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**JOEL A. SULLIVAN
Project Engineer
joel.sullivan@us.af.mil
DSN 787-8162
Comm (937) 257-8162**

**SUSAN J. EVANS
Qualification Test Engineer
susan.evans@us.af.mil
DSN 787-7445
Comm (937) 257-7445**

**Development of the MQ-9 Reaper Engine Container,
CNU-696/E**

**AFMC LSO/LOP
AIR FORCE PACKAGING TECHNOLOGY & ENGINEERING FACILITY
WRIGHT PATTERSON AFB, OH 45433-5540
12 February 2008**

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AFPTEF PROJECT NO. 06-P-104

TITLE: Development of the MQ-9 Reaper Engine Container

ABSTRACT

The Air Force Packaging Technology Engineering Facility (AFPTEF) was tasked with the design of a new shipping and storage container for the MQ-9 Reaper Engine in March of 2006. The new container is designed to replace the fiberboard box currently used. The current container is not reusable and provides minimal shock protection and no environmental protection against corrosion. Additionally, the fiberboard box can not house the engine in the Quick Engine Change (QEC) configuration. AFPTEF used proven design techniques to meet these design requirements.

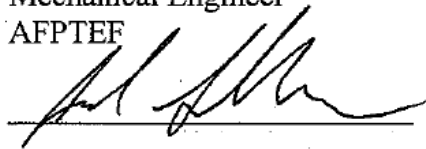
The CNU-696/E, designed to SAE ARP1967A, is an aluminum, long-life, controlled breathing, reusable shipping and storage container. The new container protects the Engine mechanically and environmentally. The container passed all qualification tests per ASTM D4169.

The CNU-696/E container not only meets user requirements but also provides an economic saving for the Air Force. The savings will be thousands of dollars per Engine over the twenty-year life span of the container.

Total man-hours: 1500

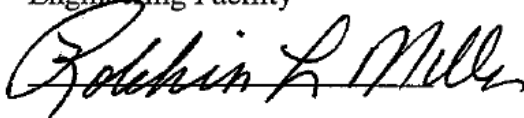
PROJECT ENGINEER:

Joel Sullivan
Mechanical Engineer
AFPTEF



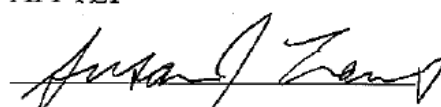
APPROVED BY:

Robbin Miller
Chief, Air Force
Packaging Technology
Engineering Facility



TEST ENGINEER:

Susan Evans
Mechanical Engineer
AFPTEF



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INTRODUCTION

BACKGROUND – Reaper program office personnel at Wright-Patterson AFB contacted AFPTEF to request the design of a reusable container for the MQ-9 Reaper Engine that would eliminate current shipping and storage risks. The Reaper Engine is currently shipped in a fiberboard box. The box does not have environmental controls and is not sealed by the nature of its construction. These two factors allow the container to “breathe” with continuously changing environmental conditions. There is no means to control breathing or remove the excess moisture that results, which could cause a corrosion problem on the Engine. The box also lacks any shock protection and can not house the engine in its QEC configuration. The current packaging degrades readily and cannot be stored outside. The Reaper Engine container is one of a family of new AFPTEF container designs that better protect assets in the shipping and storage cycle. Containers were also designed for the Reaper Fuselage, Reaper Wings and Reaper Propeller.

REQUIREMENTS – AFPTEF, Program Office personnel and General Atomics agreed upon a list of requirements during initial design discussions. Many of these requirements were not met by the fiberboard box. 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
- Engine shock/vibration limited to 10 Gs
- Reusable and designed for long life (20 years)
- Designed for QEC configuration
- Low maintenance
- Field repairable hardware
- Forklift capabilities
- No loose packing material
- Compatibility with support equipment (Engine Hoist)

DEVELOPMENT

DESIGN – The Reaper Engine Shipping and Storage Container (CNU-696/E) design meets all the users’ requirements. The CNU-696/E is a sealed, welded aluminum, controlled breathing, reusable container (Appendix 2, Figure 1). The container is engineered for the physical and environmental protection of the Engine during worldwide transportation and storage. The container consists of a base, cradle, and completely removable cover equipped with the special features listed below. Guide posts (Appendix 2, Figure 2) keep the cover from coming in contact with the Engine during cover removal and replacement. The base is a double walled extrusion combined with a 10 inch I-beam skid with 4-way enclosed forklift openings, humidity indicator, pressure equalizing valve (1.5 psi pressure/ 1.5 psi vacuum), internal document receptacle, 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 81.3 inches length, 49.8 inches width, and 58.1 inches height. Container empty weight is 898 pounds, and 1497 pounds with the engine in place.

An aluminum cradle system is integrated into the base and suspended on four stainless steel helical wire rope isolators at 45 degree angles that provide shock and vibration protection to 10 G's (Appendix 2, Figure 2). Prior to installation of the Engine the Beta Tube must be secured in the aluminum box in the center of the cradle (Appendix 2, Figure 5). The QEC Engine is then attached to the cradle system by inserting the four threaded pins of the engine truss and tightening four aluminum knobs (Appendix 2, Figure 3). The knobs are locked in place with quick pins. A clamp is then rotated up to close on the aft end of the engine truss (Appendix 2, Figure 4). There are no detachable parts on the container other than the container lid, which eliminates FOD risks.

REAPER ENGINE CONTAINER FEATURES	
Pressure Equalizing Valve	1
Humidity Indicator	1
Desiccant Port	1
Internal Document Receptacle	1
Forkliftable	Yes
Cover Latches	16
Cover Lift Handles	None
Cover Lift Rings	2
Cover Tether Rings	None
Base Lift Handles	None
Base Tie-down Rings	4
Stacking Capability	Yes

PROTOTYPE – AFPTEF fabricated one CNU-696/E prototype container in house for testing. The prototype container was fabricated in accordance with (IAW) all requirements and tolerances of the container drawing package. 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 non-reparable Reaper engine, to which lead shot had been added to ensure a correct test weight (Appendix 2, Figure 8). The primary triaxial accelerometer used to record actual accelerations sustained by the engine was mounted on the fuel control unit. The test load weight was 1497 pounds.

TEST PLAN – The test plan primary references were ASTM D 4169 and SAE ARP 1967 (Appendix 1). The test methods specified in this test plan constituted the procedure for performing the tests on the container. The performance criteria for evaluation of container acceptability were specified at 10 Gs maximum and an initial and final leak rate of 0.05 psi per hour at 1.5 psi. These tests are commonly applied to special shipping containers providing rough handling protection to sensitive items. The tests were performed at AFPTEF, Building 70, Area C, Wright-Patterson AFB.

ITEM INSTRUMENTATION – The test load was instrumented with a piezoelectric triaxial accelerometer mounted on the engine housing as close to the center of mass as possible (Appendix 2, Figure 6). However, after the first drop noise from the shifting lead shot (placed inside the engine to ensure the correct test mass) severely interfered with data recording. A second triaxial accelerometer was mounted on the fuel control unit (Appendix 2, Figure 7) and testing continued using data recorded from this accelerometer. Primary accelerometer axis orientations were as follows:

X Axis - Directed through container Forward and Aft sides.

Y Axis - Directed through container Left and Right (desiccant port) 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 1.5 psi. Maximum allowable leak rate is 0.05 psi per hour. (Appendix 2, Figure 9).

Results – The container passed the leak test with a leak rate less than the maximum allowed rate of 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 -1.5 psi. Maximum allowable pressure increase rate is 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 0.05 psi per hour.

TEST SEQUENCE 3 – Rotational Drops

Procedure – At the customer's request, a drop height of 15 inches (12 inches is the standard drop height for this size container) was used to perform four corner and four edge drops onto a smooth concrete surface, and the impact levels were recorded. The maximum allowed impact level for the item was 10 Gs. (Appendix 2, Figures 10 & 11)

Results – All of the recorded impact peak G data (unfiltered) was equal to or less than the maximum allowed 10 Gs. The recorded waveforms show numerous sharp peaks which duplicate, to a much lesser degree, peaks recorded during experimental drops using an accelerometer mounted on the engine housing; these peaks were determined to be noise caused by shifting of the loose lead shot inside the engine and not true impact waveforms. In addition, the accelerometer location on the fuel control unit was not ideal since the unit was not near the center of gravity, and was potentially permitting transmission of other impact noise (internal fuel control unit parts, shifting of nearby movable or loose parts, independent motion of the unit itself) to be transmitted to the accelerometer.

Because of this noise, all waveform data was filtered at frequencies ranging from 55 Hz to 85 Hz as appropriate for that waveform. The filter frequency for these complex shock pulses was conservatively calculated as 10 times the base frequency of the shock pulse. The filtered peak G data differed by 1 G or less. There was no damage to either the container or the item. The container met the test requirements. (Appendix 3, Tables 1 & 3 and Waveforms.)

TEST SEQUENCE 4 – Lateral Impact (Pendulum Impact)

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

Results – All recorded unfiltered impact peak G data was greater than the maximum allowed 10 Gs. For the reasons stated in Test Sequence 2, this data was also filtered to remove as much extraneous noise as possible. After filtering only the aft end impact peak G was greater than allowed, 12 Gs. However, the sharp peak recorded in the Y (left-right direction) on this impact is believed to be

due to noise from the shifting internal mass and the placement of the accelerometer, and not a true indication of overall impact Gs. There was no damage to either the container or the item. The container met the test requirements. (Appendix 3, Tables 1 & 3 and Waveforms.)

TEST SEQUENCE 5 – 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. 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. (Appendix 2, Figure 13)

Results - The most significant resonant frequency of the packaged item occurred at 10.70 Hz, and increased very slightly during the dwell period to 10.98 Hz. The maximum transmissibility throughout the test was 3.36 (data filtered as described above), which is less than the design goal of 5 Hz when the resonant frequency is less than 15 Hz. At the end of the test period, there was no damage to the container or item. The container met the test requirements. (Appendix 3, Tables 2 & 4 and Waveforms)

TEST SEQUENCE 6 – Loose Load Vibration Test, 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 14).

The table frequency was increased from 3.5 Hz until the container left the table surface (approximately 4.2 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 4.2 Hz for 2 hours. The maximum peak amplitude during this time for any axis was less than 2 Gs, not including response peaks showing noise spikes. These noise spikes virtually disappeared by the end of the 2 hour test, partly due to settling of the lead shot in the engine, and leakage of shot. The disappearance of the spikes during the test period as the shot

compacted lends further credence to AFPTEF's belief that noise spikes measured during rotational drops were caused largely by the loose lead shot. At the end of testing there was no visible damage to the either the container or the item. The container met the test requirements. (Appendix 3, Waveforms)

TEST SEQUENCE 7 – Leak 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 0.05 psi per hour.

TEST SEQUENCE 8 – 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 0.05 psi per hour.

TEST CONCLUSIONS – No damage occurred during the above testing to the container, isolation system or test item. All impact levels are at or below the item fragility limit of 10 Gs, with one exception explained above. Therefore, the container and mounting system do provide adequate protection for the engine.

FIT & FUNCTION TESTING

Fit and function testing was completed on site at AFPTEF with the Reaper Engine that was supplied for prototype testing.

CONCLUSIONS

No damage occurred during the above testing to the container, mounting system or test item. There was no evidence of any contact or impact between the engine and the container walls or lid. All impact levels are below the item fragility limit of 10 G's with the exception of the occurrence outlined above. The CNU-696/E aluminum container was accepted by the Predator Program Office at Wright-Patterson AFB. The container met all the user's requirements. The container can protect a Reaper Engine during world-wide transportation and storage and will save the Air Force tens of thousands of dollars in O&M costs.

RECOMMENDATIONS

AFPTEF recommends that new containers be procured and delivered to avoid damage to Reaper Engines currently in the logistics cycle, thus mitigating overall shipping risks. All fiberboard boxes for the Reaper Engine should be replaced.

APPENDIX 1: Test Plan

AF PACKAGING TECHNOLOGY AND ENGINEERING FACILITY (Container Test Plan)				AFPTEF PROJECT NUMBER: 06-P-104	
CONTAINER SIZE (L x W x D) INTERIOR:		WEIGHT (LBS) GROSS:		CUBE (CU. F)	QUANTITY:
EXTERIOR:		ITEM:			DATE:
78.6 x 47.0 x 51.5		1497*		136.1	Sep 07
ITEM NAME: Reaper Engine				MANUFACTURER:	
CONTAINER NAME: Reusable Shipping & Storage Container				CONTAINER COST:	
PACK DESCRIPTION: Extruded Aluminum Cntr., Test Load of a Reaper Engine					
CONDITIONING: As noted below					
TEST NO.	REF STD/SPEC AND TEST METHOD OR PROCEDURE NO'S	TEST TITLE AND PARAMETERS	CONTAINER ORIENTATION	INSTRUMENTATION	
		<u>NOTE</u> No damage to contents is acceptable and Package must be in serviceable condition. Serviceable means remains sealed, with no deformities, etc. <u>Quality Conformance Tests</u> 1. <u>Examination of Product.</u> 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. 2. <u>Weight Test.</u> SAE ARP 1967 Par. 4.5.8.3.7 Container with engine shall be weighed. <u>Performance Tests</u> 3. <u>Leak Test.</u> SAE ARP 1967 Par. 4.5.2 Pneumatic pressure at 1.5 psi and vacuum retention at 1.5 psi. After temperature stabilization, pressure drop shall not exceed 0.05 psi per hour. Perform leak test again at end of test series.	Ambient temp. Ambient temp. Ambient temp.	Visual Inspection (VI) Scale Pressure Transducer (PT)	
COMMENTS: *Does not include weight of Beta Tube Case					
PREPARED BY: Joel A. Sullivan, Mechanical Engineer			APPROVED BY: Robbin L. Miller, Chief AFPTEF		

AF PACKAGING TECHNOLOGY AND ENGINEERING FACILITY (Container Test Plan)					AFPTEF PROJECT NUMBER: 06-P-104	
CONTAINER SIZE (L x W x D) INTERIOR:		EXTERIOR:		WEIGHT GROSS:	ITEM:	CUBE (CU. F)
78.6 x 47.0 x 51.5		81.3 x 49.8 x 58.1		1497*	599*	136.1
QUANTITY:		DATE:				
1		Sep 07				
ITEM NAME: Reaper Engine				MANUFACTURER:		
CONTAINER NAME: Reusable Shipping & Storage Container					CONTAINER COST:	
PACK DESCRIPTION: Extruded Aluminum Cntr., Test Load of a Reaper Engine						
CONDITIONING: As noted below						
TEST NO.	REF STD/SPEC AND TEST METHOD OR PROCEDURE NO'S	TEST TITLE AND PARAMETERS			CONTAINER ORIENTATION	INSTRUMENTATION
4.	<u>Rotational Drop Tests (Ambient Temperature).</u> SAE ARP 1967 Par. 4.5.3 ASTM D 4169 ASTM D 6179 Methods A & B	Drop height shall be 15". Item shall not sustain more than 10G's.			One drop on all bottom corners (4 drops) and one drop on all edges (4 drops).	VI Tri-axial Accelerometer
5.	<u>Lateral Impact Test (Ambient Temperature).</u> SAE ARP 1967 Par. 4.5.6 ASTM D 4169 ASTM D 880 Procedure B	Impact velocity 7.3 ft/s. Item shall not sustain more than 10G's.			One impact on each end and one on each side (4 impacts).	VI and Tri-axial Accelerometer
6.	<u>Vibration Test, Resonance Sweep and Dwell.</u> 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 and Tri-axial Accelerometer
COMMENTS: *Does not include weight of Beta Tube Case						
PREPARED BY: Joel A. Sullivan, Mechanical Engineer				APPROVED BY: Robbin L. Miller, Chief AFPTEF		

AF PACKAGING TECHNOLOGY AND ENGINEERING FACILITY (Container Test Plan)				AFPTEF PROJECT NUMBER: 06-P-104	
CONTAINER SIZE (L x W x D) INTERIOR: 78.6 x 47.0 x 51.5 EXTERIOR: 81.3 x 49.8 x 58.1		WEIGHT GROSS: 1497* ITEM: 599*		CUBE (CU. F) 136.1	QUANTITY: 1 DATE: Sep 07
ITEM NAME: Reaper Engine				MANUFACTURER:	
CONTAINER NAME: Reusable Shipping & Storage Container				CONTAINER COST:	
PACK DESCRIPTION: Extruded Aluminum Cntr., Test Load of a Reaper Engine					
CONDITIONING: As noted below					
TEST NO.	REF STD/SPEC AND TEST METHOD OR PROCEDURE NO'S	TEST TITLE AND PARAMETERS	CONTAINER ORIENTATION	INSTRUMENTATION	
7.	Loose Load Vibration Test, Repetitive Shock. 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 than two hours.	Ambient temp. Blocking shall be used to keep cntr. in place, do not restrict vertical or rotational movement	VI and Tri-axial Accelerometer	
8.	Leak Test. SAE ARP 1967 Par. 4.5.2	Pneumatic pressure at 1.5 psi and vacuum retention at 1.5 psi. After temperature stabilization, pressure drop shall not exceed 0.05 psi per hour. Perform leak test again at end of test series.	Ambient temp.	Pressure Transducer (PT)	
COMMENTS: *Does not include weight of Beta Tube Case					
PREPARED BY: Joel A. Sullivan, Mechanical Engineer			APPROVED BY: Robbin L. Miller, Chief AFPTEF		

APPENDIX 2: Fabrication & Testing Photographs



Figure 1. Closed Container.



Figure 2. Engine in container base.

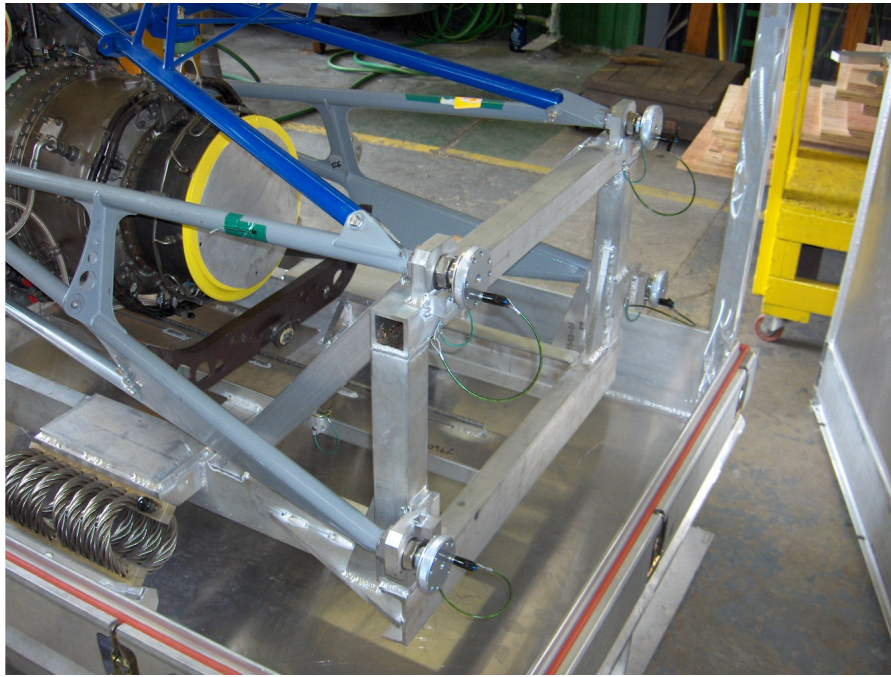


Figure 3. Fwd Attachment Points



Figure 4. Aft Attachment Clamp



Figure 5. Beta Tube Box.

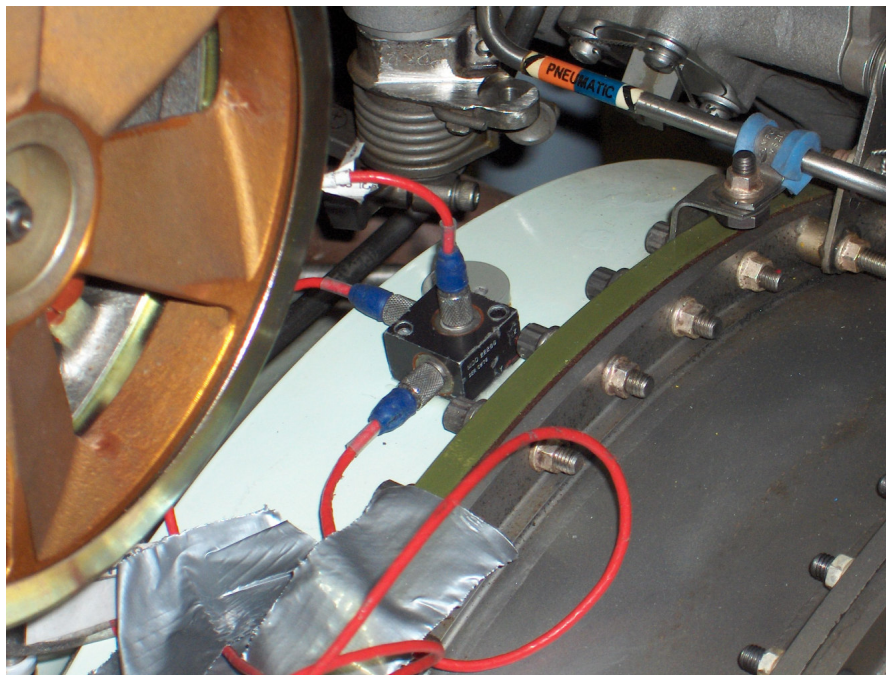


Figure 6. Placement of accelerometer on engine housing.

