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Development of the C-17 Nose Landing Gear Container, CNU-691/E

AFMC LSO/LOP
AIR FORCE PACKAGING TECHNOLOGY & ENGINEERING FACILITY
WRIGHT PATTERSON AFB, OH 45433-5540
April 2007

NOTICE

AFPTEF PROJECT NO. 05-P-106
TITLE: Development of the C-17 Nose Landing Gear Container

ABSTRACT

The Air Force Packaging Technology Engineering Facility (AFPTEF) was tasked with the design of a new shipping and storage container for the C-17 Nose Landing Gear (NLG) in March of 2004. The new container will replace the wood crates presently used.

The current containers' lack of mechanical and environmental protection prompted AFPTEF's design of a new container. The container developed, CNU-691/E, will protect the NLG mechanically and environmentally. The CNU-691/E, designed to ARP1967A, is an aluminum, long-life, controlled breathing, reusable container. The container passed all qualification tests per ASTM D4169.

The CNU-691/E container will not only meet the users' requirements but will also provide an economic saving for the Air Force. The savings will be thousands of dollars over the twenty-year life span of the container.

Total AFPTEF man-hours associated with this project is approximately 750.

PROJECT ENGINEER:

Joel Sullivan
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TEST ENGINEER:

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Mechanical Engineer
AFPTEF

APPROVED BY:

Robbin Miller
Chief, Air Force
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20 July 2007

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INTRODUCTION:

BACKGROUND - The C-17 Sustainment group (564 ACSS/GFL) located at Warner Robins AFB requested the Air Force Packaging Technology and Engineering Facility (AFPTEF) develop a long-life aluminum container for the Nose Landing Gear. The container is a replacement for the current wood container which degrades readily during use and can not be stored outside. The new NLG container is one of a family of new AFPTEF container designs to protect C-17 items that are being damaged in the shipping and storage cycle. Containers were also designed for the MLG axle beams, MLG posts, full MLG assemblies, nose radome, HUD, brake assembly, OBIGGS winch and thrust reversers.

REQUIREMENTS – AFPTEF, Boeing and Robins AFB personnel agreed upon a list of requirements during initial design discussions. Many of these requirements were not being met by the wood container. The requirements are as follows:

- Sealed/controlled-breathing container that protects against varied environmental conditions and weather during either inside or outside shipping and storage
- No loose packing material.
- Shock/Vibration resistance up to 50 G's.
- Long Life (20 years).
- Low maintenance.
- Field repairable container hardware.
- Forklift capabilities (due to weight).

DEVELOPMENT

DESIGN – The C-17 NLG Shipping and Storage Container (CNU-691/E) design meets all the users' requirements. The CNU-691/E (see Appendix 2, Figure 1) is a sealed, welded aluminum, controlled breathing, reusable container. The container is engineered for the physical and environmental protection of the landing gear during worldwide transportation and storage. The container consists of a low profile base and completely removable cover equipped with the special features listed below. The base is a skid/double-walled base extrusion with forklift openings, humidity indicator, document holder, pressure equalizing valve (10.5 kPa (1.5 psi)) pressure/ 10.5 kPa (1.5 psi) vacuum) and desiccant port for easy replacement of desiccant (controls dehumidification). A silicone rubber gasket and quick release cam-over-center latches create a water/air-tight seal at the base-cover interface. Container external dimensions are 2428.2 mm (95.6 in) in length, 1590.0 (62.6 in) in width, and 1673.9 mm (65.9 in) in height. Container empty weight is 502.1 kg (1107 lbs), and 1132.6 kg (2497 lbs) with the landing gear and installation kit in place.

An aluminum cradle/frame system is integrated into the container base that rigidly mounts the NLG to the container using three clamps, two aft and one forward (see

Appendix 2, Figures 2, 3 & 4). There are also two nylon straps used to prevent the landing gear tires from rotating.

In addition to the landing gear, there are also two parts boxes in the container (see Appendix 2, Figure 5) that accommodate the installation kit that ships with the landing gear. These compartments are located on the aft end of the container and are made of welded aluminum. There are no detachable parts on the container other than the cover, which eliminates FOD risks.

C-17 NLG CONTAINER FEATURES	
Pressure Equalizing Valve	2
Humidity Indicator	1
Desiccant Port	1
Document Receptacle	1
Forkliftable	Yes
Cover Latches	28
Cover Lift Handles	None
Cover Lift Rings	4
Cover Tether Rings	None
Base Lift Handles	None
Base Tie-down Rings	4
Stacking Capability	Yes

PROTOTYPE – AFPTEF fabricated one CNU-691/E prototype container (see Appendix 2, Figure 6 and 7) in house for testing. The prototype container was fabricated in accordance with (IAW) all requirements and tolerances of the container drawing package, and had a tare weight of 502.1 kg (1107 lbs). The drawing package used for prototype fabrication has been released for the manufacture of production quantities of the container. Each face of the container was uniquely identified for testing identification as shown below.

DESIGNATED SIDE	CONTAINER FEATURE
Top	Cover Top
Aft	Desiccant Port
Right	Right Side from Aft
Left	Left Side from Aft
Forward	Opposite Aft
Bottom	Base Bottom

QUALIFICATION TESTING

TEST LOAD – The test load was a reparable C-17 Nose Landing Gear (see Appendix 2, Figures 6 & 7). A triaxial accelerometer, used to record actual accelerations sustained by the NLG, was mounted on the test load as close to the center of mass as possible (see Appendix 2, Figure 8). The test load weight was 630.5 kg (1390 lbs).

TEST PLAN – The test plan primary references were ASTM D 4169 and SAE ARP 1967 (see Appendix 1). The test methods specified in this test plan constituted the procedure for performing the tests on the NLG container. The performance criteria for evaluation of container acceptability were specified at 50 Gs maximum and an initial and final leak rate of 0.35 kPa (0.05 psi) per hour at 10.5 kPa (1.5 psi). These tests are commonly applied to special shipping containers providing rough handling protection to sensitive items. The tests were performed in January and February 2007 at AFPTEF, Building 70, Area C, Wright-Patterson AFB.

ITEM INSTRUMENTATION – The test load was instrumented with a piezoelectric triaxial accelerometer mounted as close as possible to the NLG's center of mass at approximately a 45° angle. Accelerometer axis orientations were as follows:

X Axis - Directed through container Forward and Aft sides .
Y Axis - Directed through container Left and Right sides.
Z Axis - Directed through container Top and Bottom sides (Vertical motion).

See Appendix 4 for detailed accelerometer and other instrumentation information.

TEST SEQUENCES – Note: All test sequences were performed at ambient temperature and humidity, unless otherwise noted in the test procedure.

TEST SEQUENCE 1 – Leak Test

Procedure – The desiccant port cover was removed and replaced with a port cover modified for attachment of the digital manometer and vacuum/pressure pump lines. The container was closed and sealed. The leak test was conducted at ambient temperature and pressure. The pneumatic pressure leak technique was used to pressurize the container to a minimum test pressure of 10.5 kPa (1.5 psi). Maximum allowable leak rate is 0.35 kPa (0.05 psi) per hour. (see Appendix 2, Figure 9).

Results – The container passed the leak test with a leak rate less than the maximum allowed rate of 0.35 kPa (0.05 psi) per hour.

TEST SEQUENCE 2 – Vacuum Retention Test

Procedure – The desiccant port cover was removed and replaced with a port cover modified for attachment of the digital manometer and vacuum/pressure pump lines. The container was closed and sealed. The vacuum retention test was conducted at ambient temperature and pressure. The air inside the container was evacuated to a minimum vacuum of -10.5 kPa (-1.5 psi). Maximum allowable pressure increase rate is 0.35 kPa (0.05 psi) per hour. (see Appendix 2, Figure 9).

Results – The container passed the vacuum retention test with a pressure increase rate less than the maximum allowed rate of 0.35 kPa (0.05 psi) per hour.

TEST SEQUENCE 3 – Vibration Test, Resonance Dwell

Procedure – The container was rigidly attached to the vibration platform. A sinusoidal vibration excitation was applied in the vertical direction and cyclically swept for 7.5 minutes at 2 minutes per octave to locate the resonant frequency. Input vibration from 5 to 12.5 Hz was at 0.125-inch double amplitude. Input vibration from 12.5 to 50.0 Hz was at 1.0 G (0 to peek). All signals were electronically filtered using a two-pole Butterworth filter with a 600 Hz cutoff frequency. The peak transmissibility values during the up and down frequency sweeps were noted for use in determining the frequency search range for the resonance dwell test.

The vibration controller swept up the frequency range until the resonant frequency was reached. This frequency was manually tracked for a 30 minute resonance dwell test. The test was conducted at ambient temperature. (See Appendix 2, Figure 13)

Results - The most significant resonant frequencies of the packaged item ranged from an initial 19.26 Hz to 18.78 Hz. The maximum transmissibility throughout the test was 2.4. At the end of the test period, there was no damage to the container or nose landing gear. The container met the test requirements. (See Appendix 3, Table 2 and Waveforms.)

TEST SEQUENCE 4 – Loose Load Vibration, Repetitive Shock

Procedure – A sheet of 3/4-inch plywood was bolted to the top of the vibration table, and the container was placed on the plywood. Restraints were used to prevent the container from sliding off the table. The container was allowed approximately 1/2-inch unrestricted movement in the horizontal direction from the centered position on the table (Appendix 2, Figure 13).

The table frequency was increased from 3.5 Hz until the container left the table surface (approximately 4.22 Hz). At one-inch double amplitude, a 1/16-inch-thick flat metal feeler could be slid freely between the table top and the container under all points of the container. Repetitive shock testing was conducted for 2 hours at ambient temperature.

Results - The loaded container was vibrated at 4.22 Hz for 2 hours. The maximum peak amplitude during this time for any axis was less than 2 Gs. At the end of testing there was no visible damage to the either the container or the item. The container met the test requirements. (See Appendix 3, Waveforms.)

TEST SEQUENCE 5 – Leakage Test

Procedure – Test Sequence 1 was repeated.

Results – The container passed the leak test with a leak rate less than the maximum allowed rate of 0.35 kPa (0.05 psi) per hour.

TEST SEQUENCE 6 – Rotational Drops

Procedure – An Assurance Level I drop height of 305 mm (12 in.) was used to perform four corner and four edge drops onto a smooth concrete surface The impact levels were recorded. The maximum allowed impact level for the NLG was 50 Gs. (see Appendix 2, Figures 10 & 11)

Results – All recorded impacts were less than the maximum allowed 50 Gs. There was no damage to either the container or the item. The container met the test requirements. (see Appendix 3, Table 1 and Waveforms.)

TEST SEQUENCE 7 – Leakage Test

Procedure – Test Sequence 1 was repeated.

Results – The container passed the leak test with a leak rate less than the maximum allowed rate of 0.35 kPa (0.05 psi) per hour.

TEST SEQUENCE 8 – Lateral Impact (Pendulum Impact)

Procedure – The container was placed on the pendulum test apparatus and impacted once on each side and each end. The container impact velocity was 2.2 m/sec (7.3 ft/sec). (see Appendix 2, Figure 12)

Results – All recorded impacts were less than the maximum allowed 50 Gs. There was no damage to either the container or the item. The container met the test requirements. (see Appendix 3, Table 1 and Waveforms.)

TEST SEQUENCE 9 – Leakage Test

Procedure – Test Sequence 1 was repeated.

Results – The container passed the leak test with a leak rate less than the maximum allowed rate of 0.35 kPa (0.05 psi) per hour.

TEST SEQUENCE 10 – Vacuum Retention Test

Procedure – Test Sequence 2 was repeated.

Results – The container passed the vacuum retention test with a pressure increase rate less than the maximum allowed rate of 0.35 kPa (0.05 psi) per hour.

TEST CONCLUSIONS – No damage occurred during the above testing to the container, isolation system or test item. All impact levels are well below the item fragility limit of

50 Gs. Therefore, the container and mounting system do provide adequate protection for the landing gear.

FIT & FUNCTION TESTING

Fit and function testing was completed on site at AFPTEF with the landing gear and loose parts that were supplied for prototype testing. The packaging process has yet to be demonstrated.

CONCLUSIONS

The CNU-691/E aluminum container passed all tests and was accepted by the users at Robins AFB. The container met all the user's requirements. The container can protect a C-17 Nose Landing Gear during world-wide transportation and storage. The container will save the Air Force hundreds of thousands of dollars in O&M costs.

RECOMMENDATIONS

AFPTEF recommends that the new containers be procured and delivered as needed to avoid future damage, thus mitigating overall shipping risks. All wood crates for the NLG should be replaced.

