		Ø
PAD #3 A					3	1.5	44		103.742		Ø
B					3	1.5	32		103.754		Ø
C					3	1.5	45		103.741		Ø
PAD #4 A					3	1.5	12		103.774		Ø
B					3	1.5	26		103.760		Ø
C					3	1.5	37		103.749		Ø
/ DRB 5-10-90											
PAD #1 A					3	1.7	30	-			2300
B					3	1.7	58	-			"
C					3	1.7	02	-			"
PAD #2 A					3	1.5	98	-			600
B					3	1.5	88	-			"
C					3	1.5	56	-			"
PAD #3 A					3	1.6	61	-			2300
B					3	1.6	01	-			"
C					3	1.5	99	-			"
PAD #4 A					3	1.5	46	-			600
B					3	1.5	54	-			"
C					3	1.5	50	-			"

VOID
W/ST
PSI
READING

A10

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STA	+			H. I.	-			Corr	Elev.	Des. Elev.	REMARKS P.S.I.
	Snc	Scl	Mic		Snc	Scl	Mic				
				108.286							
Pad #1 A					3	1.7	47	/	103.539		2300
B					3	1.7	77	/	103.509		"
C					3	1.7	15	/	103.571		"
Pad #2 A					3	1.6	04	/	103.682		600
B					3	1.5	88	/	103.698		"
C					3	1.5	55	/	103.731		"
Pad #3 A					3	1.6	14	/	103.672		2300
B					3	1.6	18	/	103.668		"
C					3	1.6	06	/	103.680		"
Pad #4 A					3	1.5	50	/	103.736		600
B					3	1.5	56	/	103.730		"
C					3	1.5	50	/	103.736		"
Pad #1 A					3	1.8	07	/	103.479		4600
B					3	1.8	51	/	103.435		"
C					3	1.7	66	/	103.520		"
Pad #2 A					3	1.6	20	/	103.666		1200
B					3	1.6	01	/	103.685		"
C					3	1.5	57	/	103.729		"
Pad #3 A					3	1.6	66	/	103.620		4600
B					3	1.6	81	/	103.605		"
C					3	1.6	52	/	103.634		"
Pad #4 A					3	1.5	70	/	103.716		1200
B					3	1.5	69	/	103.717		"
C					3	1.5	55	/	103.731		"
Pad #1 A					3	1.8	71	/	103.415		7000
B					3	1.9	32	/	103.354		"
C					3	1.8	25	/	103.461		"
Pad #2 A					3	1.6	33	/	103.653		1800
B					3	1.6	03	/	103.683		"
C					3	1.5	55	/	103.731		"
Pad #3 A					3	1.7	43	/	103.543		7000
B					3	1.7	74	/	103.512		"
C					3	1.7	20	/	103.566		"
Pad #4 A					3	1.5	96	/	103.690		1800
B					3	1.5	83	/	103.703		"
C					3	1.5	61	/	103.725		"

STA	+			H. I.	-			Cores	ELEV.	DES. ELEV.	REMARK P.S.T.
	Stn	Sec	Mic		Stn	Sec	Mic				
				108.286							
PAD#1	A				3	1.6	43	/	103.613		Ø
	B				3	1.6	58	/	103.628		"
	C				3	1.6	32	/	103.654		"
PAD#2	A				3	1.5	45	/	103.741		"
	B				3	1.5	42	/	103.744		"
	C				3	1.5	33	/	103.753		"
PAD#3	A				3	1.5	66	/	103.720		"
	B				3	1.5	57	/	103.729		"
	C				3	1.5	62	/	103.724		"
PAD#4	A				3	1.5	11	/	103.775		"
	B				3	1.5	23	/	103.763		"
	C				3	1.5	33	/	103.753		"
PAD#1	A				3	1.8	57	/	103.429		7000
	B				3	1.9	18	/	103.368		"
	C				3	1.8	15	/	103.471		"
PAD#2	A				3	1.6	32	/	103.654		1800
	B				3	1.6	01	/	103.685		"
	C				3	1.5	53	/	103.733		"
PAD#3	A				3	1.7	56	/	103.530		7000
	B				3	1.7	87	/	103.499		"
	C				3	1.7	29	/	103.557		"
PAD#4	A				3	1.6	02	/	103.684		1800
	B				3	1.5	89	/	103.697		"
	C				3	1.5	68	/	103.723		"
PAD#1	A				3	1.6	43	/	103.643		Ø
	B				3	1.6	59	/	103.627		"
	C				3	1.6	31	/	103.655		"
PAD#2	A				3	1.5	45	/	103.741		"
	B				3	1.5	41	/	103.745		"
	C				3	1.5	32	/	103.754		"
PAD#3	A				3	1.5	90	/	103.716		"
	B				3	1.5	60	/	103.726		"
	C				3	1.5	65	/	103.721		"
PAD#4	A				3	1.5	11	/	103.775		"
	B				3	1.5	23	/	103.763		"
	C				3	1.5	32	/	103.754		Ø
CLOSE ON T.B.M.					Ø	8.2	85		100.001	(100.000)	✓ DRB 5-10-90