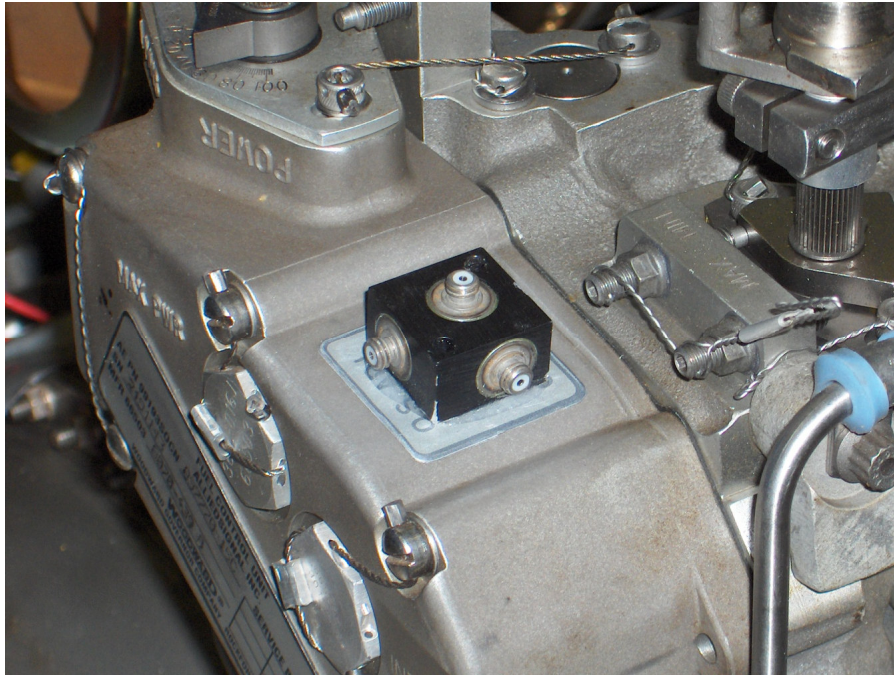


Figure 7. Placement of accelerometer on fuel control unit.



Figure 8. Weighing of container.



Figure 9. Pressure Test Set-up (for both pressure and vacuum).



Figure 10. Rotational Edge Drop.



Figure 11. Rotational Corner Drop.



Figure 12. Pendulum Impact Test.



Figure 13. Resonance Sweep and Dwell Test.



Figure 14. Repetitive Shock Test.

APPENDIX 3: Test Data

Table 1. Reaper Engine Impact Test Summary (filtered data)

IMPACT TYPE	TEST TEMPERATURE	IMPACT LOCATION	RESULTANT PEAK G
ROTATIONAL - EDGE	ambient	forward-bottom	9
ROTATIONAL - EDGE	ambient	aft-bottom	9
ROTATIONAL - EDGE	ambient	left-bottom	5
ROTATIONAL - EDGE	ambient	right-bottom	8
ROTATIONAL - CORNER	ambient	forward-left	10
ROTATIONAL - CORNER	ambient	forward-right	8
ROTATIONAL - CORNER	ambient	aft-left	8
ROTATIONAL - CORNER	ambient	aft-right	9
LATERAL IMPACT - FACE	ambient	forward	8
LATERAL IMPACT - FACE	ambient	aft	12
LATERAL IMPACT - FACE	ambient	left	8
LATERAL IMPACT - FACE	ambient	right	8

TABLE 2. Container Resonant Frequency and Transmissibility Values (from filtered waveforms).

TEST TEMPERATURE	DWELL TIME	RESONANT FREQUENCY	TRANSMISSIBILITY
Ambient	1 min	10.70 Hz	3.17
Ambient	15 min	10.84 Hz	3.04
Ambient	30 min	10.98 Hz	3.36

Table 3. Reaper Engine Impact Test Summary (unfiltered data)

IMPACT TYPE	TEST TEMPERATURE	IMPACT LOCATION	RESULTANT PEAK G
ROTATIONAL - EDGE	ambient	forward-bottom	10
ROTATIONAL - EDGE	ambient	aft-bottom	10
ROTATIONAL - EDGE	ambient	left-bottom	6
ROTATIONAL - EDGE	ambient	right-bottom	9
ROTATIONAL - CORNER	ambient	forward-left	10
ROTATIONAL - CORNER	ambient	forward-right	8
ROTATIONAL - CORNER	ambient	aft-left	9
ROTATIONAL - CORNER	ambient	aft-right	10
LATERAL IMPACT - FACE	ambient	forward	12
LATERAL IMPACT - FACE	ambient	aft	17
LATERAL IMPACT - FACE	ambient	left	12
LATERAL IMPACT - FACE	ambient	right	12

TABLE 4. Container Resonant Frequency and Transmissibility Values (from unfiltered waveforms).

TEST TEMPERATURE	DWELL TIME	RESONANT FREQUENCY	TRANSMISSIBILITY
Ambient	1 min	10.70 Hz	3.04
Ambient	15 min	10.84 Hz	3.68
Ambient	30 min	10.98 Hz	3.36

NOTE: The first set of the following waveforms are filtered data, with the filtering frequency shown at the top of the waveform traces. The second set of waveforms is the unfiltered data provided for comparison.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Sep 28 2007 10:50 Test Engineer: Evans
Test Type: Edge Impact Point: Forward edge
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 93.20; H. Angle: 42.86; Filter: = 75 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	926. mS	-0.01 g's	-7.12 g's	-85.24 In/s	131 mS	1	2
2	926. mS	0.11 g's	-1.82 g's	-5.96 In/s	131 mS	1	2
3	926. mS	0.10 g's	5.54 g's	14.78 In/s	131 mS	1	2
R	926. mS	0.15 g's	8.64 g's	86.71 In/s	131 mS	1	2

Remarks

PEAK Gs X: 7 Y: 2 Z: 6 Peak Gs Resultant: 9. Filtered at 75 Hz.

Accelerometer mounted on engine body near CG.

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Ch4=Resultant.

Right side = desiccant port (long) side. Ambient temperature/humidity.

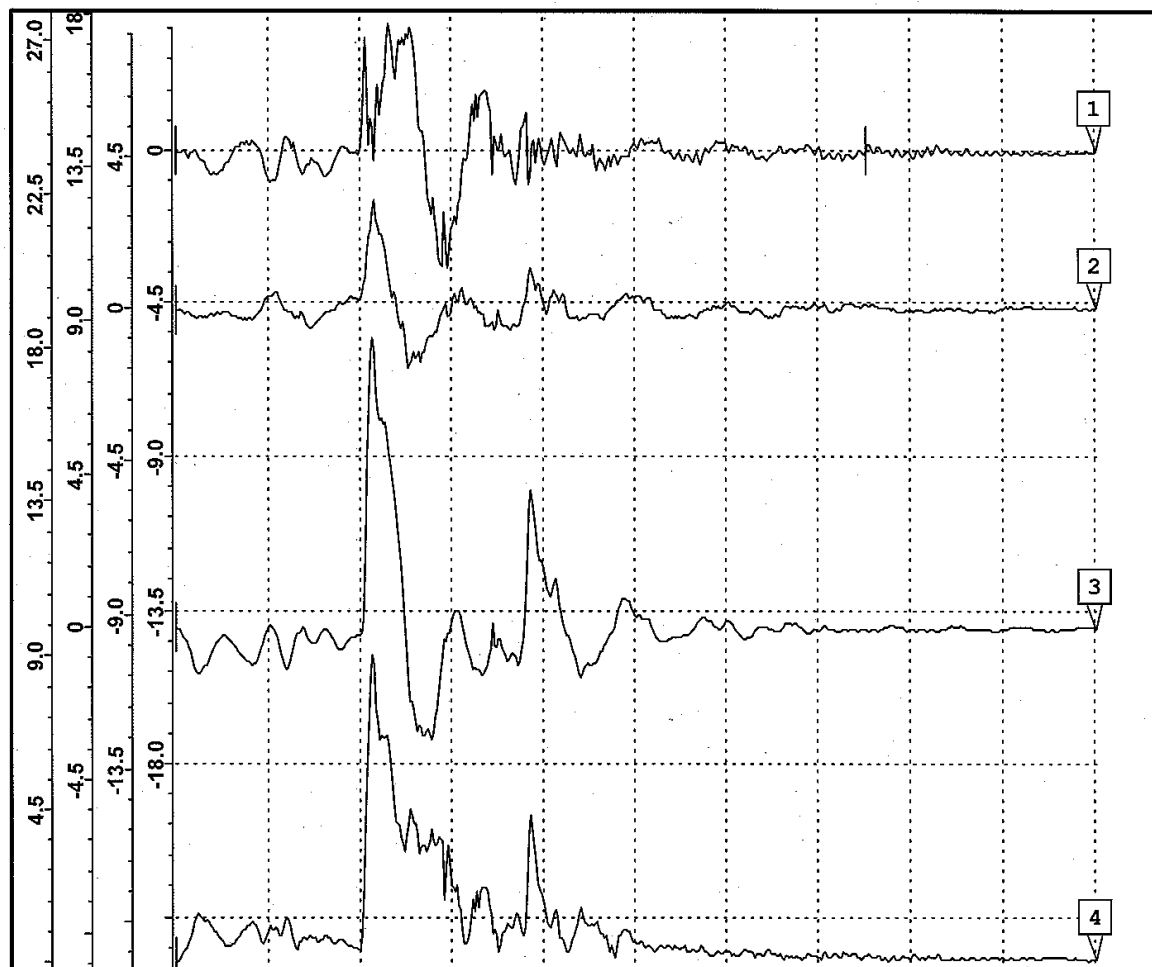
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N CW78.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 9 2007 11:37 Test Engineer: Evans
Test Type: Edge Impact Point: Aft edge
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 82.42; H. Angle: 338.69; Filter: = 85 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	983. mS	0.02 g's	3.75 g's	18.32 In/s	131 mS	1	2
2	983. mS	0.17 g's	3.59 g's	5.18 In/s	131 mS	1	2
3	983. mS	-0.07 g's	8.48 g's	1.23 In/s	131 mS	1	2
R	983. mS	0.18 g's	9.05 g's	19.08 In/s	131 mS	1	2

Remarks

PEAK Gs X: 4 Y: 4 Z: 8 Peak Gs Resultant: 9. Filtered at 85 Hz.

Accelerometer mounted on fuel control unit.

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Ch4=Resultant.

Right side = desiccant port (long) side. Ambient temperature/humidity.

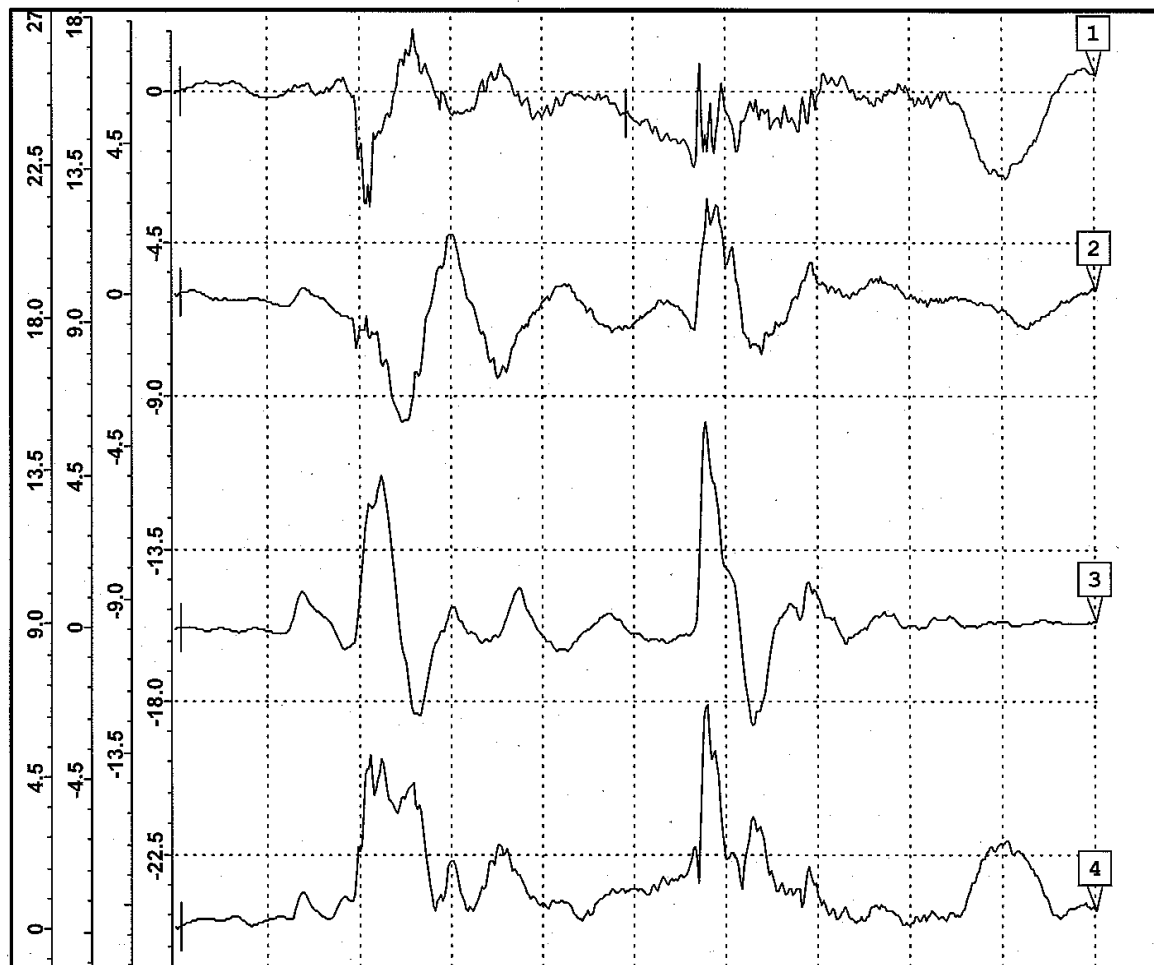
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 9 2007 13:52 Test Engineer: Evans
Test Type: Edge Impact Point: Left edge
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 126.40; H. Angle: 184.30; Filter: = 85 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	634. mS	-0.65 g's	-3.40 g's	-28.60 In/s	131 mS	1	2
2	634. mS	-0.88 g's	-3.74 g's	-144.97 In/s	131 mS	1	2
3	634. mS	-0.07 g's	4.46 g's	38.39 In/s	131 mS	1	2
R	634. mS	1.10 g's	5.09 g's	152.67 In/s	131 mS	1	2

Remarks

PEAK Gs X: 3 Y: 4 Z: 4 Peak Gs Resultant: 5. Filtered at 85 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

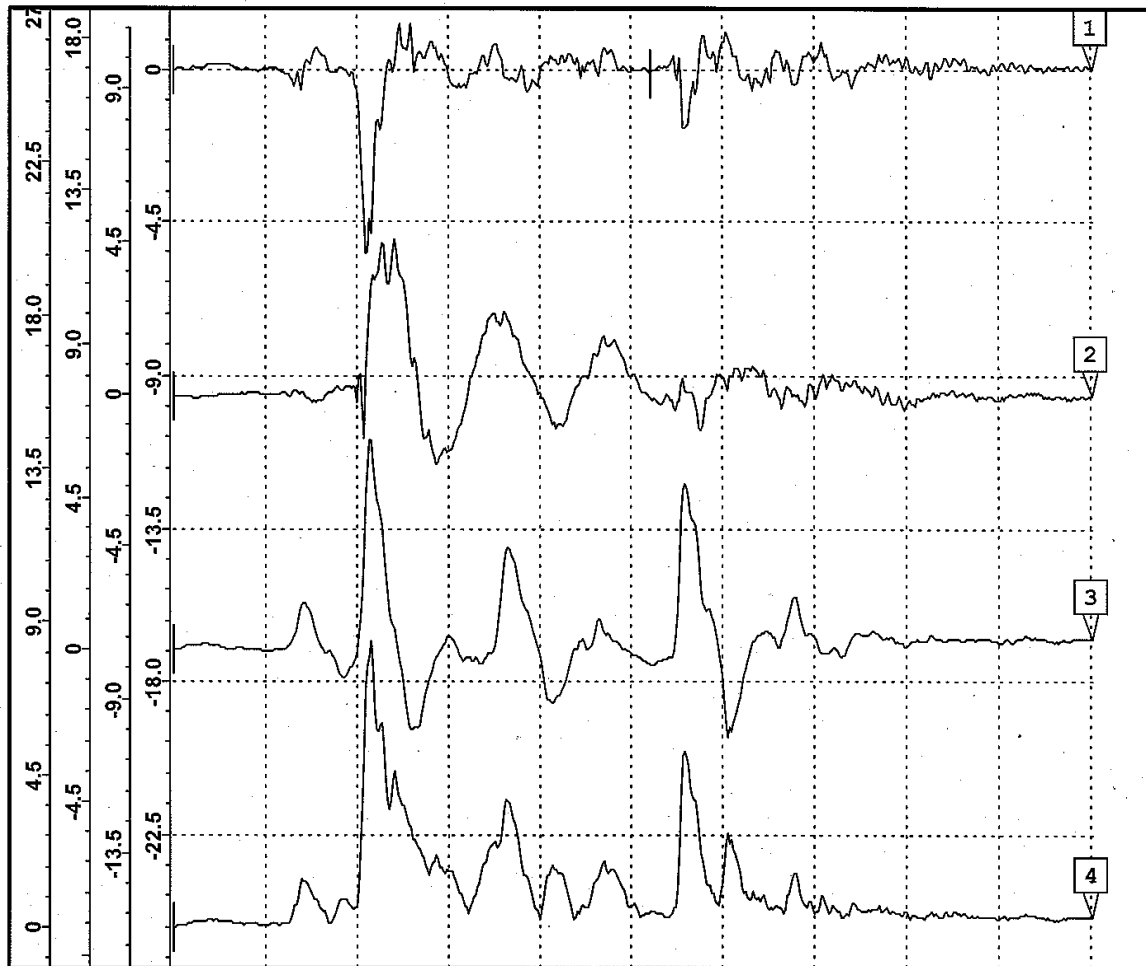
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Sep 28 2007 10:40 Test Engineer: Evans
Test Type: Edge Impact Point: Right edge
Container/Item: Aluminum/Edge Drop Height: 15 inches

V. Angle: 101.54; H. Angle: 259.50; Filter: = 85 Hz



	Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
●	1	680. mS	-0.09 g's	-5.69 g's	-12.10 In/s	131 mS	1	2
○	2	680. mS	-0.08 g's	4.59 g's	141.52 In/s	131 mS	1	2
○	3	680. mS	-0.45 g's	6.21 g's	59.38 In/s	131 mS	1	2
○	R	680. mS	0.47 g's	8.41 g's	153.94 In/s	131 mS	1	2

Remarks

PEAK Gs X: 6 Y: 5 Z: 6 Peak Gs Resultant: 8. Filtered at 85 Hz.

Accelerometer mounted on fuel control unit.

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Ch4=Resultant.

Right side = desiccant port (long) side. Ambient temperature/humidity.

