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MODEL NO: 560XL

REPORT NO: PR-560XL-009

560XL-5599 FOLLOW-ON INVESTIGATION (NETJETS TAIL N613QS)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

REFERENCES

The following documents form a part of this report. Unless a specific revision of one of these documents is specified, the revision in effect at the time of original issue of this document shall apply. If components or specification documents are added to this document by revision, the revision level of the specific applicable specification document at the time of issue of the revision to this document shall apply to those components unless otherwise specified.

Cessna Documents

PR-560XL-008	Landing Gear Uncommanded Retract Investigation
9912491	Nose Landing Gear Actuator
9912537	Main Landing Gear Actuator
	Model 560XL Maintenance Manual

Cessna Drawings

5527504	ACTUATOR ASSY-UNLOCK & SEQUENCE
6617005	HYDRAULIC SYSTEM INSTL-NOSE GEAR
6617015	HYDRAULIC TUBES CABIN FAIRING DETAILS & INSTL
6617022	HYDRAULIC SUB PANEL DETAILS, ASSY & INSTL
6617085	HYDRAULIC TUBES CABIN FAIRING DETAILS & INSTL
6617201	HYDRAULIC TUBES WING FAIRING DETAILS & INSTL
6617210	HYDRAULIC TUBES AFT FAIRING DETAILS & INSTL
6617355	HYDRAULIC INSTL, FWD CABIN
6617360	HYDRAULIC INSTL, FWD FAIRING
6627100	HYDRAULIC SYSTEM INSTL-MLG WHEELWELL
6627105	HYDRAULIC TUBES FUEL CELL DETAILS & INSTL
6678320	LANDING GEAR MONITOR & CONTROL WIRING DIAGRAM ASSY
6618704	PRINTED CIRCUIT BOARD ASSY – LANDING GEAR

6618735	PRINTED CIRCUIT BOARD ASSY – LANDING GEAR CONTROL
6628015	WIRE ROUTING INSTL – MLG
6618723	PRINTED CIRCUIT BOARD ASSY - HYDRAULIC

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

CB	Circuit Breaker
CC	Cubic Centimeter
CMM	Component Maintenance Manual
FAA	Federal Aviation Administration
FT	Feet
GAL	Gallon
GOG	Gear On Ground
GPM	Gallons Per Minute
HYD	Hydraulic
HIRF	High-Intensity Radiated Fields
ID	Inside Diameter
IN	Inch
LB	Pound
LH	Left-Hand
M&P	Material & Process
N2	High Pressure Turbine Speed
OD	Outside Diameter
PCB	Printed Circuit Board
PSI	Pounds Per Square Inch
RH	Right-Hand
S	Stroke
Sec	Second
S/N	Serial Number
T/R	Thrust Reverser
WCSC	Wichita Citation Service Center
WOW	Weight on Wheels

1. OBJECT

This report is a follow-up report to PR-560XL-008 Landing Gear Uncommanded Retract Investigation: 560XL-5599. It documents the continuing efforts by Cessna Engineering and Cessna suppliers to investigate the circumstances around and possible causes of the landing gear collapse of 560XL-5599 on April 15, 2008. Reference Accident Summary in Cessna report PR-560XL-008.

2. CESSNA ENGINEERING ACTIVITY

2.1 Ruptured Tube Analysis

The ruptured 6627002-16 Tube Assy that was found during one of the first tests preformed when the aircraft arrived at the Wichita Citation Service Center (WCSC) was analyzed.

The wall thickness of this tube was approximately 0.042 to 0.045 in., (measured on areas where the primer was removed from the OD). The nominal wall thickness was specified to be 0.049 inches. According to ANSI H35.2, the tolerance on wall thickness for nominal 0.049" wall drawn aluminum tubing is 0.003", so this tube in its current condition is below minimum tolerance. The tube also displayed some bulging that expanded the tube OD from the nominal 0.500" diameter to approximately 0.560-0.570" in several areas. Longitudinal cracking of the OD primer coating is further evidence of tube OD expansion, which accounts for the reduction in wall thickness.