BK # 95-4
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CRADLE LOAD TEST @ LAB "A"

GC/AC
5/2/90

MARCH 13, 1990

OVERLOAD TEST @ PINNED EXT. CRADLE 2

HORIZ. OBSERVATIONS - SPREAD

INST #	PAD #	READING	LOAD (PST)	INST #	PAD #	READING	LOAD (PST)
* 2	4	0.549	0.0	* 1	1	0.929	0.0
* 2	3	0.549	"	* 1	2	0.929	"
* 2	4	0.544	670	* 1	1	0.858	2600
* 2	3	0.543	2600	* 1	2	0.882	670
* 2	4	0.559	1300	* 1	1	0.774	5300
2	3	0.563	5300	1	2	0.851	1300
* 2	4	0.564	2000	* 1	1	0.705	8000
2	3	0.578	8000	1	2	0.824	2000
* 2	4	0.558	0.0	* 1	1	0.874	0.0
2	3	0.570	"	* 1	2	0.902	0.0

STATION	BS +			H.I.	FS -			CORR	ELEV. HEIGHT	Design	Remark
	STK	SCALE	mic		STK	SCALE	mic				
TBM RANDOM	-	6.0	13	106.013						100.000	
PAD #3 A)					3.0	1.6	76		101.337	.156	0.0
B)					"	1.6	58		101.355		
C)					"	1.6	62		101.351		
#4 A)					3.0	1.6	21		101.392		
B)					"	1.6	36		101.377		
C)					"	1.6	45		101.368		0.0
#2 A)					3.0	1.6	19		101.394		
B)					"	1.6	24		101.389		
C)					"	1.6	25		101.388		
#1 A)					3.0	1.6	49		101.364	.102	0.0
B)					"	1.6	43		101.370		
C)					"	1.6	48		101.365		
TBM					0.0	6.0	15	-	99.998	100.000	200.002
PAD #1 A)					3.0	1.7	84		101.229		
B)					3.0	1.7	99		101.214		2600
C)					"	1.7	56		101.257		
PAD #2 A)					3.0	1.6	93		101.320		670
B)					"	1.6	93		101.320		
C)					"	1.6	63		101.350		
#3 A)					3.0	1.7	01		101.312		
B)					"	1.6	95		101.318		2600
C)					"	1.6	89		101.324		
#4 A)					3.0	1.6	44		101.369		
B)					"	1.6	59		101.354		670
C)					"	1.6	54		101.359		
TBM					-	6.0	13		100.00		
PAD #1 A)					3.0	1.9	54		101.059		
B)					"	1.9	97		101.016		5300
C)					"	1.9	00		101.113		
#2 A)					3.0	1.7	40		101.273		
B)					"	1.7	20		101.293		
C)					"	1.6	75		101.338		1300
#3 A)					3.0	1.6	78		101.335		
B)					"	1.6	82		101.331		5300
C)					"	1.6	85		101.328		
#4 A)					3.0	1.6	38		101.375		
B)					"	1.6	46		101.367		1300
C)					"	1.6	41		101.372		
TBM					-	6.0	13		100.00		