APPENDIX 1: Test Plan

AF PACKAGING TECHNOLOGY AND ENGINEERING FACILITY
(Container Test Plan)

CONTAINER SIZE (L x W x D) INTERIOR: 95.1 X 62.1 X 57.6	EXTERIOR: 95.6 X 62.6 X 68	WEIGHT GROSS: 2854	ITEM: 1369.9	CUBE (CU. F) 235.5	QUANTITY: 1	DATE: 25 Oct 05

AFPTEF PROJECT NUMBER: 05-P-106

ITEM NAME: C-17 Nose Landing Gear

MANUFACTURER:

CONTAINER NAME: Reusable Shipping & Storage Container

CONTAINER COST:

PACK DESCRIPTION: Extruded Aluminum Cntr., Test Load of a C-17 Nose Landing Gear

CONDITIONING: As noted below

TEST NO.	REF STD/SPEC AND TEST METHOD OR PROCEDURE NO'S	TEST TITLE AND PARAMETERS	CONTAINER ORIENTATION	INSTRU-MENTATION
		NOTE No damage to contents is acceptable and Package must be in serviceable condition. Serviceable means remains sealed, with no deformities, etc.		
		Quality Conformance Tests		
1.	**Examination of Product.** **SAE ARP 1967 Par. 4.5.1 Table I**	Container shall be carefully examined to determine conformance with material, workmanship, and requirements as specified in Table and drawings.	Ambient temp.	Visual Inspection (VI)
2.	**Weight Test.** **SAE ARP 1967 Par. 4.5.8.3.7**	Container shall be weighed.	Ambient temp.	Scale
		Performance Tests		
3.	**Leak Test.** **SAE ARP 1967 Par. 4.5.2**	Pneumatic pressure at 10.5 kPa (1.5 psi) and vacuum retention at10.5 kPa (1.5 psi). After temperature stabilization, pressure drop shall not exceed 0.35 kPa (0.05 psi) per hour. Perform leak test again at end of test series.	Ambient temp.	Water Manometer (WM) or Pressure Transducer (PT)

COMMENTS:

PREPARED BY: Joel A. Sullivan, Mechanical Engineer

APPROVED BY: Robbin L. Miller, Chief AFPTEF

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AF PACKAGING TECHNOLOGY AND ENGINEERING FACILITY
(Container Test Plan)

AFPTEF PROJECT NUMBER: 05-P-106

CONTAINER SIZE (L x W x D) INTERIOR:	EXTERIOR:	WEIGHT GROSS:	ITEM:	CUBE (CU. F)	QUANTITY:	DATE:
95.1 X 62.1 X 57.6	95.6 X 62.6 X 68	2854	1369.9	235.5	1	25 Oct 05

ITEM NAME: C-17 Nose Landing Gear

MANUFACTURER:

CONTAINER NAME: Reusable Shipping & Storage Container

CONTAINER COST:

PACK DESCRIPTION: Extruded Aluminum Cntr., Test Load of a C-17 Nose Landing Gear

CONDITIONING: As noted below

TEST NO.	REF STD/SPEC AND TEST METHOD OR PROCEDURE NO'S	TEST TITLE AND PARAMETERS	CONTAINER ORIENTATION	INSTRU-MENTATION
5.	**Vibration Test.**			
	SAE ARP 1967 Par. 4.5.5 ASTM D 4169 ASTM D 999	The container shall be vibrated from 5 Hz to 50 Hz at a sweep rate of one half octave per minute with a total sweep time of 7.5 minutes. Container shall then be vibrated for 30 minutes at the predominant resonance. Input excitation shall be 0.125 in double amplitude or 1 G limits.	Ambient temp. Rigidly attach container to exciter	VI Tri-axial Accelerometer
	SAE ARP 1967 Par. 4.5.5 ASTM D 4169 ASTM D 999	Container shall be vibrated IAW ASTM D 4169, Method D 999 for not less that two hours.	Ambient temp. Blocking shall be used to keep cntr. in place, do not restrict vertical or rotational movement	VI Tri-axial Accelerometer
6.	**Rotational Drop Tests (Ambient Temperature).**			
	SAE ARP 1967 Par. 4.5.3 ASTM D 4169 ASTM D 6179 Methods A&B	Drop height shall be 305 mm (12"). Item shall not sustain more than 50G's.	Ambient temp. One drop on all bottom corners (4 drops) and one drop on all edges (4 drops).	VI Tri-axial Accelerometer
7.	**Lateral Impact Test (Ambient Temperature).**			
	SAE ARP 1967 Par. 4.5.6 ASTM D 4169 ASTM D 880 Procedure B	Impact velocity 2.2 m/sec (7.3 ft/sec). Item shall not sustain more than 50G's.	Ambient temp. One impact on each end and one on each side (4 impacts).	VI Tri-axial Accelerometer

COMMENTS:

PREPARED BY: Joel A. Sullivan, Mechanical Engineer

APPROVED BY: Robbin L. Miller, Chief AFPTEF

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AF PACKAGING TECHNOLOGY AND ENGINEERING FACILITY (Container Test Plan)					AFPTEF PROJECT NUMBER: 05-P-106	
CONTAINER SIZE (L x W x D) INTERIOR: 95.1 X 62.1 X 57.6	EXTERIOR: 95.6 X 62.6 X 68	WEIGHT GROSS: 2854	ITEM: 1369.9	CUBE (CU. F) 235.5	QUANTITY: 1	DATE: 25 Oct 05
ITEM NAME: C-17 Nose Landing Gear				MANUFACTURER:		
CONTAINER NAME: Reusable Shipping & Storage Container					CONTAINER COST:	
PACK DESCRIPTION: Extruded Aluminum Cntr., Test Load of a C-17 Nose Landing Gear						
CONDITIONING: As noted below						

TEST NO.	REF STD/SPEC AND TEST METHOD OR PROCEDURE NO'S	TEST TITLE AND PARAMETERS	CONTAINER ORIENTATION	INSTRU-MENTATION
8.	**Leak Test.** **SAE ARP 1967 Par. 4.5.2**	Pneumatic pressure at 10.5 kPa (1.5 psi) and vacuum retention at 10.5 kPa (1.5 psi). After temperature stabilization, pressure drop shall not exceed 0.35 kPa (0.05 psi) per hour. Perform leak test again at end of test series.	Ambient temp.	Water Manometer (WM) or Pressure Transducer (PT)
9.	**Leak Design Test.** **SAE ARP 1967 Par. 4.5.2.3**	Pneumatic pressure to 21.0 kPa (3.0 psi) and 17.5 kPa (2.5 psi) vacuum. Failure of any component is not acceptable. Measure deflection.	Ambient temp.	Water Manometer (WM) or Pressure Transducer (PT)

COMMENTS:	
PREPARED BY: Joel,A. Sullivan, Mechanical Engineer	APPROVED BY: Robbin L. Miller, Chief AfPTEF

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APPENDIX 2: Fabrication & Testing Photographs

Figure 1. The finished container includes many important features.

Figure 2. Two aft clamps and one forward clamp hold the gear in place. Nylon straps prevent the tires from rotating.

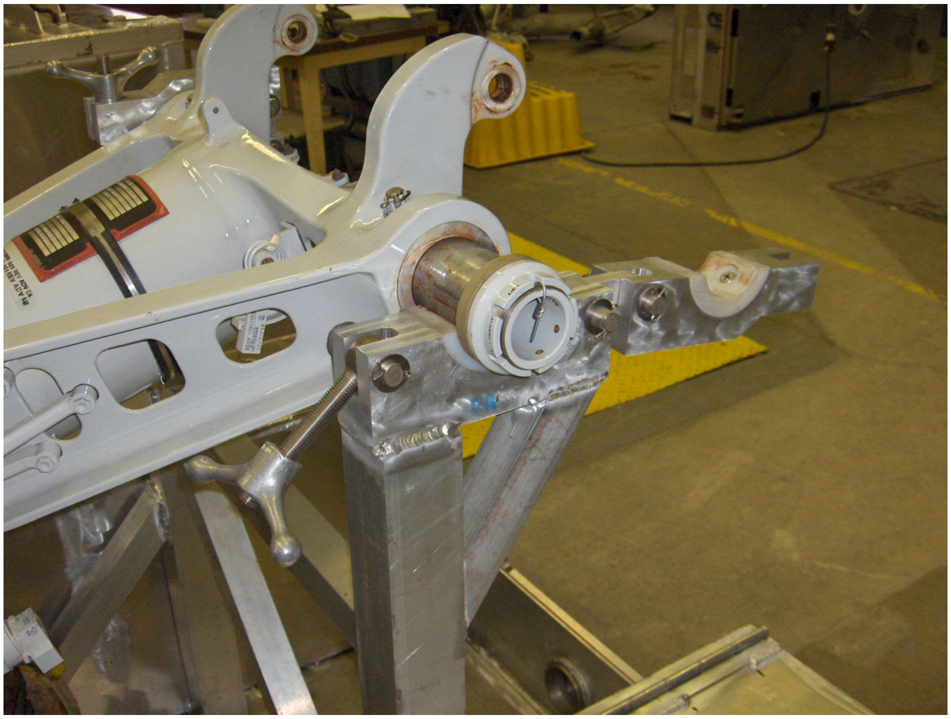


Figure 3. Aft clamp in open position.

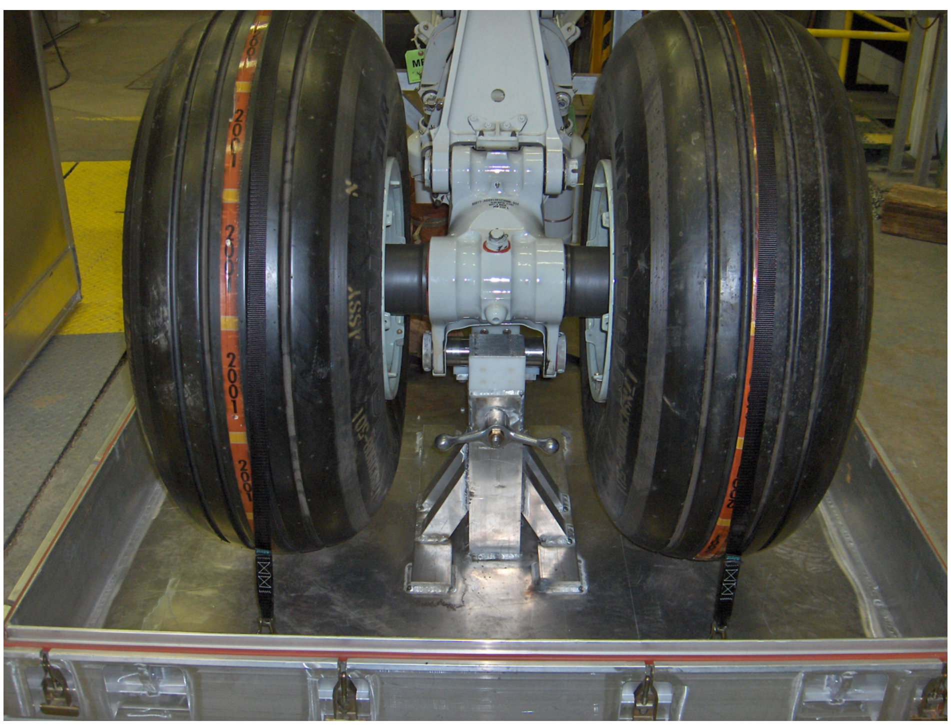


Figure 4. Forward clamp and tire straps.

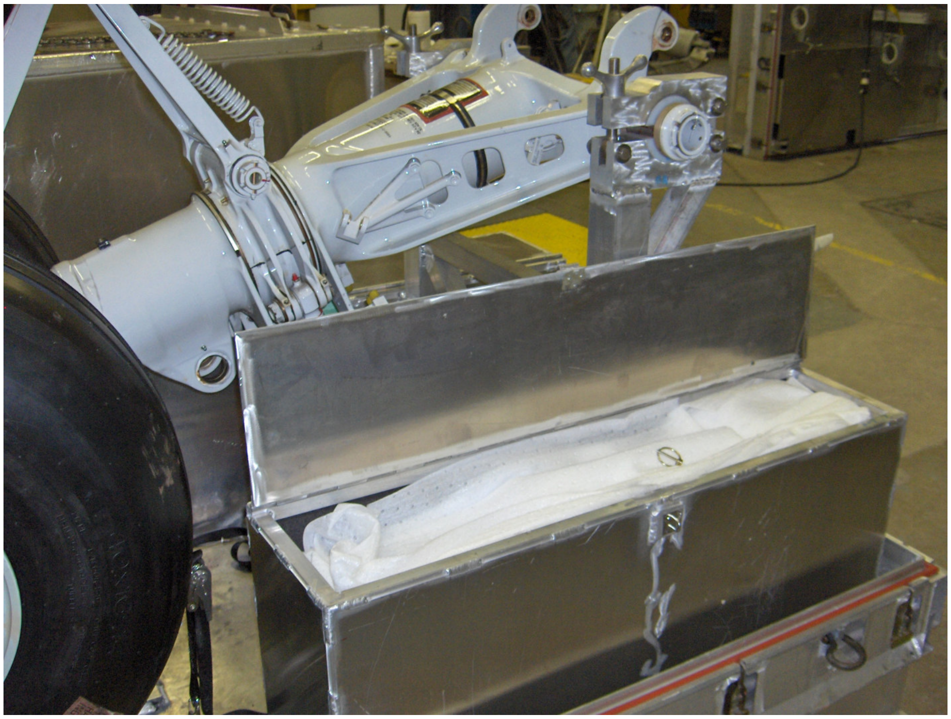


Figure 5. Parts box packed with installation kit.

Figure 6. NLG in container base.

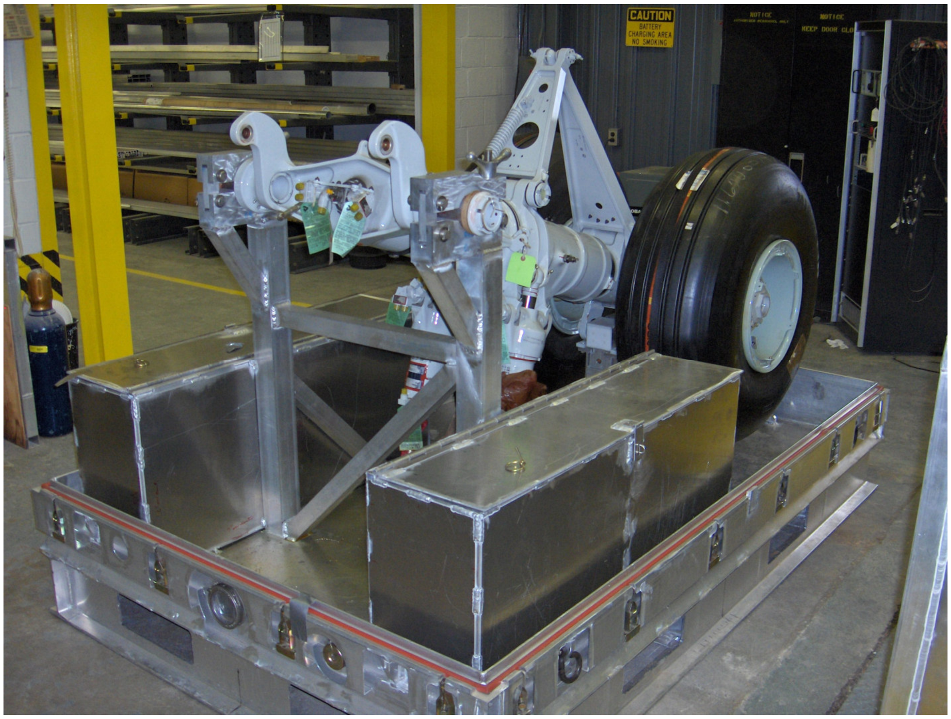


Figure 7. NLG in container base.