The tube assembly exhibited a longitudinal split measuring approximately 0.775 inches in length along the tube wall at the approximate mid-tube location. The tube was longitudinally sectioned at the burst. No visible tube defects or flaws were found on the ID surfaces that could have caused or contributed to the burst (Note: the tube was not examined at magnification in cross-section at this time). The fracture surface at the burst was characteristic of ductile overload. No pre-existing flaws were found.

The chemical composition of the tube was determined using energy-dispersive x-ray spectroscopy in the electron microscope, and was found to be consistent with 5052 aluminum alloy, as specified in the engineering drawing parts list.

Comparison of the cross section of the bulged tube to that of a nominal tube is consistent with the finding that the tube was of correct dimension and bulged due to high pressure: tube cross sectional area for nominal .5x.049 tube is .069426 in^2; final cross section is approximately 0.567 per M&P analysis; given same cross sectional area, the tube wall would have to be 0.0423”. This is consistent with the M&P analysis showing tube wall between 0.042” and .045”. Other tube properties were also consistent with tube design. Therefore, it is concluded that the tube matched type design before the accident. Reference Appendix A – Ruptured 6627002-16 Tube Analysis for pictures and material analysis.

2.2 Fluid Loss Analysis

The primary purpose of this section is to exercise the assumption made implicitly with much of the discussion regarding potential root cause. That assumption is that the ability of the hydraulic system to stow thrust reversers at the end of the accident sequence requires that the hydraulic system would also have been capable of unlocking and attempting to extend the RH and Nose landing gear which were in fact in the up and locked position before, during, and after the final T/R stow operation. Both T/R operation and the flaps being pushed up by the ground would ensure that the hydraulic system was energized the whole time the aircraft was on the skid plate. Since fluid remained in the hydraulic reservoir, and the gear remained in the up and locked position, the gear valve must not have been in the gear extend position.

The following analysis is not conclusive, but the fluid found in the reservoir after the incident is consistent with the amount that would be expected if the gear control valve were not in the extend position during the event. Volume analysis is also consistent with the likelihood that the gear retract side of the hydraulic landing gear actuators were filled with vaporized fluid resulting from gear retraction without the hydraulic cylinders being filled with fluid. Low pressure forming as gear retract side volume increases without input of hydraulic fluid results in a fluid and fluid vapor mix that is restored to normal when the gear is blown down pneumatically. The analysis shows that the end reservoir volume is consistent with a normally serviced reservoir. If the reservoir had been overserviced to the 360 in^3 level, only 135 in^3 would have been available to leak overboard during the event. If the gear control valve had been commanding extend it is expected that it would have routed the entire volume into the fuel tank through the gear extend plumbing breach. The pumps would have been capable of pumping 285 in^3 from the time the aircraft was on the skid rail to when power was turned off. Therefore, fluid volume analysis concludes that the gear control manifold was not in the gear extend position after gear collapse. Reference Appendix I – Fluid Loss Addendum.

TABLE 2-1: RESERVIOR VOLUME ANALYSIS

This worksheet will track the hydraulic reservoir volume to see if the final reading adds any insight as to the likely failure mode.				
Reservoir Max overfull	360	in^3		
Reservoir Full mark	215	in^3	Gear extended, other surfaces stowed.	
Nominal fluid thermal expansion	25	in^3		
Reservoir Refill mark	175	in^3		
Reservoir post Accident reading	187	in^3		
	Volume in^3			
Actuator	Extend	Retract	Reservoir delta to extend actuator	Reservoir delta to retract actuator
Nose Gear	19.8	6.2	-13.6	13.6