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STATION				HI				CORR	ELEV HEIGHT	Design	REMARK
	STK	SCALE	MIC		STK	SCALE	MIC				
TBM											
PAD #1 A)					3.0	2.0	83		100.930		
B)					"	2.1	49		100.864		8000
C					"	2.0	10		101.003		
#2 A					3.0	1.7	78		101.235		2000
B					"	1.7	48		101.265		
C					"	1.6	88		101.325		
#3 A					3.0	1.6	68		101.345		
B					"	1.6	78		101.335		8000
C					"	1.6	82		101.331		
#4 A					3.0	1.6	50		101.363		
B					"	1.6	58		101.355		2000
C					"	1.6	49		101.364		
TBM					-	6.0	13		120.000	100.000	
PAD #1 A					3.0	1.7	58		101.255		
B					"	1.7	72		101.241		0.0
C					"	1.7	44		101.269		
#2 A					3.0	1.6	60		101.353		
B					"	1.6	58		101.355		
C					"	1.6	46		101.367		0.0
#3 A					3.0	1.6	46		101.367		
B					"	1.6	32		101.381		
C					"	1.6	48		101.365		
#4 A					3.0	1.6	08		101.405		
B					"	1.6	24		101.389		0.0
C					"	1.6	36		101.377		
TBM					-	6.0	14		99.999	100.000	EOC.000

OK
07-11-11

Radii (in inches)

Load	Pad 1	Pad 3	Average
0	0	0	0
2300	28.1081241	32.0000083	30.054
4600	26.3333728	30.0000221	28.167
7000	25.1220216	31.0448342	28.083
Use 28"			
Load	Pad 2	Pad 4	Average
0	0	0	0
600	30.4000079	16.4705882	23.435
1200	25.5555694	16	20.778
1800	30.000002	15.7575758	22.878
Use 22"			

Appendix B

B-1

Angle (in radians)

LOAD	Pad 1	Pad 3	Average
0	0	0	0
2300	.00185	.00125	.00155
4600	.00300	.0021	.00255
7000	.00410	.00335	.003725
LOAD	Pad 2	Pad 4	Average
0	0	0	0
600	.00125	.00085	.00105
1200	.00180	.00125	.001525
1800	.00200	.00165	.001825

PAD 1

	A	B	C	D	E	F
1	Load psi	Vert Disp. B	Vert Disp. C	Sine of Angle	Horz Disp.	Radius
2	0	0	0	0	0	#DIV/0!
3	2300	0.13	0.093	0.00185	0.052	28.1081241
4	4600	0.204	0.144	0.003	0.079	26.3333728
5	7000	0.285	0.203	0.0041	0.103	25.1220216
6	PAD 2					
7	Load psi	Vert Disp. B	Vert Disp. C	Sine of Angle	Horz Disp.	Radius
8	0	0	0	0	0	#DIV/0!
9	600	0.047	0.022	0.00125	0.038	30.4000079
10	1200	0.06	0.024	0.0018	0.046	25.5555694
11	1800	0.062	0.022	0.002	0.06	30.00002
12	PAD 3					
13	Load psi	Vert Disp. B	Vert Disp. C	Sine of Angle	Horz Disp.	Radius
14	0	0	0	0	0	#DIV/0!
15	2300	0.086	0.061	0.00125	0.04	32.0000083
16	4600	0.149	0.107	0.0021	0.063	30.0000221
17	7000	0.242	0.175	0.00334999	0.104	31.0448342
18	PAD 4					
19	Load psi	Vert Disp. B	Vert Disp. C	Sine of Angle	Horz Disp.	Radius
20	0	0	0	0	0	#DIV/0!
21	600	0.03	0.013	0.00085	0.014	16.4705882
22	1200	0.043	0.018	0.00125	0.02	16
23	1800	0.057	0.024	0.00165	0.026	15.7575758

$\text{Vert Disp.} = \frac{\text{Vertical Reading at Load } \phi - \text{Reading at Load Given}}{\phi - \text{Reading at given Load}}$
 $\text{Horz Disp} = \text{Horz Reading at Load } \phi - \text{Reading at given Load}$
 $\text{Angle} = (\text{Vert. Disp. B} - \text{Vert. Disp C}) / 2\phi^*$
 $\text{Sine of Angle} = \text{Angle (when angle is in radians)}$
 $\text{Radius} = \text{Horz. Disp.} / \text{Sine of Angle}$

