SENTINEL

TEST PLAN NO. 79

TEST PLAN COVER SHEET

TEST TITLE: ULTAFOAM COMPRESSION TEST	
PRODUCT MODEL: 650 AND 680	
ORIGINATED BY: S. Gemi	DATE: 8 OCT 98
TEST PLAN REVIEW	
ENGINEERING APPROVAL: S. Gemi	DATE: 8 OCT 98
QUALITY ASSURANCE APPROVAL: Nicholas J Massa	DATE: 9 Oct 98
REGULATORY APPROVAL: C. Rongen	DATE: 9 Oct 98
COMMENTS:	
TEST RESULTS REVIEW	
ENGINEERING APPROVAL:	DATE: 16 OCT 98
QUALITY ASSURANCE APPROVAL: Nicholas J Massa	DATE: 20 Oct 98
REGULATORY APPROVAL: C. Rongen	DATE: 22 Oct 98

Amersham QSA

PURPOSE

This test plan describes an experiment to determine the typical compression and energy absorption characteristics of the foam material used in the Sentinel radiography device and transport packages. The foam is Vultafoam, part number 16-L-708 and 16-L-720, manufactured by General Latex and Chemical Corp. The tests involve dropping a steel bar onto foam samples and measuring the depth of compression. Tests will be done at various temperatures.

MEASURING AND TEST EQUIPMENT

Required measuring and test equipment includes:

1. Steel bar and guide tube
2. Scale (calibrated)
3. Thermocouples and thermocouple reader (calibrated)
4. Ruler, one meter long, OR tape measure
5. Graduated cylinder (1 ml accuracy)
6. Caliper (0.001 inch accuracy)
7. Oven
8. Freezer or cooler with dry ice

TEST SPECIMEN PREPARATION

A total of 12 test specimens (identified in Table 1) are to be made using this test plan and work instruction WI-AS40. All the test specimens are to be contained in a ½ pint tin can. Test specimen foam mixtures are determined in Table 4 to simulate representative volumes of the model 650 and model 680 in the ½ pint cans.

Table 1. Foam Specimens

Set No.	Number of Specimens	Foam Part No.	Can Top Open or Closed
1	3	16-L-708	Open
2	3	16-L-708	Closed
3	3	16-L-720	Open
4	3	16-L-720	Closed

Can Preparation

1. Identify each can with its set number and specimen number 1 through 3.
2. For Sets 2 and 4, drill a small hole (about ½ inch diameter) in the top of the can lid.
3. Weigh each tin can and record the weight before adding the Vultafoam. Record the weight in attached foam compression test data sheets.
4. Measure the volume of a can without the top on and a can with the top on. Note: Based on previous observations the volume of a can without a top on is typically 257 ± 2 mL. Measure the volume by filling the can with water and measuring the water volume with the graduated cylinder. Record the volume for each can in the attached foam compression test data sheets.

Foam Component Density

Determine the density of Vultafoam components. For each component (16-L-708 and 16-L-1720) perform the following steps:

a) Weigh the graduated cylinder when empty and dry.

b) Fill the graduated cylinder with the component and record the volume in Table 2.

c) Weigh the cylinder to determine the weight of the component and record in Table 2.

d) Repeat this procedure for the other component.

e) Calculate the density of the component in Table 2

Foam Mass Required

Determine the mass of mixture used in the Vultafoam work instruction (WI-AS40-01) for Model 650 and 680 using Table 3.

Foam Mixture Required for Test Can

Determine the mass of mixture to use in the test sets by completing Table 4.

Test Set Preparation

1. For Test Set 1, mix Vultafoam components A and B in the volume ratio specified in the WI for the model 650 or 680 as appropriate. Record the volume of each component in test date sheet (mix enough foam to prepare the number of cans which can be foamed in about 3 minutes). Mix the Vultafoam parts using a pistol drill with a stirrer for approximately five seconds.
2. Place the test can on the scale and zero the scale. Pour the required mixture weight (as determined in Table 4) into the test can. Record the weight in the attached data sheets. Remove the can from the scale.
3. For test sets 2 and 4 place the lid on the can and tap edges with a rubber mallet to ensure the lid is tight.
4. Repeat steps 1 through 3 for the remaining test set cans.
5. After the foam has cured, remove the top of the can for Sets 2 and 4. For Sets 1 and 3, cut the top of the foam flush with the top of the can. Record the cure time in the attached data sheets.
6. Weigh each can and record value in the attached data sheets.
7. Calculate the effective density in the attached data sheets.
8. Cut approximately ¼" off the top and bottom of the can to obtain a level surface for the drop test.
9. Record the foam height of the test specimen.
10. Drill a small hole in the center of the side of the test can shell approximately 1 inch deep for the thermocouple.

TEST INSTRUCTIONS

Document completion of these test instructions on the attached data sheet.

Test Preparation:

1. Verify all measuring and test equipment is in calibration.
2. Fabricate and measure specimens as described above.
3. Insert the thermocouple into the foam approximately in the center of the can.
4. Place one of each type of specimen in oven set to a temperature of at least 100°F for at least one hour.
5. Place one of each type of specimen in a freezer set to –40°F or lower or in a cooler with dry ice for at least one hour.
6. Allow one of each type of specimen to remain at room temperature for testing.

7. Mount the guide tube over a clean, flat surface such that the tube is vertical (see Figure 2). Make sure the guide tube is mounted such that the drop height of the steel bar can be accurately measured and both ends of the tube will be unobstructed during the test (i.e., make sure that air can easily escape the tube as the bar is dropped).

Compression Test:

1. Position the steel bar in the guide tube and measure the drop height.
2. Record the temperature of the test specimen as it is removed from the oven/freezer.
3. Place the specimen on the test surface and secure in place. Immediately drop the bar onto the specimen.
4. Measure the depth of compression.
5. Record any observations regarding damage to the specimen.

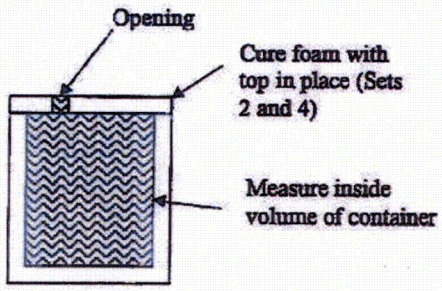

Figure 1. Foam Container

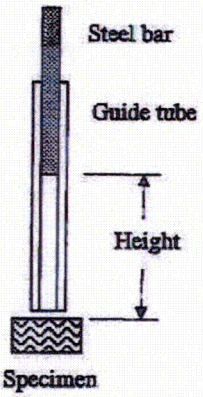

Figure 2. Test Set Up

Table 2. Vultafoam Component Density

Set No.	Part	Empty Cylinder Wgt. (A) (lbs)	Volume of Component (B) (mL)	Wgt of Cylinder w/Comp (C) (lbs)	Calculated Density (C-A)/(B/29.575) (lbs/oz)
16-L-1708	A				
	B				
16-L-1720	A				
	B				

Note: Volume conversion: 1 oz. = 29.575 ml

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Table 3. Vultafoam Mixture Weight Used in Model 650 and 680

Model	Foam Type	Part A			Part B			Total Mass of Mixture used in device ($m_A + m_B$)
		Vol_A * (oz)	ρ_A (From Table 2)	m_A $(Vol_A)(\rho_A)$	Vol_B * (oz)	ρ_B (From Table 2)	m_B $(Vol_B)(\rho_B)$	
650	16-L-708	24			30			
680	16-L-720	225			281			

* Volumes of A and B from WIAS40

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Table 4. Vultafoam Mixture Required for Test Cans

Test Sets	Foam Type	Total Mass of Mixture in Device (From Table 3) (A)	Volume Ratio Vol_{Can} / Vol_{Device} * (B)	Mass of Vultafoam Added to Test Can (lbs) (A*B)
1,2	16-L-708		0.057	
3,4	16-L-720		0.010	

* Based on scoping estimates (Attachment A and B)

Completed by: _____ Date: _____

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Foam Compression Test Data Sheet

Equipment

Description	Model/Serial Number(s)	Calibration Date(s)
Steel bar #1		N/A
Steel bar #2		N/A
Thermocouple/thermometer		
Scale #1		
Scale #2		
Height Gage		
Oven		N/A
Additional Equipment:		
Graduated Cylinder		N/A
Ruler/tape measure		N/A

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Foam Compression Test Data Sheet
- 16-L-708 (8 pcf Density) Foam
- Free Rise

Set 1 – Free Rise Specimens	Specimen 1-1	Specimen 1-2	Specimen 1-3
1. Can empty weight (lbs)			
2. Can volume (mL)			
3. Volume of Component A / B in mixture (ml)			
4. Weight of Vultafoam added to can (lbs)			
5. Cure time (min)			
6. Filled weight (lbs)			
7. Foam height, Pre-drop (in)			
8. Heating/cooling time (min)			
9. Specimen temperature (°F)			
10. Drop Bar Used			
11. Bar drop height (in)			
12. Foam height, Post-drop (in)			

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Foam Compression Test Data Sheet
- 16-L-708 (8 pcf density) Foam
- Contained Specimens

Set 2 – Contained Specimens	Specimen 2-1	Specimen 2-2	Specimen 2-3
13. Can empty weight (lbs)			
14. Can volume (mL)			
15. Volume of Component A / B in mixture (ml)			
16. Weight of Vultafoam added to can (lbs)			
17. Cure time (min)			
18. Filled weight (lbs)			
19. Foam height, Pre-drop (in)			
20. Heating/cooling time (min)			
21. Specimen temperature (°F)			
22. Drop Bar Used			
23. Bar drop height (in)			
24. Foam height, Post-drop (in)			

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Foam Compression Test Data Sheet
- **16-L-720 (20 pcf Density) Foam**
- **Free Rise**

Set 3 -- Free Rise Specimens	Specimen 3-1	Specimen 3-2	Specimen 3-3
25. Can empty weight (lbs)			
26. Can volume (mL)			
27. Volume of Component A / B in mixture (ml)			
28. Weight of Vultafoam added to can (lbs)			
29. Cure time (min)			
30. Filled weight (lbs)			
31. Foam height, Pre-drop (in)			
32. Heating/cooling time (min)			
33. Specimen temperature (°F)			
34. Drop Bar Used			
35. Bar drop height (in)			
36. Foam height, Post-drop (in)			

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Foam Compression Test Data Sheet
- 16-L-720 (20 pcf Density) Foam
- Contained Specimen

Set 4 – Contained Specimens	Specimen 4-1	Specimen 4-2	Specimen 4-3
37. Can empty weight (lbs)			
38. Can volume (mL)			
39. Volume of Component A / B in mixture (ml)			
40. Weight of Vultafoam added to can (lbs)			
41. Cure time (min)			
42. Filled weight (lbs)			
43. Foam height, Pre-drop (in)			
44. Heating/cooling time (min)			
45. Specimen temperature (°F)			
46. Drop Bar Used			
47. Bar drop height (in)			
48. Foam height, Post-drop (in)			

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VULTAFOAM IMPACT TEST RESULTS

PURPOSE

To document the results of impact testing conducted on Vultafoam 16-L-708 and 16-L-720 test specimens at AEA Technology.

SUMMARY

Vultafoam 16-L-708 and 16-L-720 specimens were produced in ½ pint (8 fluid ounce) cans to simulate the typical foam formed in Sentinel Model 650 and 680 radiography devices during manufacturing. The samples were then tested to determine the effects of temperature and foam density on the compression characteristics of the foam at various impact energies by dropping a 1-inch diameter steel bar from various heights. Test results are summarized below in Table 1 and detailed results are in Tables 2 through 5. Test data sheets and equipment calibration records can be found in Attachment A and Attachment B respectively.