LH Main Gear	16.1	43.7	27.6	-27.6
RH Main Gear	16.1	43.7	27.6	-27.6
4 T/R actuators	86	27.6	-58.4	58.4
2 Speed Brakes	10.6	8.5	-2.2	2.2
		Actuators stay full of fluid	Retract cavitates on collapse	Cavitate on collapse and gear extend fluid lost to burst
Sequence of Events	Time (sec)	Reservoir volume (in^3)		
1. Touchdown	17.92	214.2	214.2	214.2
2. T/R deploy		272.6	272.6	272.6
3. Speed brakes extend		270.4	270.4	270.4
Loss of gear downlock	19.38			
Loss of weight on wheels	29.15			
4. LH main actuator retract		242.8	286.5	270.4
Wing and flap runway scars	30.13			
5. Nose gear retract		229.2	292.7	270.4
Skid rail runway scar begins	31.6			
6. RH main actuator retract		201.7	308.8	270.4
Aircraft stops	38.92			
7. T/R stow	44.79	143.3	250.4	212.0
8. Gear blowdown	later	250.4	250.4	212.0
9. Fluid cool down	later	225.4	225.4	187.0

* The Flap actuator volumes were omitted because of unknown position of flaps during accident.

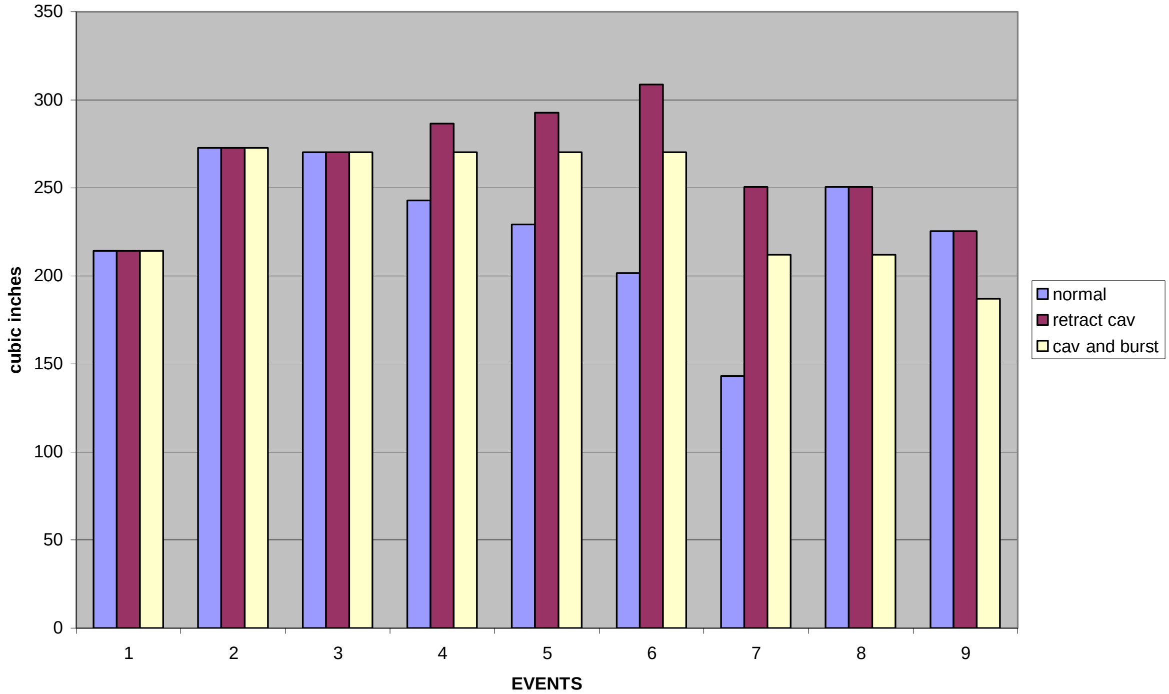

FIGURE 2-1: HYDRAULIC RESERVOIR VOLUME

2.3 Runway Data Analysis and Comparison AltAir Data

Measurements taken on the runway following the accident indicate the following:

LH Wing tip contacts runway for 190 feet

LH Wing tip and flap contact runway for additional 180 feet

Aircraft on skid rail for additional 590 feet

This indicates LH gear collapse started before the beginning of the 190 feet, Nose gear collapse occurred during the first 190 feet, RH gear collapse occurred during the 180 feet, and the aircraft was on the skid rail for the final 590 feet.