* 20 is the given length of the pad from ME-223932-1

PAD1

	G	Angle	Load
1	Angle (in rad)	(in deg)	
2	0	0	0
3	0.00185	.105997	2300
4	0.003	.1718868	4600
5	0.00409999	.2349113	7000
6	PAD 2		
7	Angle (in rad)		
8	0	0	0
9	0.00125	.0716196	600
10	0.0018	.1031322	1200
11	0.002	.1145914	1800
12	PAD 3		
13	Angle (in rad)		
14	0	0	0
15	0.00125	.0716196	2300
16	0.0021	.1203209	4600
17	0.00335	.1919401	7000
18	PAD 4		
19	Angle (in rad)		
20	0	0	0
21	0.00085	.0487014	600
22	0.00125	.0716196	1200
23	0.00165	.0945379	1800

Cradle 2

Pts A and B

(B5)

PAD 1

	A	B	C	D	E
1	Load psi	Vert Disp. A	Vert Disp. B	Angle (rad)	Horz Disp.
2	0	0	0	0	0
3	2300	0.114	0.13	0.00114286	0.052
4	4600	0.174	0.204	0.00214286	0.079
5	7000	0.238	0.285	0.00335714	0.103
6	PAD 2				
7	Load psi	Vert Disp. A	Vert Disp. B	Angle (rad)	Horz Disp.
8	0	0	0	0	0
9	600	0.061	0.047	0.001	0.038
10	1200	0.077	0.06	0.00121429	0.046
11	1800	0.09	0.062	0.002	0.06
12	PAD 3				
13	Load psi	Vert Disp. A	Vert Disp. B	Angle (rad)	Horz Disp.
14	0	0	0	0	0
15	2300	0.07	0.086	0.00114286	0.04
16	4600	0.122	0.149	0.00192857	0.063
17	7000	0.199	0.242	0.00307143	0.104
18	PAD 4				
19	Load psi	Vert Disp. A	Vert Disp. B	Horz Disp.	Angle (rad)
20	0	0	0	0	0
21	600	0.038	0.03	0.014	0.00057143
22	1200	0.058	0.043	0.02	0.00107143
23	1800	0.084	0.057	0.026	0.00192857

$$\text{Angle} = (\text{Vert Disp B} - \text{Vert. Disp. A}) / 14 *$$

*14 is the given width of the pad
from ME-223932-1

CRADLE 1

	A	B	C	D	E	F
1	LOAD	VERT DISP B	VERT DISP C	SIN OF ANGLE	HORZ DISP.	RADIUS
2						
3	Pad 1	Pad 1	Pad 1	Pad 1	Pad 1	Pad 1
4	0	0	0	0	0	#DIV/0!
5	2300	0.066	0.043	0.00135294	0.03	22.173913
6	4600	0.173	0.116	0.00335294	0.081	24.1578947
7	7000	0.295	0.204	0.00535294	0.144	26.9010989
8	Pad 2	Pad 2	Pad 2	Pad 2	Pad 2	Pad 2
9	0	0	0	0	0	#DIV/0!
10	600	-0.009	-0.012	0.00017647	-0.002	-11.333333
11	1200	0.01	-0.004	0.00082353	0.022	26.7142857
12	1800	0.034	0.006	0.00164706	0.048	29.1428571
13	Pad 3	Pad 3	Pad 3	Pad 3	Pad 3	Pad 3
14	0	0	0	0	0	#DIV/0!
15	2300	0.083	0.06	0.00135294	0.018	13.3043478
16	4600	0.093	0.067	0.00152941	0.021	13.7307692
17	7000	0.094	0.07	0.00141176	0.009	6.375
18	Pad 4	Pad 4	Pad 4	Pad 4	Pad 4	Pad 4
19	0	0	0	0	0	#DIV/0!
20	600	0.024	0.016	0.00047059	0.019	40.375
21	1200	0.029	0.018	0.00064706	0.01	15.4545455
22	1800	0.019	0.006	0.00076471	-0.002	-2.6153846

LOAD	PAD 1 Radius	Pad 3 Radius	Average Radius
0	0	0	0
2300	22.174	13.304	17.739
4600	24.158	13.731	18.9445
7000	26.901	6.375	16.638
LOAD	Pad 2 Radius	Pad 4 Radius	Average Radius
0	0	0	0
600	-11.333	40.375	14.521
1200	26.714	15.455	21.0845
1800	29.143	-2.615	13.264