Table 1. Test Summary

Set No.	Foam Part No.	Open / Closed	Specimen No.	Effective Density (lb/ft³)	Test Temp (F)	Drop Height (in)	Drop Energy (ft-lbs)	Foam Compression (in)	Foam Strain
1	16-L-708	Open	1	10.4	-54	48.75	17.875	.359	.134
			2	10.1	71	40.13	14.713	.374	.135
			3	10.2	105	40.13	14.713	.352	.132
2	16-L-708	Closed	1	12.7	-45	48.75	45.906	.864	.320
			2	13.0	70	40.18	14.733	.214	.083
			3	12.8	120	56.75	20.808	.189	.071
3	16-L-720	Open	1	24.3	-50	99.00	93.225	.321	.116
			2	24.1	70	67.63	63.685	.255	.090
			3	24.5	134	99.00	93.225	.262	.098
4	16-L-720	Closed	1	25.7	-63	99.13	93.347	.410	.152
			2	26.1	70	84.25	79.335	.296	.109
			3	28.7	117	99.00	93.225	.265	.097
5	16-L-708	Open	1	10.3	71	56.75	20.808	.466	.176
			2	10.3	71	48.88	46.029	1.060	.400
6	16-L-708	Closed	1	12.6	70	48.88	46.024	.856	.318
			2	12.7	71	56.75	53.440	.810	.299
7	16-L-720	Open	1	23.8	70	98.75	92.990	.349	.124
			2	24.8	70	98.88	93.112	.383	.136
8	16-L-720	Closed	1	28.8	70	99.00	93.225	.265	.097
			2	28.9	70	99.13	93.343	.289	.107

TEST DESCRIPTION

The impact testing discussed below was conducted in accordance with AEA Test Plan 79. Vultafoam test specimens were prepared in ½ pint tin cans to simulate representative volumes of the Sentinel Model 650 and 680 radiography devices. The amount of foam required in the test containers was determined experimentally. The foam for the specimens was then mixed following the guidelines in AEA Work Instruction WI-AS40. After the samples were allowed to cure, they were either cooled in dry ice, left at room temperature, or heated in an oven for approximately one hour. The test specimens were then impacted with 1-inch diameter steel bars (either 4.4 lb or 11.3 lb) and the depth of foam compression was measured. The method of determining the foam required in the test containers, the preparation of the test specimens, the impact test method, and the test equipment are described below.

Determination of Foam Required in Test Containers

The amount of Vultafoam required in the test container to simulate representative volumes of the Sentinel Model 650 and 680 was determined experimentally. First, the densities of the Vultafoam parts (A and B) for each foam type (708 and 720) were determined by weighing a known volume of each foam part. The foam density was then multiplied by the volume called for in the foam work instruction and the ratio of the device volume to the test container volume to determine the mass of Vultafoam required in each test container. These calculations are included in the test data sheets (Attachment B). The calculation to determine the volume ratio of each device to the test container is included in Attachment C.

Preparation of Test Specimens

A total of 20 foam test specimens were prepared in ½ pint tin cans. Twelve foam specimens were prepared as specified in the test plan. Four additional test sets, with two specimens each, were also produced and left at room temperature to provide additional data points. The tops of test cans for test sets 1, 3, 5, and 7 were left open. The lids for test sets 2, 4, 6, and 8 were drilled with a small hole (Figure 1) and placed on the cans after the foam was poured. This was intended to be representative of the opening used to fill the actual devices.

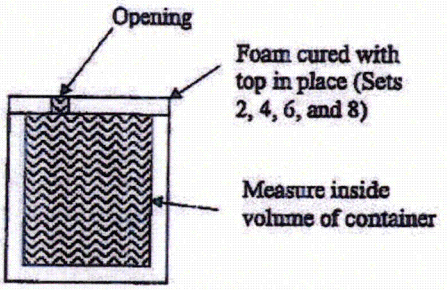

Figure 1. Test Container

The empty volume and weight of the test specimens were determined before the foam was poured so that the density of the foam could be determined after it cured. The volume of a can with the lid off and with the lid in place was verified by filling the can with water and measuring the volume of the water with a graduated cylinder. Each can was then weighed and the data was recorded in the test plan data sheets.

The foam was mixed and poured in accordance with AEA Work Instruction WI-AS40. Batches of the foam mixture were prepared in a sufficient quantity to fill two or three specimens at a time. After the samples were allowed to cure for at least 2 hours, the overflow foam was trimmed and the lids on the contained test cans were removed. The test specimens were then weighed to determine effective density of the foam. The foam density calculations are provided in Attachment D. The top and bottom of the test specimen can was then trimmed with the lathe

to provide a flat and level impact surface and a thermocouple hole was drilled in the side of the can. Foam height for each test specimen was then recorded. Finally, the test specimens were either cooled in dry ice, left at room temperature, or heated in an oven.

Impact Test Method

To test the compression characteristics of the foam, a 1-inch diameter steel impact bar was dropped from various heights. A guide tube was used to ensure the bar impacted the foam squarely (Figure 2). The foam specimens were placed on a solid steel impact surface and clamped horizontally in place to ensure the samples would not move sideways during impact.

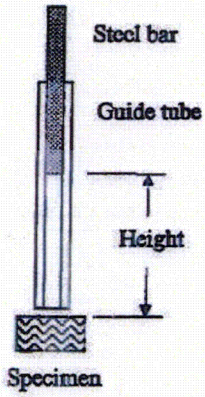

Figure 2. Test Set Up

TEST RESULTS

Detailed test results are shown in Tables 2 through 5. Observations for each test are described in the notes of the Table 2. Note, for the majority of 20 PCF specimens the steel bar was observed rebounding after the initial impact.

Table 2. Test Details 16-L-708 (8 PCF) Free Rise Specimens

	Specimen number									
	1-1		1-2		1-3		5-1		5-2	
Container empty weight (lbs)	0.108		0.099		0.098		0.098		0.108	
Container volume (mL)	258		258		258		258		258	
Mixture Volume A & B (mL)	133	150	133	150	133	150	133	150	133	150
Mixture Weight A & B (lbs)	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354
Vultafoam added to Can - Weight (lbs)	0.230		0.242		0.226		0.230		0.170	
Cure time (min)	175		175		175		135		135	
Filled Weight (excess removed) (lbs)	0.203		0.191		0.191		0.192		0.202	
Effective density (lbs/ft^3)	10.4		10.1		10.2		10.3		10.3	
Specimen temperature (F)	-54		71		105		71		71	
Vultafoam height, pre-drop (in)	2.683		2.763		2.697		2.642		2.647	
Bar weight (lbs)	4.4		4.4		4.4		4.4		11.3	
Bar drop height (in)	48.75		40.13		40.13		56.75		48.88	
Bar area (in2)	0.75		0.75		0.75		0.75		0.79	
Vultafoam height, post-drop (in)	2.324		2.389		2.315		2.176		1.587	
Calculated compression (in)	0.359		0.374		0.352		0.466		1.060	
Strain	0.134		0.135		0.132		0.176		0.400	
Kinetic Energy at Impact (ft-lbs)	17.875		14.713		14.713		20.808		45.029	
Observations (See Notes)	1		1		1		1		1	

1 - Steel bar did not bounce at impact
2 - Steel bar bounced < 1/8" above foam surface
3 - Steel bar bounced < 1/2" above foam surface
4 - Radial Crack in Foam from Impact
5 - Steel bar impacted foam at small angle <5 deg
6 - Steel bar impacted foam at small angle <10 deg
7 - Rebound impression in Foam

Table 3. Test Details 16-L-708 (8 PCF) Contained Specimens

	Specimen number									
	2-1		2-2		2-3		6-1		6-2	
Container empty weight (lbs)	0.109		0.109		0.109		0.099		0.098	
Container volume (mL)	257		257		257		257		257	
Mixture Volume A & B (mL)	141	159	141	159	141	159	134	150	134	150
Mixture Weight A & B (lbs)	0.375	0.375	0.375	0.375	0.375	0.375	0.356	0.356	0.356	0.356
Vultafoam added to Can - Weight (lbs)	0.220		0.224		0.220		0.252		0.226	
Cure time (min)	160		160		160		155		155	
Filled Weight (excess removed) (lbs)	0.224		0.227		0.225		0.213		0.213	
Effective density (lbs/ft^3)	12.7		13.0		12.8		12.6		12.7	
Specimen temperature (F)	-45		70		120		70		71	
Vultafoam height, pre-drop (in)	2.700		2.582		2.667		2.694		2.706	
Bar weight (lbs)	11.3		4.4		4.4		11.3		11.3	
Bar drop height (in)	48.75		40.18		56.75		48.88		56.75	
Bar area (in2)	0.79		0.75		0.75		0.79		0.79	
Vultafoam height, post-drop (in)	1.836		2.368		2.478		1.838		1.896	
Calculated compression (in)	0.864		0.214		0.189		0.856		0.810	
Strain	0.320		0.083		0.071		0.318		0.299	
Kinetic Energy at Impact (ft-lbs)	45.906		14.733		20.808		46.024		53.440	
Observations (See Notes)	1,4		2		2		1		1	

Table 4. Test Details 16-L-720 (20 PCF) Free Rise Specimens

	Specimen number									
	3-1		3-2		3-3		7-1		7-2	
Container empty weight (lbs)	0.108		0.109		0.098		0.098		0.098	
Container volume (mL)	258		258		258		258		258	
Mixture Volume A & B (mL)	219	249	219	249	219	249	189	214	189	214
Mixture Weight A & B (lbs)	0.580	0.580	0.580	0.580	0.580	0.580	0.500	0.500	0.500	0.500
Vultafoam added to Can - Weight (lbs)	0.372		0.372		0.346		0.374		0.370	
Cure time (min)	140		140		140		135		135	
Filled Weight (excess removed) (lbs)	0.329		0.329		0.321		0.315		0.324	
Effective density (lbs/ft^3)	24.3		24.1		24.5		23.8		24.8	
Specimen temperature (F)	-50		70		134		70		70	
Vultafoam height, pre-drop (in)	2.76		2.831		2.678		2.812		2.813	
Bar weight (lbs)	11.3		11.3		11.3		11.3		11.3	
Bar drop height (in)	99.00		67.63		99.00		98.75		98.88	
Bar area (in2)	0.79		0.79		0.79		0.79		0.79	
Vultafoam height, post-drop (in)	2.439		2.576		2.416		2.463		2.430	
Calculated compression (in)	0.321		0.255		0.262		0.349		0.383	
Strain	0.116		0.090		0.098		0.124		0.136	
Kinetic Energy at Impact (ft-lbs)	93.225		63.685		93.225		92.990		93.112	
Observations (See Notes)	1,4		2		2,6		3,4		1	