Comparison to Alt Air data will assume loss of squat switch is coincident with LH wing tip contacting runway, time = 12:52:29.15.

Comparison to Alt Air data will assume airspeed data is equal to ground speed.

Alt Air shows Weight on Wheels for one second before loosing gear down and locked indication, time = 12:52:19.38. Ten seconds elapses before Weight on Wheels indication is lost, time = 12:52:29.15. Therefore, the aircraft was on the ground for 10 seconds during rollout prior to LH gear collapse. This matches crew statements. Alt Air data analysis shows time to traverse 190 feet for nose gear to collapse took approximately 1.0 second, approximately time 12:52:30.15. Traversing the additional 180 feet for RH gear to collapse took approximately, 1.5 seconds; approximately time 12:52:31.6. This calculation is validated by similarity of the measured runway marks of 960 feet total length to calculated total distance of 1009 feet. It is possible to estimate hydraulic system flow rate based on Engine N2 data from Alt Air. It is assumed that aircraft power was turned off at end of Alt Air dataset, time = 12:52:45.76. Therefore, valves in the hydraulic system would loose power at that time. The gear control valve would center if it had been powered to another position, and working properly. If fluid were being lost from hydraulic system through the tube breach in the gear extend line, it would stop at this time even though engines continue to spool down towards N2=0 where pumps stop rotation. Consistent with the gear control manifold not in the gear extend position. Reference Appendix J – Runway Scars for diagram of the scars. Also reference Appendix J in Report PR-560XL-008 for Alt Air Data.

TABLE 2-2: RUNWAY & ALTAIR TIMELINE

Runway Data and AltAir Data Analysis Summary			
Event	Time (sec)	Runway Position	comments
Touchdown	17.92	-1731 ft	1731 ft prior to beginning of runway scars
Loss of Gear Downlock	19.38	-1467 ft	LH loss of downlock indication and gear

			horn sound for 10 seconds prior to LH collapse.
Loss of Weight on Wheels, LH wing contacts runway	29.15	0	Beginning of runway scars. LH Wing tip mark only.
	30.13	190 ft-measure 195 ft calculated	LH Flap track runway scars begin. Hyd system has pumped 26 in^3 since time 29.15
All gear are collapsed	31.6	370 ft-measured 383 ft-calculated	Runway scars for skid rail begin. Hyd system has pumped 26 in^3 since time 30.13
Aircraft Stops	38.92	960 ft-measured 1009 ft-calculated	
Throttles to Cutoff	44.79		Thrust Reverser Stow was prior to Throttles to Cutoff
End of Alt Air Data	45.76		Assume power off. Hyd system has pumped 285 in^3 since time 31.6.

2.4 Hydraulic Fluid Analysis

Fluid analysis determined the fluid collected from the actuators to have been dirtier than is expected or typical in service. It is possible that the container or method of gathering the sample resulted in an erroneously high reading due to addition of external contaminants. Components torn down as part of this investigation did not show any adverse affects due to highly contaminated fluid. Specifically, there was no buildup of contaminant identified in the actuator, actuator lock mechanism, hydraulic manifold, valve, or control solenoids. Contamination is not a likely cause of this incident. Reference Appendix D – Hydraulic Fluid Analysis for results.