	G	H	I	J	K	L
1	ANGLE	HORZ READING	VERT READ A	VERT READ B	VERT READ C	
2						
3	Pad 1	Pad 1	Pad 1	Pad 1	Pad 1	Pad 1
4	0	1.512	110.712	110.698	110.696	
5	0.00135294	1.482	110.667	110.632	110.653	
6	0.00335294	1.431	110.574	110.525	110.58	
7	0.00535294	1.368	110.465	110.403	110.492	
8	Pad 2	Pad 2	Pad 2	Pad 2	Pad 2	Pad 2
9	0	1.499	110.725	110.733	110.726	
10	0.00017647	1.501	110.716	110.742	110.738	
11	0.00082353	1.477	110.685	110.723	110.73	
12	0.00164706	1.451	110.652	110.699	110.72	
13	Pad 3	Pad 3	Pad 3	Pad 3	Pad 3	Pad 3
14	0	0.581	110.64	110.628	110.639	
15	0.00135294	0.563	110.57	110.545	110.579	
16	0.00152941	0.56	110.567	110.535	110.572	
17	0.00141176	0.572	110.572	110.534	110.569	
18	Pad 4	Pad 4	Pad 4	Pad 4	Pad 4	Pad 4
19	0	0.59	110.689	110.699	110.695	
20	0.00047059	0.571	110.658	110.675	110.679	
21	0.00064706	0.58	110.648	110.67	110.677	
22	0.00076471	0.592	110.654	110.68	110.689	

Load	Pad 1 Angle	Pad 3 Angle	Average Angle
0	0	0	0
2300	.001353	.001353	.001353
4600	.003353	.001329	.002441
7000	.005353	.001412	.003383
Load	Pad 2 Angle	Pad 4 Angle	Average Angle
0	0	0	0
600	.0001765	.0004706	.0003235
1200	.0008235	.0006471	.0007353
1800	.001647	.0007647	.0012058

	A	B	C	D	E	F
1	Load	Vert Disp.	Vert Disp.	Sine of Angle	Horz Disp.	Radius
2	0	0	0	0	0	#DIV/0!
3	2300	0.13	0.093	0.00194737	0.052	26.7027196
4	4600	0.204	0.144	0.00315789	0.079	25.0167082
5	7000	0.285	0.203	0.00431579	0.103	23.8659277
6						
7	Load	Vert Disp.	Vert Disp.	Sine of Angle	Horz Disp.	Radius
8	0	0	0	0	0	#DIV/0!
9	600	0.047	0.022	0.00131579	0.038	28.8800083
10	1200	0.06	0.024	0.00189474	0.046	24.2777923
11	1800	0.062	0.022	0.00210526	0.06	28.5000211
12						
13	Load	Vert Disp.	Vert Disp.	Sine of Angle	Horz Disp.	Radius
14	0	0	0	0	0	#DIV/0!
15	2300	0.086	0.061	0.00131579	0.04	30.4000088
16	4600	0.149	0.107	0.00221052	0.063	28.5000232
17	7000	0.242	0.175	0.00352631	0.104	29.4925984
18						
19	Load	Vert Disp.	Vert Disp.	Sine of Angle	Horz Disp.	Radius
20	0	0	0	0	0	#DIV/0!
21	600	0.03	0.013	0.00089474	0.014	15.6470609
22	1200	0.043	0.018	0.00131579	0.02	15.2000044
23	1800	0.057	0.024	0.00173684	0.026	14.9697045

Load	Pad 1 Radius	Pad 3 Radius	Average Radius
0	0	0	0
2300	26.703	30.400	28.551
4600	25.017	28.500	26.7585
7000	23.866	29.492	26.679
Load	Pad 2 Radius	Pad 4 Radius	Average Radius
0	0	0	0
600	28.880	15.647	22.2635
1200	24.278	15.200	19.739
1800	28.500	14.969	21.735

	G
1	Angle
2	0
3	0.00194737
4	0.00315789
5	0.00431578
6	
7	Angle (in rad)
8	0
9	0.00131579
10	0.00189474
11	0.00210526
12	
13	Angle (in rad)
14	0
15	0.00131579
16	0.00221053
17	0.00352632
18	
19	Angle (in rad)
20	0
21	0.00089474
22	0.00131579
23	0.00173684