Table 5. Test Details 16-L-720 (20 PCF) Contained Specimens

	Specimen number									
	4-1		4-2		4-3		8-1		8-2	
Container empty weight (lbs)	0.098		0.099		0.099		0.098		0.098	
Container volume (mL)	257		257		257		257		257	
Mixture Volume A & B (mL)	227	258	227	258	227	258	189	215	189	215
Mixture Weight A & B (lbs)	0.601	0.601	0.601	0.601	0.601	0.601	0.501	0.501	0.501	0.501
Vultafoam added to Can - Weight (lbs)	0.376		0.376		0.372		0.376		0.376	
Cure time (min)	130		130		130		125		125	
Filled Weight (excess removed) (lbs)	0.331		0.336		0.359		0.359		0.360	
Effective density (lbs/ft^3)	25.7		26.1		28.7		28.8		28.9	
Specimen temperature (F)	-63		70		117		70		70	
Vultafoam height, pre-drop (in)	2.706		2.708		2.725		2.719		2.709	
Bar weight (lbs)	11.3		11.3		11.3		11.3		11.3	
Bar drop height (in)	99.13		84.25		99.00		99.00		99.13	
Bar area (in2)	0.79		0.79		0.79		0.79		0.79	
Vultafoam height, post-drop (in)	2.296		2.412		2.460		2.454		2.420	
Calculated compression (in)	0.410		0.296		0.265		0.265		0.289	
Strain	0.152		0.109		0.097		0.097		0.107	
Kinetic Energy at Impact (ft-lbs)	93.347		79.335		93.225		93.225		93.343	
Observations (See Notes)	1,4		3,5		2,6		3,5,7		3,5	

ATTACHMENT A – TEST DATA SHEETS

Table 2. Vultafoam Component Density

Set No.	Part	Empty Cylinder Wgt. (A) (lbs) #S1	Volume of Component (B) (mL)	Wgt of Cylinder w/Comp (C) (lbs) #S1	Calculated Density (C-A)/(B/29.575) (lbs/oz)
16-L-1708	A	.2768	50	.4094	.0784
	B	.2739	50	.3922	.0700
16-L-1720	A	.2771	50	.4093	.0782
	B	.2756	50	.3922	.0690

T= 69.9 F
USING ~~G-S-12~~ G-G-11

Note: Volume conversion: 1 oz. = 29.575 ml

Completed by: S. Gra Date: 15 OCT 98

witnessed ~~Check~~ by: Date: 15 OCT 98
15 OCT 98

CHECKED BY: 15 OCT 98

#S1 DENOTES SCALE USED WAS SCALE #1

#S2 DENOTES SCALE USED WAS SCALE #2

Foam Compression Test Data Sheet

Equipment

Description	Model/Serial Number(s)	Calibration Date(s)
Steel bar #1	T10236 / SN01	N/A
Steel bar #2	T10248 / SN01	N/A
Thermocouple/thermometer (T)	ENG-11 , ENG-12	SERVICED 8-OCT-98 DUE 8-OCT-99
Scale #1 (#S1)	8200 / SR87840011	SERVICED 8-MAY-98 DUE 8-NOV-98
Scale #2 (High Precision) (#S2)	500C / 834468	SERVICED 8-MAY-98 DUE 8-NOV-98
Height Gage (HG)	MITUTOYO / 027	SERVICED 8-JUN-98 DUE 8-JUN-99
Oven	THERMOLYNE 1300	N/A
Additional Equipment:		
Graduated Cylinder (GC)	PYREX 100 ML	N/A
Ruler/tape measure (TM)		N/A

Completed by: S. Gu Date: 15 OCT 98

Check by: MBBgd Date: 15 Oct 98

Foam Compression Test Data Sheet
- 16-L-708 (8 pcf Density) Foam
- Free Rise

	Set 1 – Free Rise Specimens	Specimen 1-1	Specimen 1-2	Specimen 1-3
(#S1)	1. Can empty weight (lbs)	.108	.099	.098
(GC)	2. Can volume (mL)	258	258	258
(1)	3. Volume of Component A/B in mixture (ml)	133/150 (.354/.354 LBS)	→	→
(#S2)	4. Weight of Vultafoam added to can (lbs)	.230	.242	.226
	5. Cure time (min)	175	175	175
(#S1)	6. Filled weight (lbs)	.203	.191	.191
(HG)	7. Foam height, Pre-drop (in)	2.683	2.763	2.667
	8. Heating/cooling time (min)	60	NA	60
(T)	9. Specimen temperature (°F)	-54	71	105
	10. Drop Bar Used	#1 (4 4 LBS)	#1	#1
(TH)	11. Bar drop height (in)	48.75	40.13	40.13
(HG)	12. Foam height, Post-drop (in)	2.324	2.389	2.315
	OBSERVATIONS	(2)	(2)	(2)

Completed by: S. Gra Date: 15 OCT 98

Check by: MBoyd Date: 15 Oct 98

NOTES:

(1) MEASURING SMALL QUANTITIES OF COMPONENTS BY VOLUME PROVED TO BE DIFFICULT AND INACCURATE DURING TRIAL RUNS. SINCE THE WORK INSTRUCTION ALLOWS MIXING COMPONENTS IN A 1:1 RATIO BY WEIGHT, THE COMPONENT VOLUMES WERE CALCULATED USING (COMPONENT WEIGHT MEASUREMENTS) AND DENSITY FACTORS FROM TABLE 2.

(2) DROP BAR DID NOT BOUNCE.

(3) DROP BAR BOUNCED LESS THAN 1/8 INCH.

(4) DROP BAR BOUNCED LESS THAN 1/2 INCH.

(5) RADIAL CRACKS PRODUCED BY IMPACT.

(6) IMPACT SURFACE AT LESS THAN 5° ANGLE.

(7) IMPACT SURFACE AT LESS THAN 10° ANGLE.

(#S1) USED SCALE #1

(#S2) USED SCALE #2

Foam Compression Test Data Sheet
- 16-L-708 (8 pcf density) Foam
- Contained Specimens

	Set 2 – Contained Specimens	Specimen 2-1	Specimen 2-2	Specimen 2-3
#S1	13. Can empty weight (lbs)	.109	.109	.109
GC	14. Can volume (mL)	257	257	257
1	15. Volume of Component A/B in mixture (ml)	141 / 159 (.375/.375 LBS)	→	→
#S2	16. Weight of Vultafoam added to can (lbs)	.220	.224	.220
	17. Cure time (min)	160	160	160
#S1	18. Filled weight (lbs)	.224	.227	.225
HG	19. Foam height, Pre-drop (in)	2.700	2.582	2.695
	20. Heating/cooling time (min)	60	NA	60
T	21. Specimen temperature (°F)	-45	70	120
	22. Drop Bar Used	#2 (11.3 LBS)	#1 (4.4 LBS)	#1
Tm	23. Bar drop height (in)	48.75	40.18	56.75
HG	24. Foam height, Post-drop (in)	1.836	2.368	2.478
	OBSERVATIONS	(2) (5)	(3)	(3)

Completed by: S. Gum Date: 15 OCT 98

Check by: MB Boyd Date: 15 Oct 98

Foam Compression Test Data Sheet
- 16-L-720 (20 pcf Density) Foam
- Free Rise

	Set 3 -- Free Rise Specimens	Specimen 3-1	Specimen 3-2	Specimen 3-3
(#S1)	25. Can empty weight (lbs)	.108	.109	.098
(GC)	26. Can volume (mL)	258	258	258
(I)	27. Volume of Component A/B in mixture (ml)	219 / 249 (.580 / .580 LBS)	→	→
(#S2)	28. Weight of Vultafoam added to can (lbs)	.372	.372	.346
	29. Cure time (min)	140	140	140
(#S)	30. Filled weight (lbs)	.329	.329	.321
(HG)	31. Foam height, Pre-drop (in)	2.760	2.831	2.678
	32. Heating/cooling time (min)	60	NA	60
(T)	33. Specimen temperature (°F)	-50	70	134
	34. Drop Bar Used	#2 (11.3 LBS)	#2	#2
(TM)	35. Bar drop height (in)	99.00	67.63	99.00
(HG)	36. Foam height, Post-drop (in)	2.439	2.576	2.416
	OBSERVATIONS	(2) (5)	(3)	(3) (7)

Completed by: S. Gen Date: 15 OCT 98

Check by: MBoyd Date: 15 Oct 98

Foam Compression Test Data Sheet
- 16-L-720 (20 pcf Density) Foam
- Contained Specimen

	Set 4 – Contained Specimens	Specimen 4-1	Specimen 4-2	Specimen 4-3
(#S1)	37. Can empty weight (lbs)	.098	.099	.099
(GC)	38. Can volume (mL)	257	257	257
(I)	39. Volume of Component A/B in mixture (ml)	227/258 (.600/.602 LBS)	→	→
(#S2)	40. Weight of Vultafoam added to can (lbs)	.376	.376	.372
	41. Cure time (min)	130	130	130
(#S1)	42. Filled weight (lbs)	.331	.336	.359
(HG)	43. Foam height, Pre-drop (in)	2.706	2.708	2.725
	44. Heating/cooling time (min)	60	NA	60
(T)	45. Specimen temperature (°F)	-63	70	117
	46. Drop Bar Used	#2 (11.3 LBS)	#2	#2
(Tm)	47. Bar drop height (in)	99.13	84.25	99.00
(HG)	48. Foam height, Post-drop (in)	2.296	2.412	2.460
	OBSERVATIONS	(2) (5)	(4) (6)	(4) (6)

Completed by: S. Gu Date: 15 OCT 98

Check by: MCBayol Date: 15 Oct 98

Foam Compression Test Data Sheet
- 16-L-708 (8 pcf Density) Foam
- Free Rise

	Set 1 – Free Rise Specimens	Specimen ~~1-1~~ S-1	Specimen ~~1-2~~ S-2	~~Specimen 1-3~~
(#S1)	1. Can empty weight (lbs)	.098	.108	
(VC)	2. Can volume (mL)	258	258	
(1)	3. Volume of Component A / B in mixture (ml)	133 / 150 (.354 / .354 LBS) →	→	→
(#S2)	4. Weight of Vultafoam added to can (lbs)	.230	.170	
	5. Cure time (min)	135	135	
(#S1)	6. Filled weight (lbs)	.192	.202	
(HG)	7. Foam height, Pre-drop (in)	2.642	2.647	
	8. Heating/cooling time (min)	NA	NA	
(T)	9. Specimen temperature (°F)	71	71	
	10. Drop Bar Used	#1 (4.4 LBS)	#2 (11.3 LBS)	
(TM)	11. Bar drop height (in)	56.75	48.88	
(HG)	12. Foam height, Post-drop (in)	2.176	1.587	
	OBSERVATIONS	(2)	(2)	

Completed by: S. Gr... Date: 15 Oct 98

Check by: MBB... Date: 15 Oct 98

Foam Compression Test Data Sheet
- 16-L-708 (8 pcf density) Foam
- Contained Specimens

	Set 2 – Contained Specimens	Specimen ~~2-1~~ 6-1	Specimen ~~2-2~~ 6-2	~~Specimen 2-3~~
(#S1)	13. Can empty weight (lbs)	.099	.098	
(GC)	14. Can volume (mL)	257	257	
(1)	15. Volume of Component A/B in mixture (ml)	134/150 → (.354/.358 lbs) →		
(#S2)	16. Weight of Vultafoam added to can (lbs)	.252	.226	
	17. Cure time (min)	155	155	
(#S1)	18. Filled weight (lbs)	.213	.213	
(HG)	19. Foam height, Pre-drop (in)	2.694	2.706	
	20. Heating/cooling time (min)	NA	NA	
(T)	21. Specimen temperature (°F)	70	71	
	22. Drop Bar Used	#2 (11.3 lbs)	#2	
(Tm)	23. Bar drop height (in)	48.88	56.75	
(HG)	24. Foam height, Post-drop (in)	1.838	1.896	
	OBSERVATIONS	(2)	(2)	