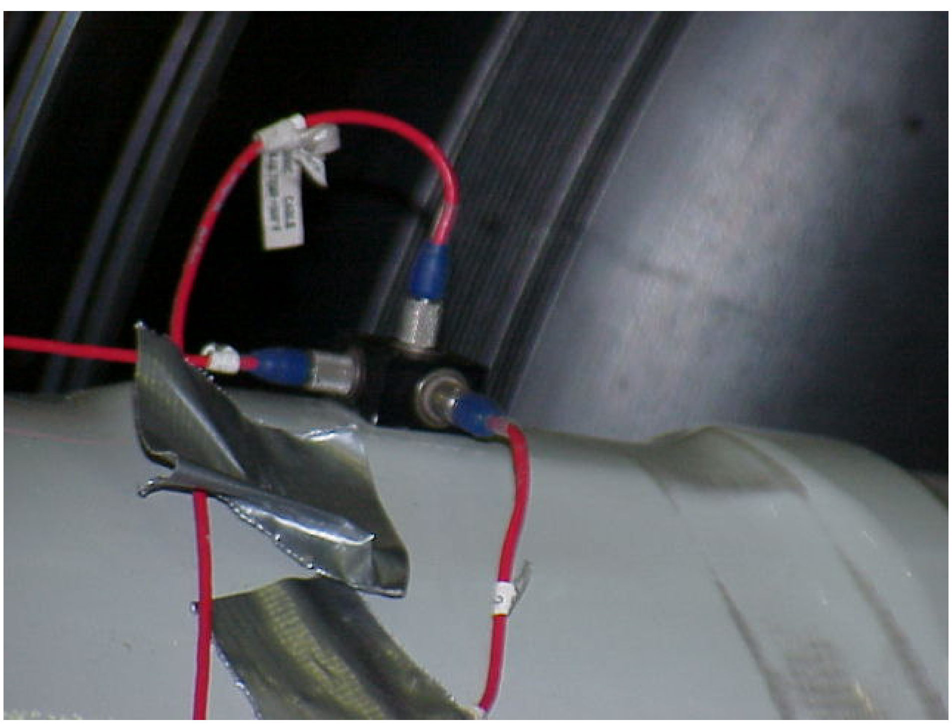


Figure 8. Accelerometer mounted on NLG.

Figure 9. Pressure Test.

Figure 10. Edgewise Rotational Drop.

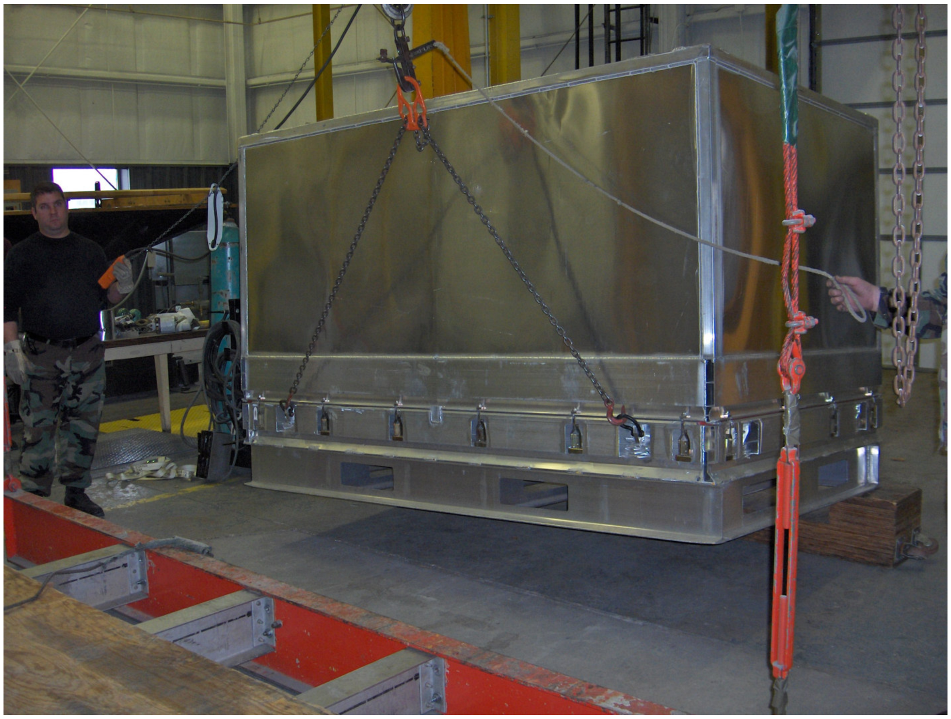


Figure 11. Cornerwise Rotational Drop.

Figure 12. Pendulum Impact Test.

Figure 13. Vibration Testing Set-up (difference between Resonance Dwell and Repetitive Shock tests indistinguishable by photograph). .

APPENDIX 3: Test Data

Table 1. Nose Landing Gear Impact Test Summary

IMPACT TYPE	TEST TEMPERATURE	IMPACT LOCATION	RESULTANT PEAK G
ROTATIONAL - CORNER	ambient	forward-left	15
ROTATIONAL - CORNER	ambient	forward-right	15
ROTATIONAL - EDGE	ambient	forward-bottom	29
ROTATIONAL - CORNER	ambient	aft-left	20
ROTATIONAL - CORNER	ambient	aft-right	21
ROTATIONAL - EDGE	ambient	aft-bottom	44
ROTATIONAL - EDGE	ambient	left-bottom	25
ROTATIONAL - EDGE	ambient	right-bottom	39
LATERAL IMPACT - FACE	ambient	forward	15
LATERAL IMPACT - FACE	ambient	aft	28
LATERAL IMPACT - FACE	ambient	left	22
LATERAL IMPACT - FACE	ambient	right	20

TABLE 2. Container Resonant Frequency and Transmissibility Values.

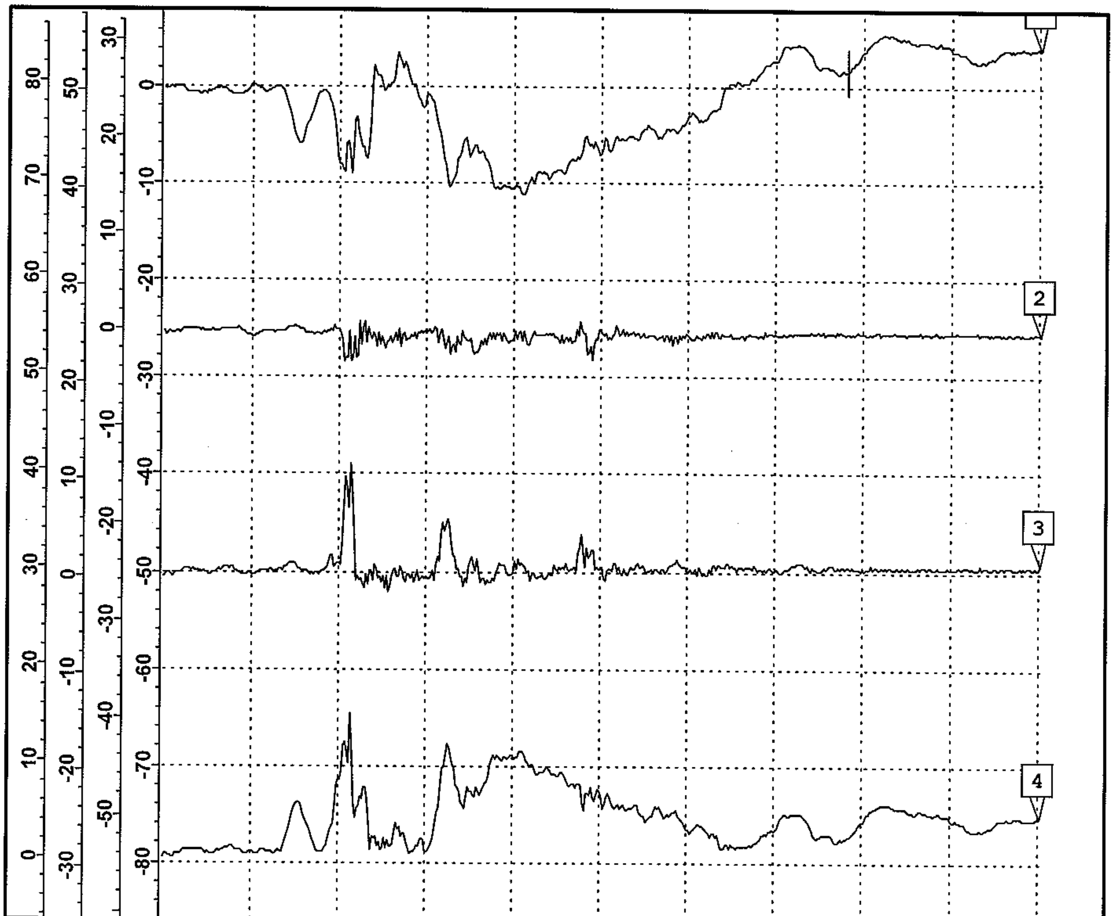
TEST TEMPERATURE	DWELL TIME	RESONANT FREQUENCY	TRANSMISSIBILITY
Ambient	1 min	19.26 Hz	2.4
Ambient	15 min	19.66 Hz	2.1
Ambient	30 min	18.78 Hz	2.4

C17 NOSE LANDING GEAR

ROTATIONAL DROP TEST

Time:	**Jan 31 2007 14:03**	**Test Engineer:**	**Evans**
Test Type:	**Corner Drop**	**Impact Point:**	**Forward Left Corner**
Container/Item:	**Aluminum/NLG**	**Drop Height:**	**12 inches**

V. Angle: 32.19;H.Angle: 101.64;



	Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
◉	1	1.02 S	1.67 g's	-11.42 g's	-1123.68 In/s	131 mS	1	2
○	2	1.02 S	-0.21 g's	-4.75 g's	-159.75 In/s	131 mS	1	2
○	3	1.02 S	1.03 g's	11.67 g's	363.14 In/s	131 mS	1	2
○	R	1.02 S	1.97 g's	15.03 g's	1191.65 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 15 Gs. PEAK G (Z): 12 Gs.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.). Ch.4=Resultant.

Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP1967. Accel. S/N 16473.

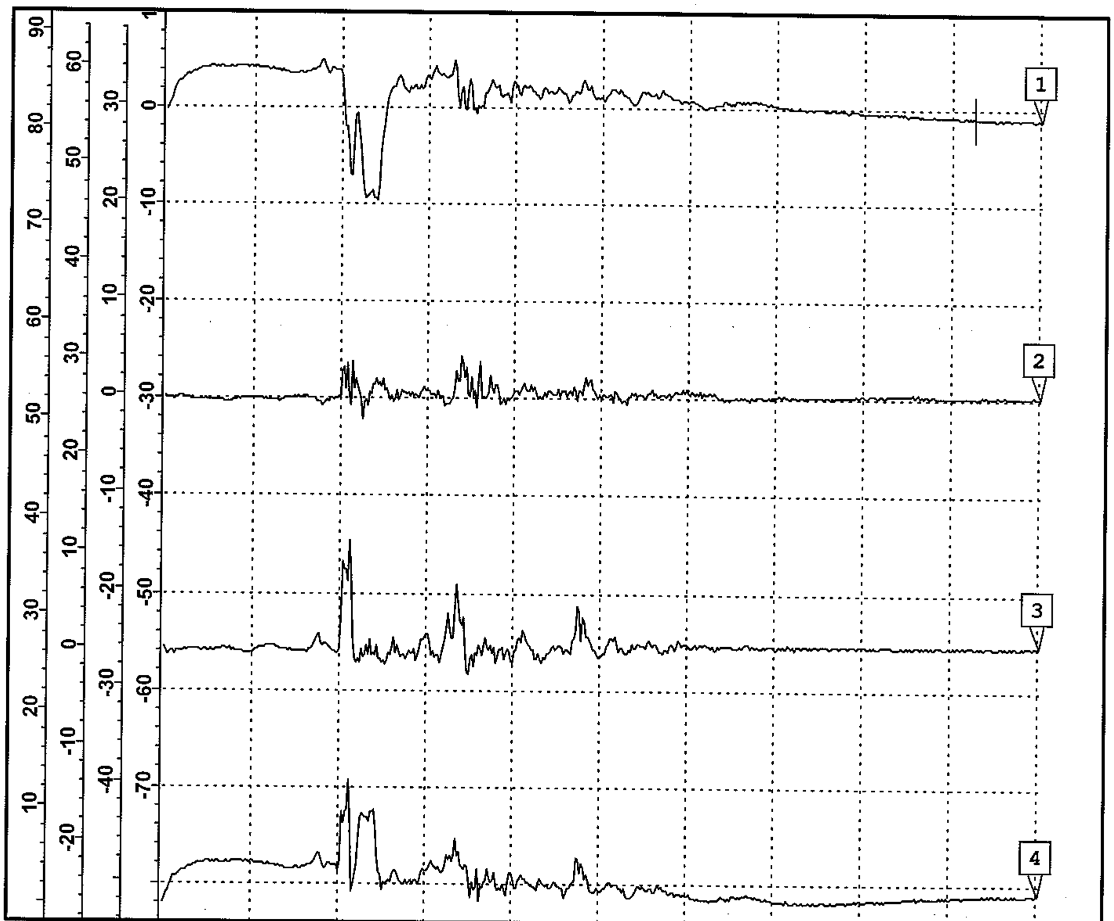
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

ROTATIONAL DROP TEST

Time:	Jan 31 2007 15:33	Test Engineer:	Evans
Test Type:	Corner	Impact Point:	Forward Right Corner
Container/Item:	Aluminum/NLG	Drop Height:	12 inches

V. Angle: 169.94;H.Angle: 94.40;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.21 S	-0.90 g's	-10.13 g's	565.00 In/s	131 mS	1	2
2	1.21 S	-0.01 g's	6.29 g's	63.84 In/s	131 mS	1	2
3	1.21 S	0.16 g's	11.88 g's	48.02 In/s	131 mS	1	2
R	1.21 S	0.91 g's	14.72 g's	570.61 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 15 Gs. PEAK G (Z): 12 Gs.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.). Ch.4=Resultant.

Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARO1967. Accel. S/N 16473.