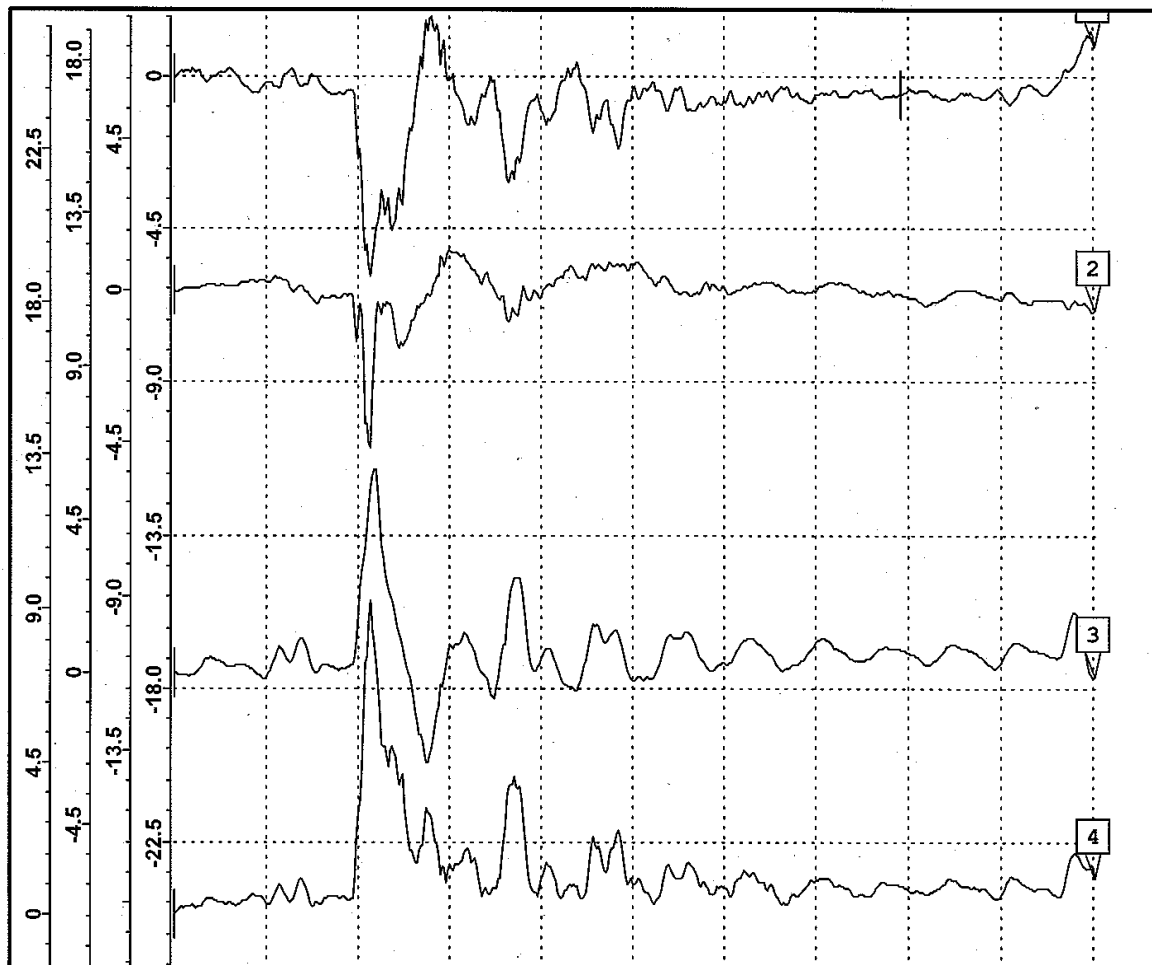
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 9 2007 14:03 Test Engineer: Evans
Test Type: Corner Impact Point: Forward left corner
Container/Item: Aluminum/Edge Drop Height: 15 inches

V. Angle: 126.27; H. Angle: 98.88; Filter: = 80 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.03 S	-0.49 g's	-6.08 g's	-293.03 In/s	131 mS	1	2
2	1.03 S	-0.10 g's	-5.04 g's	19.96 In/s	131 mS	1	2
3	1.03 S	0.66 g's	5.99 g's	215.07 In/s	131 mS	1	2
R	1.03 S	0.83 g's	9.46 g's	364.03 In/s	131 mS	1	2

Remarks

PEAK Gs X: 6 Y: 5 Z: 6 Peak Gs Resultant: 10. Filtered at 80 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

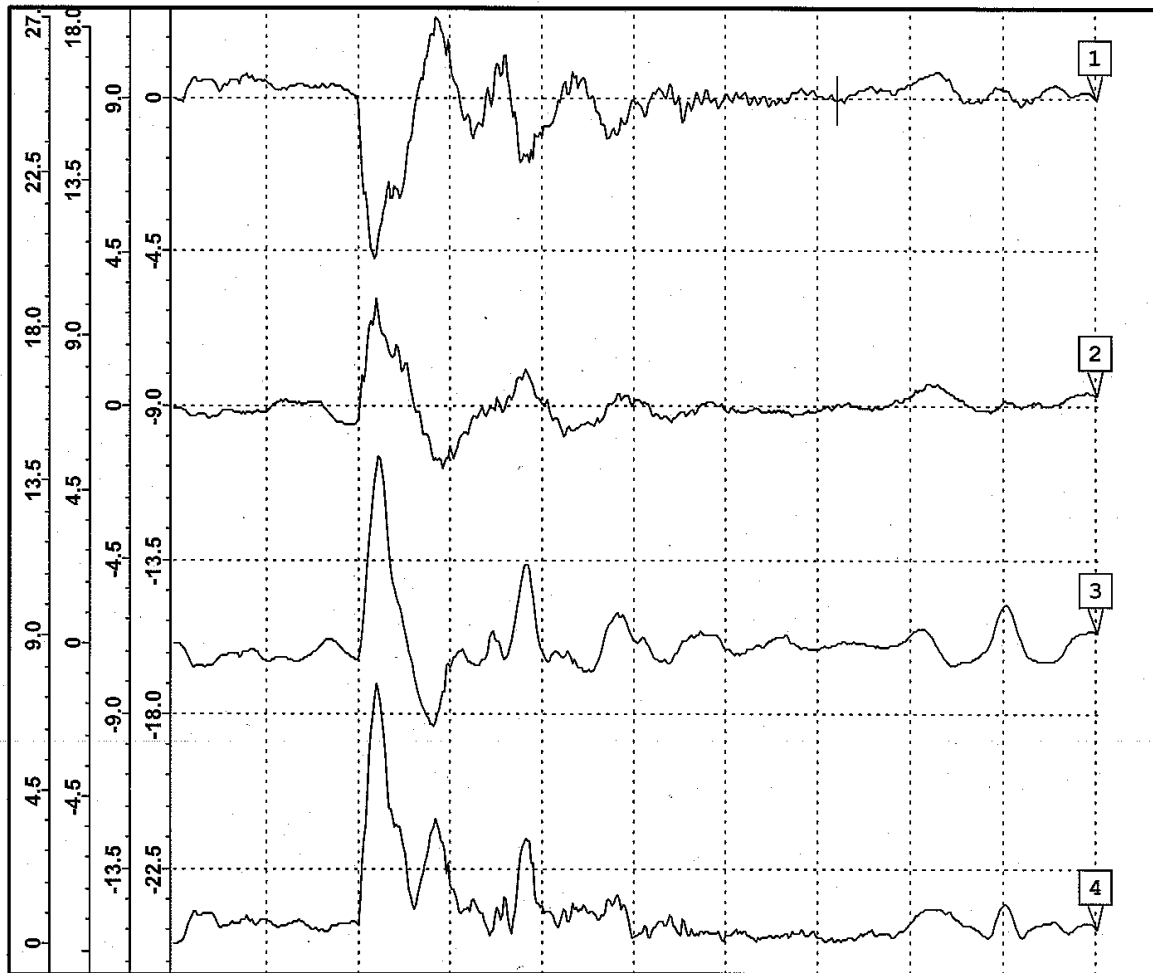
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Sep 28 2007 11:21 Test Engineer: Evans
Test Type: Corner Impact Point: Forward right corner
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 104.65; H. Angle: 359.21; Filter: = 75 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	942. mS	-0.03 g's	-4.71 g's	-54.06 In/s	131 mS	1	2
2	942. mS	0.10 g's	3.23 g's	-4.85 In/s	131 mS	1	2
3	942. mS	-0.00 g's	5.48 g's	-3.13 In/s	131 mS	1	2
R	942. mS	0.10 g's	7.58 g's	54.36 In/s	131 mS	1	2

Remarks

PEAK Gs X: 5 Y: 3 Z: 5 Peak Gs Resultant: 8. Filtered at 75 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

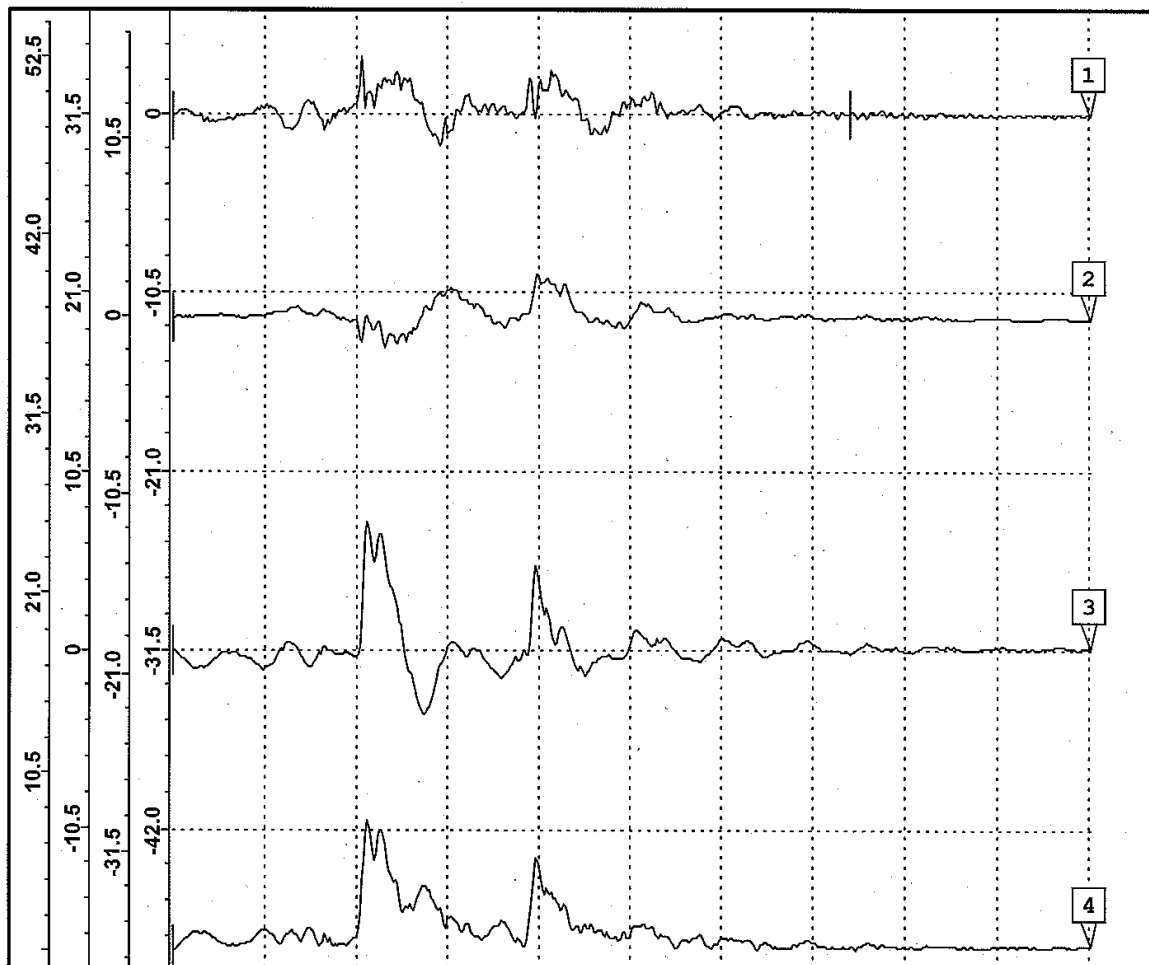
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 10 2007 9:45 Test Engineer: Evans
Test Type: Corner Impact Point: Aft left corner
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 61.15; H.Angle: 250.58; Filter: = 80 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	967. mS	0.10 g's	3.59 g's	118.77 In/s	131 mS	1	2
2	967. mS	-0.06 g's	2.65 g's	53.71 In/s	131 mS	1	2
3	967. mS	-0.17 g's	7.56 g's	44.59 In/s	131 mS	1	2
R	967. mS	0.21 g's	7.64 g's	137.77 In/s	131 mS	1	2

Remarks

PEAK Gs X: 4 Y: 3 Z: 8 Peak Gs Resultant: 8. Filtered at 80 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

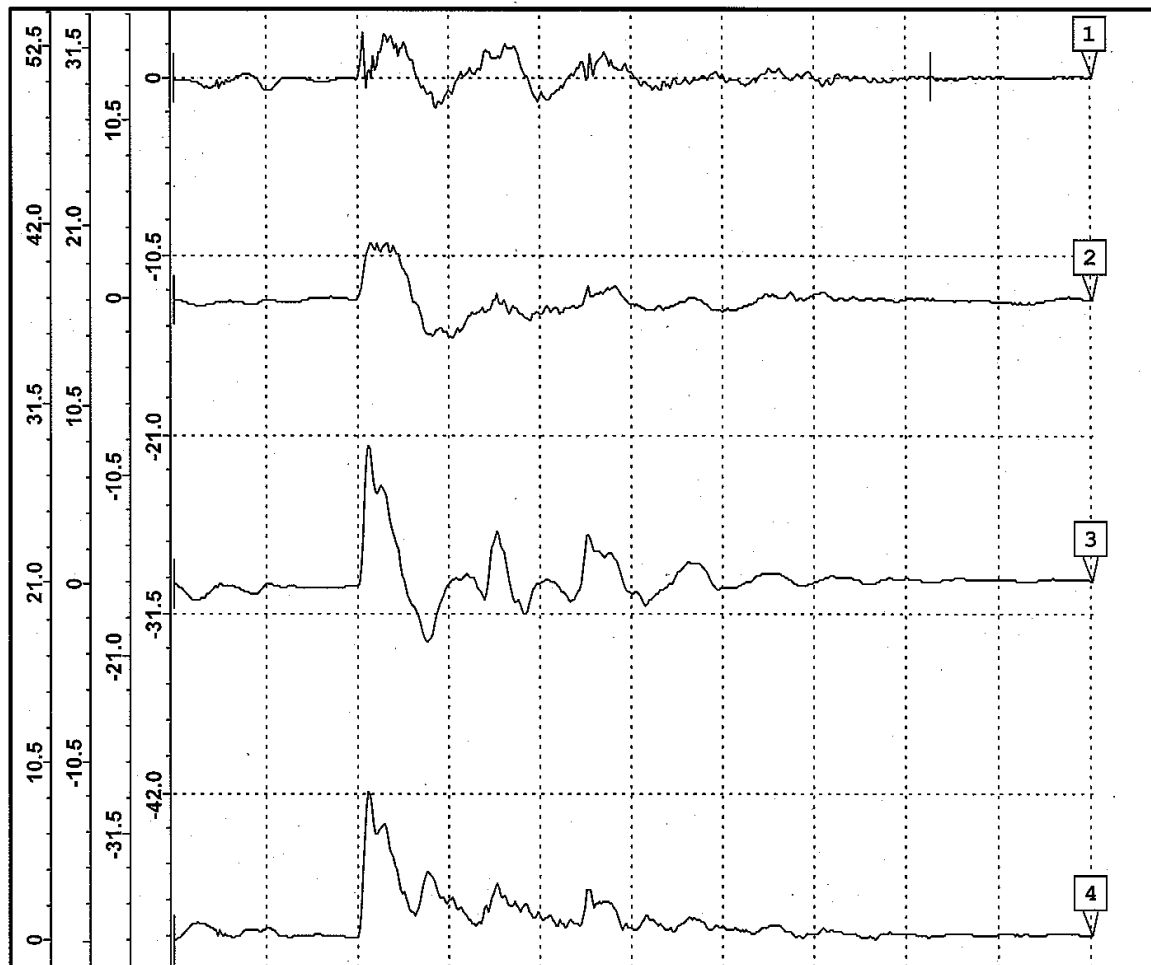
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 10 2007 9:42 Test Engineer: Evans
Test Type: Corner Impact Point: Aft right corner
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 28.21; H.Angle: 78.21; Filter: = 70 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.08 S	0.20 g's	2.77 g's	51.10 In/s	131 mS	1	2
2	1.08 S	0.02 g's	3.38 g's	-29.95 In/s	131 mS	1	2
3	1.08 S	0.11 g's	8.19 g's	114.26 In/s	131 mS	1	2
R	1.08 S	0.23 g's	8.71 g's	128.70 In/s	131 mS	1	2

Remarks

PEAK Gs X: 3 Y: 3 Z: 8 Peak Gs Resultant: 9. Filtered at 70 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

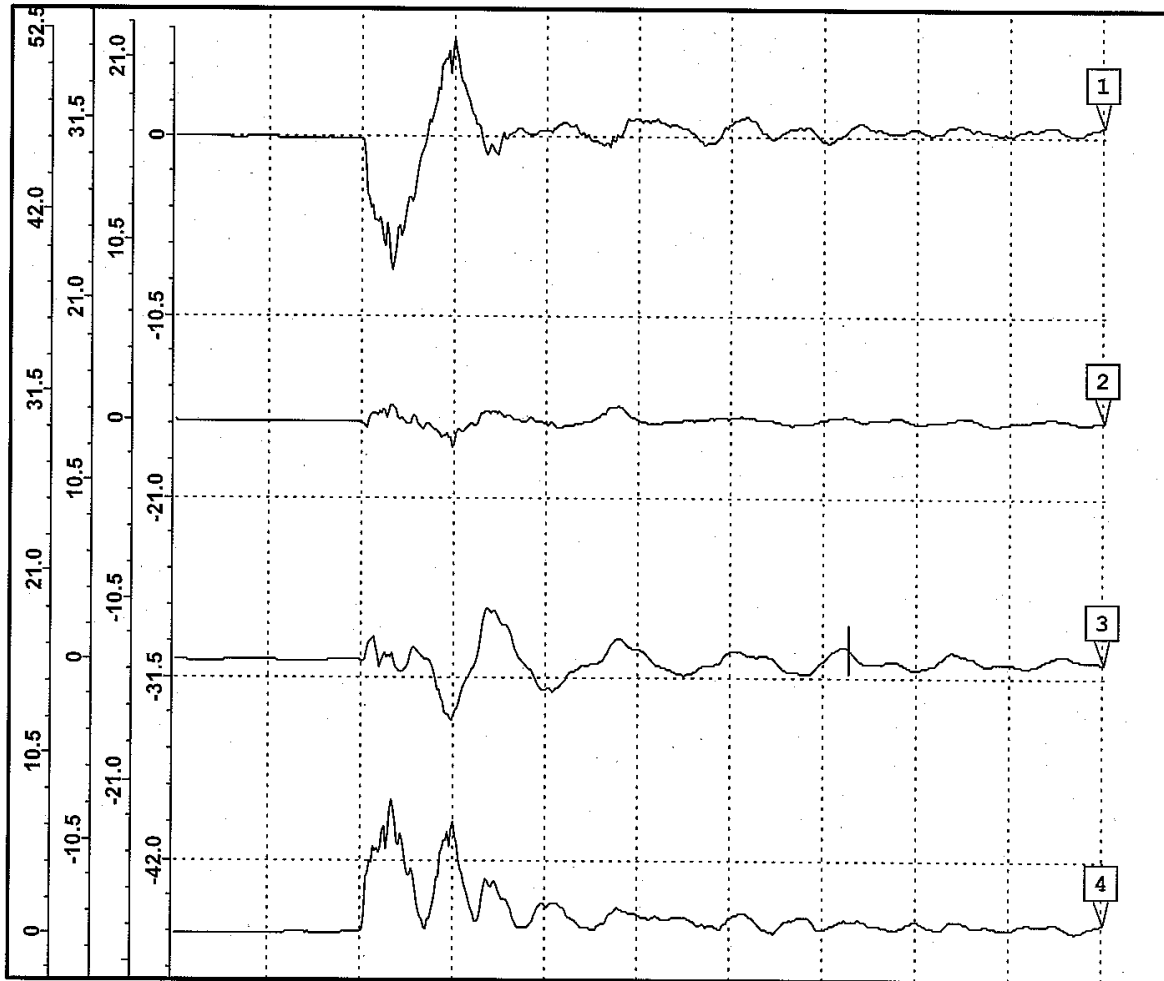
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

PENDULUM IMPACT TEST

Time: Oct 10 2007 10:25 Test Engineer: Evans
Test Type: Side impact Impact Point: Forward side
Container/Item: Aluminum/Engine Impact Velocity 7.3 ft/s

V. Angle: 54.35; H. Angle: 69.72; Filter: = 65 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
☐ 1	949. mS	0.46 g's	-7.90 g's	-11.66 In/s	131 mS	1	2
☐ 2	949. mS	0.22 g's	-1.65 g's	17.29 In/s	131 mS	1	2
☒ 3	949. mS	0.61 g's	-3.53 g's	-41.63 In/s	131 mS	1	2
☐ R	949. mS	0.80 g's	7.97 g's	46.56 In/s	131 mS	1	2

Remarks

PEAK Gs X: 8 Y: 2 Z: 4 Peak Gs Resultant: 8. Filtered at 65 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

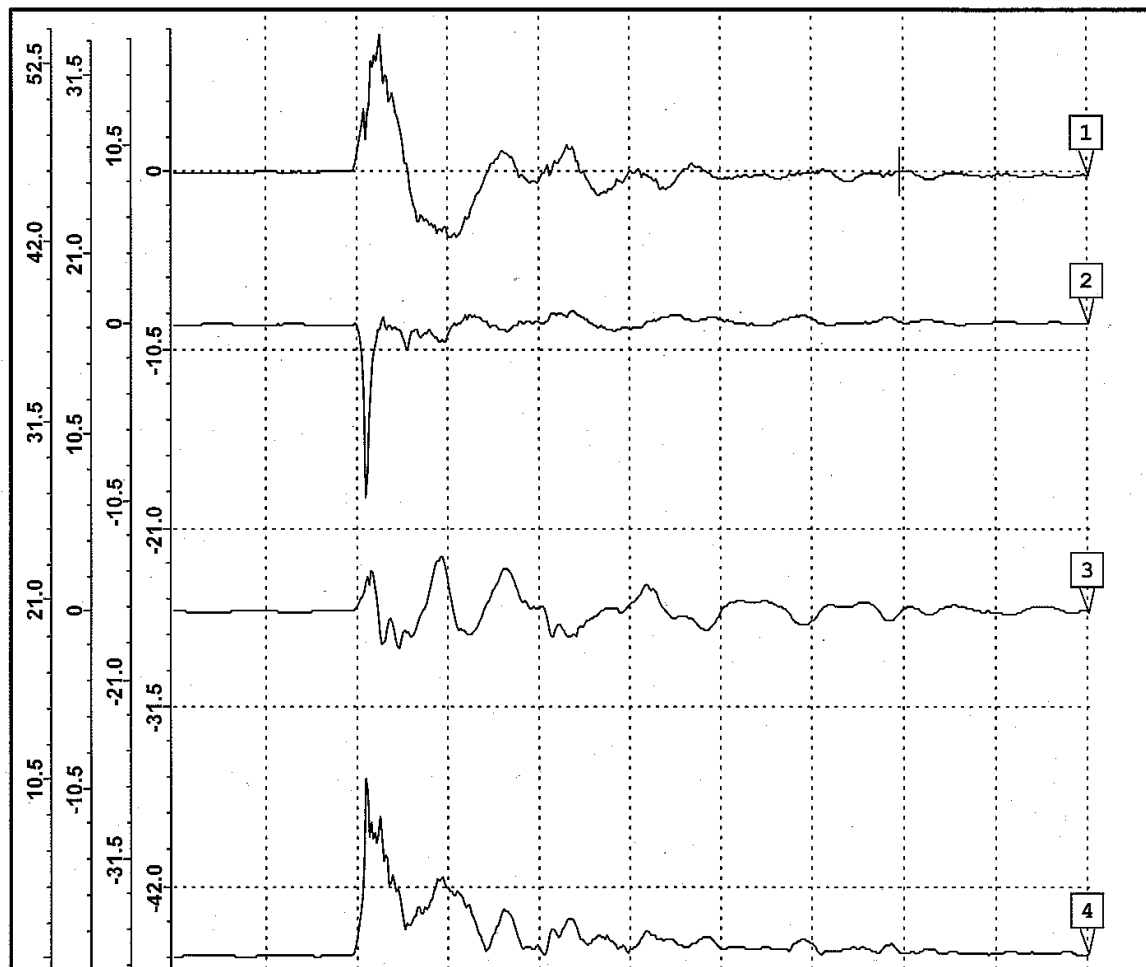
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