Completed by: S. Gu Date: 15 Oct 98

Check by: MR Boyd Date: 15 Oct 98

Foam Compression Test Data Sheet
- 16-L-720 (20 pcf Density) Foam
- Free Rise

	Set 3 – Free Rise Specimens	Specimen ~~3-1~~ 7-1	Specimen ~~3-2~~ 7-2	~~Specimen 3-3~~
#S1	25. Can empty weight (lbs)	.098	.098	
GC	26. Can volume (mL)	258	258	
I	27. Volume of Component A/B in mixture (ml)	189 / 214 → (.500 / .500 LBS) →		
#S2	28. Weight of Vultafoam added to can (lbs)	.374	.370	
	29. Cure time (min)	135	135	
#S1	30. Filled weight (lbs)	.315	.324	
HG	31. Foam height, Pre-drop (in)	2.812	2.813	
	32. Heating/cooling time (min)	NA	NA	
T	33. Specimen temperature (°F)	70	70	
	34. Drop Bar Used	#2 (11.3 LBS)	#2	
TM	35. Bar drop height (in)	98.75	98.88	
HG	36. Foam height, Post-drop (in)	2.463	2.430	

OBSERVATIONS (4) (5) (2)

Completed by: S. Gianni Date: 15 OCT 98

Check by: [signature] Date: 15 Oct 98

Foam Compression Test Data Sheet
- 16-L-720 (20 pcf Density) Foam
- Contained Specimen

	Set 4 – Contained Specimens	~~Specimen 4-1~~ 8-1	~~Specimen 4-2~~ 8-2	~~Specimen 4-3~~
(#S1)	37. Can empty weight (lbs)	.098	.098	
(GC)	38. Can volume (mL)	257	257	
(1)	39. Volume of Component A/B in mixture (ml)	189 / 215 → (.500 / .502 LBS) →		
(#S2)	40. Weight of Vultafoam added to can (lbs)	.376	.376	
	41. Cure time (min)	125	125	
(#S1)	42. Filled weight (lbs)	.359	.360	
(HG)	43. Foam height, Pre-drop (in)	2.719	2.709	
	44. Heating/cooling time (min)	NA	NA	
(T)	45. Specimen temperature (°F)	70	70	
	46. Drop Bar Used	#2 (11.3 LBS)	#2	
(TM)	47. Bar drop height (in)	99.00	99.13	
(HG)	48. Foam height, Post-drop (in)	2.454	2.420	
	OBSERVATIONS	(4) (6)	(4) (6)	

Completed by: S. Gramm Date: 15 OCT 98

Check by: M Bayol Date: 15 Oct 98

TEST PLAN #79
S. G. 15 OCT 98

VOLUME OF COMPONENT A/B IN MIXTURE (mL)

16-L-708 A (.4094 - .2768) = .1326 LBS. PER 50 mL
B (.3922 - .2739) = .1183 PER 50 mL

16-L-720 A (.4093 - .2771) = .1322 PER 50 mL
B (.3922 - .2756) = .1166 PER 50 mL

Specimen 1-1 → 1-3 Batch. (wgt_A = .354 LBS, wgt_B = .354 LBS) — 5-1 + 5-2 (wgt = .354 LBS)

16-L-708 A (.354 / .1326) * 50 = 133 mL — 133 mL
B (.354 / .1183) * 50 = 150 mL — 150 mL

Specimen 2-1 → 2-3 BATCH. (wgt_A = .375 LBS, wgt_B = .375 LBS) — 6-1 + 6-2 (wgt = .356 LBS)

16-L-708 A (.375 / .1326) * 50 = 141 mL — 134 mL
B (.375 / .1183) * 50 = 159 mL — 150 mL

Specimen 3-1 → 3-3 BATCH (wgt_A = .580 LBS, wgt_B = .580 LBS) — 7-1 + 7-2 (wgt = .500 LBS)

16-L-720 A (.580 / .1322) * 50 = 219 mL — 189 mL
B (.580 / .1166) * 50 = 249 mL — 214 mL

Specimen 4-1 → 4-3 BATCH (wgt_A = .601 LBS, wgt_B = .601 LBS) — 8-1 + 8-2 (wgt = .501 LBS)

16-L-720 A (.601 / .1322) * 50 = 227 mL — 189 mL
B (.601 / .1166) * 50 = 258 mL — ~~258 mL~~ 215 mL

SG 15 OCT 98

Effective Foam Density

Wgt of Foam = .203 − .108 = .095 LBS.

Vol of Can = 258 mL × 3.53×10^{-6} FT^3 = .00912 FT^3

1 mL = .0000353 FT^3

Density = .095 / .00912 = 10.43 LB/FT^3

ATTACHMENT B – EQUIPMENT CALIBRATION RECORDS

127 Riverneck Road
Chelmsford, MA 01824
Telephone: 978 - 459-9480
FAX # 978 - 453-6336
WEBSITE: http://www.tekserv.com

CALIBRATION REPORT

SERVICE NUMBER:	SN-0226212
CONTRACT NUMBER:	SENTINEL

A59848

AEA TECHNOLOGIES
40 NORTH AVENUE

BURLINGTON MA 01803

DATE RECEIVED	CUSTOMER P.O.	ASSET NUMBER
10/08/98	2887	ENG-11

MANUFACTURER	
OMEGA	
MODEL	**SERIAL NUMBER**
TYPE K	NONE
DESCRIPTION	
THERMOCOUPLE	

TEMP.	HUMIDITY	PRIOR CAL.	CAL. CYCLE	DATE OF TEST	NEXT TEST DUE
23.00°C	50.00%		12 MO	10/08/98	10/08/99

WORK REQUESTED	SERVICES RENDERED	REMARKS
CALIBRATE/CERTIFY	CALIBRATED/CERTIFIED	READINGS AS RECEIVED

PROCEDURE USED	N.I.S.T. TEST NUMBER	TECHNICIAN
MANUFACTURER'S	413348-433349-259071-LRAN	POULIN

CALIBRATION CHECKED TO: MANUFACTURER'S SPECIFICATIONS ADJUSTED TO: MANUFACTURER'S SPECIFICATIONS

MANUFACTURER	MODEL	SERIAL	ACCURACY	DATE CALIBRATED
BUILDLINE	9540	52-310	MFG.	2/24/98

TEKSERV CERTIFIES THAT ALL CALIBRATION EQUIPMENT USED IN THE TEST IS TRACEABLE TO N.I.S.T. AND THE TEST WAS PERFORMED IN ACCORDANCE WITH MIL-STD-45662A, ISO9002, ISO-10012-1, ANSI/NCSL-Z540-1-1994.

CERTIFIED BY

READINGS AS
RECEIVED

TEKSERV
CALIBRATION DATA

Manufacturer: OMEGA
Serial Number : —
Date of Test : 10-9-94
Technician: m.p.
Prior cal: 5-25-93

Model : TYPE K
DATA AS RECEIVED ✓

Asset Number: ENG-11

THERMOCOUPLE 6 POINT CALIBRATION

T/C TYPE K

Standard	Measured value	Tolerance
-60.00	-56.3	AS-15
-40.00	-37.6	
0.00	0.6	
50.00	49.7	
100.00	99.9	
200.00	201.9	

See attached CALIBRATION REPORT for traceability information

tc.6pt

127 Riverneck Road
Chelmsford, MA 01824
Telephone: 978 - 459-9480
FAX # 978 - 453-6336
WEB SITE: http://www.tekserv.com

CALIBRATION REPORT

SERVICE NUMBER:	SN-0226210
CONTRACT NUMBER:	SENTINEL

A59847

AEA TECHNOLOGIES
40 NORTH AVENUE

BURLINGTON MA 01803

DATE RECEIVED	CUSTOMER P.O.	ASSET NUMBER
10/08/98	2887	ENG-12

MANUFACTURER	
OMEGA	
MODEL	**SERIAL NUMBER**
HH-21	T-179139
DESCRIPTION	
THERMOMETER	

TEMP.	HUMIDITY	PRIOR CAL.	CAL. CYCLE	DATE OF TEST	NEXT TEST DUE
23.00°C	30.00%	9/25/97	12 MO	10/08/98	10/08/99

WORK REQUESTED	SERVICES RENDERED	REMARKS
CALIBRATE/CERTIFY	CALIBRATED/CERTIFIED	IN TOLERANCE AS RCV'D

PROCEDURE USED	N.I.S.T. TEST NUMBER	TECHNICIAN
MANUFACTURER'S	413348-433349-259071-LRAN	POULIN

CALIBRATION CHECKED TO: MANUFACTURER'S SPECIFICATIONS ADJUSTED TO: MANUFACTURER'S SPECIFICATIONS

MANUFACTURER	MODEL	SERIAL	ACCURACY	DATE CALIBRATED
ANALOGIC	AN6520	8904010	MFG.	7/03/98

TEKSERV CERTIFIES THAT ALL CALIBRATION EQUIPMENT USED IN THE TEST IS TRACEABLE TO N.I.S.T. AND THE TEST WAS PERFORMED IN ACCORDANCE WITH MIL-STD-45662A, ISO9002, ISO-10012-1, ANSI/NCSL-Z540-1-1994.

CERTIFIED BY _____

IN TOLERANCE AS RECEIVED

TEKSERV
CALIBRATION DATA

OMEGA Model HH-21
Serial Number: T 179139
Date of test: 10-8-98
Prior Cal: 9-25-97
Technician: M. P.

Data as Received ✓
Data After Adjustment
Data After Repair
Asset Number: ENG-12

Range	Reading	Specification
Deg.C Type J		
- 100.0	-99.6	+/-(0.1%rdg+0.5'C)
0.0	0.3	"
100.0	100.3	"
500.0	500.0	"
Deg.F Type J		
- 100.0	-99.3	+/-(0.1%rdg+1.0'F)
32.0	32.6	"
200.0	200.5	"
650.0	650.4	"
1200.0	1199.9	"
Deg.C Type K		
- 100.0	-99.5	+/-(0.1%RDG+0.5'C)
0.0	0.4	"
100.0	100.4	"
600.0	599.9	"
1000.0	1000.2	"
Deg.F Type K		
- 100.0	-99.1	+/-(0.1%rdg+1.0'F)
32.0	32.9	"
200.0	200.7	"
600.0	600.4	"
1600.0	1600.5	"
Deg.C Type T		
- 100.0	-99.5	+/-(0.1%rdg+0.5'C)
0.0	0.3	"
100.0	100.2	"
350.0	350.1	"
Deg.F Type T		
- 100.0	-99.4	+/-(0.1%rdg+1.0'F)
32.0	32.5	"
100.0	100.3	"
500.0	500.3	"

Mettler-Toledo, Inc.
Scales & Systems

METTLER TOLEDO

CERTIFICATE OF CALIBRATION No.:#1492-97

This is to certify that the below listed weighing equipment was tested and found to be within the NIST tolerances according to the requirements listed in NIST Handbook 44 for weighing devices and in accordance with MIL-STD 45662A. See the Test Record and Service Report for details on errors found and corrections made.

Model #	Serial #	ID	Location	Capacity	Inspector	Next Date Due
1#10#	242		SHIPPING	1## LB	LEO A.	11/98
DWM-IV	F16383		SHIPPING	5### LB	"	11/98
DS1#	35#14		QC	11# LB	"	11/98
4#1#	1126131		QC	125 LB	"	11/98
892#	267		QC	2## LB	"	11/98
DYNO	D35##		QC	5## LB	"	11/98
8582	2642125		STK RM	1# LB	"	11/98
82##	SR81846611		STK RM	1# LB	"	11/98
5##C	834468		STK RM	5## GR	"	11/98
2K BEAM	L482397		ASSEMBLY	2### LB	"	11/98

Date Test Performed: 5/6/98

Purchase Order No.:
Note: This document may be reproduced and a copy placed at each device if required.