Load

0
2300
4600
7000

Load

0
600
1200
1800

AVERAGE ANGLE
Pads 1+3
0
.00163
.00268
.00392
Pads 2+4
0
.00111
.00161
.00192

Procedure for Testing the Structural Adequacy of the EC Cryostat Carriage

1. Fit pinned extensions to the carriage.
 - 1.1 Check mating of bearing surfaces.
 - 1.2 Weld nuts (8) to carriage and fix extensions with bolts or studs.
2. Assemble test apparatus.
 - 2.1 Use shims as necessary to level carriage.
 - 2.2 Properly locate 12" diameter aluminum shims on upper plates of the carriage.
 - 2.3 Place jacks on top of shims.
 - 2.4 Lift lower beams and place on jacks.
 - 2.5 Place 11.5" spacers atop beam assembly.
 - 2.6 Lift upper beams and place on spacers.
 - 2.7 Place four vertical links for operating load test. Make sure 6" dia. shims are properly located.
jacks to top of upper beam assembly.
 - 2.8 Set up optical instruments and install rules for measuring deflections.

3. Operating Load Test (Ref. 3740.220-MD-279338)

- 3.1 Record initial arm positions.
- 3.2 Simultaneously pressurize 150 ton jacks to 2300 psig., pressurize 100 ton jacks to 600 psig. Visually inspect apparatus for excessive distortions, misalignments, etc.
- 3.3 Record all deflection information.
- 3.4 Slowly increase the pressure in the jacks and take readings at 4600 psig (150T), 1200 psig (100T), and 7000 psig (150T), 1800 psig (100T)
- 3.5 Reduce the pressure in all of the jacks to zero and record readings.
- 3.6 Repressurize and record readings at 4600 psig (150T), 1200
- 3.7 Reduce pressure to zero and record readings.
- 3.8 Remove all optical equipment.

4. Lift Load Test (Ref. 3740-MD-279312)

- 4.1 Place lift test links at outer points.
 - 4.2 Energize jacks and record pressure.
 - 4.3 Connect links to pinned extensions and assure that links are vertical.
 - 4.4 Slowly pressurize jacks to 2600 psig.(150T) and 670 psig. (100T), watching for signs of yielding, etc.
 - 4.5 Slowly increase pressure in jacks and take readings at 5300 psig. (150T), 1300 psig. (100T) and 8000 psig. (150T) , 2000 psig. (100T).
 - 4.6 Reduce pressure to zero
5. Disassemble apparatus and move pieces to long-term storage. Return equipment.
6. Remove pinned extensions and arrange for long-term storage.

7. Place carriage on heavy duty carts and roll outside for storage.

EC CARRIAGE TEST FIXTURE

EMPTY WT. OF VESSEL (MODULES + VESSELS):

191,550# (REAR)

31425# (FRONT)

LIFT TEST @ 125%:

240,000# REAR

40,000# FRONT

WEIGHT WITH ARGON:

220000# REAR

36000# FRONT

TRANSVERSE BEAMS

$$M_{max} = 240,000 (51.5) = 12,360,000$$

$$f_b = 23800 \quad (.66)(36ksi)$$

$$S_{REQ} = 519$$

$$S_{W36 \times 150} = 504$$

ADD PLATES ON TOP & BOTTOM

	A	y	Ay	Ad ²	I
① → 1/2" x 12"	6	36.6	219.6	1981.98	.125
② → W36 x 150	44.2	18.425	814.385	0	9040
③ → 1/2" x 12"	6	25	1.5	1981.90	.125
	56.2		1035.485	3963.96	9040.25

$$\bar{y} = 18.425$$

$$I = 13004.21$$

$$S = 706 \quad \text{ok}$$

SHEAR

$$F_V = .4(36) = 14.4 \text{ ksi}$$

$$A_{\min} = \frac{240,000}{14,400} = 16.7 \quad \text{ok}$$

WEB CRIPPLING

USE 12" Φ SHM

$$\frac{240,000}{.625(12 + 2(1.875))} = 24380 < 27,000 \quad (.75)(36)$$

LONGITUDINAL BEAMS

$$R_1 = \frac{36,000(72.125 - 13.0625) + 220,000(21.0625)}{72.125} = 93726 \text{ \#}$$

$$R_2 = \frac{36,000(13.0625) + 220,000(72.125 - 21.0625)}{72.125} = 162274 \text{ \#}$$