PENDULUM IMPACT TEST

Time: Oct 10 2007 12:38 Test Engineer: Evans
Test Type: Side impact Impact Point: Aft side
Container/Item: Aluminum/Engine Impact Velocity 7.3 ft/s

V. Angle: 51.41; H. Angle: 341.01; Filter: = 55 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.04 S	0.17 g's	8.07 g's	-3.14 In/s	131 mS	1	2
2	1.04 S	0.20 g's	-11.24 g's	-6.04 In/s	131 mS	1	2
3	1.04 S	-0.07 g's	3.24 g's	7.42 In/s	131 mS	1	2
R	1.04 S	0.27 g's	11.65 g's	10.07 In/s	131 mS	1	2

Remarks

PEAK Gs X: 8 Y: 11 Z: 3 Peak Gs Resultant: 12. Filtered at 55 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

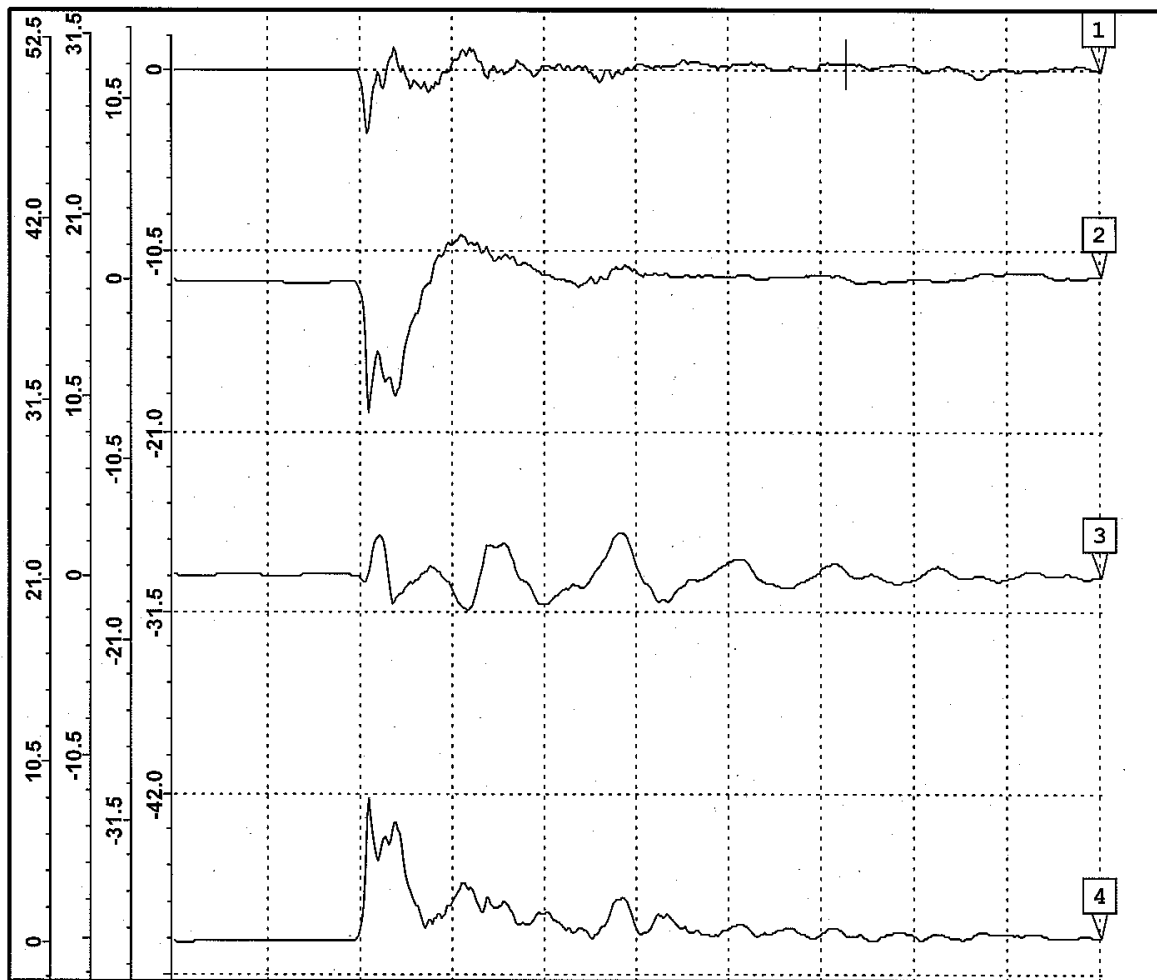
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

PENDULUM IMPACT TEST

Time: Oct 10 2007 10:55 Test Engineer: Evans
Test Type: Side Impact Point: Left side
Container/Item: Aluminum/Engine Impact Velocity 7.3 ft/s

V. Angle: 35.36; H.Angle: 61.05; Filter: = 55 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	949. mS	0.33 g's	-3.65 g's	19.56 In/s	131 mS	1	2
2	949. mS	0.11 g's	-7.63 g's	-35.88 In/s	131 mS	1	2
3	949. mS	0.21 g's	2.47 g's	-11.00 In/s	131 mS	1	2
R	949. mS	0.41 g's	8.42 g's	42.32 In/s	131 mS	1	2

Remarks

PEAK Gs X: 4 Y: 7 Z: 2 Peak Gs Resultant: 8. Filtered at 55 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

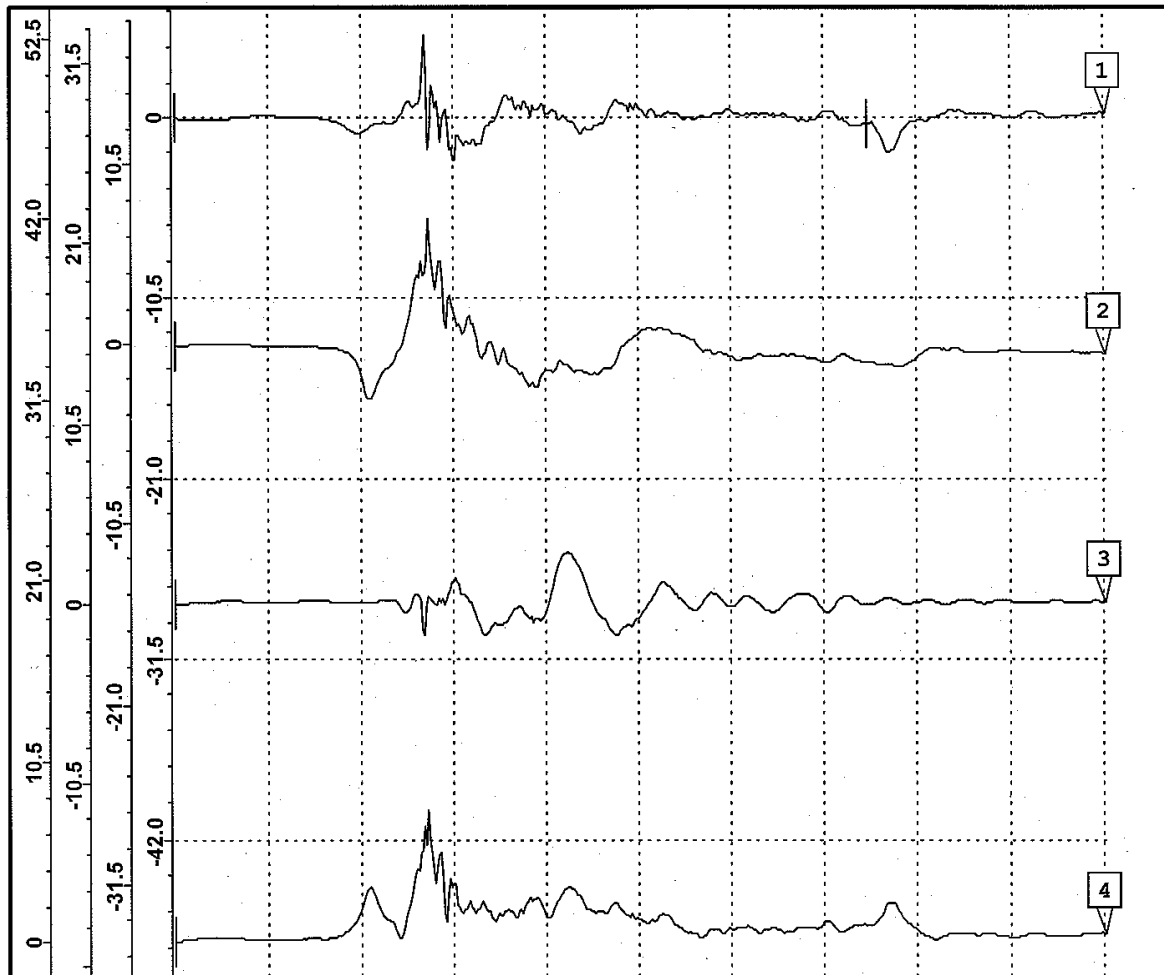
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

PENDULUM IMPACT TEST

Time: Oct 10 2007 12:51 Test Engineer: Evans
Test Type: Side impact Impact Point: Right side
Container/Item: Aluminum/Engine Impact Velocity 7.3 ft/s

V. Angle: 108.87; H.Angle: 184.78; Filter: = 60 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	975. mS	-0.30 g's	5.02 g's	9.54 In/s	131 mS	1	2
2	975. mS	-0.89 g's	7.41 g's	-47.18 In/s	131 mS	1	2
3	975. mS	-0.07 g's	2.99 g's	15.01 In/s	131 mS	1	2
R	975. mS	0.94 g's	7.62 g's	50.42 In/s	131 mS	1	2

Remarks

PEAK Gs X: 5 Y: 7 Z: 3 Peak Gs Resultant: 8. Filtered at 60 Hz.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

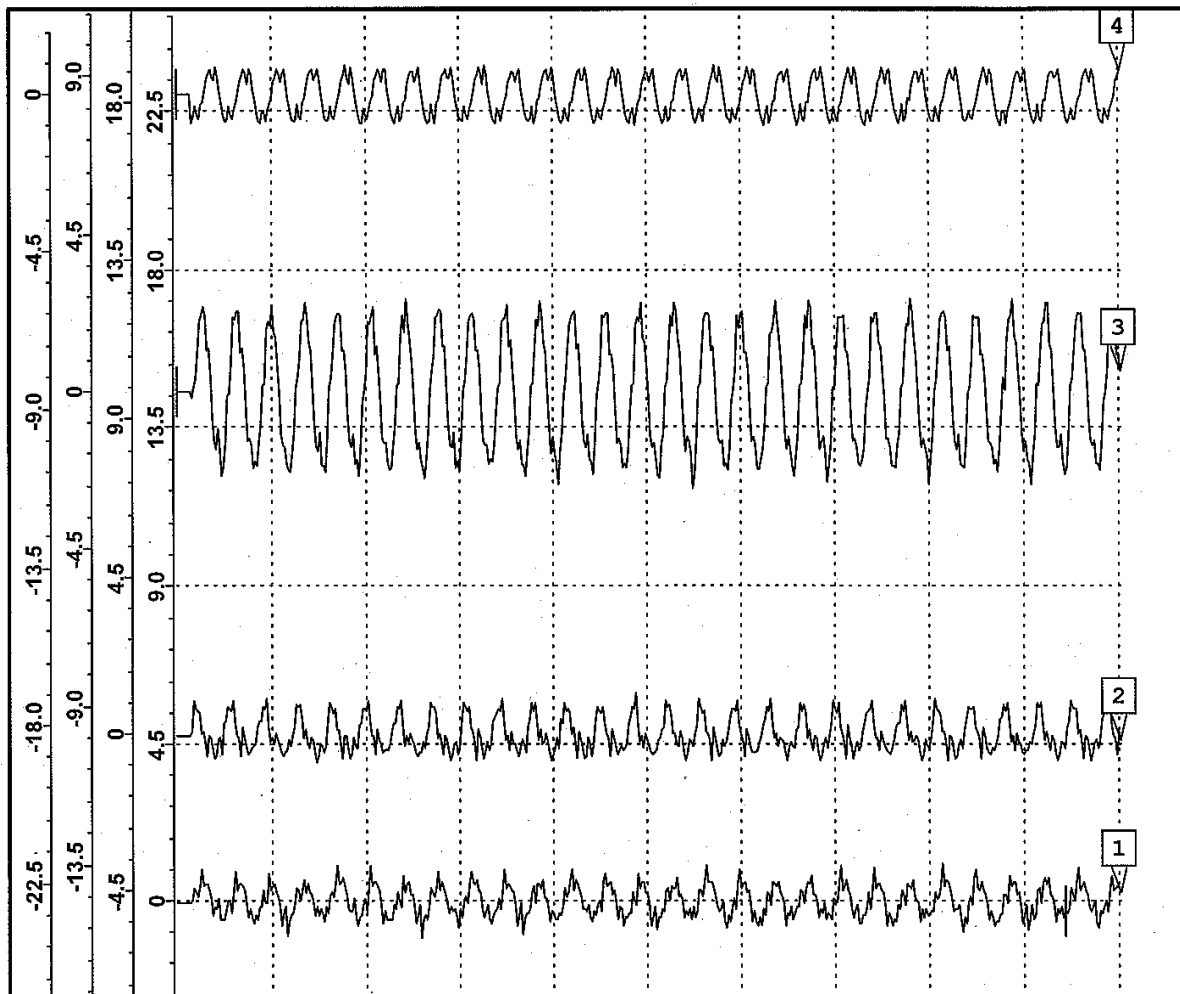
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

RESONANCE DWELL

Time: Oct 15 2007 16:00 Test Engineer: Evans
Test Stage: Dwell Frequency: 10.70 Hz
Test Item: Aluminum/Engine Time in Test: 1 minute

Filter: Ch.1 = 75 Hz Ch.2 = 75 Hz Ch.3 = 75 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	2.46 S	-0.26 g's	1.18 g's	13.37 In/s	262 mS	1	2
2	2.47 S	0.19 g's	1.20 g's	15.21 In/s	262 mS	1	2
3	2.47 S	-1.24 g's	-2.94 g's	-8.44 In/s	262 mS	1	2
4	2.51 S	0.04 g's	-0.90 g's	-31.78 In/s	262 mS	1	2

Remarks

Transmissibility: 3.17 Filtered at 75 Hz.

Peak Gs X: 1 Y: 1 Z: 3 Table Input(Ch.4): 1 Gs

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

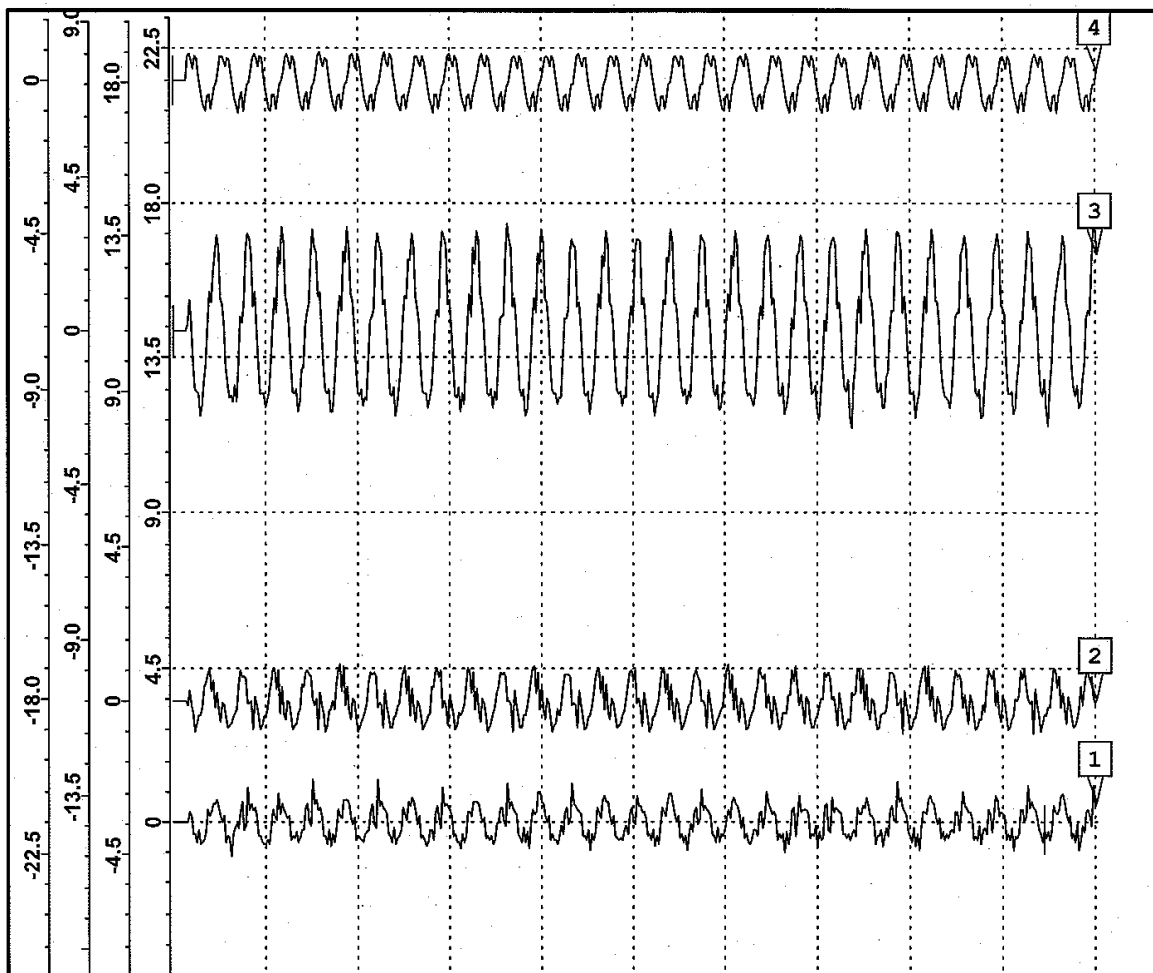
Accelerometer: Model 2228C, S/N 16473; mounted on fuel control.
ASTM D4169, ASTM D999, SAE ARP 1967

REAPER ENGINE

RESONANCE DWELL

Time: Oct 15 2007 16:15 Test Engineer: Evans
Test Stage: Dwell Frequency: 10.84 Hz
Test Item: Aluminum/Engine Time in Test: 15 minutes

Filter: Ch.1 = 80 Hz Ch.2 = 80 Hz Ch.3 = 80 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	2.47 S	-0.18 g's	1.26 g's	26.69 In/s	262 mS	1	2
2	2.48 S	-0.15 g's	1.34 g's	2.80 In/s	262 mS	1	2
3	2.50 S	0.97 g's	3.25 g's	-51.60 In/s	262 mS	1	2
4	2.41 S	-0.86 g's	-0.94 g's	-7.46 In/s	262 mS	1	2

Remarks

Transmissibility: 3.04 Filtered at 80 Hz.

Peak Gs X: 1 Y: 1 Z: 3 Table Input(Ch.4): 1 G

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Accelerometer: Model 2228C, S/N 16473; mounted on fuel control.

Right side = desiccant port (long) side. Ambient temperature/humidity.