METTLER TOLEDO INC. Steven Dawn
(Service Manager)

Date: 10/9/98

CUSTOMER: AMERSHAM CORP

STREET ADDRESS: 40 North AVE

CITY & STATE: BURLINGTON MA

METTLER TOLEDO INC.
TEST RECORD AND SERVICE REPORT

PAGE 1 OF 1

CUSTOMER CONTACT: DAVE ANNIS

DUE DATE 11-8-98 DATE SERVICE RENDERED: 5-8-98

	SCALE IDENTIFICATION				CHART/INDIC.		LOCATION OF SCALE	TEST LOAD APPLIED / ERROR IN GRADUATIONS					CORR		SERVICES RENDERED; PARTS
	MODEL	SERIAL #	MAKE	I.D. #	CAP.	GRAD.							Y	N	
1	DIAMTR	F16383	Flex Weigh	F16383	5K lb	1 lb	Shipping	0 / 0	100 / 0	200 / 0	300 / 0	500 / 0		✓	CAL OK
2	DSC4848	12486		1"	5K lb	BASE		550 / 0	550 / 0	550 / 0	550 / 0	—		✓	Shift good.
3	10100	242	Peloozie	242	100 lb	4 oz		0 / ±6	25 / +1	50 / 0	75 / 0	100 / 0	✓		NOTES
4								—	—	—	—	—			
5	4010	1126131	Peloozie	1126131	125 lb	.2 lb	QC	~~550~~ 0	25 / 0	50 / 0	75 / 0	100 / +1		✓	CAL OK
6	D510	35014	OHAUS	3501	110 lb	.05 lb		0 / 0	25 / -4	50 / -8	75 / -11	100 / -13	✓		RECALIBRATED
7	8920	267	HANSON	267	200 lb	1 lb		0 / 0	50 / 0	100 / 0	150 / 0	200 / 0		✓	CAL OK
8	DYNO	D3500	Dillion	D3500	500 lb	2 lb		0 / 0	100 / +1	200 / +1	300 / 0	500 / +1		✓	CAL IN SPEC
9								—	—	—	—	—			
10	8200	SR8724001	NCI	269	10 lb	.002 lb	STOCK RM	0 / 0	2.5 / 0	5.0 / 0	7.5 / 0	10.0 / +1		✓	CAL OK
11	500C	834468	SETRA	834468	500 g	.001 g		0	100 / 75	200 / 0	300 / +4	500 / -2	✓		RECALIBRATED.
12	8582	2642125	TOLEDO	268	10 lb	.001 lb		0 / 0	2.5 / 0	5.0 / 0	7.5 / 0	10.0 / -1		✓	CAL OK
13								—	—	—	—	—			
14	2KBEAM	L482397	NES	L482397	2K lb	.5 lb	ASSEMBLY	0 / +3	100 / 0	200 / 0	300 / 0	500 / 0	✓		REZERO
15								—	—	—	—	—			CHECKED all COUNTER WEIGHTS

REMARKS: 3) RUBBING ON PLASTIC LENS, CAUSED JN, REMOVED POPPED OUT AND REINSTALLED

AL

CUSTOMER SIGNATURE: Dave Annis 8 MAY 98

TECHNICIAN Leo Archambault

TRACEABILITY #: _____ PROCEDURE #: Q032-07

Established in 1972

HUNT METROLOGY SERVICE, INC.
175 Jackson St. Methuen, Ma. 01844-5042
Phone: (978) 688-7278 Fax: (978) 794-4632

Calibration Certificate

Company Name: AEA TECHNOLOGY
Address: 40 NORTH AVENUE
BURLINGTON, MA. 01803

Calibration No: HMSCC-09028
Dated: AUG 3-7, 1998
Pages: 62

Department:

Phone No.: (781) 272-2000 Ext:

Fax No.: (781) 273-2216

Attention: DAVE ANNIS
P.O. No.: 2603
Technician: DAVID DICKINSON

The calibration performed on the following measuring and test equipment (M&TE) of this document are traceable to the National Institute of Standards and Technology (N.I.S.T.) through N.I.S.T. test number 821/256504-96; Dated February 26, 1997 for dimensional calibration, and/or through N.I.S.T. test number 822/254480 dated February 26, 1997 for mass calibration.

The M&TE have been cleaned and lubricated, as needed. Our technician(s) have calibrated, adjusted and/or reset the M&TE, affixed a calibration label to the M&TE, updated the corresponding record(s), and provided this calibration certificate.

The standard(s) utilized to perform the calibration have been calibrated, certified and maintained in our laboratory which sustains a temperature of 68 degrees (+/- 2 degrees F.) and less than 50% relative humidity. All records pertaining to our standards, and the masters utilized to calibrate them, are kept on file in our laboratory for a period of no less than 3 years.

The services provided, traceability to the N.I.S.T., and Hunt Metrology Service's calibration system comply with the requirements of ANSI/NCSL Z540-1-1994 and ISO 10012-1:1994(E).

The reported value is both "as found" and "as left" data, unless otherwise specified. A calibration uncertainty ratio of at least 4:1 is maintained unless otherwise stated.

Keith R. Young
Technical Manager

Hunt Metrology Service, Inc. Data Sheet HMSCC: 09028 Page 1
Customer: AEA TECHNOLOGY P.O. No.: 2603

Date Cal: 08/06/98
ID.No.: 027 (A) Manufacturer: MITUTOYO Date Due: 08/06/99
2 ID.No.: Serial No.: 701046 Technician: DD
Department: QC Model No.: 543-425-1 Cal. Proc. No: 30
Deviation u.: Standard No.: 012 Cal.: 04/08/98 Due: 10/30/98
Accuracy: +/-0.000 10" Standard No.: Cal.: Due:
Accuracy: Standard No.: Cal.: Due:
Standard No.: Cal.: Due:

Gage Type: 0-2.0" DIGITAL INDICATOR (PART 1 OF 2)

Required:	0	0.010"	0.025"	0.050"	0.100"	0.250"	0.500"	0.750"
Deviation:	REF	0	0	0	0	0	0	-.0001
Measured:	REF	0.010"	0.025"	0.050"	0.100"	0.250"	0.500"	0.7499"

Customer: AEA TECHNOLOGY P.O. No.: 2603

Date Cal: 08/06/98
ID.No.: 027 (B) Manufacturer: MITUTOYO Date Due: 08/06/99
2 ID.No.: Serial No.: 701046 Technician: DD
Department: QC Model No.: 543-425-1 Cal. Proc. No: 30
Deviation u.: Standard No.: 012 Cal.: 04/08/98 Due: 10/30/98
Accuracy: +/-0.000 10" Standard No.: Cal.: Due:
Accuracy: Standard No.: Cal.: Due:
Standard No.: Cal.: Due:

Gage Type: 0-2.0" DIGITAL INDICATOR (PART 2 OF 2)

Required:	1.0	1.25	1.50	1.75	2.00
Deviation:	0	0	+.00010"	0	0
Measured:					

ATTACHMENT C – CALCULATION OF VOLUME RATIOS

Values are estimates of true device volume based on design drawings and engineering judgement

Model 680 Projector

Shell volume (internal):
L x W x H = 13.88 x 13.63 x 9.94 = 1880.5 in^3

Shield volume:
Weight /Density = 292 lbs./0.683 lbs./in^3 = 427.5 in^3

Void volume:
Shell volume – Shield volume = 1880.5 – 427.5 = 1453 in^3

Proportion
14.44 in^3 / 1453 in^3 = 0.01 = 1%

Model 650 Projector

Shell volume (internal):
$V = \pi(3.719)^2 (8.25 - 2(0.5)) = 315\ in^3$

Shield volume:
Weight /Density = 42 lbs./0.683 lbs./in^3 = 61.5 in^3

Void volume:
Shell volume – Shield volume = 315 – 61.5 = 253.5 in^3

Volume Ratio

14.44 in^3 / 253.5 in^3 = 0.057 = 5.7%

ATTACHMENT D – EFFECTIVE DENSITY CALCULATIONS

Table 1. Calculation Table

Set No.	Specimen No.	Container Empty Weight (lbs) (A)	Container Volume (mL) (B)	Container Filled Weight (lbs) (C)	Effective Density* (lb/ft^3) (C-A)/B * 28321
1	1	.108	258	.203	10.4
	2	.099	258	.191	10.1
	3	.098	258	.191	10.2
2	1	.109	257	.224	12.7
	2	.109	257	.227	13.0
	3	.109	257	.225	12.8
3	1	.108	258	.329	24.3
	2	.109	258	.329	24.1
	3	.098	258	.321	24.5
4	1	.098	257	.331	25.7
	2	.099	257	.336	26.1
	3	.099	257	.359	28.7
5	1	.098	258	.192	10.3
	2	.108	258	.202	10.3
6	1	.099	257	.213	12.6
	2	.098	257	.213	12.7
7	1	.098	258	.315	23.8
	2	.098	258	.324	24.8
8	1	.098	257	.359	28.8
	2	.098	257	.360	28.9

* 28,321 mL = 1 ft^3

2.12.9 Technical Report 171 Sentry Transport Package Lifting Analysis dated 30 Jun 2010

QSA GLOBAL

Technical Report No. 171

QSA GLOBAL, Inc.

Engineering Department

Technical Report

SENTRY Transport Package Lifting Analysis

Prepared by: Steve Gianni Date: 24 JUN 2010

Checked by: Dwain Kinnard Date: 24 JUN 2010

Regulatory Approval: L. Pelton Date: 30 Jun 2010

Engineering Approval: Dan Ihl Date: 24 Jun 2010

1.0 Purpose:

This report documents an analysis performed on the SENTRY transport package to the lifting requirements of 10 CFR Part 71.45 (a).

2.0 SENTRY Transport Package Lifting Provisions:

The SENTRY transport package in the Standard configuration is equipped with four identical, multi-purpose Lifting/Tie-Down provisions symmetrically located around the package. Half of each lifting provision is attached to the upper portion of the cylindrically shaped welded body by three high strength bolts, two on the top flat surface and one on the curved side surface of the body. The other half of the provision is attached to the body in the same manner, but with two bolts attached to the bottom and one attached to the side of the body. See Figure 1.

The two halves of the provision are connected together by a link plate attached to each half by a load pin. The strength of the two load pins is only needed when the package is lifted using the link plate. Lifting the package with the link plate is not recommended, but this part of the provision still needs to meet the lifting requirement of 10 CFR part 71.45 (a). The recommended lifting method is to lift the package by looping high capacity straps or chains with or without a pivoting shackle through the large hole in the upper lifting provision.

The bottom end also includes a very large hex nut and bolt for added strength in emergency situations. The large hex nut and bolt will recruit the lower half of the provision if a rapid, high loading (snatch) condition occurs.

The SENTRY transport package in the Basic configuration has an array of Rivnuts for attaching a properly rated hoist ring for lifting. See Figure 10 & 11.

The center of gravity (CG) of the 780 pound (maximum) package is located approximately at its geometric center.