$$M_1 = 93726(13.0625) = 1224296$$

$$M_2 = 162274(21.0625) = 3417892$$

$$S_{W30x116} = 329 \quad \text{AREA} = 16.9$$

$$V_1 = \frac{1224296}{329} = 3721$$

$$V_2 = \frac{3417892}{329} = 10389$$

SHEAR

$$\frac{220,000}{16.9} = 13017.75$$

LONGITUDINAL BEAMS

$$S = 329$$

$$A = 16.9$$

$$R_1 = \frac{40,000(38.8125) + 240,000(45.8125)}{121.625} = 118294 \text{ #}$$

$$R_2 = \frac{40,000(36.8125) + 240,000(75.8125)}{121.625} = 161706 \text{ #}$$

$$M_1 = 118294(36.8125) = 4354698$$

$$M_2 = 161706(45.8125) = 7408156$$

$$V_1 = 13236$$

$$V_2 = 22517$$

$$f_b = 23800 = (.66)(36) \text{ ksi}$$

SHEAR

$$\frac{240000}{16.9} = 14201$$

$$F_v = .4(36) = 14.4 \text{ ksi}$$

VERTICAL MEMBERS

$$F_a = 21600$$

$$A > \frac{240,000}{\phi (21600)} = 5.56 \text{ in}^2$$

$$6 \times 6 \text{ BARS} \quad A = 36$$

$$V = \frac{240,000}{36} = 6667 \text{ ok}$$

$$M_{\max} = \frac{240,000 (24)}{4} = 1440000 \quad S = 36$$

$$V_b = \frac{1440000}{36} = 40,000$$

$$F_p = .75(50 \text{ ksi}) = 37,500$$

PLATE

$$F_y = 12000$$

$$F_v = 8000$$

$$F_p = 18000$$

$$F_a = 12000$$

SECTION A

$$\frac{P}{A} = \frac{240,000/2}{2 \times 5} = 12000$$

SECTION B

$$F_a = \frac{240,000/4}{2.5 \times 2} = 12000$$

SECTION C

$$F_v = \frac{240000/2}{14} = 8575$$

SECTION D

$$f_p = \frac{240,000/2}{2(b)} = 10,000$$

SECTION G PINNED EXTENSION

$$f_p = \frac{240,000/2}{2(3.25)} = 18461$$

SECTION J

$$f_a = \frac{240,000/2}{3(3)} = 13,333$$

SECTION E

$$e = 1.84375$$

$$f_a = \frac{240,000/2}{2(3)(1.84375)} = 10,847$$

SECTION F

$$f_v = \frac{240,000/(2)}{2(3)(3.5)} = 5715$$

PIN

$$A = \frac{240,000}{2 \left(\frac{\pi (3.25)}{4} \right)} = 47012$$

SUBJECT

NAME

R.D. Luther

14

DATE

2/13/91

REVISION DATE

Appendix E

This appendix presents plots of deflections of the arms for the various load tests as documented in App A. In all of the tests except the Operating Load Test on Carriage (or cradle) 2 it is clear that some amount of rigid body rotation has occurred. This is suspected to be the result of poor support of carriages during the tests. In particular, the carriages were supported by wood cribbing under the bottom plate.

SUBJECT

NAME

DATE

REVISION DATE

CRADLE 2Deflections of Pt. ALOAD TEST

	NW	NE	SW	SE
<u>LOAD</u>	<u>Pot #1</u>	<u>#3</u>	<u>#2</u>	<u>#4</u>
0	(.364) (.929)	(.1337) (.549)	(.1394) (.929)	(.1392) (.549)
2600/700	-.135 (.071)	-.025 (.006)	-.074 (.047)	-.023 (.005)
5300/1300	-.305 (.155)	-.002 (-.014)	-.121 (.078)	-.017 (-.010)
8000/2000	-.434 (.224)	+.008 (-.029)	-.159 (.105)	-.029 (-.015)
0	-.109 (.055)	+.030 (-.021)	-.041 (.027)	+.013 (-.009)