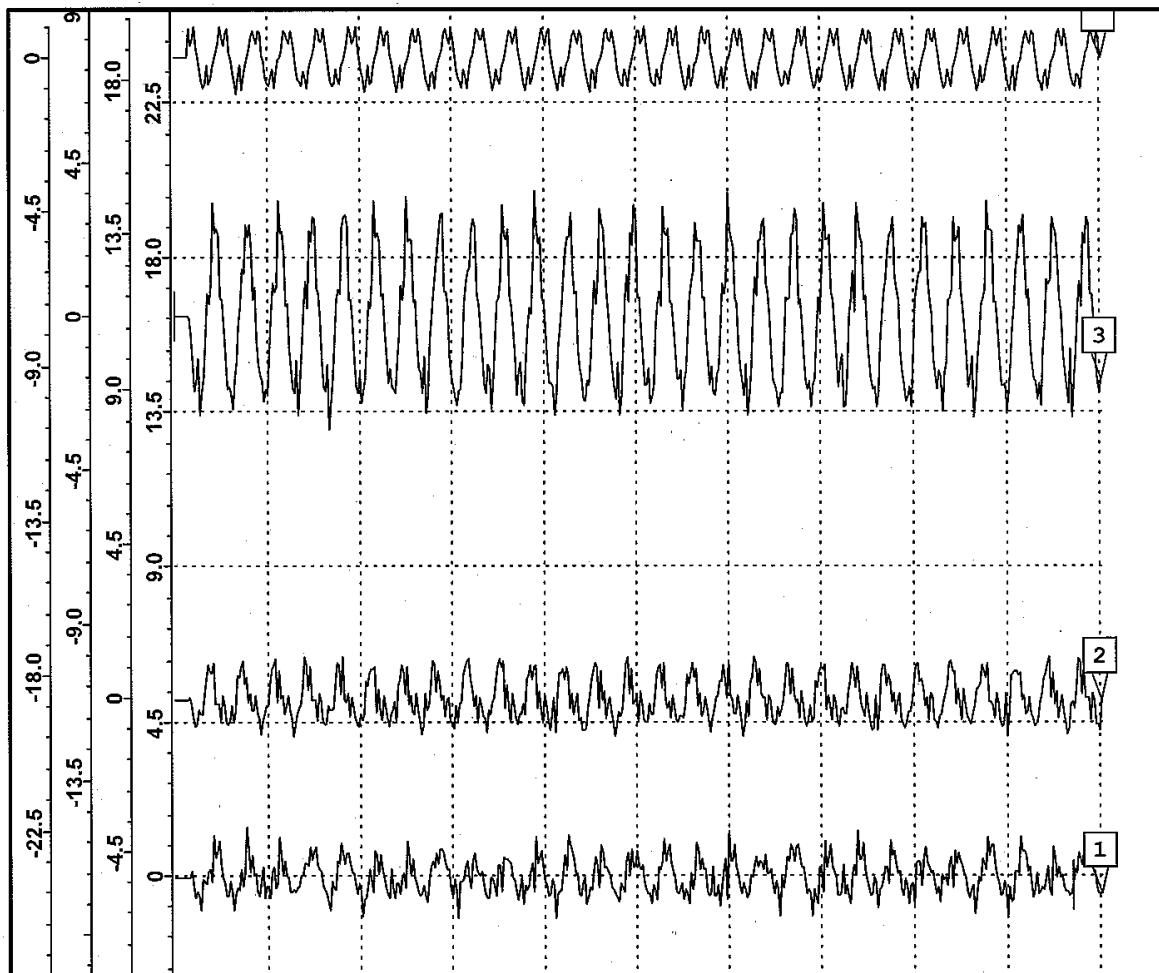
ASTM D4169, ASTM D999, SAE ARP 1967

REAPER ENGINE

RESONANCE DWELL

Time: Oct 15 2007 16:06 Test Engineer: Evans
Test Stage: Dwell Frequency: 10.98 Hz
Test Item: Aluminum/Engine Time in Test: 30 minutes

Filter: Ch.1 = 90 Hz Ch.2 = 90 Hz Ch.3 = 90 Hz



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	2.53 S	-0.29 g's	1.52 g's	-1.58 In/s	262 mS	1	2
2	2.55 S	1.07 g's	1.35 g's	5.21 In/s	262 mS	1	2
3	2.55 S	1.03 g's	3.79 g's	-40.08 In/s	262 mS	1	2
4	2.57 S	-0.09 g's	-1.03 g's	-6.59 In/s	262 mS	1	2

Remarks

Transmissibility: 3.36. Filtered at 90 Hz
Peak Gs X: 2 Y: 1 Z: 4 Table Input(Ch.4): 1 G
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Accelerometer: Model 2228C, S/N 16473; mounted on fuel control.

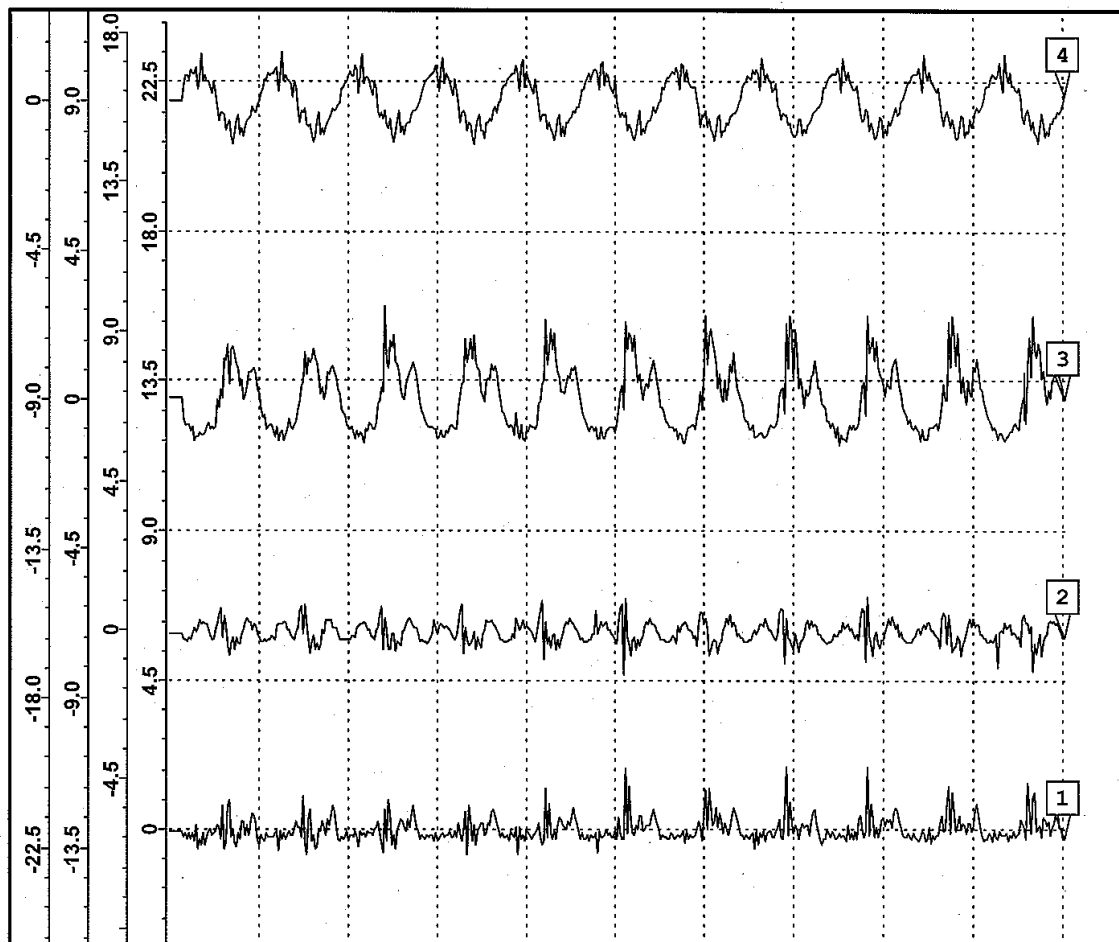
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP 1967

[All Repetitive Shock data left unfiltered]

REAPER ENGINE

REPETITIVE SHOCK

Time: Oct 16 2007 10:20 Test Engineer: Evans
Test Stage: Dwell Frequency: 4.26 Hz
Test Item: Aluminum/Engine Time in Test: 15 minutes



	Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
☐	1	2.51 S	0.59 g's	2.19 g's	9.89 In/s	262 mS	1	2
☐	2	2.48 S	-0.11 g's	-1.33 g's	-1.20 In/s	262 mS	1	2
☒	3	2.50 S	0.08 g's	3.15 g's	-24.85 In/s	262 mS	1	2
☐	4	2.47 S	0.41 g's	1.59 g's	32.43 In/s	262 mS	1	2

Remarks

Peak G X: 2.2 Hz Y: 1.3 Hz Z: 3.2 Hz Table Input(Ch.4): 1.6 Hz

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Accelerometer: Model 2228C, S/N 16473; mounted on fuel control unit.

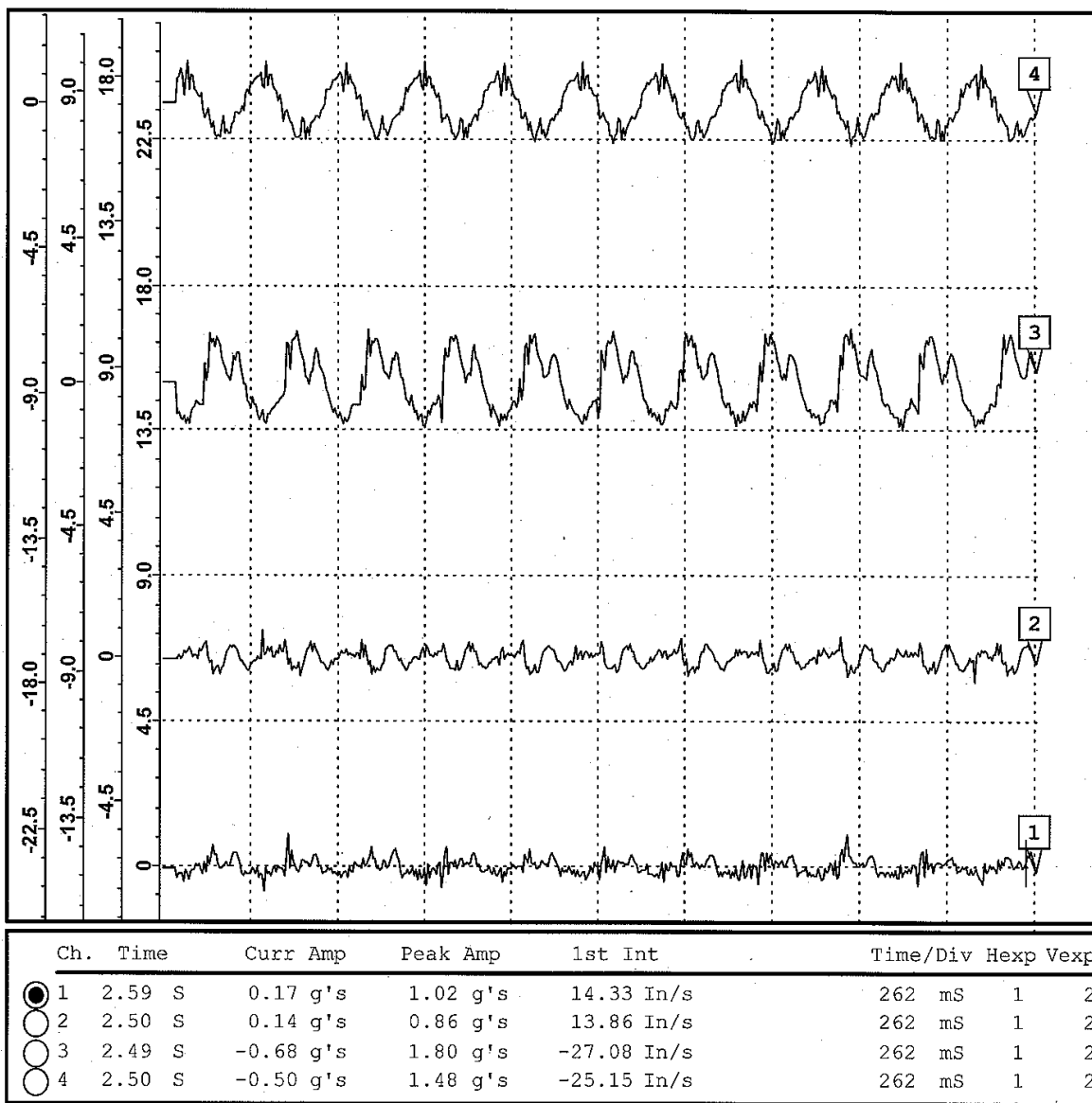
Right side = desiccant port (long) side. Ambient temperature/humidity.

ASTM D4169, ASTM D999, SAE ARP 1967

REAPER ENGINE

REPETITIVE SHOCK

Time: Oct 16 2007 11:15 Test Engineer: Evans
Test Stage: Dwell Frequency: 4.20 Hz
Test Item: Aluminum/Engine Time in Test: 70 minutes



Remarks

Peak Gs X: 1.0 Y: 0.9 Z: 1.8 Table Input Gs(Ch.4): 1.5

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

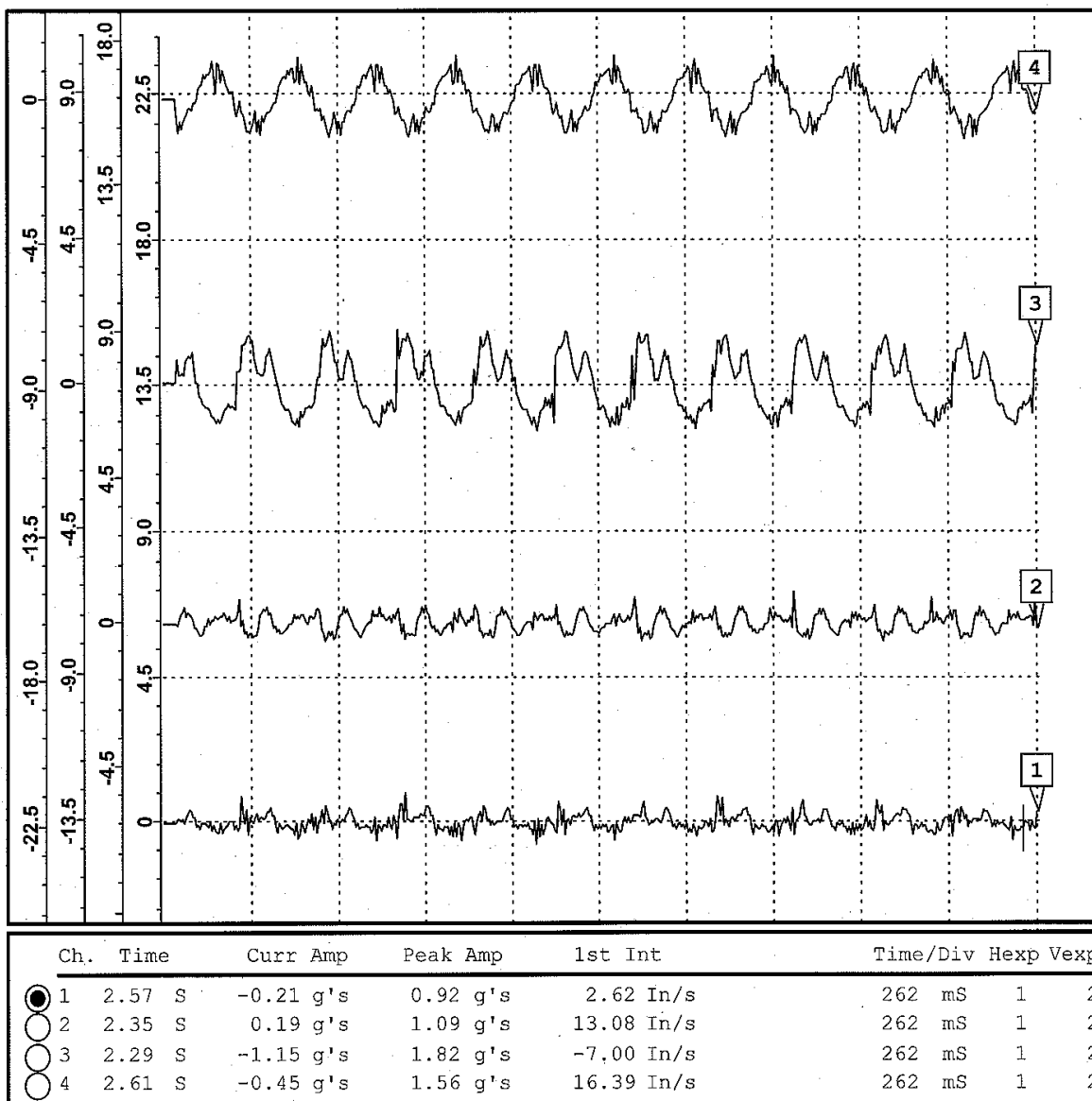
Accelerometer: Model 2228C, S/N 16473; mounted on fuel control unit.

Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP 1967

REAPER ENGINE

REPETITIVE SHOCK

Time: Oct 16 2007 12:04 Test Engineer: Evans
Test Stage: Dwell Frequency: 4.20 Hz
Test Item: Aluminum/Engine Time in Test: 120 minutes



Remarks

Peak Gs X: 0.9 Y: 1.1 Z: 1.8 Table Input Gs(Ch.4): 1.6

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Accelerometer: Model 2228C, S/N 16473; mounted on fuel control unit.

Right side = desiccant port (long) side. Ambient temperature/humidity.

ASTM D4169, ASTM D999, SAE ARP 1967

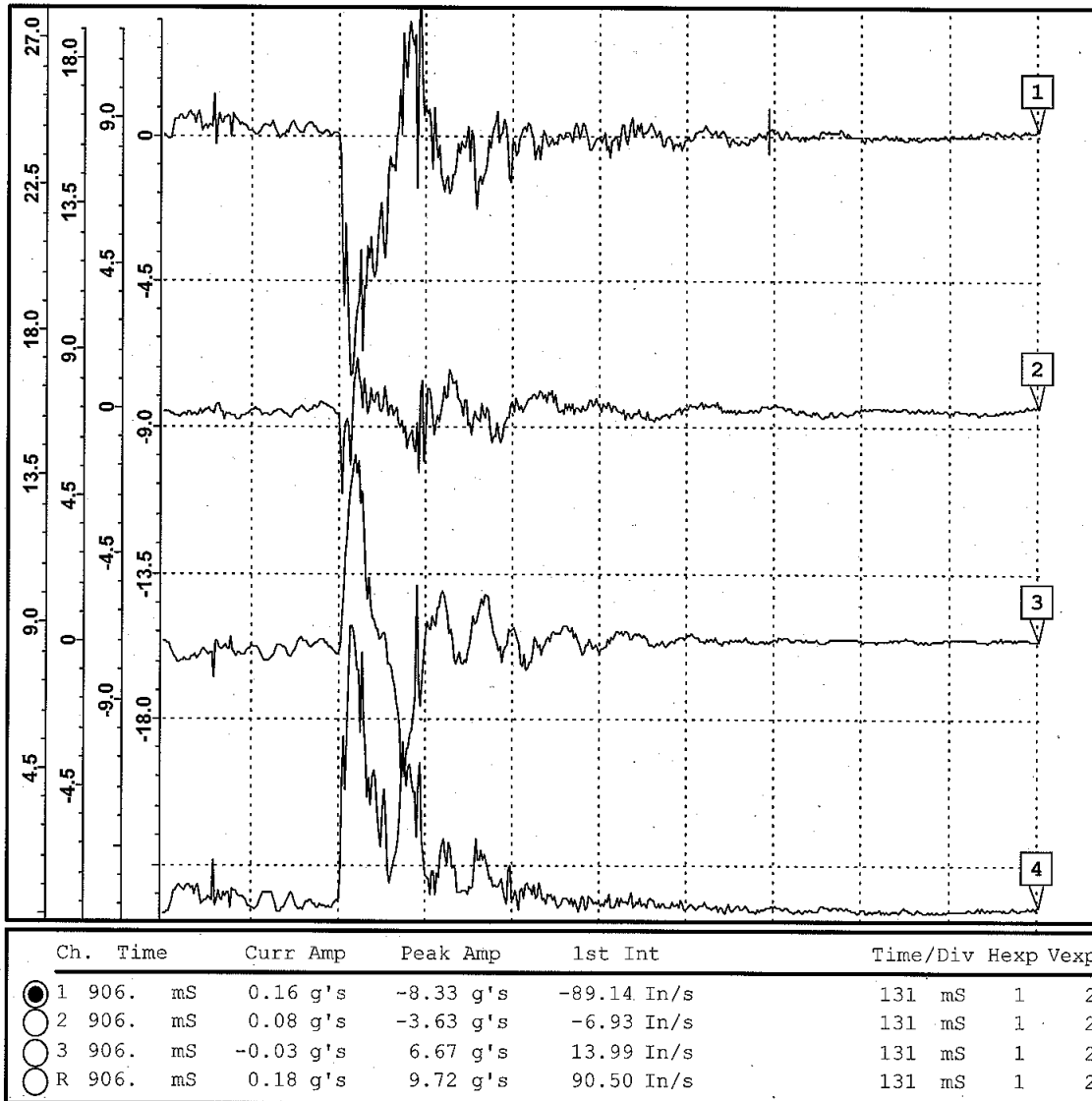
[Unfiltered waveforms]

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Sep 28 2007 10:50 Test Engineer: Evans
Test Type: Edge Impact Point: Forward edge
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 28.50; H. Angle: 341.28;



Remarks

PEAK Gs X: 8 Y: 4 Z: 7 Peak Gs Resultant: 10. Filtered at 75 Hz.
Accelerometer mounted on engine body near CG.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