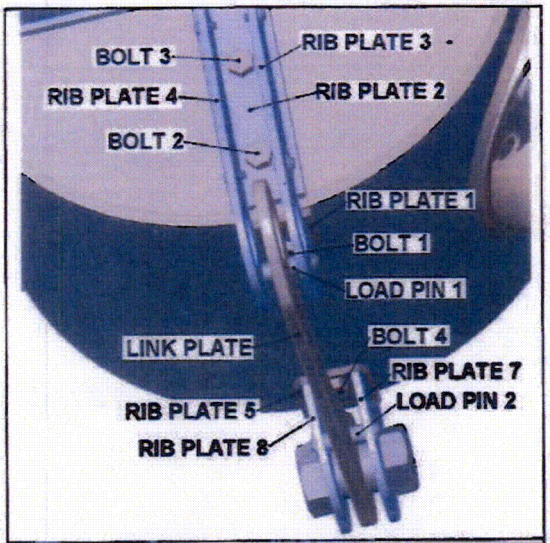

Figure 1 SENTRY Lifting Provision (1 of 4) Standard Configuration

Table 1 Lifting/Tie-Down Provision Materials List

Component Name	Material	Condition	ASTM Spec	Minimum Yield Strength, psi
Rib Plate 1 thru 8	17-4 PH STN STL	H1025	A693	145,000
Link Plate	17-4 PH STN STL	H900	A693	170,000
Bolts 1 thru 8	17-4 PH STN STL	AH	F593	105,000
Load Pin 1 & 2	17-4 PH STN STL	H900	A693	170,000
Rivnuts 1 thru 8	316 STN STL	CW	A276	93,694

3.0 Transport Lifting Requirement:

10 CFR Part 71.45 (a): Any lifting attachment that is a structural part of a package must be designed with a **minimum safety factor of three against yielding** when used to lift the package in the intended manner, and it must be designed so that **failure** of any lifting device under excessive load **would not impair the ability of the package to meet other requirements** of this subpart. Any other structural part of the package that could be used to lift the package must be capable of being rendered inoperable for lifting the package during transport, or must be designed with strength equivalent to that required for lifting attachments.

4.0 Assumptions:

1. Temperature range equal to -40 to +130 F.
2. No corrosion exists on the rib assembly and fastener components.
3. Only one lifting provision carries the load in the lifting analysis.

5.0 Analysis – Rib Assembly Lifting:

The SENTRY lifting provision or rib assembly is a structural part of the package. However, it is designed to be intentionally removed without affecting the ability of the package to meet other requirements of 10 CFR Part 71.

Lifting the transport package by only one lifting provision (rib assembly) can be considered the worst case for lifting the package. The maximum tensile load applied to the single lifting provision is equal to the maximum weight of the package or 780 lbs. See figure 2 through 4.

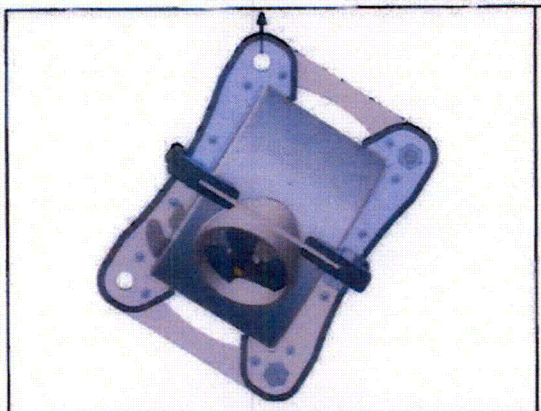

Figure 2 SENTRY Lifting from a Single Rib Assembly

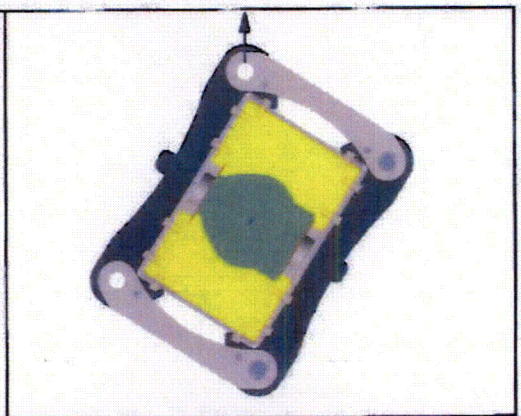

Figure 3 SENTRY Lifting from a Single Rib Assembly – Section View

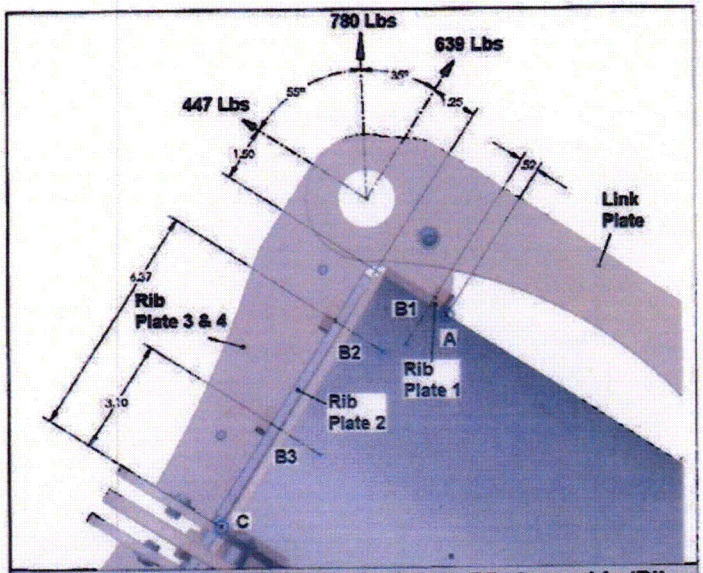

Figure 4 SENTRY Lifting from a Single Rib Assembly (Rib Plate 4 not shown) – Close-up View

The rib assembly consists of two vertical parallel plates welded to a flat horizontal plate with two mounting holes and one perpendicular plate with one mounting hole. The vertical plates are separated by a gap to allow three hex bolts to be inserted between them. The bolts pass through the mounting holes and mate into the Rivnuts. The Rivnuts are riveted into the cylindrical welded body of the transport package.

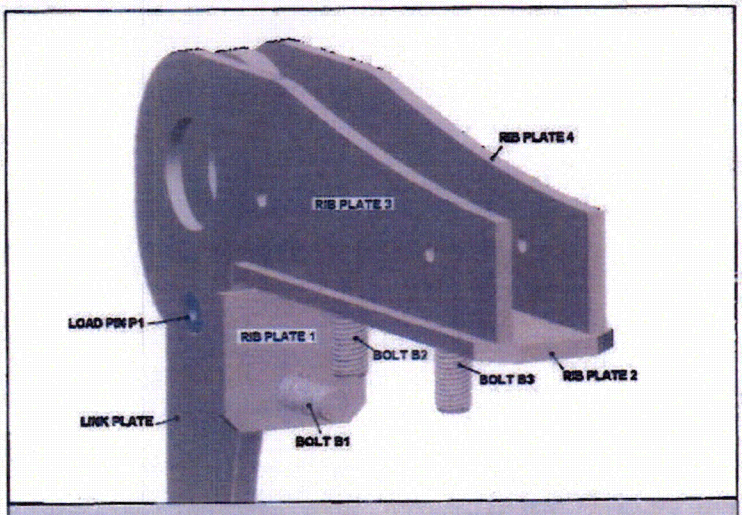

Figure 5 SENTRY Rib Assembly Close-up

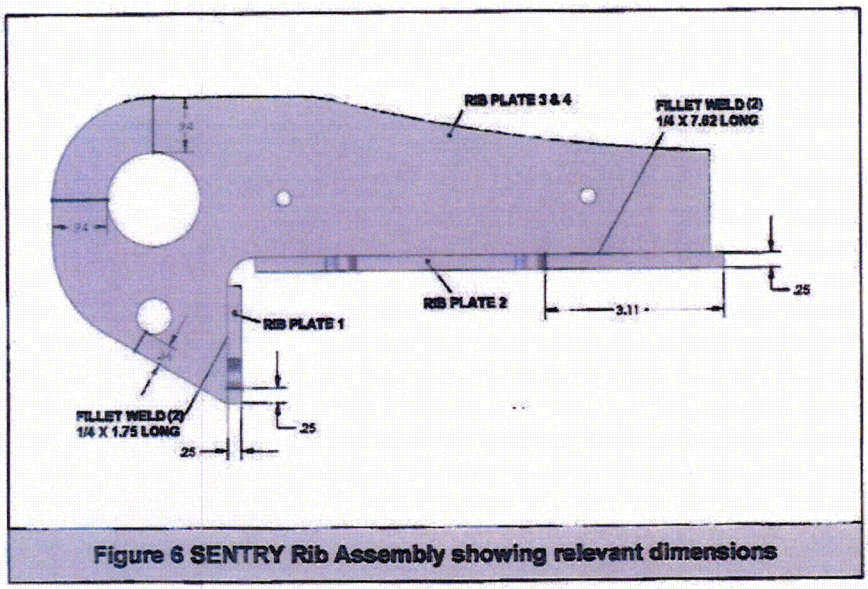

Figure 6 SENTRY Rib Assembly showing relevant dimensions

6.0 Results – Rib Assembly Lifting:

Table 2 is a summary comparing calculated factor of safeties against the required factor of safety, 3, when lifting the package by only one rib assembly as shown in Figure 4. See Appendix A for the detailed calculations. Table 2 reveals "Bolt B1 Tensile or Shear" is the worst case loading condition resulting in a calculated factor of safety equal to 8. This is over 2 times the required factor of safety of 3.

Table 2 Summary of SENTRY Lifting by Rib Analysis per 10 CFR Part 71.45(a)			
Failure Mode	Calculated Factor of Safety	Required Factor of Safety	Pass/Fail
Rib Plates 3 & 4 Shear Tear-out	87	3	Pass
Rib Plate 1 Shear Tear-out	20		Pass
Rib Plate 1 Bearing Failure	34		Pass
Rib Plate 1 Tensile Failure	139		Pass
Rivnut 1,2,&3 Thread Shear Strip	85		Pass
Rib Plate 2 Shear Tear-out	176		Pass
Rib Plate 2 Bearing Failure	24		Pass
Rib Plate 2 Tensile Failure	98		Pass
Bolt B1 Tensile Failure	8		Pass
Bolt B1 Shear Failure	8		Pass
Bolt B1 Thread Bearing Stress	75		Pass
Bolt B1 Thread Shear Strip	34		Pass
Bolt B2 Tensile Failure	79		Pass
Bolt B2 Shear Failure	49		Pass
Bolts B2 & B3 Thread Bearing Stress	320		Pass
Bolts B2 & B3 Thread Shear Strip	145		Pass
Rib Plate Weld – 639 Lbs Direction	306		Pass
Rib Plate Weld – 447 Lbs Direction	100		Pass
See Appendix A - Lifting by Rib Assembly Calculations			

7.0 Analysis – Link Plate Lifting:

The link plate is not recommended to be used as a lifting provision. However, if the package is lifted by the link plate, then it shall also meet the lifting requirements of 10 CFR Part 71.45(a).

Figures 7 through 9 show the transport package lifted by the link plate.