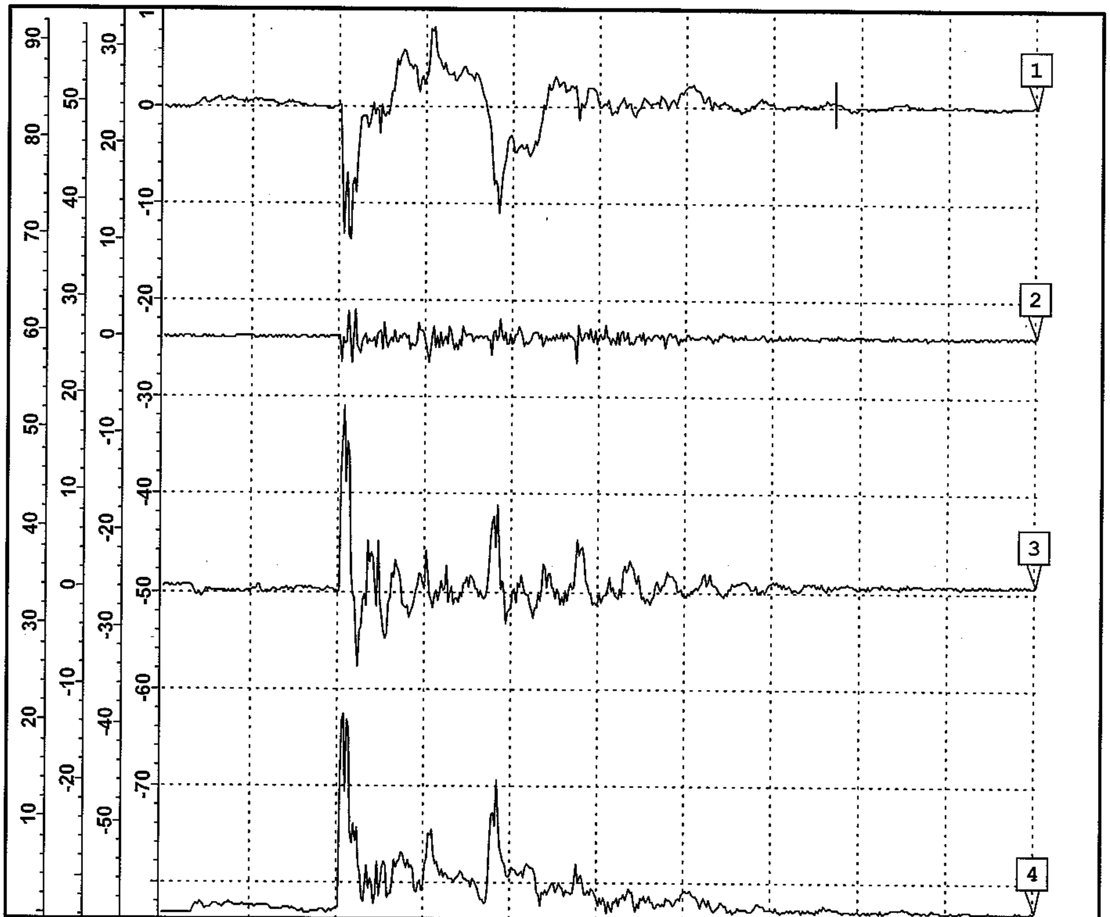
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

ROTATIONAL DROP TEST

Time:	Jan 31 2007 15:48	Test Engineer:	Evans
Test Type:	Edge Drop	Impact Point:	Forward Bottom Edge
Container/Item:	Aluminum/NLG	Drop Height:	12 inches

V. Angle: 26.51;H.Angle: 330.51;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.01 S	0.43 g's	-17.64 g's	117.14 In/s	131 mS	1	2
2	1.01 S	0.19 g's	9.93 g's	-11.90 In/s	131 mS	1	2
3	1.01 S	-0.11 g's	22.45 g's	13.28 In/s	131 mS	1	2
R	1.01 S	0.48 g's	28.55 g's	118.49 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 29 Gs. PEAK G (Z): 22 Gs.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.). Ch.4=Resultant.

Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, ASMT D6179. SAE ARP1967. Accel. S/N 16473.

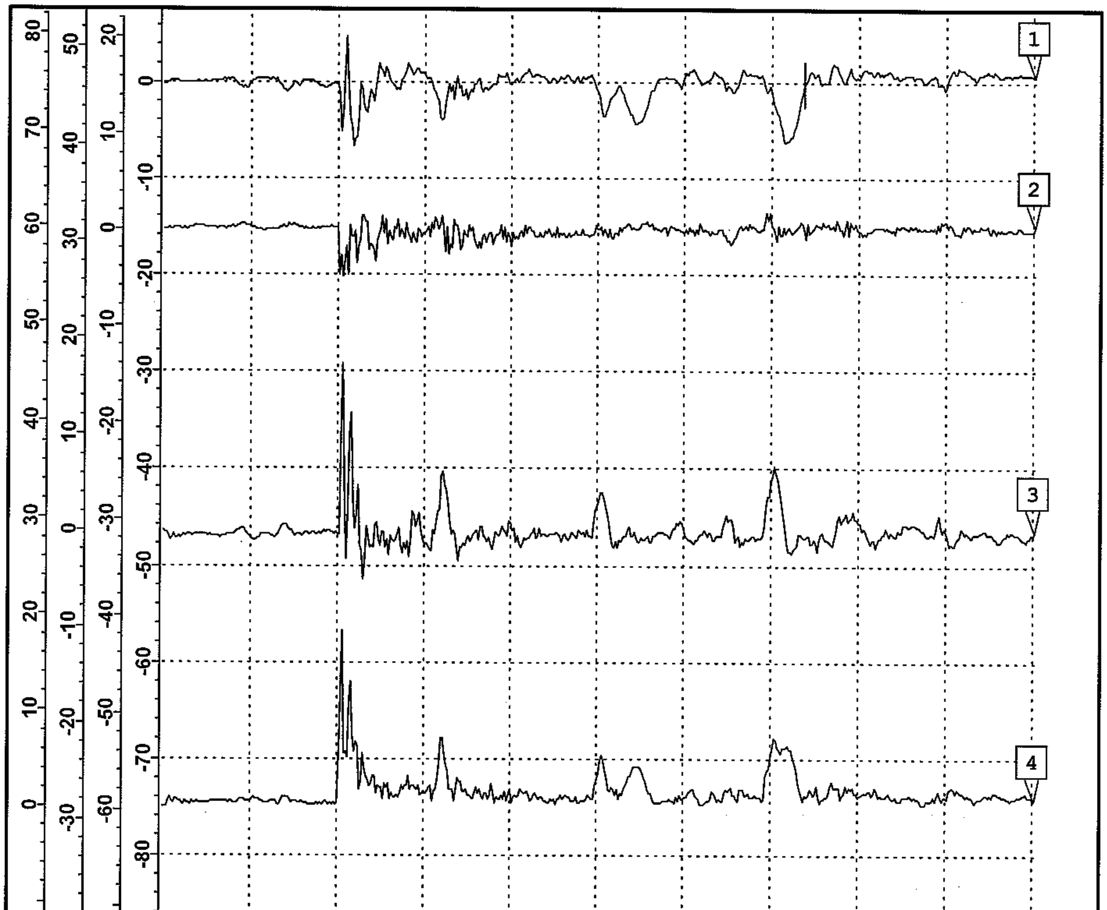
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

ROTATIONAL DROP TEST

Time:	Jan 31 2007 13:53	Test Engineer:	Evans
Test Type:	Corner	Impact Point:	Aft Left Corner
Container/Item:	Aluminum/NLG	Drop Height:	12 inches

V. Angle: 99.68;H.Angle: 281.11;



Ch.	Time		Curr Amp	Peak Amp	1st Int	Time/Div		Hexp	Vexp
1	962.	mS	-0.12 g's	-7.88 g's	-129.52 In/s	131	mS	1	2
2	962.	mS	0.13 g's	-6.04 g's	-48.06 In/s	131	mS	1	2
3	962.	mS	-0.68 g's	19.93 g's	4.15 In/s	131	mS	1	2
R	962.	mS	0.70 g's	20.19 g's	138.22 In/s	131	mS	1	2

Remarks

PEAK G RESULTANT: 20 Gs. PEAK G(Z): 20 Gs.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert). Ch4=Resultant.

Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16743.

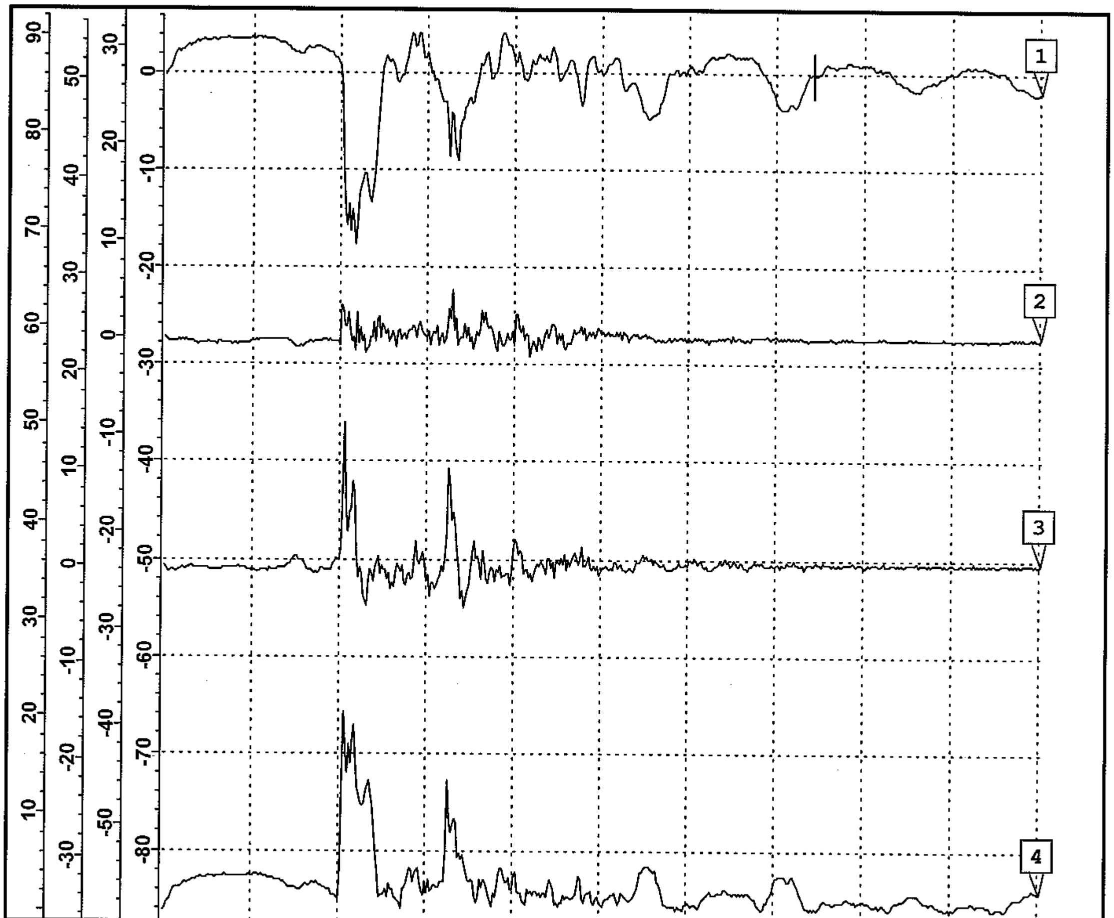
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

ROTATIONAL DROP TEST

Time:	Jan 31 2007 15:37	Test Engineer:	Evans
Test Type:	Corner Drop	Impact Point:	Aft Right Corner
Container/Item:	Aluminum/NLG	Drop Height:	12 inches

V. Angle: 124.08;H.Angle: 209.42;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	970. mS	-0.11 g's	-18.13 g's	-13.40 In/s	131 mS	1	2
2	970. mS	-0.14 g's	9.45 g's	51.28 In/s	131 mS	1	2
3	970. mS	-0.08 g's	15.15 g's	2.13 In/s	131 mS	1	2
R	970. mS	0.20 g's	20.57 g's	53.05 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 21 Gs. PEAK G (X): 18 Gs.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.). Ch.4=Resultant.

Aft Side = desiccant port end. Ambinet Temperature/humidity.
ASMT D4169, ASTM D6179. SAE ARP1967. Accel. S/N 16473.

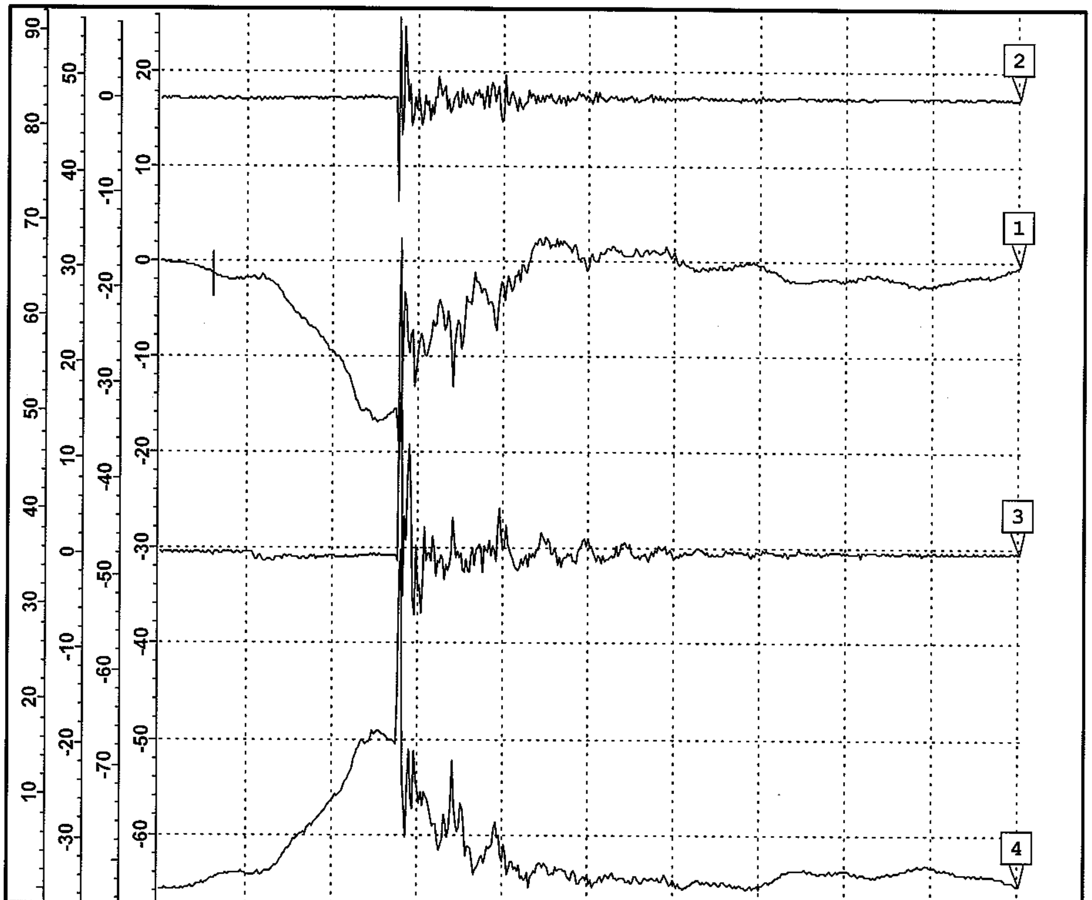
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

ROTATIONAL DROP TEST

Time:	**Jan 31 2007 15:44**	**Test Engineer:**	**Evans**
Test Type:	**Edge Drop**	**Impact Point:**	**Aft Bottom Edge**
Container/Item:	**Aluminum/NLG**	**Drop Height:**	**12 inches**

V. Angle: 171.74;H.Angle: 254.05;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	79.36 mS	-1.22 g's	-1.32 g's	-12.61 In/s	131 mS	1	2
2	79.36 mS	-0.05 g's	-0.22 g's	-0.82 In/s	131 mS	1	2
3	79.36 mS	-0.17 g's	0.22 g's	1.23 In/s	131 mS	1	2
R	79.36 mS	1.24 g's	1.32 g's	12.69 In/s	131 mS	1	2

Remarks

Peak G Resultant: 44 Gs. Peak G(Z): 41 Gs.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert). Ch.4=Resultant.

Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, Astm D6179. SAE ARP 1967. Accel S/N 16473.

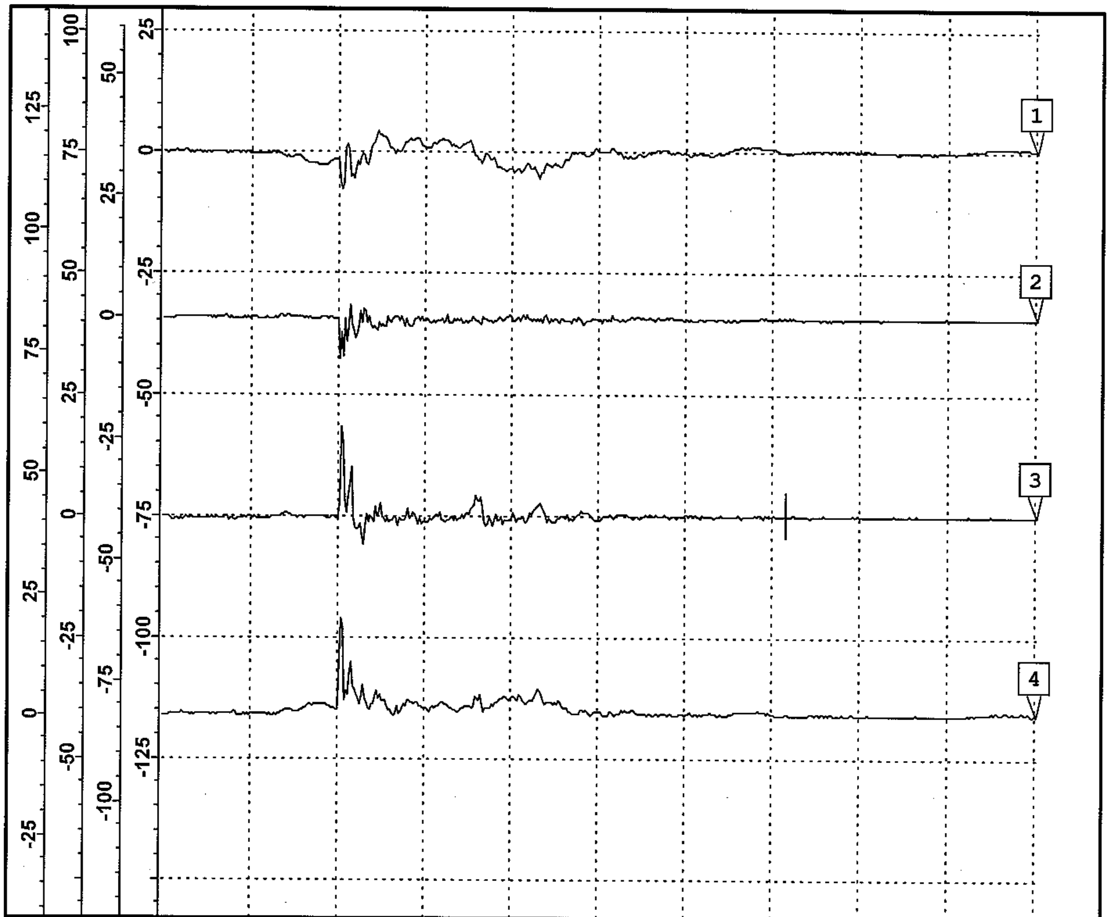
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

ROTATIONAL DROP TEST

Time:	**Jan 31 2007 13:51**	**Test Engineer:**	**Evans**
Test Type:	**Edge Drop**	**Impact Point:**	**Left Bottom Edge**
Container/Item:	**Aluminum/NLG**	**Drop Height:**	**12 inches**

V. Angle: 125.62;H.Angle: 92.16;



	Ch.	Time		Curr Amp	Peak Amp	1st Int	Time/Div		Hexp	Vexp
○	1	934.	mS	-0.23 g's	-8.78 g's	-160.77 In/s	131	mS	1	2
○	2	934.	mS	-0.01 g's	-10.75 g's	-63.35 In/s	131	mS	1	2
●	3	934.	mS	0.32 g's	23.86 g's	2.35 In/s	131	mS	1	2
○	R	934.	mS	0.40 g's	24.90 g's	172.81 In/s	131	mS	1	2

Remarks

PEAK G RESULTANT: 25 Gs. PEAK G (Z): 25 Gs.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.). Ch.4=Resultant.

Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP1967. Accel. S/N 16473.

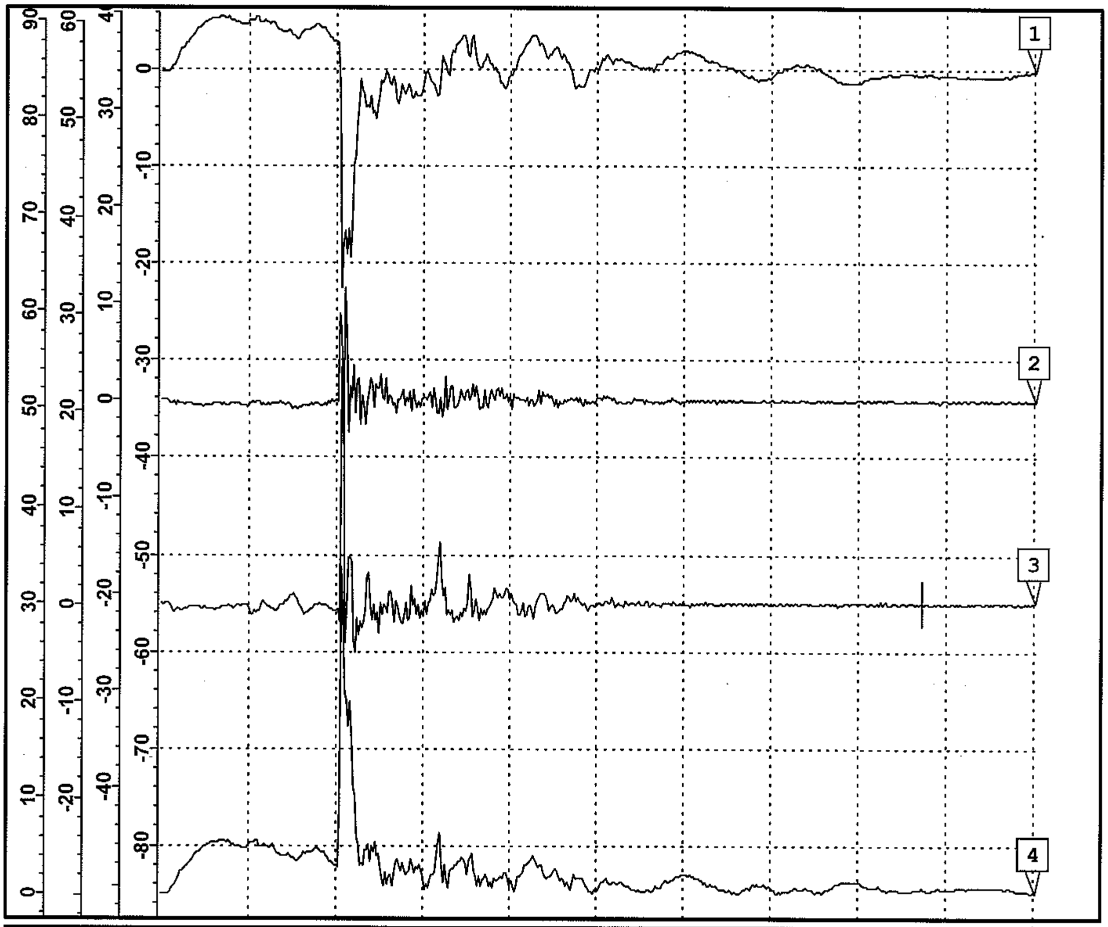
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

ROTATIONAL DROP TEST

Time:	**Jan 31 2007 15:30**	**Test Engineer:**	**Evans**
Test Type:	**Edge Drop**	**Impact Point:**	**Right Bottom Edge**
Container/Item:	**Aluminum/NLG**	**Drop Height:**	**12 inches**

V. Angle: 171.74;H.Angle: 96.23;



	Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
○	1	1.14 S	-0.58 g's	-23.02 g's	283.56 In/s	131 mS	1	2
○	2	1.14 S	-0.01 g's	15.35 g's	23.11 In/s	131 mS	1	2
●	3	1.14 S	0.08 g's	30.43 g's	15.19 In/s	131 mS	1	2
○	R	1.14 S	0.59 g's	38.54 g's	284.91 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 39 Gs. PEAK G (Z): 30 Gs.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.). Ch.4=Resultant.

Aft Side= desiccant prot end. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP1967. Accel. S/N 16473.

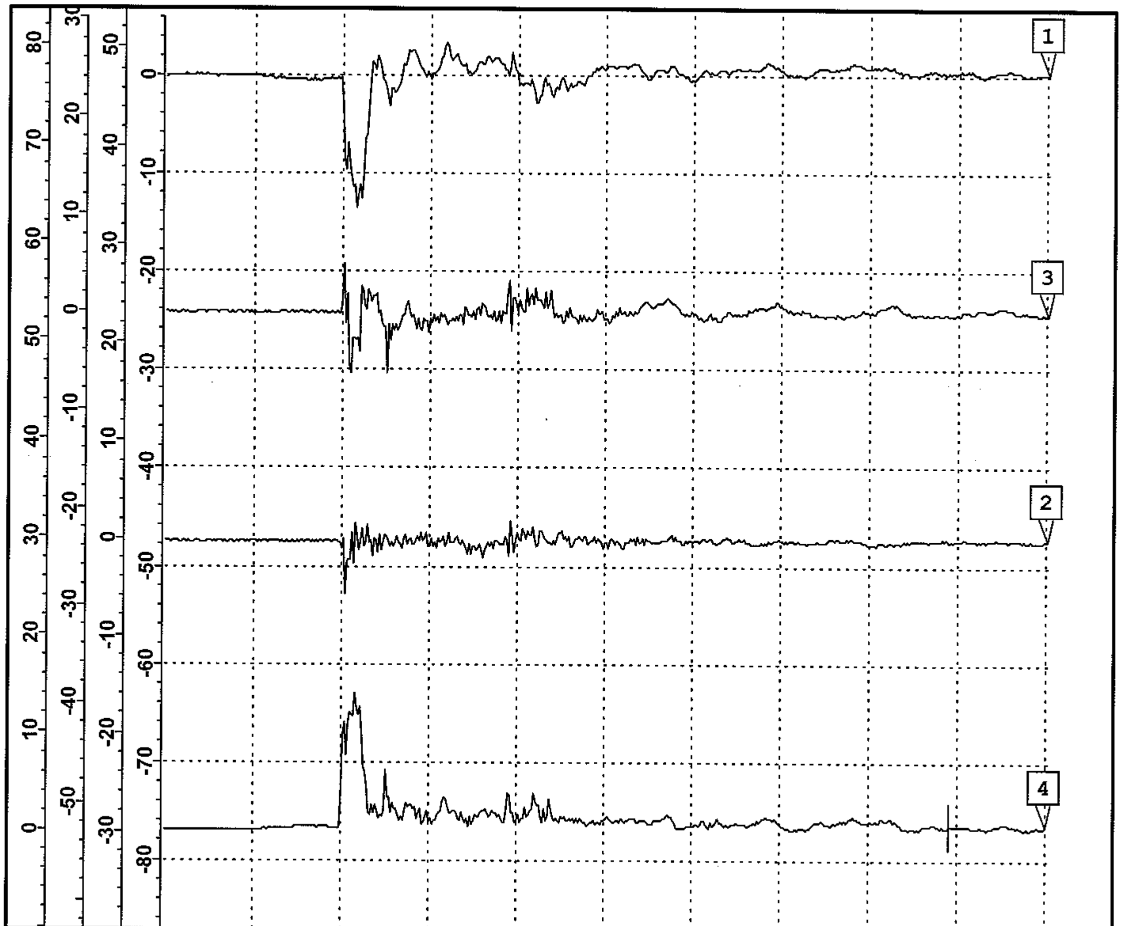
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

PENDULUM IMPACT TEST

Time:	Feb 1 2007 13:24	Test Engineer:	Evans
Test Type:	Side impact	Impact Point:	Forward side
Container/Item:	Aluminum/NLG	Impact Velocty:	7.3 ft/sec

V. Angle: 42.16;H.Angle: 255.79;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.16 S	0.27 g's	-14.40 g's	-7.76 In/s	131 mS	1	2
2	1.16 S	-0.06 g's	-6.73 g's	-25.76 In/s	131 mS	1	2
3	1.16 S	-0.24 g's	-8.54 g's	-26.42 In/s	131 mS	1	2
R	1.16 S	0.45 g's	14.77 g's	37.71 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 15 Gs. PEAK G(X): 14 Gs.