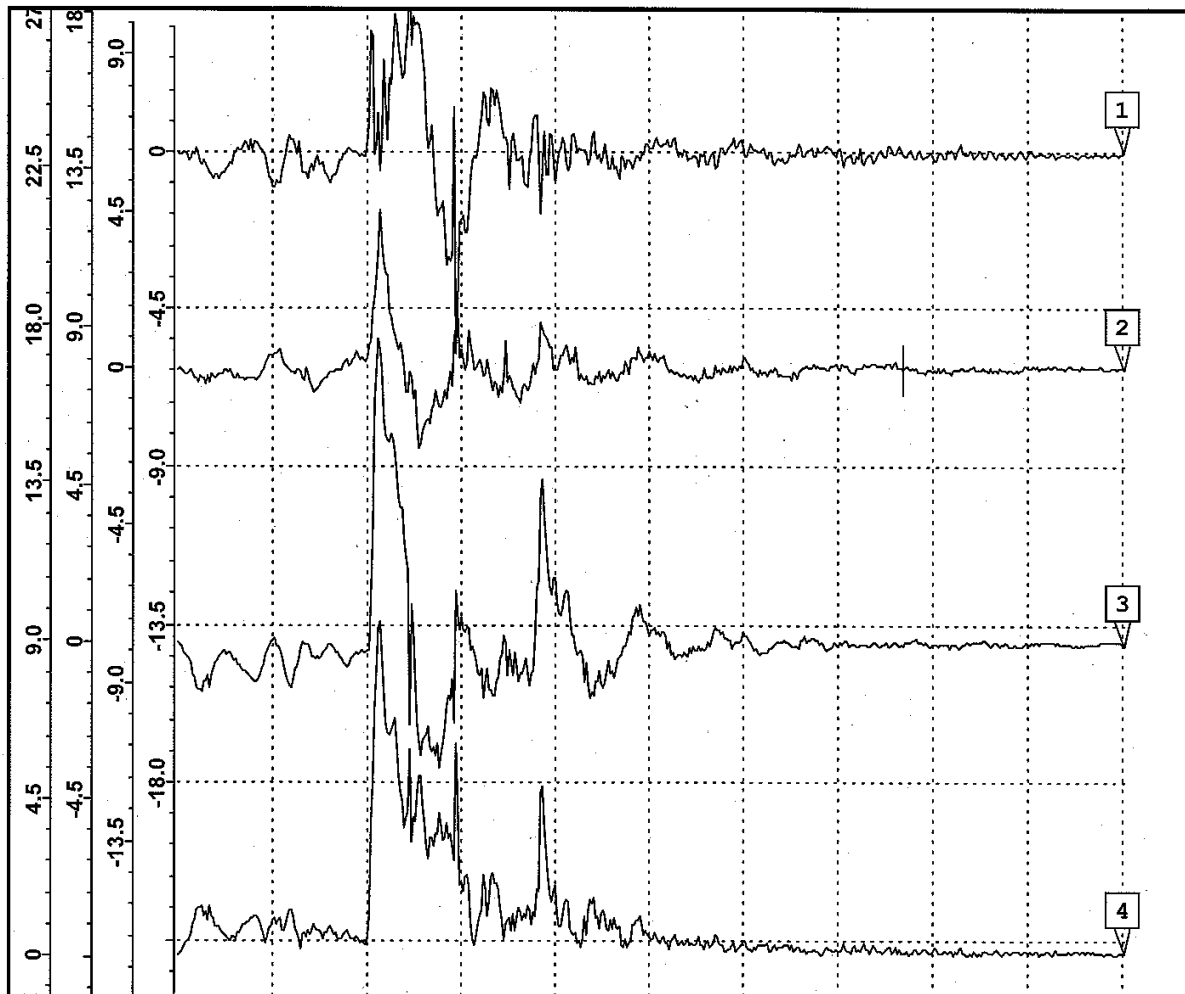
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N CW78.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 9 2007 11:37 Test Engineer: Evans
Test Type: Edge Impact Point: Aft edge
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 109.84; H. Angle: 251.78;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.00 S	-0.03 g's	-6.57 g's	20.95 In/s	131 mS	1	2
2	1.00 S	-0.02 g's	5.03 g's	8.91 In/s	131 mS	1	2
3	1.00 S	-0.07 g's	9.03 g's	-3.49 In/s	131 mS	1	2
R	1.00 S	0.08 g's	9.60 g's	23.03 In/s	131 mS	1	2

Remarks

PEAK Gs X: 7 Y: 5 Z: 9 Peak Gs Resultant: 10.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

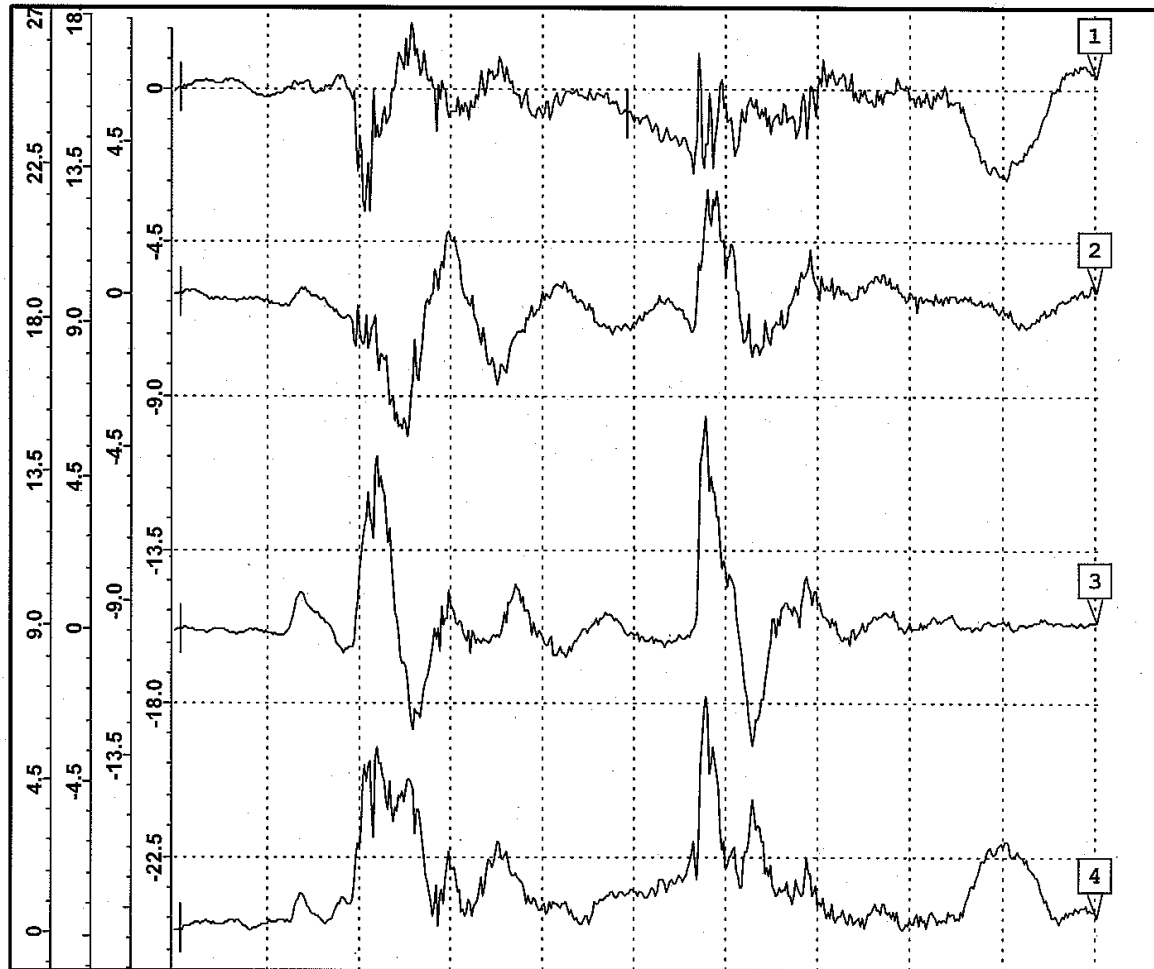
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 9 2007 13:52 Test Engineer: Evans
Test Type: Edge Impact Point: Left edge
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 127.92; H. Angle: 191.43;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	634. mS	-0.69 g's	-4.12 g's	-28.27 In/s	131 mS	1	2
2	634. mS	-0.87 g's	-4.12 g's	-146.60 In/s	131 mS	1	2
3	634. mS	-0.18 g's	5.17 g's	39.37 In/s	131 mS	1	2
R	634. mS	1.13 g's	5.76 g's	154.41 In/s	131 mS	1	2

Remarks

PEAK Gs X: 4 Y: 4 Z: 5 Peak Gs Resultant: 6.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

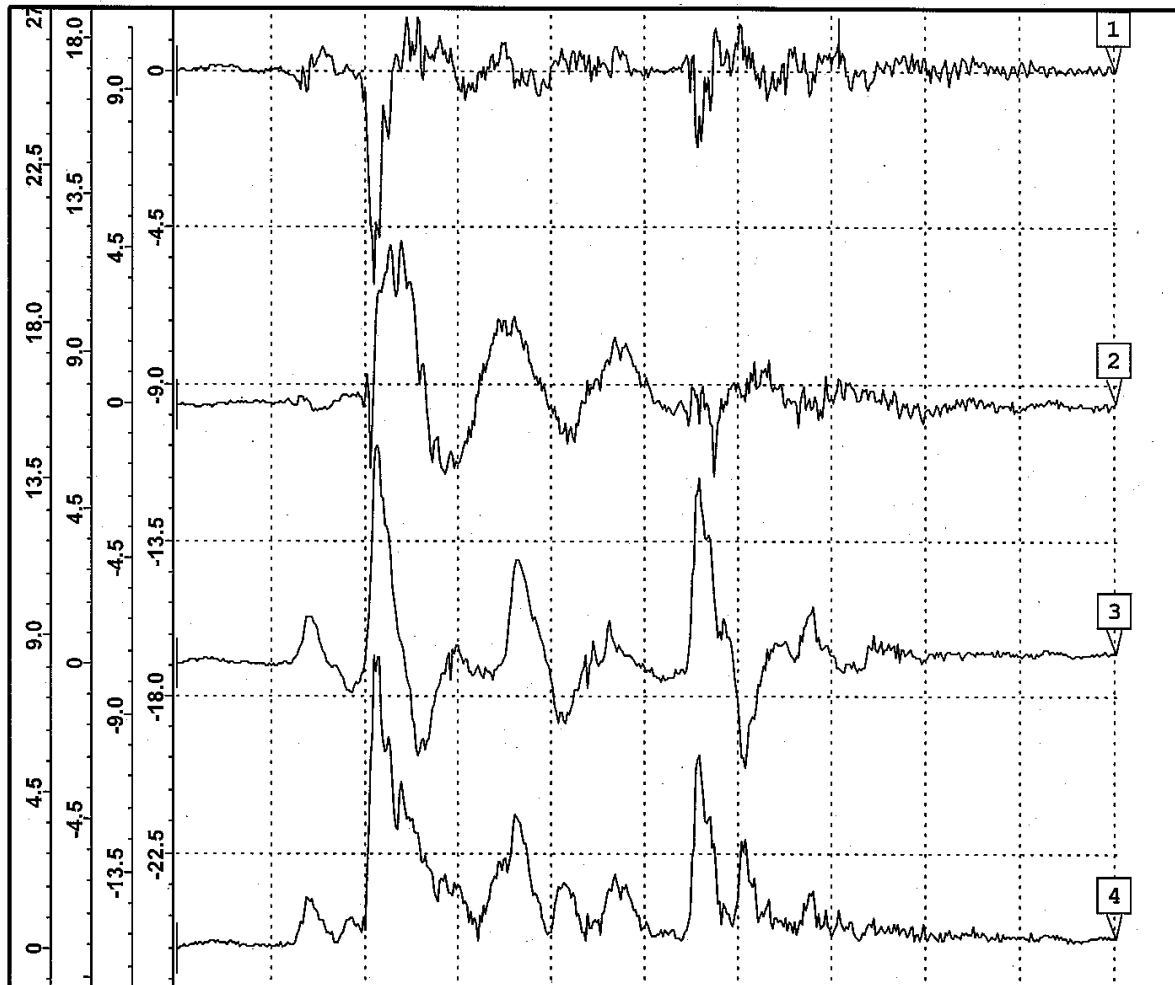
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Sep 28 2007 10:40 Test Engineer: Evans
Test Type: Edge Impact Point: Right edge
Container/Item: Aluminum/Edge Drop Height: 15 inches

V. Angle: 43.75; H. Angle: 350.92;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	924. mS	0.82 g's	-6.23 g's	-3.88 In/s	131 mS	1	2
2	924. mS	0.77 g's	4.91 g's	156.50 In/s	131 mS	1	2
3	924. mS	-0.12 g's	6.74 g's	110.96 In/s	131 mS	1	2
R	924. mS	1.13 g's	8.91 g's	191.88 In/s	131 mS	1	2

Remarks

PEAK Gs X: 6 Y: 5 Z: 7 Peak Gs Resultant: 9.

Accelerometer mounted on fuel control unit.

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Ch4=Resultant.

Right side = desiccant port (long) side. Ambient temperature/humidity.

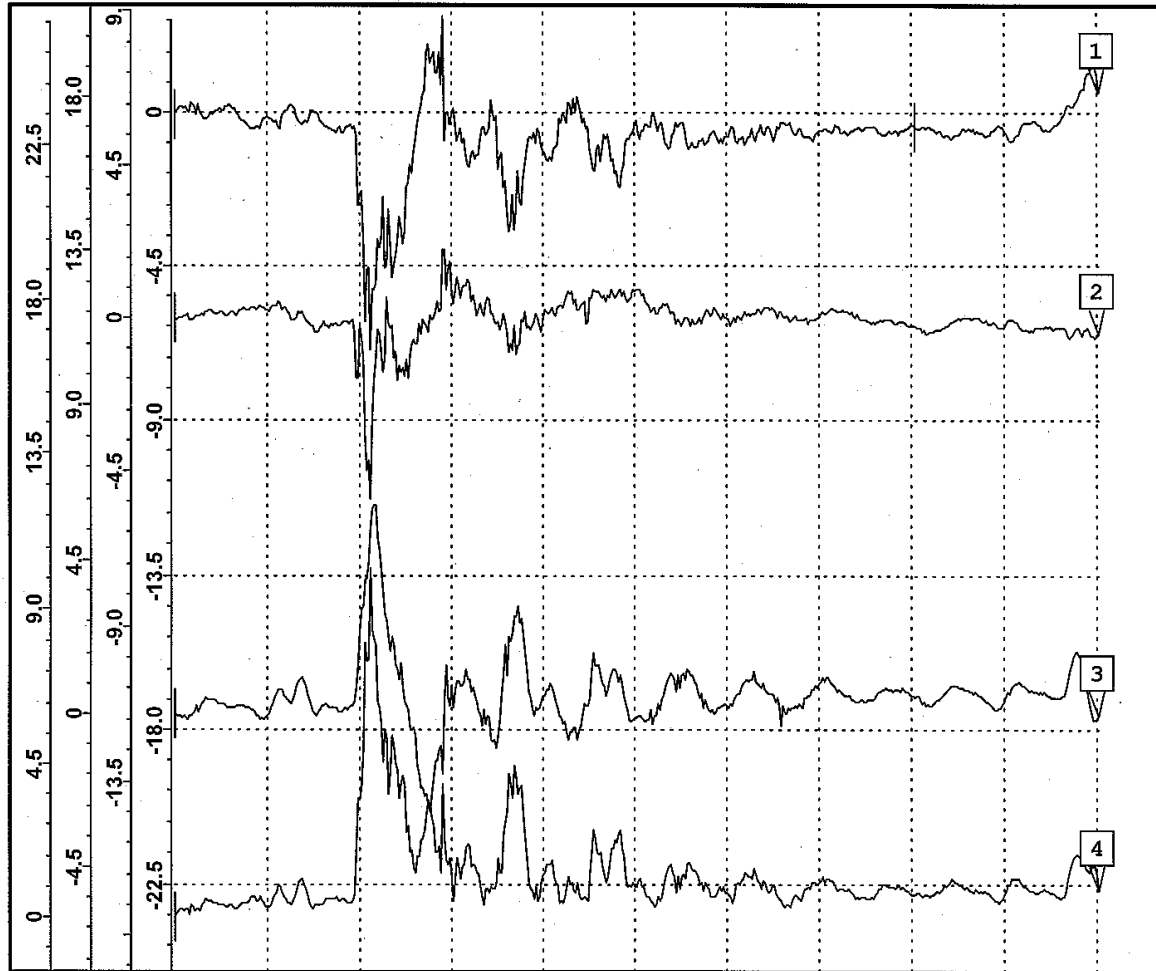
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 9 2007 14:03 Test Engineer: Evans
Test Type: Corner Impact Point: Forward left corner
Container/Item: Aluminum/Edge Drop Height: 15 inches

V. Angle: 127.45; H. Angle: 115.80;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.05 S	-0.40 g's	-7.10 g's	-295.28 In/s	131 mS	1	2
2	1.05 S	-0.23 g's	-5.77 g's	15.22 In/s	131 mS	1	2
3	1.05 S	0.47 g's	6.35 g's	215.06 In/s	131 mS	1	2
R	1.05 S	0.66 g's	10.48 g's	365.62 In/s	131 mS	1	2

Remarks

PEAK Gs X: 7 Y: 6 Z: 6 Peak Gs Resultant: 10.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

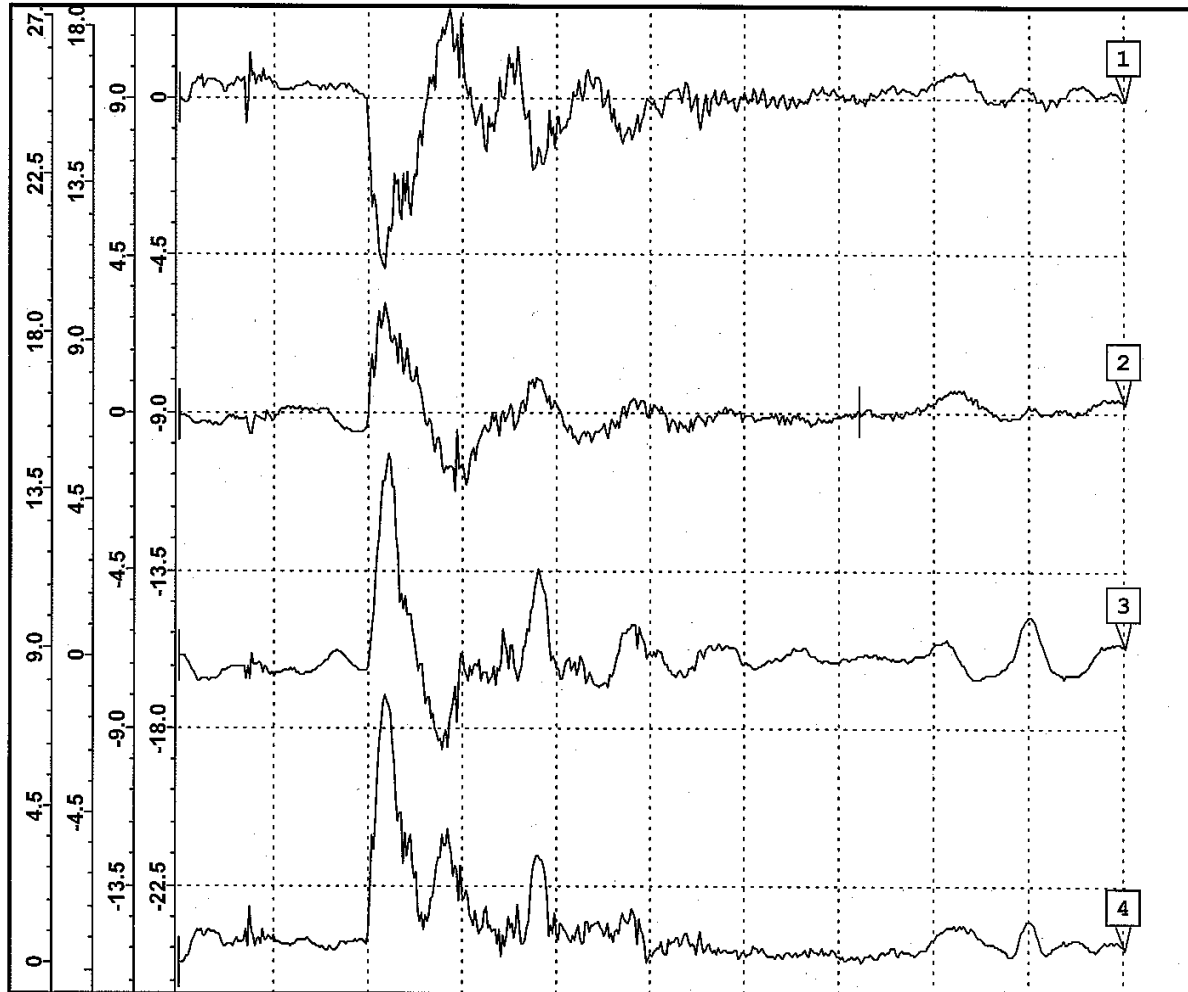
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Sep 28 2007 11:21 Test Engineer: Evans
Test Type: Corner Impact Point: Forward right corner
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 67.54; H. Angle: 7.92;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	942. mS	0.05 g's	-4.91 g's	-54.12 In/s	131 mS	1	2
2	942. mS	0.12 g's	-3.95 g's	-6.44 In/s	131 mS	1	2
3	942. mS	0.02 g's	5.88 g's	-1.26 In/s	131 mS	1	2
R	942. mS	0.13 g's	8.07 g's	54.51 In/s	131 mS	1	2

Remarks

PEAK Gs X: 5 Y: 4 Z: 6 Peak Gs Resultant: 8.

Accelerometer mounted on fuel control unit.

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Ch4=Resultant.