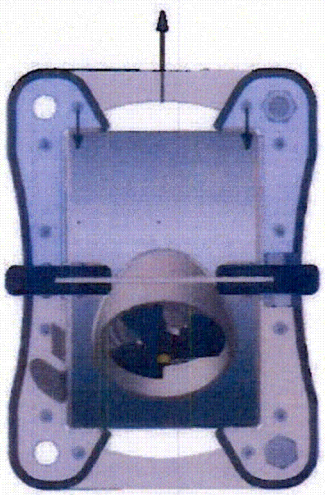

Figure 7 SENTRY Lifting from a Single Link Plate

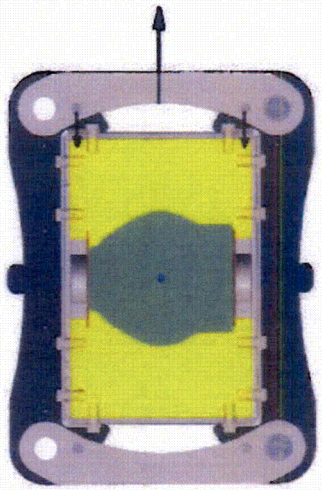

Figure 8 SENTRY Lifting from a Single Link Plate – Section View

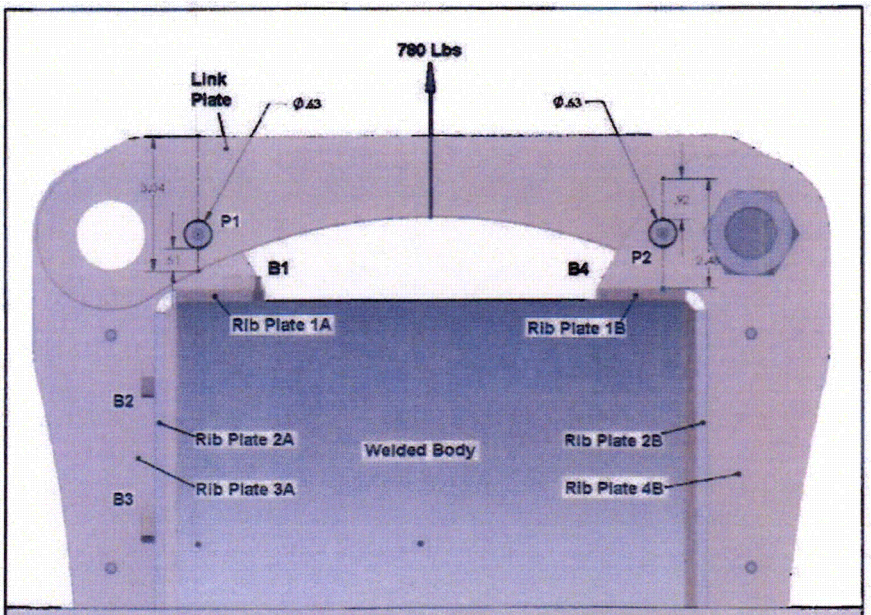

Figure 9 SENTRY Lifting from a Link Plate – Close-up Section View

8.0 Results – Link Plate Lifting:

Table 3 is a summary comparing calculated factor of safeties against the required factor of safety, 3, when lifting the package by only one link plate as shown in Figure 9. See Appendix B for the detailed calculations. Table 3 reveals "Bolt B1 or B4 Tensile Failure" is the worst case loading condition resulting in a calculated factor of safety equal to 38. This is over 12 times the required factor of safety of 3. The calculation for this loading condition is conservative since it did not take into consideration the load sharing provided by bolts B2, B3, B5 & B6 in the load direction.

Table 3 Summary of SENTRY Lifting by Link Analysis per 10 CFR Part 71.45(a)			
Failure Mode	Calculated Factor of Safety	Required Factor of Safety	Pass/Fail
Link Plate Tensile Failure - Midsection	151	3	Pass
Link Plate Shear Tear-out	84		Pass
Link Plate Bearing Failure	96		Pass
Link Plate Tensile Failure	399		Pass
Load Pin P1 or P2 Double Shear	230		Pass
Rib Plate 2 Shear Tear-out Failure	289		Pass
Rib Plate 2 Bearing Failure	39		Pass
Rib Plate 2 Tensile Failure	160		Pass
Bolt B1 or B4 Tensile Failure	38		Pass
Rib Plate 3 & 4 Shear Tear-out Failure	171		Pass
Rib Plate 3 & 4 Bearing Failure	108		Pass
Rib Plate 3 & 4 Tensile Failure	345		Pass
Rib Plate Weld – Lift Direction	501		Pass
See Appendix B - Lifting by Link Plate Calculations			

9.0 Analysis – Rivnut Lifting:

The Rivnut can be used for lifting the package in the basic configuration. Lifting the package by one Rivnut is the worst case lifting condition for this configuration. See Figures 10 & 11.

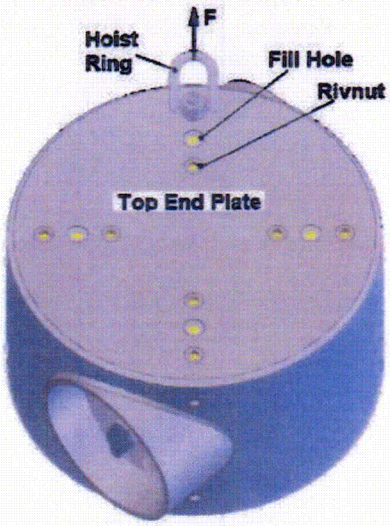

Figure 10 SENTRY Lifted by a Single Rivnut

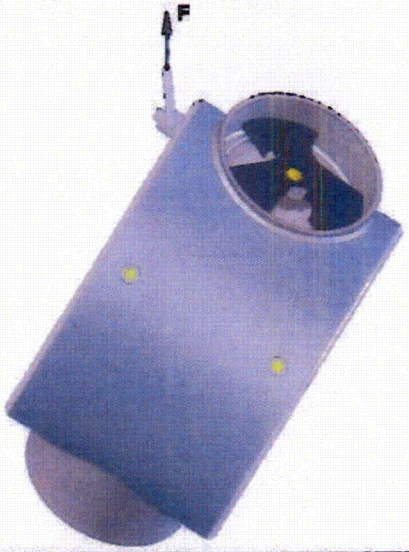

Figure 11 SENTRY Lifted by a Single Rivnut –Side View

10.0 Results – Rivnut Lifting:

Table 4 is a summary comparing calculated factor of safeties against the required factor of safety, 3, when lifting the package by only one link plate as shown in Figures 10 & 11. See Appendix C for the detailed calculations. Table 4 reveals "Rivnut 1 Shear Failure" is the worst case loading condition resulting in a calculated factor of safety equal to 7. This is over 2 times the required factor of safety of 3.

Table 4 Summary of SENTRY Lifting Rivnut Analysis per 10 CFR Part 71.45(a)

Failure Mode	Calculated Factor of Safety	Required Factor of Safety	Pass/Fail
Rivnut 1 Shear Failure	7	3	Pass
Rivnut 1 Thread Shear Strip	33		Pass
See Appendix C - Lifting by Rivnut Calculations			

11.0 Final Assessment:

The SENTRY transport package in the Standard Configuration lifted by either the rib assembly or the link plate and the package in Basic configuration lifted by one Rivnut meets the lifting requirements of 10 CFR Part 71.45 (a). No failure mode was found to be less than 3 against yielding when lifting the package by a rib assembly, link plate or Rivnut.

If the lifting provision were to fail due to excessive loading, the package is designed so that the failed provision would not impair the ability of the package to meet the other requirements of 10 CFR Part 71.

Appendix A - Lifting by Rib Assembly Calculations

Determine Rib Plates 3&4 Shear Tearout Failure			
Rtfs =	830	psi	= Tensile Stress = Fn/(2*L*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by plates 3 & 4 = F/2
t =	0.25	in	= Plate thickness
L =	0.94	in	= Distance from hole to plate edge
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	87		= Factor of Safety = Ssr/Rtfs

Determine Rib Plate 1 Shear Tearout Failure			
Rsts =	3576	psi	= Calc Shear Stress = Fd/(2*L*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fd =	447	Lbf	= Load Normal to Rib Plate 2
t =	0.25	in	= Plate thickness
L =	0.25	in	= Distance from hole to Rib 1 edge
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	20		= Factor of Safety = Ssr/Rsts

Determine Rib Plate 1 Bearing Failure			
Rbfs =	4237	psi	= Calc Bearing Stress = Fd/(d*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fd =	447	Lbf	= Load Normal to Rib Plate 2
t =	0.25	in	= Plate thickness
d =	0.42	in	= Bolt minor diameter
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	34		= Factor of Safety = Ysr/Rbfs

Determine Rib Plate 1 Tensile Failure			
Rtfs =	1040	psi	= Tensile Stress = Fd/((w-d)*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fd =	447	Lbf	= Load Normal to Rib Plate 2
t =	0.25	in	= Plate thickness
d =	0.53	in	= Hole diameter
w =	2.25	in	= Plate width
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	139		= Factor of Safety = Ysr/Rtfs

Determine Rivnut 1,2&3 Thread Shear Strip			
Nts =	534	psi	= Calc Shear Stress = Fn/(Pi*dn*(h/2))
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	260	Lbf	= Load shared by 3 Rivnuts = F/3
dn =	0.50	in	= Nut root diameter
Pi =	3.14	in	= Constant
h =	0.62	in	= Nut engagement
Ysn =	*90435*	psi	= Allowable Yield Strength
Ssn =	45217	psi	= Allowable Shear Strength = Ysn/2
Fs =	85		= Factor of Safety = Ssn/Nts

Determine Rib Plate 2 Shear Tearout Failure			
Rsts =	411	psi	= Calc Shear Stress = Fd/(2*L*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fd =	639	Lbf	= Load Normal to Rib Plate 1
t =	0.25	in	= Plate thickness
L =	3.11	in	= Distance from hole to Rib 2 edge
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	176		= Factor of Safety = Ssr/Rsts

Determine Rib Plate 2 Bearing Failure			
Rbfs =	6057	psi	= Calc Bearing Stress = Fd/(d*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fd =	639	Lbf	= Load Normal to Rib Plate 1
t =	0.25	in	= Plate thickness
d =	0.42	in	= Bolt minor diameter
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	24		= Factor of Safety = Ysr/Rbfs

Determine Rib Plate 2 Tensile Failure			
Rtfs =	1486	psi	= Tensile Stress = Fd/[(w-d)*t]
F =	780	Lbf	= Max Package Weight (Std Config)
Fd =	639	Lbf	= Load Normal to Rib Plate 1
t =	0.25	in	= Plate thickness
d =	0.53	in	= Hole diameter
w =	2.25	in	= Plate width
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	98		= Factor of Safety = Ysr/Rtfs

Determine Bolt 1 Tensile Failure (Combined Stress)			
B1ms=	13161	psi	=Max Tensile Stress on Bolt 1 = B1st/(Sqrt((B1st/2)^2 + Bss^2))
B1st =	12990	psi	= Calc Tensile Stress = Fp/A
Fd =	639	Lbf	= Load Normal to Rib Plate 1
Fp =	1843	Lbf	= Moment Load on Bolt 1 = M*Lx
A =	0.14	in^2	= Bolt Stress Area
M =	959	in-Lb	= Moment = Fd*Lm
Lm =	1.50	in	= Moment Arm
Lx =	0.52	in	= Bolt Distance to pivot point (A)
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	8		= Factor of Safety = Ysb/B1ms

Determine Bolt 1 Shear Failure (Combined Stress)			
B1ss=	6666	psi	= Max Shear Stress on Bolt 1 = Sqrt ((B1st/2)^2 + Bss^2)
Bss =	1501	psi	= Calc Tensile Stress = Fn/A
Fd =	639	Lbf	= Load Normal to Rib Plate 1
Fn =	213	Lbf	= Load shared by 3 bolts = F/3
A =	0.14	in^2	= Bolt Stress Area
Ysb =	*105000*	psi	= Allowable Yield Strength
Ssb =	52500	psi	= Allowable Shear Strength = Ysb/2
Fs =	8		= Factor of Safety = Ssb/B1ss