Ch1 = X(fwd-aft); Ch2 = Y(lft-rt); Ch3 = Z(vert); Ch4 = Resultant.

Aft side = desiccant port end. Ambient temperature _humidity.
ASTM D4169, ASTM D6179. SAE ARP1967. Accel. S/N 16473.

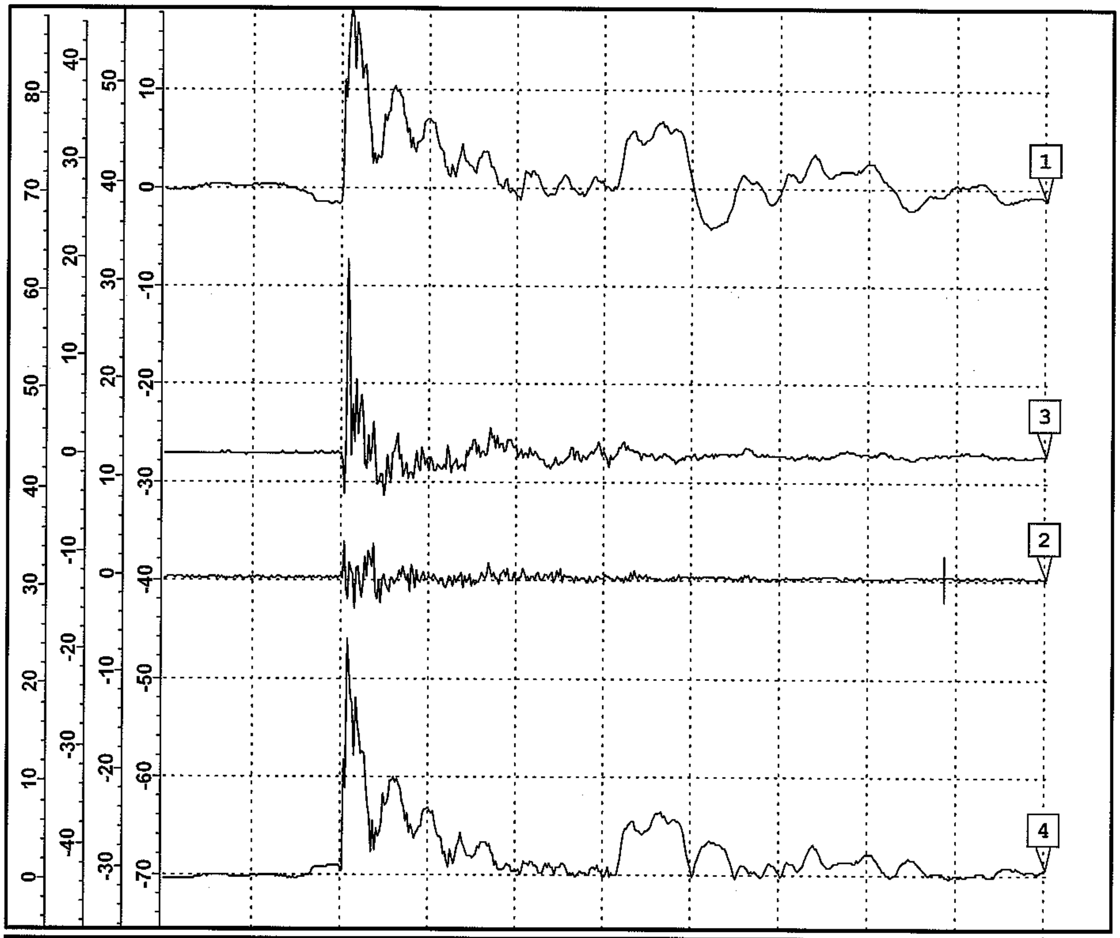
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

PENDULUM IMPACT TEST

Time:	**Feb 1 2007 13:04**	**Test Engineer:**	**Evans**
Test Type:	**Side impact**	**Impact Point:**	**Aft side**
Container/Item:	**Aluminum/NLG**	**Impact Velocty:**	**7.3 ft/sec**

V. Angle: 170.23;H.Angle: 236.89;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
○ 1	1.16 S	-0.49 g's	20.68 g's	785.70 In/s	131 mS	1	2
● 2	1.16 S	-0.05 g's	-8.32 g's	-25.90 In/s	131 mS	1	2
○ 3	1.16 S	-0.07 g's	20.24 g's	-15.44 In/s	131 mS	1	2
○ R	1.16 S	0.49 g's	27.87 g's	786.28 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 28 Gs. PEAK G(X): 21 Gs.

Ch1. = X(fwd-aft): Ch2 = Y(lft-rt); Ch3 = Z(vert.); Ch4 = Resultant.

Aft side = desiccant port end. Ambient temperature _humidity.
ASTM D4169, ASTM D6179. SAE ARP1967. Accel. S/N 16473.

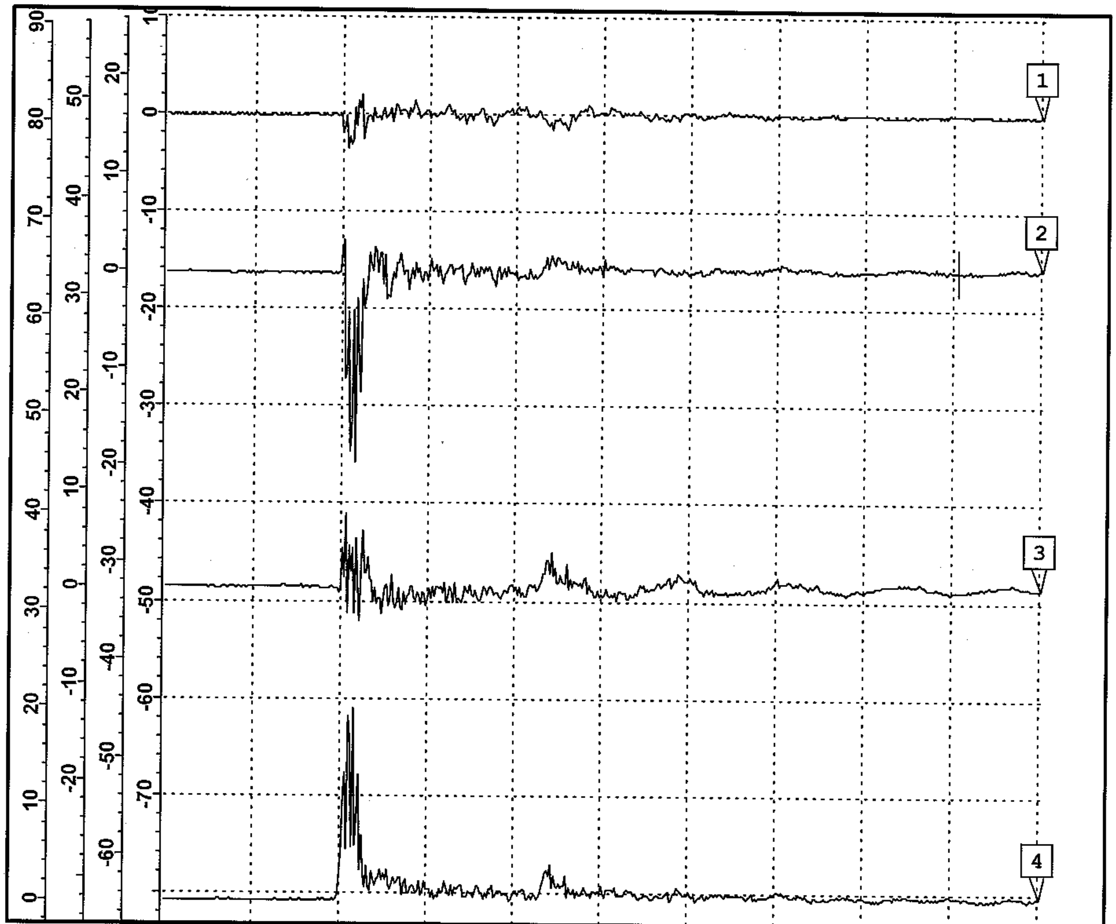
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

PENDULUM IMPACT TEST

Time:	**Feb 5 2007 16:10**	**Test Engineer:**	**Evans**
Test Type:	**Side impact**	**Impact Point:**	**Left side**
Container/Item:	**Aluminum/NLG**	**Impact Velocty:**	**7.3 ft/sec**

V. Angle: 81.53;H.Angle: 291.77;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.18 S	0.07 g's	-7.86 g's	-6.01 In/s	131 mS	1	2
2	1.18 S	0.18 g's	-21.82 g's	-25.20 In/s	131 mS	1	2
3	1.18 S	-0.45 g's	8.27 g's	-40.23 In/s	131 mS	1	2
R	1.18 S	0.49 g's	22.00 g's	47.84 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 22 Gs. PEAK G(Y): 22 Gs.

Ch1 = X(fwd-aft); Ch2 = Y(lft-rt); Ch3 = Z(vert.); Ch4 = Resultant.

Aft side = desiccant port end. Ambient temperature _humidity.
ASTM D4169, ASTM D6179. SAE ARP1967. Accel. S/N 16473.

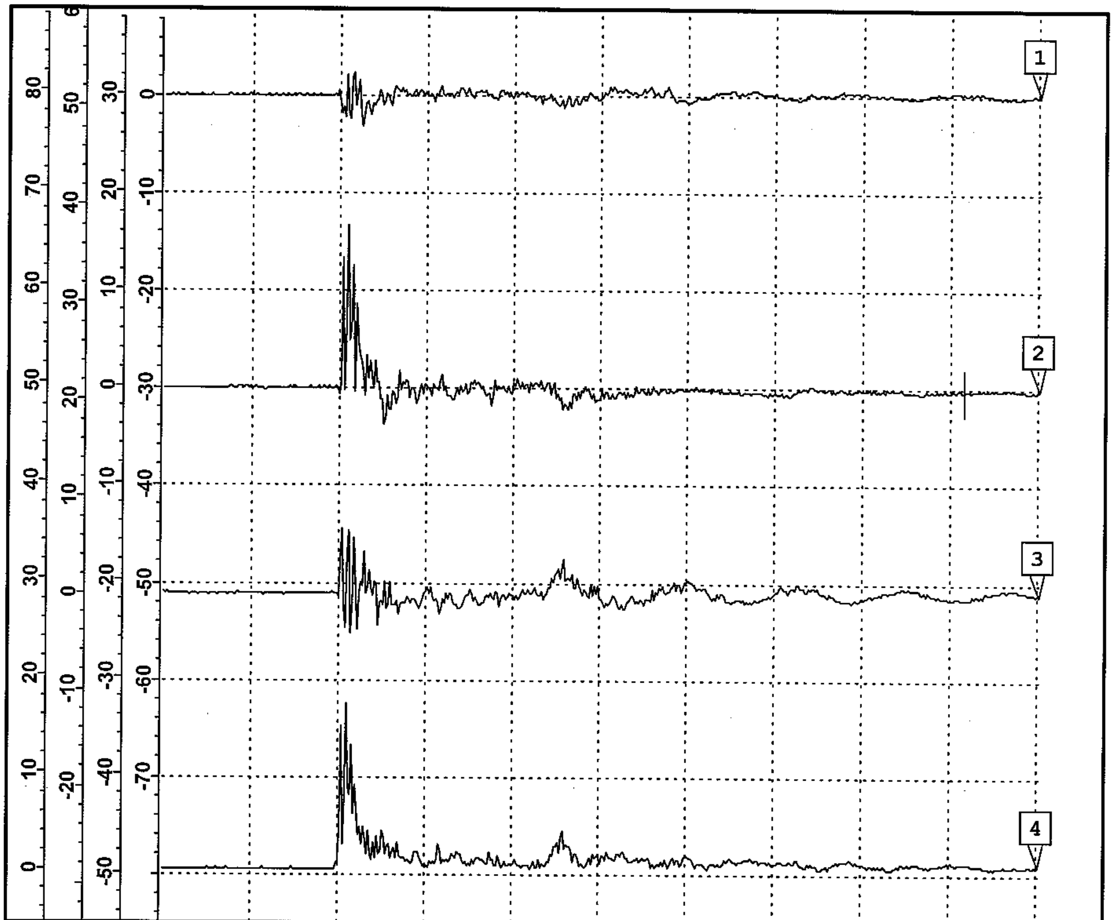
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

PENDULUM IMPACT TEST

Time:	**Feb 5 2007 15:46**	**Test Engineer:**	**Evans**
Test Type:	**Side impact**	**Impact Point:**	**Right side**
Container/Item:	**Aluminum/NLG**	**Impact Velocty:**	**7.3 ft/sec**

V. Angle: 71.61;H.Angle: 241.15;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.20 S	0.23 g's	-5.85 g's	19.62 In/s	131 mS	1	2
2	1.20 S	-0.34 g's	19.44 g's	-27.11 In/s	131 mS	1	2
3	1.20 S	-0.61 g's	9.79 g's	-52.62 In/s	131 mS	1	2
R	1.20 S	0.74 g's	19.67 g's	62.36 In/s	131 mS	1	2

Remarks

PEAK G RESULTANT: 20 Gs. PEAK G(Y): 19 Gs.

Ch1 = X(fwd-aft); Ch2 = Y(lft-rt); Ch3 = Z(vert.); Ch4 = Resultant.

Aft side = desiccant port end. Ambient temperature _humidity.
ASTM D4169; ASTM D6179. SAE ARP1967. Accel. S/N 16473.