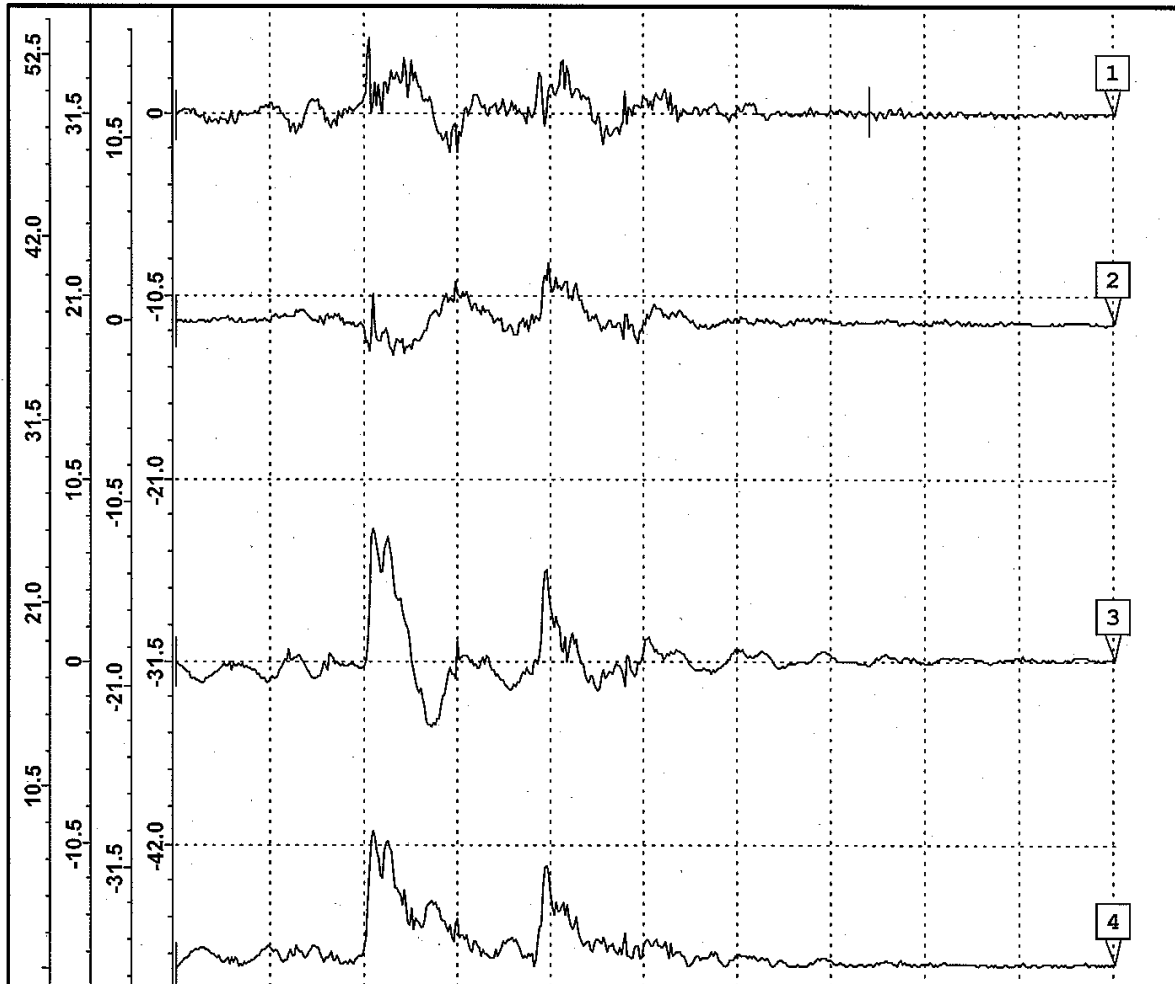
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 10 2007 9:45 Test Engineer: Evans
Test Type: Corner Impact Point: Aft left corner
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 47.26; H. Angle: 261.35;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	967. mS	0.20 g's	4.55 g's	120.33 In/s	131 mS	1	2
2	967. mS	-0.03 g's	3.81 g's	54.68 In/s	131 mS	1	2
3	967. mS	-0.21 g's	8.44 g's	43.13 In/s	131 mS	1	2
R	967. mS	0.29 g's	8.57 g's	139.03 In/s	131 mS	1	2

Remarks

PEAK Gs X: 5 Y: 4 Z: 8 Peak Gs Resultant: 9.

Accelerometer mounted on fuel control unit.

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Ch4=Resultant.

Right side = desiccant port (long) side. Ambient temperature/humidity.

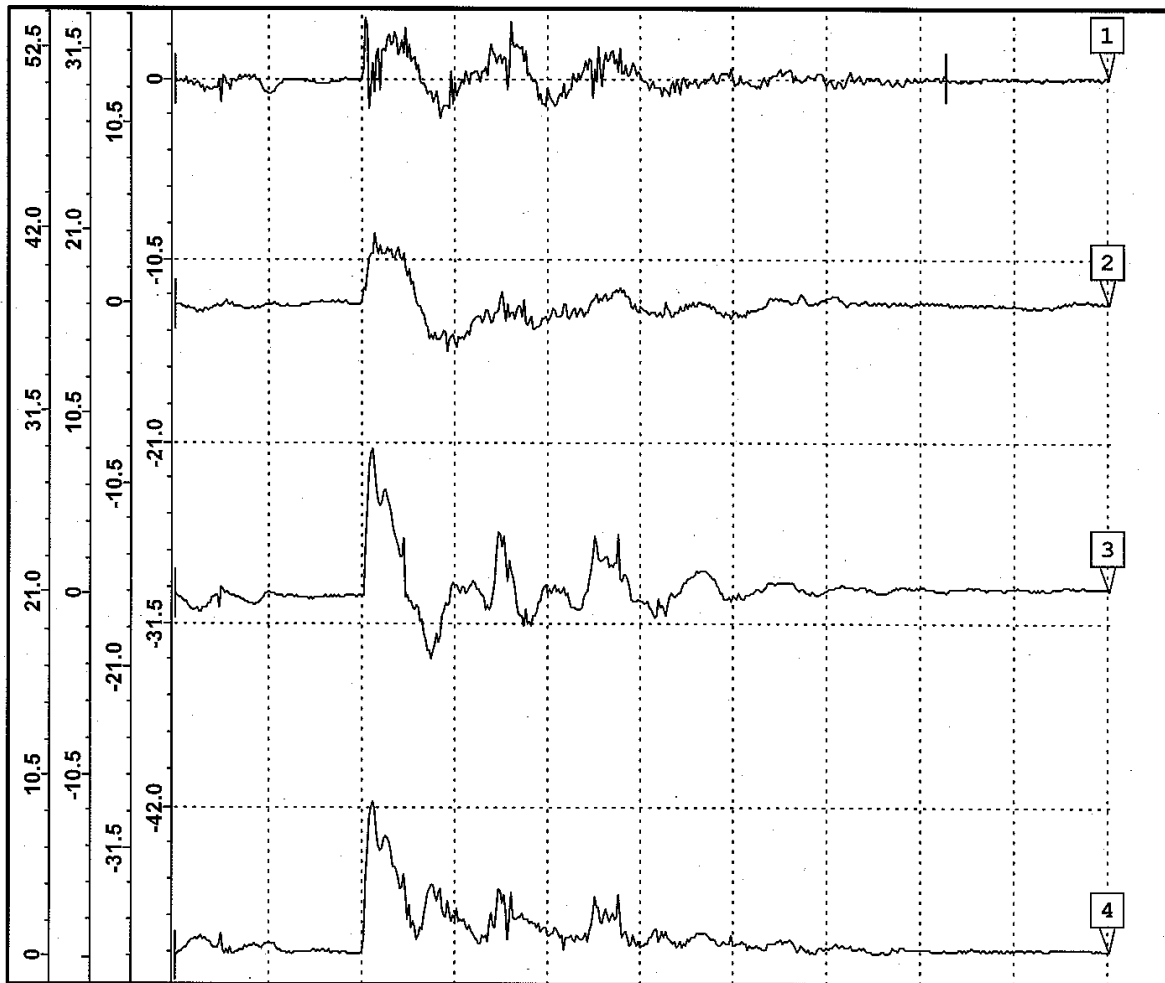
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

ROTATIONAL DROP TEST

Time: Oct 10 2007 9:42 Test Engineer: Evans
Test Type: Corner Impact Point: Aft right corner
Container/Item: Aluminum/Engine Drop Height: 15 inches

V. Angle: 15.21; H. Angle: 82.28;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.08 S	0.20 g's	3.85 g's	48.24 In/s	131 mS	1	2
2	1.08 S	0.01 g's	4.30 g's	-27.99 In/s	131 mS	1	2
3	1.08 S	0.05 g's	8.90 g's	117.48 In/s	131 mS	1	2
R	1.08 S	0.21 g's	9.51 g's	130.05 In/s	131 mS	1	2

Remarks

PEAK Gs X: 4 Y: 4 Z: 9 Peak Gs Resultant: 10.

Accelerometer mounted on fuel control unit.

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Ch4=Resultant.

Right side = desiccant port (long) side. Ambient temperature/humidity.

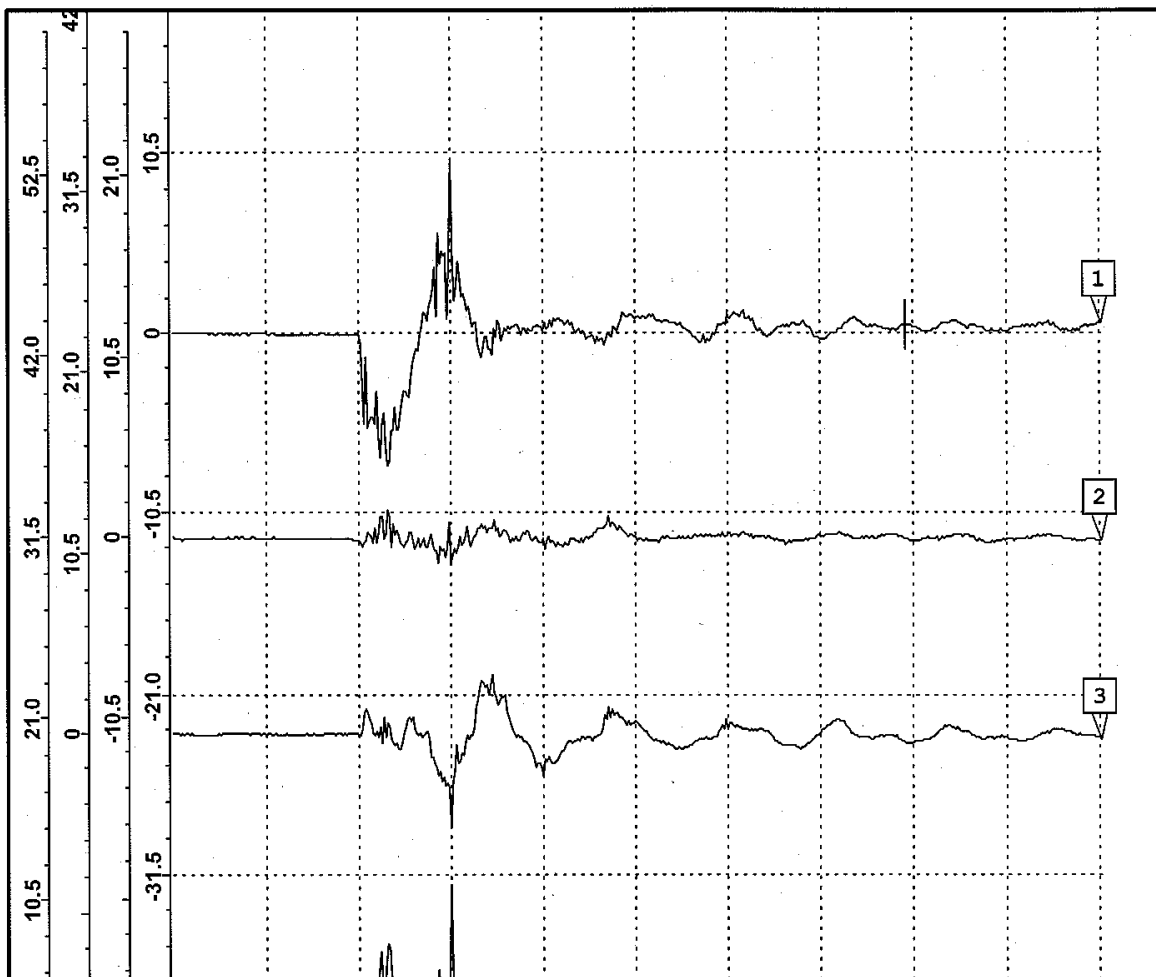
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

PENDULUM IMPACT TEST

Time: Oct 10 2007 10:25 Test Engineer: Evans
Test Type: Side impact Impact Point: Forward side
Container/Item: Aluminum/Engine Impact Velocity 7.3 ft/s

V. Angle: 51.49; H. Angle: 270.46;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	1.03 S	0.45 g's	10.60 g's	3.07 In/s	131 mS	1	2
2	1.03 S	0.00 g's	-4.89 g's	23.74 In/s	131 mS	1	2
3	1.03 S	-0.57 g's	-5.54 g's	-44.06 In/s	131 mS	1	2
R	1.03 S	0.72 g's	11.74 g's	50.14 In/s	131 mS	1	2

Remarks

PEAK Gs X: 11 Y: 5 Z: 6 Peak Gs Resultant: 12.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

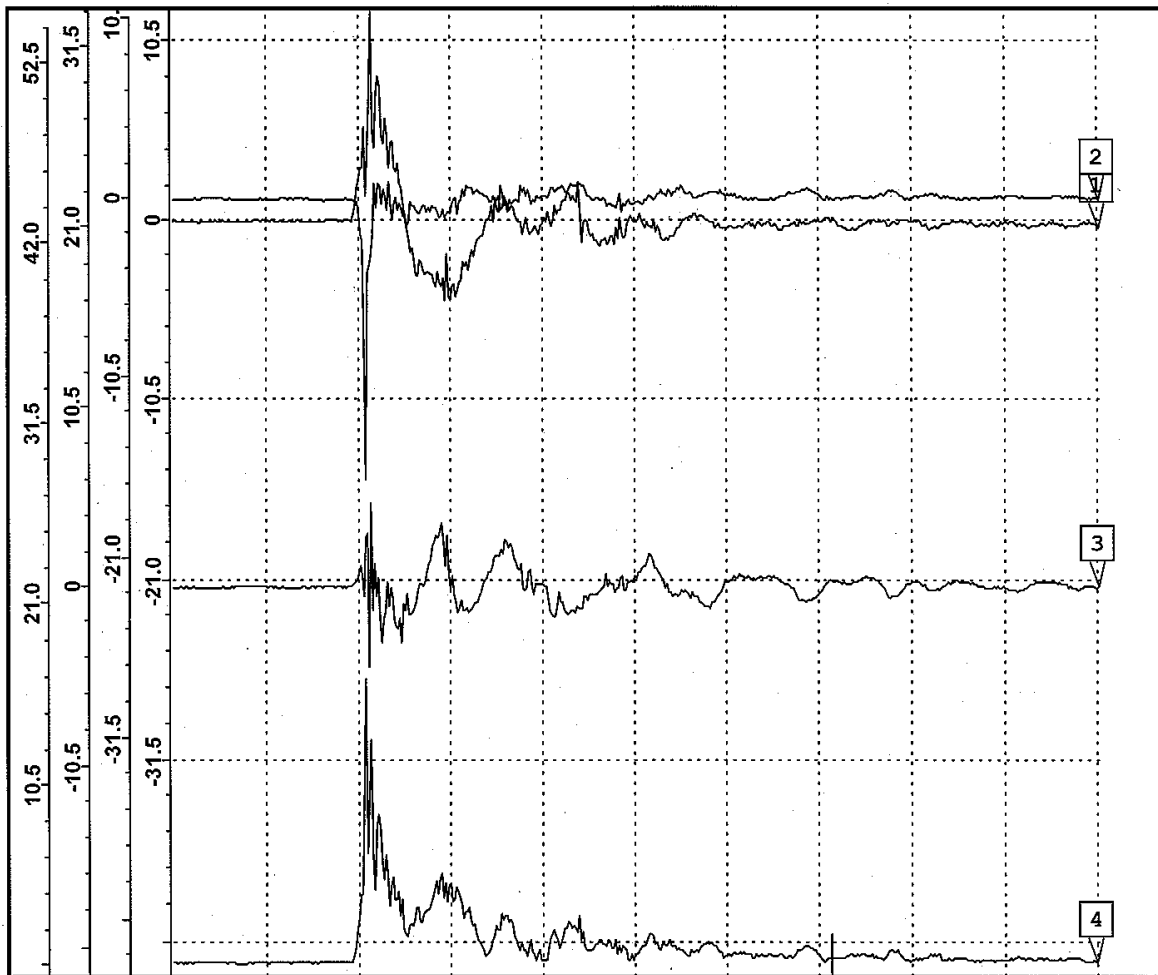
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

PENDULUM IMPACT TEST

Time: Oct 10 2007 12:38 Test Engineer: Evans
Test Type: Side impact Impact Point: Aft side
Container/Item: Aluminum/Engine Impact Velocity 7.3 ft/s

V. Angle: 88.81; H. Angle: 81.34;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	931. mS	0.01 g's	13.37 g's	4.87 In/s	131 mS	1	2
2	931. mS	0.05 g's	-16.57 g's	-15.33 In/s	131 mS	1	2
3	931. mS	0.35 g's	8.90 g's	-7.94 In/s	131 mS	1	2
R	931. mS	0.39 g's	17.01 g's	17.94 In/s	131 mS	1	2

Remarks

PEAK Gs X: 13 Y: 17 Z: 9 Peak Gs Resultant: 17.

Accelerometer mounted on fuel control unit.

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Ch4=Resultant.

Right side = desiccant port (long) side. Ambient temperature/humidity.

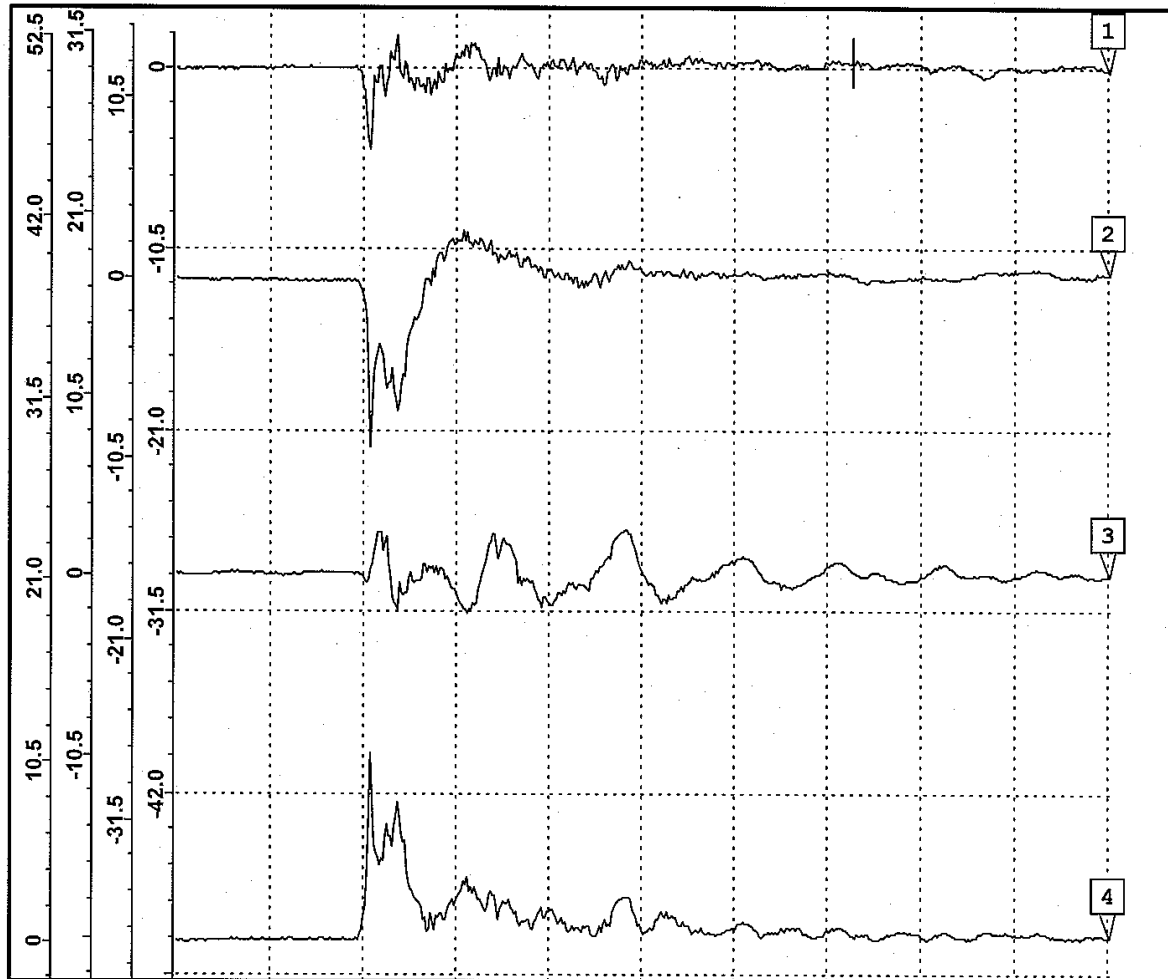
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

PENDULUM IMPACT TEST

Time: Oct 10 2007 10:55 Test Engineer: Evans
Test Type: Side Impact Point: Left side
Container/Item: Aluminum/Engine Impact Velocity 7.3 ft/s

V. Angle: 9.92; H. Angle: 66.28;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	949. mS	0.38 g's	-4.67 g's	19.23 In/s	131 mS	1	2
2	949. mS	0.03 g's	-11.16 g's	-39.81 In/s	131 mS	1	2
3	949. mS	0.06 g's	3.49 g's	-12.15 In/s	131 mS	1	2
R	949. mS	0.38 g's	12.06 g's	45.85 In/s	131 mS	1	2