Determine Bolt 1 Thread Bearing Stress			
Btbs =	1405	psi	= Thread Bearing Stress = Fd/ ((Pi/4)*(d^2-dr^2)*(h/p))
Fd =	639	Lbf	= Load applied in Rib Plate 2 direction
dr =	0.42	in	= Bolt root diameter
d =	0.50	in	= Bolt outer diameter
Pi =	3.14	in	= Constant
h =	0.62	in	= Nut engagement
p =	0.08	in	= Thread pitch = 1/13
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	75		= Factor of Safety = Ysb/Btbs

Determine Bolts 1 Thread Shear Strip			
Bts =	1555	psi	= Calc Shear Stress = Fd/(PI*dr*(h/2))
Fd =	639	Lbf	= Load applied in Rib Plate 2 direction
dr =	0.42	in	= Bolt root diameter
Pi =	3.14	in	= Constant
h =	0.62	in	= Nut engagement
Ysr =	*105000*	psi	= Allowable Yield Strength
Ssr =	52500	psi	= Allowable Shear Strength = Ysb/2
Fs =	34		= Factor of Safety = Ssb/Bts

Determine Bolt 2 Tensile Failure (Combined Stress)			
B2ms=	1329	psi	=Max Tensile Stress on Bolt 2 = B2st/(Sqrt((B2st/2)^2 + Bss^2))
B2st =	500	psi	= Calc Tensile Stress = Fp/A
Fd =	447	Lbf	= Load Normal to Rib Plate 2
Fp =	71	Lbf	= Proportion of load on Bolt2 = M*L2/SLx
A =	0.14	in^2	= Bolt Stress Area
M =	559	in-Lb	= Moment = F*Lm
Lm =	1.25	in	= Moment Arm
SLx =	50.19	in^2	= Bolt Distances Sumed (L2^2)+(L3^2)
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	79		= Factor of Safety = Ysb/B2ms

Determine Bolt 2 Shear Failure (Combined Stress)			
B2ss=	1079	psi	= Max Shear Stress on Bolt 2 = Sqrt ((B2st/2)^2 + Bss^2)
Bss =	1050	psi	= Calc Tensile Stress = Fn/A
Fd =	447	Lbf	= Load Normal to Rib Plate 2
Fn =	149	Lbf	= Load shared by 3 bolts = F/3
A =	0.14	in^2	= Bolt Stress Area
Ysb =	*105000*	psi	= Allowable Yield Strength
Ssb =	52500	psi	= Allowable Shear Strength = Ysb/2
Fs =	49		= Factor of Safety = Ssb/B2ss

Determine Bolt 2 & 3 Thread Bearing Stress			
Btbs =	328	psi	= Thread Bearing Stress = Fn/ ((PI/4)*(d^2-dr^2)*(h/p))
Fd =	447	Lbf	= Load applied in Rib Plate 1 direction
Fn =	149	Lbf	= Load shared by 3 bolts = Fd/3
dr =	0.42	in	= Bolt root diameter
d =	0.50	in	= Bolt outer diameter
Pi =	3.14	in	= Constant
h =	0.62	in	= Nut engagement
p =	0.08	in	= Thread pitch = 1/13
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	320		= Factor of Safety = Ysb/Btbs

Determine Bolts 2 & 3 Thread Shear Strip			
Bts =	363	psi	= Calc Shear Stress = Fn/(PI*dr*(h/2))
Fd =	447	Lbf	= Load applied in Rib Plate 1 direction
Fn =	149	Lbf	= Load shared by 3 bolts = Fd/3
dr =	0.42	in	= Bolt root diameter
Pi =	3.14	in	= Constant
h =	0.62	in	= Nut engagement
Ysb =	*105000*	psi	= Allowable Yield Strength
Ssb =	52500	psi	= Allowable Shear Strength = Ysb/2
Fs =	145		= Factor of Safety = Ssb/Bts

Determine Rib Plate Weld Shear Failure - 639 Lbs Direction			
Rws =	237	psi	= Tensile Stress = Fn/(Lw*Tw)
F =	639	Lbf	= Applied Load
Fn =	320	Lbf	= Load shared by 2 weld lengths = F/2
hs =	0.25	in	= Weld Size
Lw =	7.62	in	= Total Weld Length - 639 Lbs Direction
Tw =	0.18	in	= Weld Throat Dimension = .7071*hs
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	306		= Factor of Safety = Ssr/Rws

Determine Rib Plates Weld Shear Failure - 447 Lbs Direction			
Rws =	722	psi	= Tensile Stress = Fn/(Lw*Tw)
F =	447	Lbf	= Applied Load
Fn =	224	Lbf	= Load shared by 2 weld lengths = F/2
hs =	0.25	in	= Weld Size
Lw =	1.75	in	= Total Weld Length - 447 Lbs Direction
Tw =	0.18	in	= Weld Throat Dimension = .7071*hs
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	100		= Factor of Safety = Ssr/Rws

Appendix B - Lifting by Link Plate Calculations

Determine Link Plate Tensile Failure at Midsection			
Lts =	1128	psi	= Calc Tensile Stress = F/A
F =	780	Lbf	= Max Package Weight (Std Config)
X =	1.82	in	= Min Link Length
t =	0.38	in	= Link Plate thickness
A =	0.69	in^2	= Min Plate Stress Area = X*t
Ysi =	*170000*	psi	= Allowable Yield Strength
Fs =	151		= Factor of Safety = Ysi/Lts

Determine Link Plate Shear Teerout Failure			
Lsts =	1006	psi	= Calc Shear Stress = Fn/(2*w*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by 2 ends = F/2
t =	0.38	in	= Link Plate thickness
w =	0.51	in	= Distance from hole to edge
Ysi =	*170000*	psi	= Allowable Yield Strength
Ssi =	85000	psi	= Allowable Shear Strength = Ysi/2
Fs =	84		= Factor of Safety = Ssi/Lsts

Determine Link Plate Bearing Failure			
Lbfs =	1770	psi	= Calc Bearing Stress = Fn/(dp*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by 2 ends = F/2
dp =	0.58	in	= Pin diameter
t =	0.38	in	= Link Plate thickness
Ysi =	*170000*	psi	= Allowable Yield Strength
Fs =	96		= Factor of Safety = Ysi/Lbfs

Determine Link Plate Tensile Failure			
Ltfs =	425	psi	= Tensile Stress = Fn/[(w-d]*t]
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by 2 ends = F/2
d=	0.63	in	= Hole diameter
t =	0.38	in	= Link Plate thickness
w =	3.04	in	= Link Plate width
Ysi =	*170000*	psi	= Allowable Yield Strength
Fs =	399		= Factor of Safety = Ysi/Ltfs

Determine Load Pin Double Shear Failure			
Pdss =	738	psi	= Calc Tensile Stress = Fn/(A*2)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by 2 pins = F/2
d =	0.58	in	= Pin diameter
A =	0.264	in^2	= Pin Area = $Pi*d^2/4$
Pi =	3.142	in	= Constant
Ysp =	170000	psi	= Allowable Yield Strength
Fs =	230		= Factor of Safety = Ysp/Pdss

Determine Rib Plate 2 Shear Tearout Failure			
Rsts =	251	psi	= Calc Shear Stress = Fn/(2*L*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by 2 plates = F/2
t =	0.25	in	= Rib Plate thickness
w =	3.11	in	= Distance from hole to edge
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	289		= Factor of Safety = Ssr/Rsts

Determine Rib Plate 2 Bearing Failure			
Rbfs =	3697	psi	= Calc Bearing Stress = Fn/(dp*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by 2 plates = F/2
dp =	0.42	in	= Bolt minor diameter
t =	0.25	in	= Rib Plate thickness
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	39		= Factor of Safety = Ysr/Rbfs

Determine Rib Plate 2 Tensile Failure			
Rtfs =	907	psi	= Tensile Stress = Fn/((w-d)*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by 2 plates = F/2
d =	0.53	in	= Hole diameter
t =	0.25	in	= Rib Plate thickness
w =	2.25	in	= Rib Plate width
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	160		= Factor of Safety = Ysr/Rtfs

Determine Bolt 1 Tensile Failure			
B1ms=	2748	psi	=Max Tensile Stress on Bolt 1 = Fn/A
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	390	Lbf	= Load shared by 2 Bolts = F/2
A =	0.14	in^2	= Bolt Stress Area
Ysb =	*105000*	psi	= Allowable Yield Strength
Fs =	38		= Factor of Safety = Ysb/B2ms

Determine Rib Plate 3 & 4 Shear Tearout Failure			
Rsts =	424	psi	= Calc Shear Stress = Fn/(2*L*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	195	Lbf	= Load shared by 4 plates = F/4
t =	0.25	in	= Rib Plate thickness
L =	0.92	in	= Distance from hole to edge
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	171		= Factor of Safety = Ssr/Rsts

Determine Rib Plates 3 & 4 Bearing Failure			
Rbfs =	1345	psi	= Calc Bearing Stress = Fn/(dp*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	195	Lbf	= Load shared by 4 plates = F/4
dp =	0.58	in	= Pin diameter
t =	0.25	in	= Rib Plate thickness
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	108		= Factor of Safety = Ysr/Rbfs

Determine Rib Plate 3 & 4 Tensile Failure			
Rtfs =	420	psi	= Tensile Stress = Fn/((w-d)*t)
F =	780	Lbf	= Max Package Weight (Std Config)
Fn =	195	Lbf	= Load shared by 4 plates = F/4
d =	0.625	in	= Hole diameter
t =	0.25	in	= Rib Plate thickness
w =	2.48	in	= Rib Plate width
Ysr =	*145000*	psi	= Allowable Yield Strength
Fs =	345		= Factor of Safety = Ysr/Rtfs

Determine Rib Plate Weld Shear Failure - Lift Direction			
Rws =	145	psi	= Tensile Stress = F/(Lw*Tw)
F =	780	Lbf	= Max Package Weight (Std Config)
hs =	0.25	in	= Weld Size
Lw =	30.48	in	= Total Weld Length - Lift Direction
Tw =	0.18	in	= Weld Throat Dimension = .7071*hs
Ysr =	*145000*	psi	= Allowable Yield Strength
Ssr =	72500	psi	= Allowable Shear Strength = Ysr/2
Fs =	501		= Factor of Safety = Ssr/Rws

Appendix C - Lifting by Single Rivnut Calculations

Determine Rivnut 1 Shear Failure			
Nss =	6306	psi	= Calc Tensile Stress = F/A
F =	700	Lbf	= Max Package Weight (Basic Config)
A =	0.11	in^2	= Nut Stress Area
dr =	0.50	in	= Nut root diameter
d =	0.63	in	= Nut Outer Diameter
Ysn =	*93694*	psi	= Allowable Yield Strength
Ssn =	46847	psi	= Allowable Shear Strength = Ysn/2
Fs =	7		= Factor of Safety = Ssn/Nss

Determine Rivnut 1 Thread Shear Strip			
Nts =	1438	psi	= Calc Shear Stress = F/(Pi*dr*(h/2))
F =	700	Lbf	= Max Package Weight (Basic Config)
dr =	0.50	in	= Nut root diameter
Pi =	3.14	in	= Constant
h =	0.62	in	= Nut engagement
Ysn =	*93694*	psi	= Allowable Yield Strength
Ssn =	46847	psi	= Allowable Shear Strength = Ysn/2
Fs =	33		= Factor of Safety = Ssn/Nts

2.12.10 Technical Report 172 Sentry Transport Package Tie-Down Analysis dated 21 Jul 2010