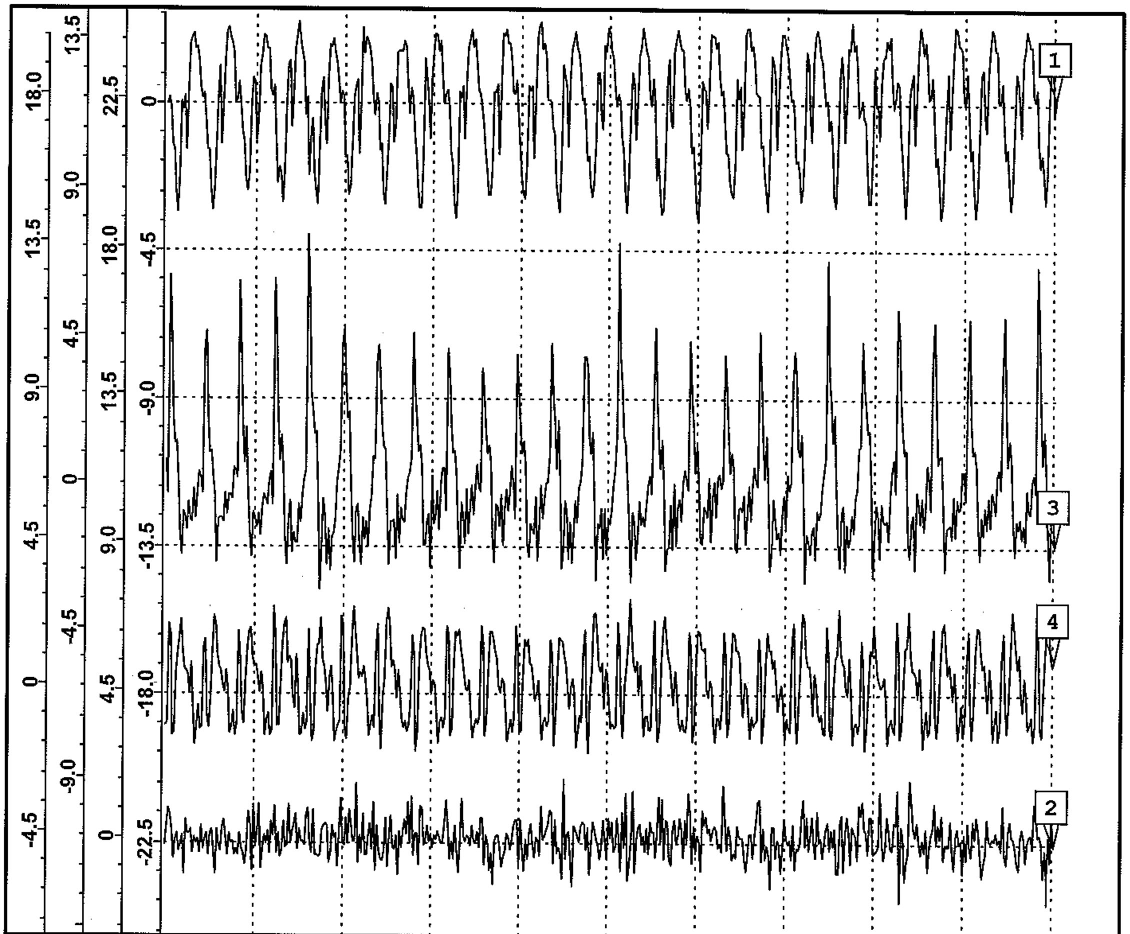
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

RESONANCE DWELL

Time:	**Feb 12 2007 12:48**	**Test Engineer:**	**Evans**
Test Type:	**Vibration**	**Frequency:**	**19.26 Hz**
Container/Item:	**Aluminum/NLG**	**Test Time:**	**1 minute**

Filter: Ch.1 = 500 Hz Ch.2 = 500 Hz Ch.3 = 500 Hz Ch.4 = 500 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
○ 1	1.30 S	1.16 g's	-3.80 g's	1.67 In/s	131 mS	2	2
● 2	1.30 S	-1.27 g's	2.72 g's	3.76 In/s	131 mS	2	2
○ 3	1.30 S	0.33 g's	9.00 g's	25.69 In/s	131 mS	2	2
○ 4	1.30 S	2.03 g's	2.63 g's	13.96 In/s	131 mS	2	2

Remarks

Transmissibility Z: 2.40. Transmissibility X: 1.59.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.); Ch.4=Table Input.

Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP1967. Accel. S/N 16473.

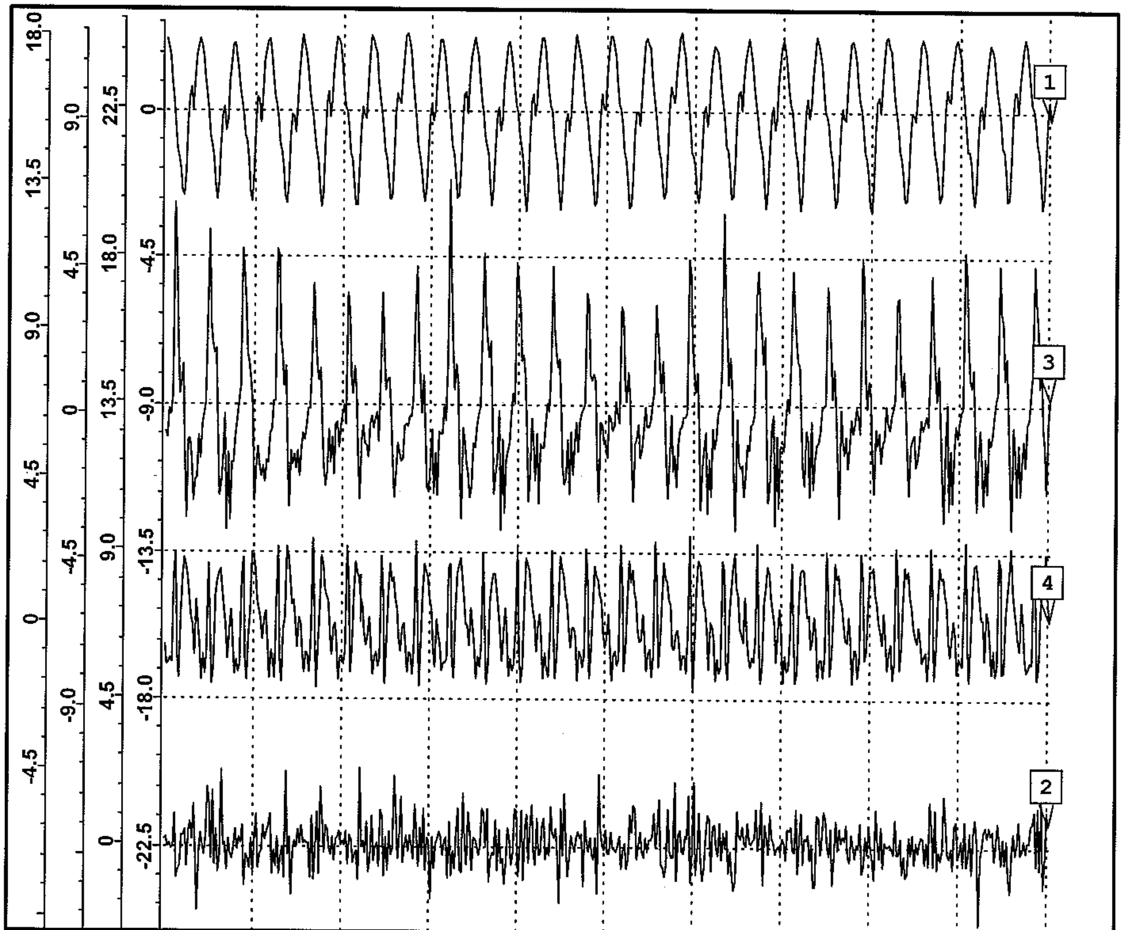
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

RESONANCE DWELL

Time:	Feb 12 2007 13:05	Test Engineer:	Evans
Test Type:	Vibration	Frequency:	19.66 Hz
Container/Item:	Aluminum/NLG	Test Time:	15 minutes

Filter: Ch.1 = 50 Hz Ch.2 = 500 Hz Ch.3 = 500 Hz Ch.4 = 500 Hz



Ch.	Time		Curr Amp	Peak Amp	1st Int	Time/Div		Hexp	Vexp
1	862.	mS	2.28 g's	-3.05 g's	4.85 In/s	131	mS	2	2
2	839.	mS	-0.21 g's	-2.90 g's	11.92 In/s	131	mS	2	2
3	855.	mS	-1.55 g's	8.21 g's	9.09 In/s	131	mS	2	2
4	289.	mS	0.75 g's	2.68 g's	2.84 In/s	131	mS	2	2

Remarks

Transmissibility Z: 2.11. Transmissibility X: 1.62.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.); Ch.4=Table Input.

Aft Side = desiccant port end. Ambient Temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP1967. Accel. S/N 16473.

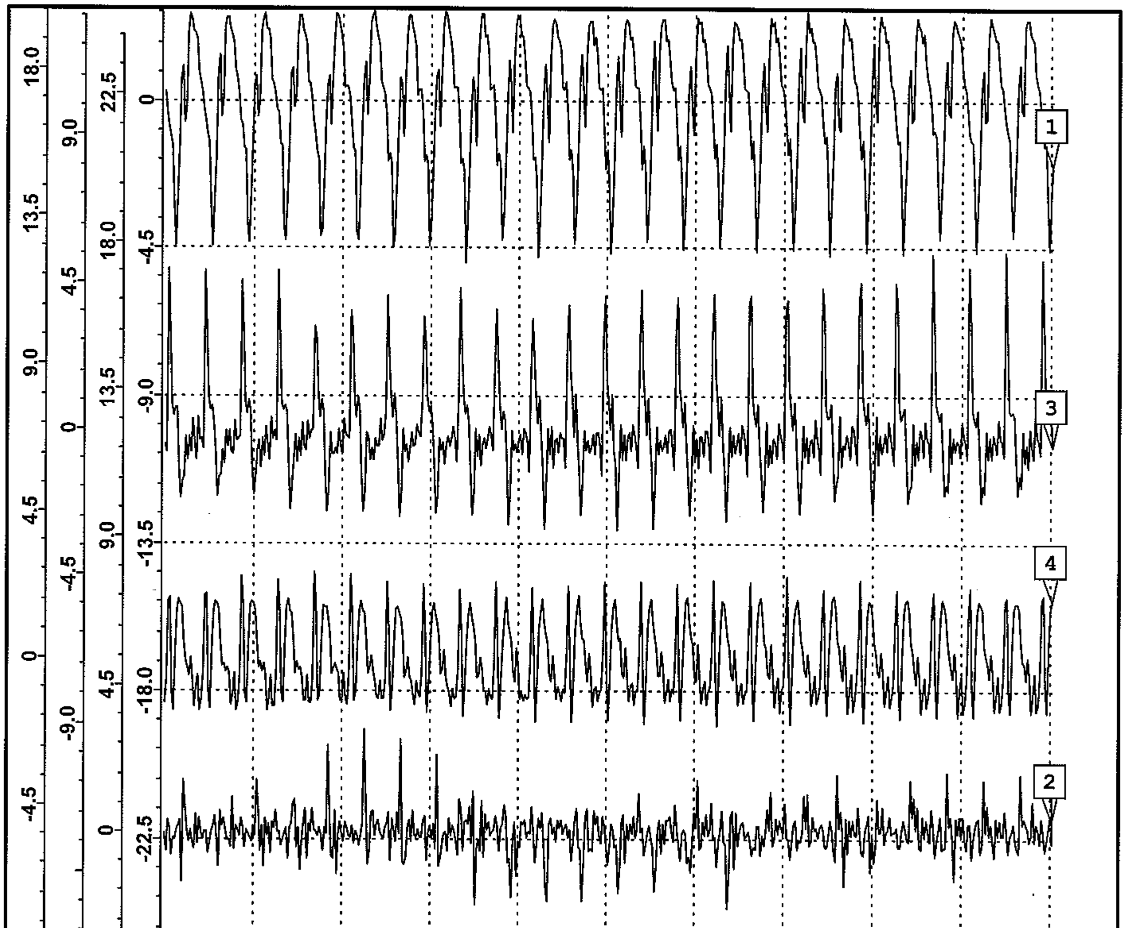
GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

RESONANCE DWELL

Time:	Feb 12 2007 13:21	Test Engineer:	Evans
Test Type:	Vibration	Frequency:	18.78 Hz
Container/Item:	Aluminum/NLG	Test Time:	30 minutes

Filter: Ch.1 = 500 Hz Ch.2 = 500 Hz Ch.3 = 500 Hz Ch.4 = 500 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
○ 1	1.30 S	-1.89 g's	-4.90 g's	2.93 In/s	131 mS	2	2
● 2	1.30 S	0.40 g's	3.28 g's	0.98 In/s	131 mS	2	2
○ 3	-10. mS	-0.46 g's	-0.46 g's	0.00 In/s	131 mS	2	2
○ 4	-10. mS	-1.34 g's	-1.34 g's	0.00 In/s	131 mS	2	2

Remarks

Transmissibility Z: 2.42. Transmissibility X: 1.96.

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.); Ch.4=Table Input.