OP. LOAD TEST

<u>LOAD</u>	<u>#1</u>	<u>#3</u>	<u>#2</u>	<u>#4</u>
0	(.653) (.877)	(.742) (.566)	(.743) (.908)	(.774) (.555)
2300/600	-.114 (.052)	-.070 (.040)	-.061 (.038)	-.038 (.024)
4600/1200	-.174 (.079)	-.122 (.063)	-.077 (.046)	-.058 (.020)
7000/1800	-.238 (.103)	-.193 (.104)	-.090 (.060)	-.084 (.022)
0	-.010 (.063)	-.022 (.019)	-.002 (.009)	+.001 (.002)
7000/1800	-.224 (.055)	-.212 (.113)	-.089 (.059)	-.090 (.031)
0	-.010 (.006)	-.026 (.019)	-.002 (.006)	+.001 (+.001)

SUBJECT

NAME

DATE

REVISION DATE

GRADE 2.
OP. TEST
P.A.

CRADLE 2.
Points B & C

Carriage 2 Rear -

SUBJECT

NAME

DATE

REVISION DATE

CRADLE 2
LOAD TEST
Point A

SUBJECT

NAME

DATE

REVISION DATE

CRADLE 1 - D'LOAD TESTP.T.A ONLY

<u>LOAD</u>	<u>NW</u>	<u>NE</u>	<u>SW</u>	<u>SE</u>
2600/670	-.049	-.1058	-.003	-.010
5300/1300	-.082	-.144	-.006	-.030
8000/2000	-.064	-.1238	-.011	-.066
0	-.011	-.045	+0.004	-.006
8000/2000	-.064	-.1240	-.013	-.068

- D.P. LOAD TEST

	<u>#1</u>	<u>#3</u>	<u>#2</u>	<u>#4</u>
0	(.712) (.512)	(.640) (.581)	(.727) (.499)	(.689) (.590)
2300/600	-.045 (.030)	-.070 (.018)	-.011 (-.002)	-.031 (+.019)
4600/1200	-.138 (.081)	-.073 (.021)	-.042 (.022)	-.041 (+.010)
7000/1800	-.247 (.144)	-.068 (.009)	-.075 (.048)	-.035 (-.002)
0	-.030 (.020)	+0.011 (-.029)	-.021 (.006)	+0.011 (-.011)
7000/1800	-.125 (.147)	-.074 (.009)	-.074 (.051)	-.032 (-.008)
0	-.036 (.025)	+0.012 (-.030)	-.019 (.008)	+0.013 (-.014)

FERMILAB

ENGINEERING NOTE

SECTION

PROJECT

SERIAL-CATEGORY

PAGE

E-9

SUBJECT

NAME

DATE

REVISION DATE

GRADE 1
OP. TEST
Buit A

Cradle 1

Points B & C

Carriage 1 Rear -

FERMILAB

ENGINEERING NOTE

SECTION

PROJECT

SERIAL-CATEGORY

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.300 .600

NE

CRADLE 1
OLAD TEST
POINT A

.600 .300

NW

.060 .120

SE

.120 .060

SW

SUBJECT

NAME

DATE

REVISION DATE

CRADLE 1 - OPNG. TESTA+C
2

<u>LOAD</u>	<u>NW</u>	<u>NE</u>	<u>SW</u>	<u>SE</u>
0	(.704) (.512)	(.640) (.581)	(.727) (.499)	(.692) (.590)
2300/600	-.044 (.030)	-.066 (.018)	.000 (-.002)	-.024 (-.019)
4600/1200	-.127 (.081)	-.071 (.021)	-.020 (.022)	-.030 (.010)
7000/1800	-.225 (.144)	-.070 (.009)	-.041 (.048)	-.021 (-.002)
0	-.027 (.020)	+0.009 (-.029)	-.015 (-.006)	+0.008 (-.001)
7000/1800	-.230 (.147)	-.075 (.009)	-.040 (.051)	-.021 (-.008)
0	-.033 (.025)	+0.010 (-.030)	-.014 (.008)	-.009 (-.014)

A+B
2

	<u>#1</u>	<u>#3</u>	<u>#2</u>	<u>#4</u>
0	(.705)	(.634)	(.730)	(.694)
2300/600	-.086	-.076	-.001	-.028
4600/1200	-.156	-.083	-.026	-.035
7000/1800	-.271	-.081	-.055	-.027
0	-.032	+0.012	-.017	+0.011
7000/1800	-.277	-.089	-.053	-.026
0	-.038	-.013	-.016	+0.012