Remarks

PEAK Gs X: 5 Y: 11 Z: 3 Peak Gs Resultant: 12.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

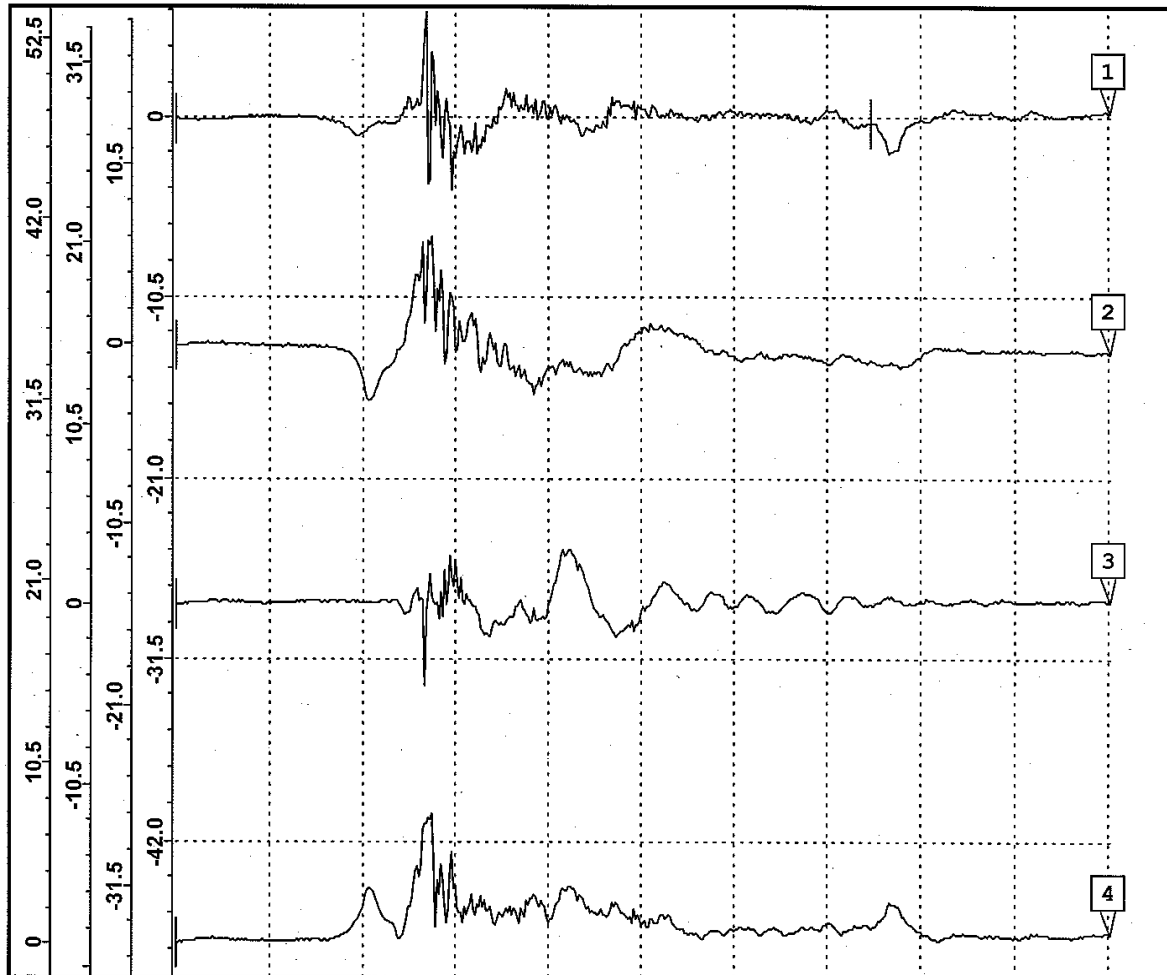
Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

PENDULUM IMPACT TEST

Time: Oct 10 2007 12:51 Test Engineer: Evans
Test Type: Side impact Impact Point: Right side
Container/Item: Aluminum/Engine Impact Velocity 7.3 ft/s

V. Angle: 107.89; H. Angle: 182.09;



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	975. mS	-0.27 g's	7.15 g's	6.51 In/s	131 mS	1	2
2	975. mS	-0.83 g's	11.00 g's	-70.55 In/s	131 mS	1	2
3	975. mS	-0.03 g's	-4.93 g's	19.71 In/s	131 mS	1	2
R	975. mS	0.87 g's	12.06 g's	73.54 In/s	131 mS	1	2

Remarks

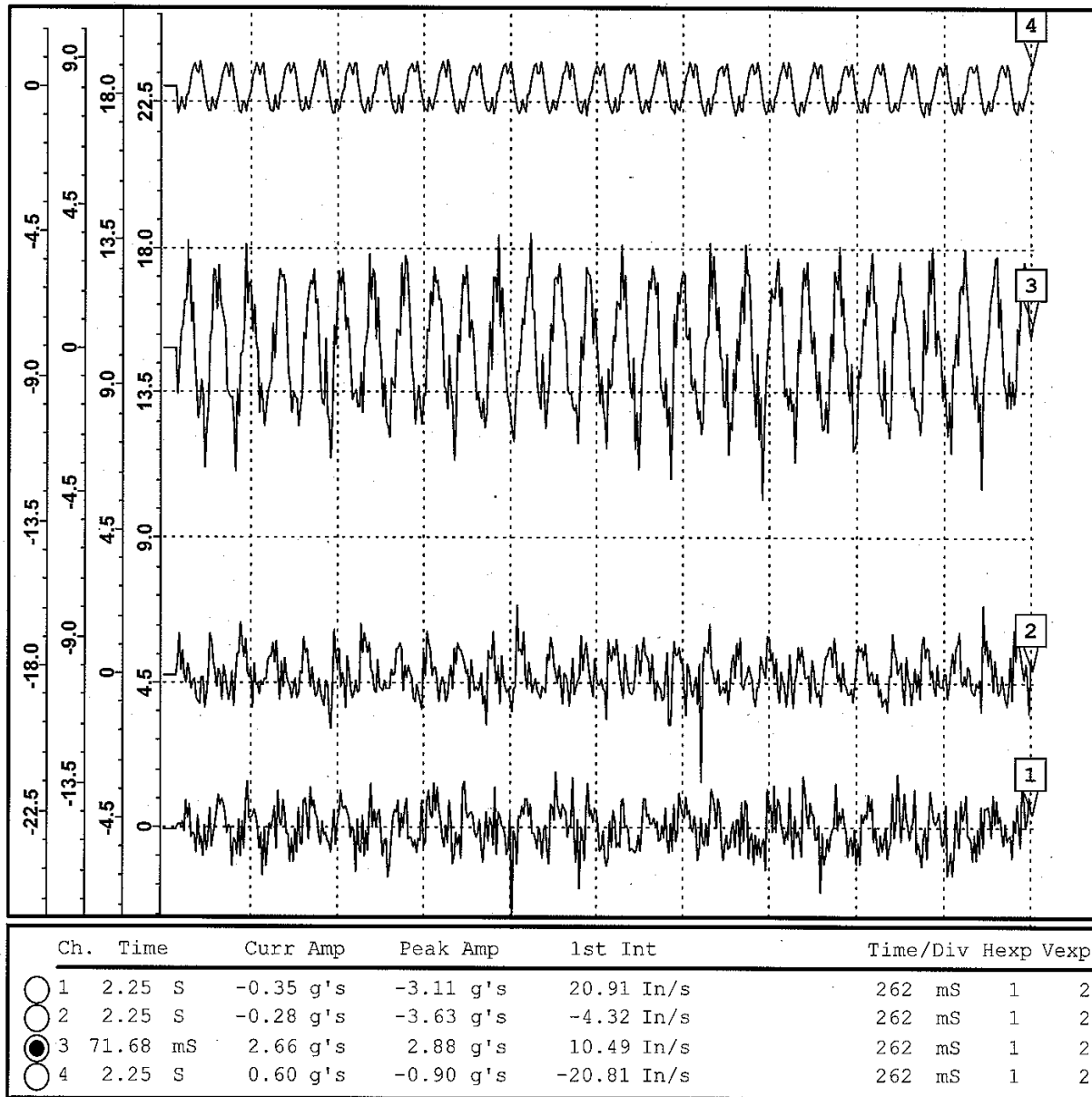
PEAK Gs X: 7 Y: 11 Z: 5 Peak Gs Resultant: 12.
Accelerometer mounted on fuel control unit.
Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).
Ch4=Resultant.

Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D6179. SAE ARP 1967. Accel. S/N 16473.

REAPER ENGINE

RESONANCE DWELL

Time: Oct 15 2007 16:00 Test Engineer: Evans
Test Stage: Dwell Frequency: 10.70 Hz
Test Item: Aluminum/Engine Time in Test: 1 minute



Remarks

Transmissibility: 3.04

Peak G X: 3Gs Y: 4 Gs Z: 5 Gs Table Input(Ch.4): 1 Gs

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

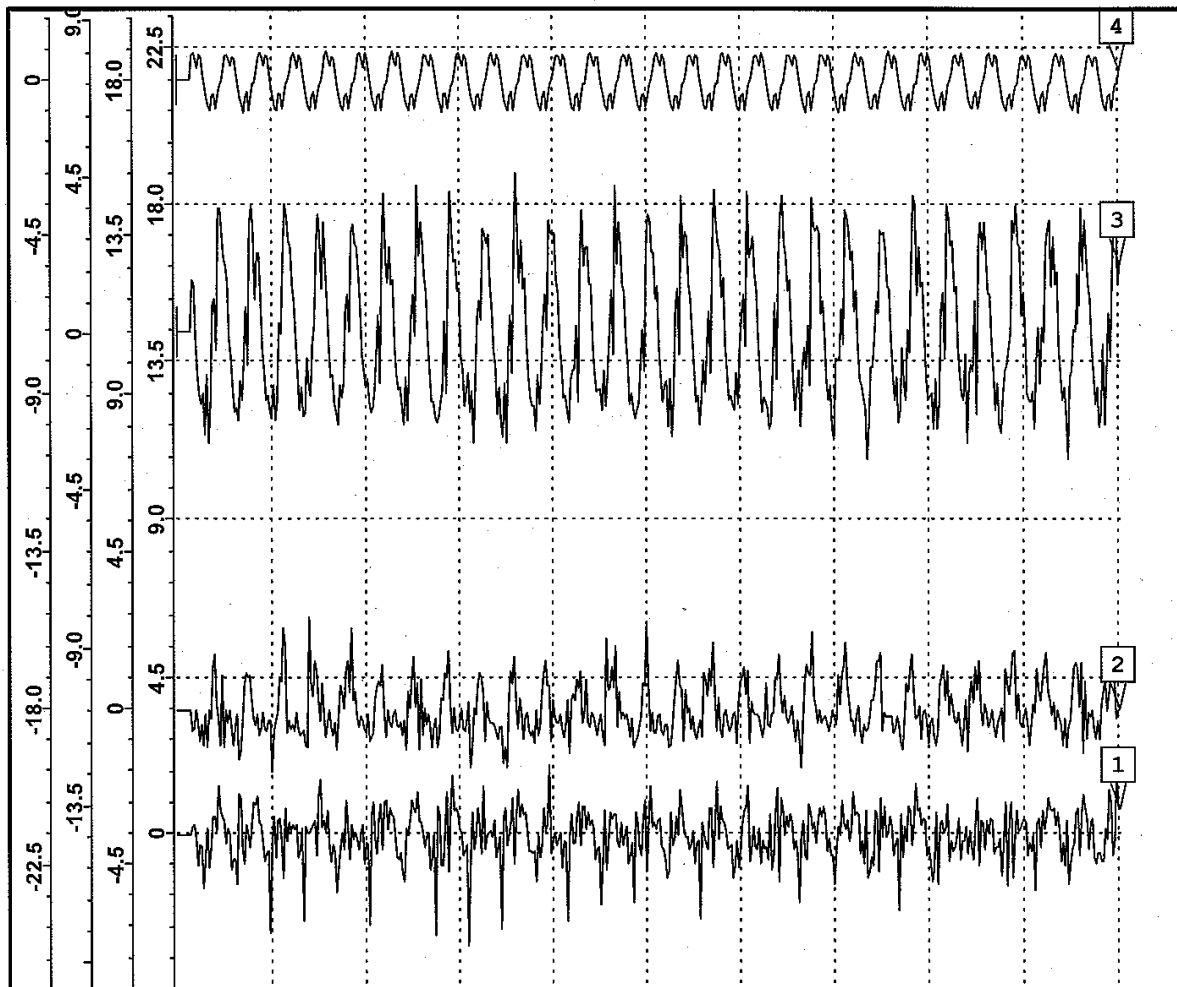
Accelerometer: Model 2228C, S/N 16473; mounted on fuel control.

ASTM D4169, ASTM D999, SAE ARP 1967

REAPER ENGINE

RESONANCE DWELL

Time: Oct 15 2007 16:15 Test Engineer: Evans
Test Stage: Dwell Frequency: 10.84 Hz
Test Item: Aluminum/Engine Time in Test: 15 minutes



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	2.47 S	0.41 g's	3.41 g's	-50.86 In/s	262 mS	1	2
2	2.48 S	-0.35 g's	2.97 g's	-29.20 In/s	262 mS	1	2
3	2.50 S	0.96 g's	5.81 g's	48.74 In/s	262 mS	1	2
4	2.41 S	-0.86 g's	-0.94 g's	-7.46 In/s	262 mS	1	2

Remarks

Transmissibility: 3.68

Peak Gs X: 3 Y: 3 Z: 6 Table Input(Ch.4): 1 G

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Accelerometer: Model 2228C, S/N 16473; mounted on fuel control.

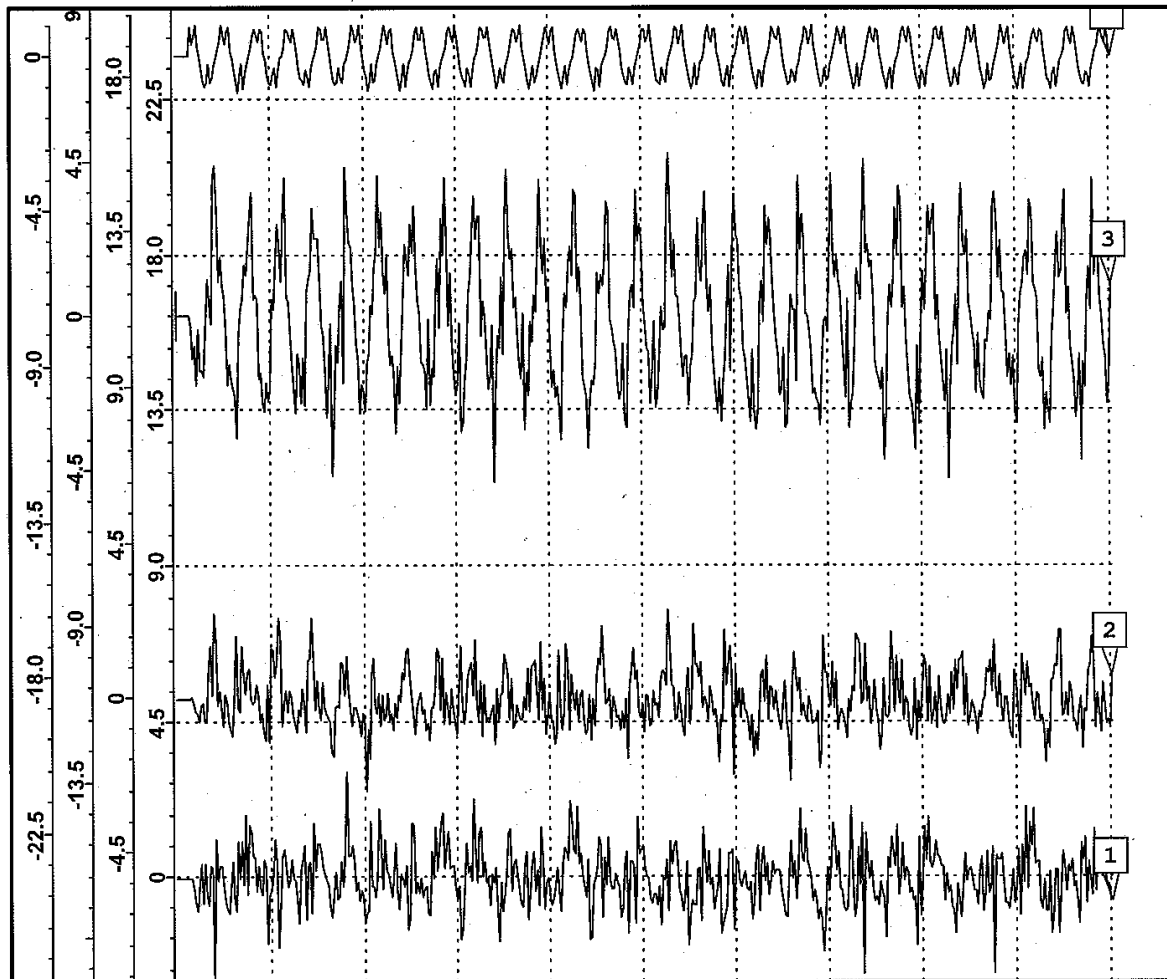
Right side = desiccant port (long) side. Ambient temperature/humidity.

ASTM D4169, ASTM D999, SAE ARP 1967

REAPER ENGINE

RESONANCE DWELL

Time: Oct 15 2007 16:06 Test Engineer: Evans
Test Stage: Dwell Frequency: 10.98 Hz
Test Item: Aluminum/Engine Time in Test: 30 minutes



Ch.	Time	Curr Amp	Peak Amp	1st Int	Time/Div	Hexp	Vexp
1	2.53 S	0.99 g's	3.57 g's	-17.79 In/s	262 mS	1	2
2	2.53 S	-1.45 g's	4.65 g's	-28.05 In/s	262 mS	1	2
3	2.53 S	-3.45 g's	-6.58 g's	-44.38 In/s	262 mS	1	2
4	2.53 S	-0.57 g's	-1.03 g's	0.81 In/s	262 mS	1	2

Remarks

Transmissibility: 3.36.

Peak Gs X: 4 Y: 5 Z: 7 Table Input(Ch.4): 1 G

Ch.1=X(forward-aft); Ch.2=Y(left-right); Ch.3=Z(vertical).

Accelerometer: Model 2228C, S/N 16473; mounted on fuel control.

Right side = desiccant port (long) side. Ambient temperature/humidity.
ASTM D4169, ASTM D999, SAE ARP 1967

APPENDIX 4: Test Instrumentation

PRESSURE TEST EQUIPMENT - Test sequences 1, 2, 7 & 8

EQUIPMENT	MANUFACTURER	MODEL	SN	CAL. DATE
Digital Manometer	Yokogawa	2655	82DJ6001	Oct 07
Digital Manometer	Yokogawa	2655	82DJ6009	Jul 07

ROUGH HANDLING TEST EQUIPMENT - Test sequences 3, 4, 5 & 6

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	Sep 07
Data Acquisition	GHI Systems	CAT	Ver. 2.7.1	N/A

APPENDIX 5: Distribution List

DISTRIBUTION LIST

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

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

448 MSUG/GBMST
TINKER AFB OK 73145

84 MSUG/GBMSCA
HILL AFB UT 84056-5805

542 MSUG/GBMSCA
ROBINS AFB GA 31098-1670

658 AESS/LG (ATTN: GERALD WILLIAMS)
2640 LOOP ROAD WEST
WRIGHT-PATTERSON AFB OH 45433-5540

GENERAL ATOMICS
ATTN: DAVID LEVY
16761 VIA DEL CAMPO CT
SAN DIEGO, CA 92127

APPENDIX 6: Report Documentation

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 12-02-2008		2. REPORT TYPE Technical, Final Project Report		3. DATES COVERED (From - To) March 06 - November 07	
4. TITLE AND SUBTITLE Development of the MQ-9 Reaper Engine Container				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Joel A. Sullivan, Project Engineer joel.sullivan@us.af.mil, DSN 787-8162, Comm. (937) 257-8162 Susan J. Evans, Qualification Test Engineer susan.evans@us.af.mil, DSN 787-7445, Comm. (937) 257-7445				5d. PROJECT NUMBER 06-P-104	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Packaging Technology and Engineering Facility AFMC LSO/LOP 5215 THURLOW ST, STE 5, BLDG 70C WRIGHT-PATTERSON AFB OH 45433-5540				8. PERFORMING ORGANIZATION REPORT NUMBER 08-R-01	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT The Air Force Packaging Technology Engineering Facility (AFPTEF) was tasked with the design of a new shipping and storage container for the MQ-9 Reaper Engine in March of 2006. The new container is designed to replace the fiberboard box currently used. The current container is not reusable and provides minimal shock protection and no environmental protection against corrosion. Additionally, the fiberboard box can not house the engine in the Quick Engine Change (QEC) configuration. AFPTEF used proven design techniques to meet these design requirements. The CNU-696/E, designed to SAE ARP1967A, is an aluminum, long-life, controlled breathing, reusable shipping and storage container. The new container protects the Engine mechanically and environmentally. The container passed all qualification tests per ASTM D4169. The CNU-696/E container not only meets user requirements but also provides an economic saving for the Air Force. The savings will be thousands of dollars per Engine over the twenty-year life span of the container.					
15. SUBJECT TERMS CNU-696/E, MQ-9 Reaper Engine Container, Aluminum Container, Reusable Container, Design, Test, Long Life					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Joel A. Sullivan
U	U	U	UU	60	19b. TELEPHONE NUMBER (Include area code) (937) 257-8162