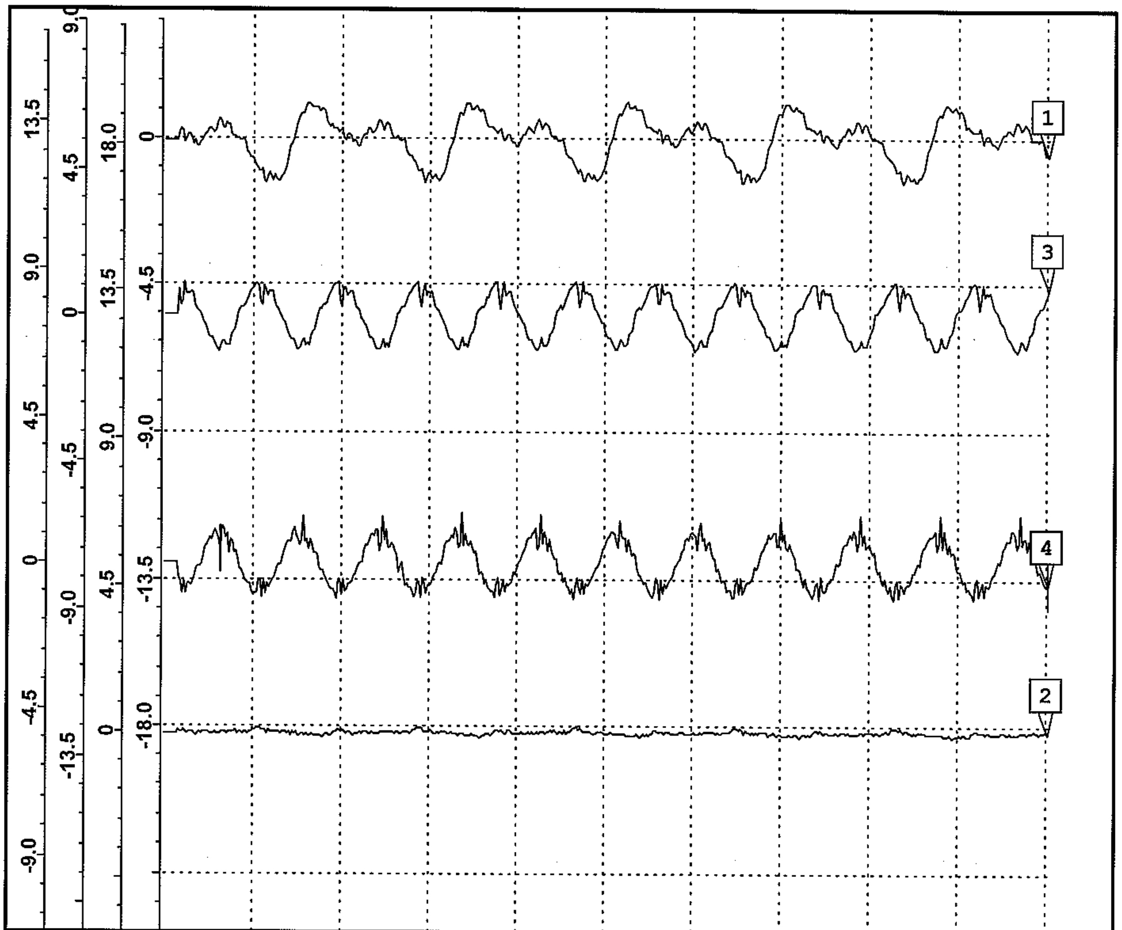
Aft Side = desiccant prot end. Ambient temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP1967. Accel. S/N 16473.

GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

REPETITIVE SHOCK

Time:	**Feb 23 2007 9:58**	**Test Engineer:**	**Evans**
Test Type:	**Vibration**	**Frequency:**	**4.22 Hz**
Container/Item:	**Aluminum/NLG**	**Test Time:**	**15 minutes**



	Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
○	1	2.62 S	-0.49 g's	-1.36 g's	12.00 In/s	262 mS	1	2
○	2	2.62 S	-0.01 g's	0.21 g's	2.64 In/s	262 mS	1	2
○	3	2.62 S	0.78 g's	-1.10 g's	-10.97 In/s	262 mS	1	2
●	4	2.45 S	-0.69 g's	1.60 g's	9.09 In/s	262 mS	1	2

Remarks

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.); Ch.4=Table Input.

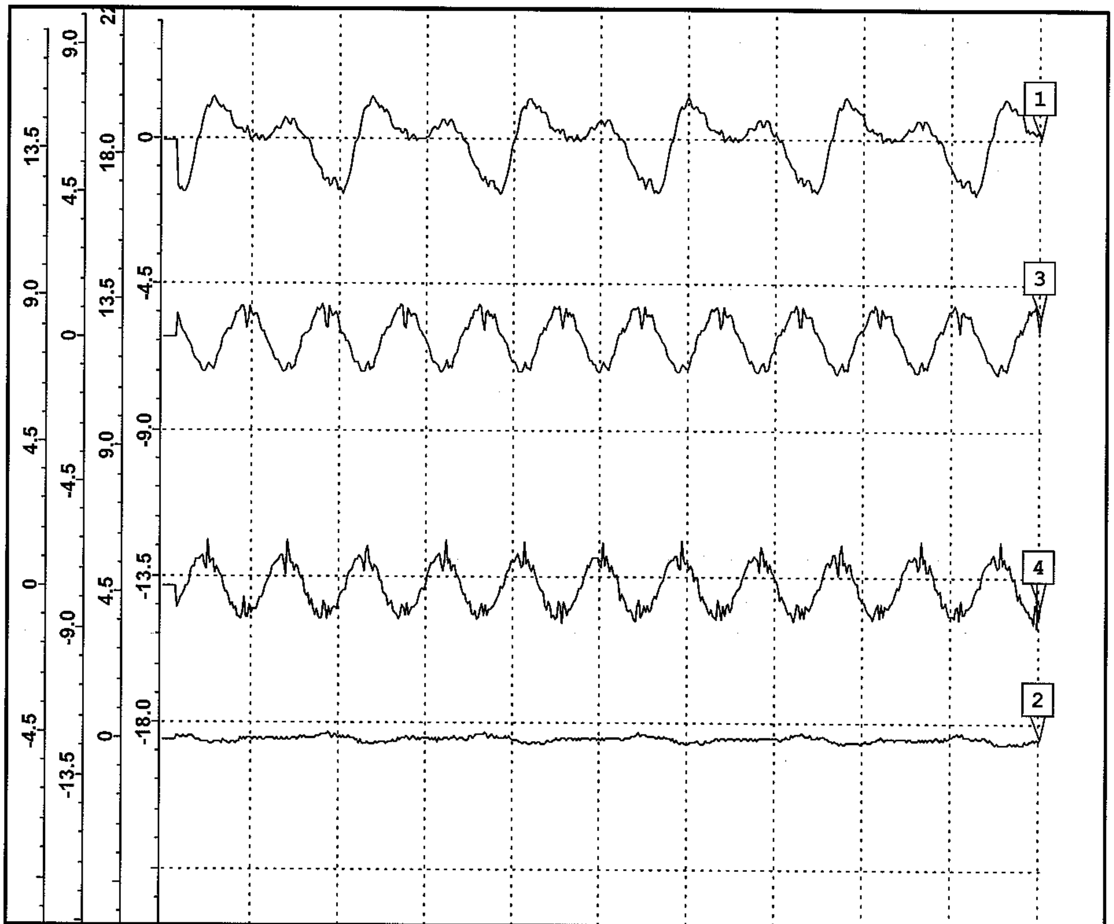
Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP1967.

GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

REPETITIVE SHOCK

Time:	Feb 23 2007 10:45	Test Engineer:	Evans
Test Type:	Vibration	Frequency:	4.22 Hz
Container/Item:	Aluminum/NLG	Test Time:	1 hour



	Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
○	1	2.61 S	0.26 g's	-1.70 g's	12.72 In/s	262 mS	1	2
○	2	2.61 S	0.03 g's	0.24 g's	-0.76 In/s	262 mS	1	2
○	3	2.61 S	0.69 g's	-1.14 g's	-11.01 In/s	262 mS	1	2
●	4	2.61 S	-0.48 g's	1.55 g's	27.94 In/s	262 mS	1	2

Remarks

Ch.1=X(fwd0aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.).; Ch.4=Table Input.

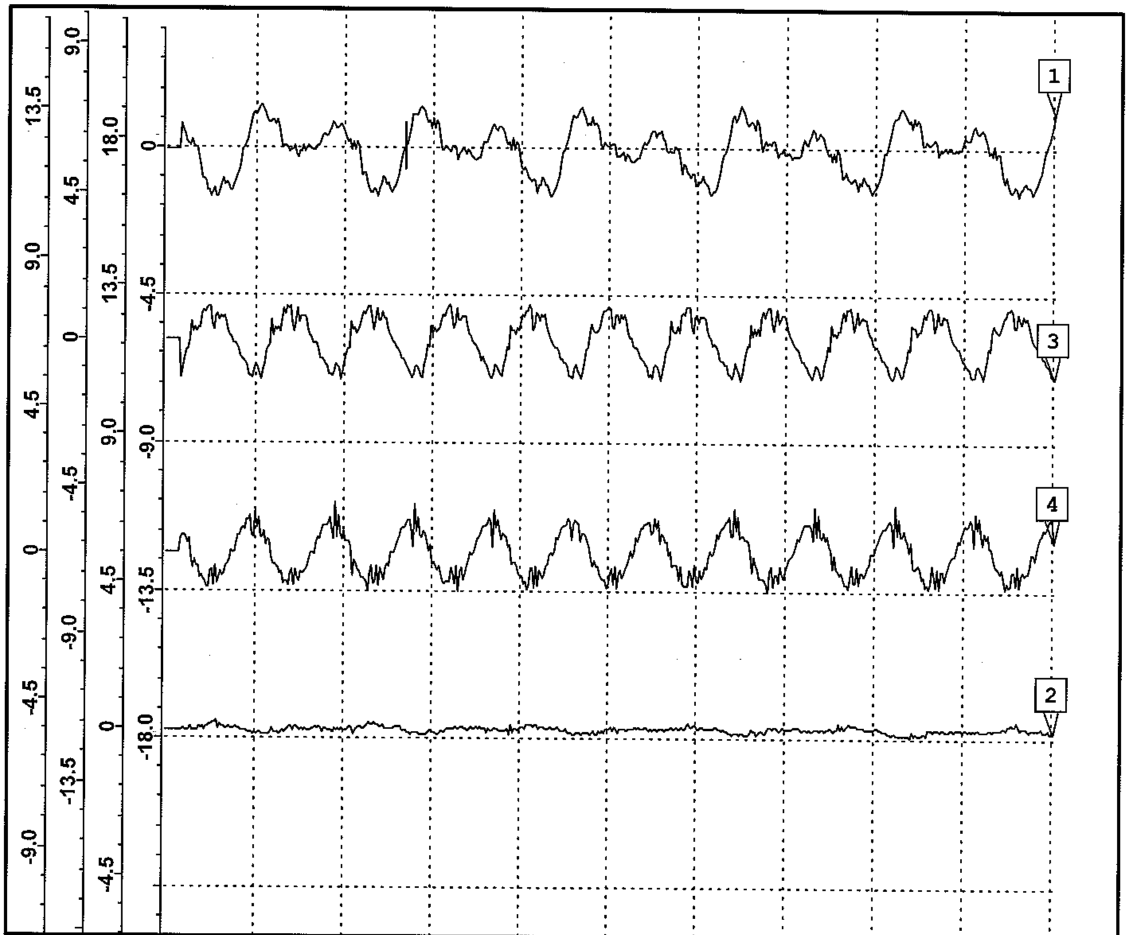
Aft Side = desiccant port end. Ambient temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP1967.

GHI SYSTEMS, INC. CAT SYSTEM

C17 NOSE LANDING GEAR

REPETITIVE SHOCK

Time:	**Feb 23 2007 14:01**	**Test Engineer:**	**Evans**
Test Type:	**Vibration**	**Frequency:**	**4.22 Hz**
Container/Item:	**Aluminum/NLG**	**Test Time:**	**2 hours**



	Ch.	Time		Curr Amp	Peak Amp	1st Int	Time/Div		Hexp	Vexp
◉	1	701.	mS	0.08 g's	-1.56 g's	-41.69 In/s	262	mS	1	2
○	2	2.62	S	-0.11 g's	-0.30 g's	7.12 In/s	262	mS	1	2
○	3	2.62	S	-1.13 g's	-1.27 g's	4.70 In/s	262	mS	1	2
○	4	2.62	S	0.37 g's	1.65 g's	4.89 In/s	262	mS	1	2

Remarks

Ch.1=X(fwd-aft); Ch.2=Y(lft-rt); Ch.3=Z(vert.); Ch.4=Table Input.

Aft Side = desiccant prot end. Ambient temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP1967.

GHI SYSTEMS, INC. CAT SYSTEM

APPENDIX 4: Test Instrumentation

PRESSURE TEST EQUIPMENT - Test sequences 1 & 6

EQUIPMENT	MANUFACTURER	MODEL	SN	CAL. DATE
Digital Manometer	Yokogawa	2655	82DJ6009	15 Dec 06

ROUGH HANDLING TEST EQUIPMENT - Test sequences 2 - 5.

EQUIPMENT	MANUFACTURER	MODEL	SN	CAL. DATE
Shock Amplifier	Endevco	2775A	ER34	NA
Shock Amplifier	Endevco	2775A	ER33	NA
Shock Amplifier	Endevco	2775A	EL81	NA
Item Accelerometer	Endevco	2228C	16473	20 Sep 06
Data Acquisition	GHI Systems	CAT	Ver. 2.7.1	N/A

APPENDIX 5: Distribution List

DISTRIBUTION LIST

DTIC/O
DEFENSE TECHNICAL INFORMATION CENTER
FORT BELVOIR VA 22060-6218

AFMC LSO/LO
WRIGHT-PATTERSON AFB OH 45433-5540

448 MSUG/GBMST
TINKER AFB OK 73145

84 MSUG/GBMUM
HILL AFB UT 84056-5805

542 MSUG/GBMSCA
ROBINS AFB GA 31098-1670

564 ACSS/GFLC (ATTN: ERMA GOMEZ)
44 GREEN STREET, #100
WARNER ROBINS, GA 31093

516 AESG/LGP (ATTN: STAN SMIGIEL)
2590 LOOP ROAD WEST
WRIGHT-PATTERSON AFB OH 45433-5540

THE BOEING COMPANY
ATTN: GUY BREDESEN M/C C078-0432
2401 E WARDLOW RD
LONG BEACH, CA 90801-5608

APPENDIX 6: Report Documentation

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
20-07-2007	TECHNICAL, FINAL PROJECT REPORT	August 2005-April 2007

4. TITLE AND SUBTITLE
Development of the C-17 Nose Landing Gear Container, CNU-691/E

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Joel A. Sullivan
Susan J. Evans

5d. PROJECT NUMBER
05-P-106

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
HQ AFMC LSO/LOP
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13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report is responsible for documenting the design and qualification testing of the CNU-691/E container. The container developed will protect the Nose Landing Gear mechanically, environmentally, and make the item much more easy to maneuver during worldwide shipment and storage. The CNU-691/E, designed per ARP1967A, is an aluminum, long life, controlled breathing, reusable container. The container passed all qualification test ASTM D4169 as well as field tests. The CNU-691/E container will not only meet the users' requirements but will also provide an economic savings in O&M costs. The CNU-691/E container was designed, prototyped and tested in house at the Air Force Packaging Technology & Engineering Facility and is qualified for production release.

15. SUBJECT TERMS
CNU-691/E, C-17 Nose Landing Gear, Aluminum Container, Reusable Container, Long-Life Container, Design, Test

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