2.5 Extend Line Burst and Manifold Extend Position

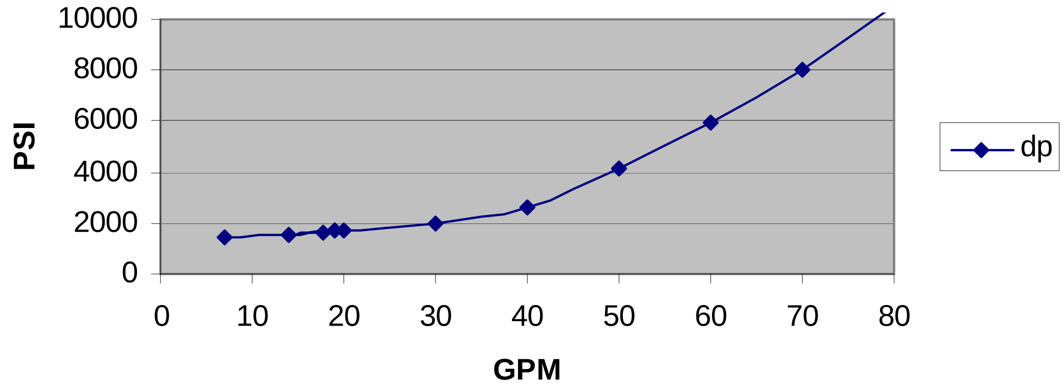

FIGURE 2-2: ΔP EXTRAP EXTEND COMMANDED

Pressure drop data taken on incident gear extend manifold (reported in PR-560XL-008 Section 4.14 Aircraft landing gear system checkout – 09/04/08) was extrapolated. Composite curve based on hydraulic relief valve having equivalent area to 0.2 inch diameter orifice when in fully open position, per Pneu Draulics, Inc. The above graph assumes flow is coming from gear extend line back through gear control valve into system pressure, back through system relief valve, through manifold return back to hydraulic reservoir.

This is the flow path that would be present if a gear collapsed while the hydraulic system were commanding gear extend.

To develop 4000 psi in gear extend lines by collapsing of gear, gear actuator piston velocity would have to achieve approximately 50 GPM system flow rate. For a single main collapse, piston velocity = 50gpm*231in^3/gal*1 minute/60 seconds / 1.22in^2 extend area= 158 in/sec.

If 2 main gear actuators contributed, then velocity = 79 in/sec.

Average velocity for 13.2 inch actuator stroke collapsing in 1 second is 13.2 in/sec. If LH landing gear actuator traveled from actuator stroke of .55 to 11.3 (gear on center position to point of wing contacting ground), then peak velocity with uniform .0625g acceleration would be 22 in/sec with duration of .94 sec. Twenty two inch per second is significantly lower than the 79 in/sec needed for both main actuators working together to produce 50 gpm or the 158 in/sec for a single main collapsing. It will be concluded without further analysis that if collapse time were on the order of 1.0 second, it is unlikely that the tube burst occurred while gear control manifold was in the extended position.

2.6 Gear Geometry and Force Relationship

Relationship derived by A. Heiman from CATIA V4 geometric model, calculated at typical NetJet aircraft weight. Reference Appendix K – Weight vs Gear Geometry Table.

Actuator force to support mid position gear = 0.4497*S^5 - 11.794*S^4 + 119.56*S^3 - 540.01*S^2 + 2911*S - 1453.5.

Main Landing Gear Actuator extend area equals 1.22 in^2. At 1500 psi it is capable of exerting approximately 1800 lbs to extend the main landing gear assembly, or support it against further retraction. The data indicates that the presence of gear extend pressure, or hydraulic pressure resulting from hydraulic lock, at 1500 psi would support against further gear collapse up to 1.4 inches into the gear actuator retraction stroke, which is 13.2 inches fully retracted. An actuator force out put of 4500 lbs occurs at an actuator retraction of 2.8ins, which exceeds the tube burst pressure of 3750 psi. This observation indicates that a tube failure could occur at any retraction point at or beyond 2.8 ins.

Main Landing Gear Actuator retract area equals 3.31 in^2. The retract area is larger than the extend area due to the standpipe design which minimizes gear extend volume. At 1500 psi the actuator is capable of exerting approximately 5000 lbs to retract the sidebrace. This appears to be enough to defeat the overcenter advantage, but does not account for the opposing loads from runway to tire friction. Immediately following touchdown the normal loading on the tire is relatively low, so friction and resistance from the tire to allow ground retraction would be at its lowest.

This data supports the notion that the hydraulic system may be capable of holding the aircraft during the 10 second period between loss of down lock and loss of weight on wheels. This is true for either a commanded gear extend or hydraulic lock in the gear extend plumbing. In either case, as airspeed is decreased, or side load conditions occur through ground conditions, the hydraulic system will be overcome by static loads as gear is becoming more retracted.
Reference Appendix K – Weight vs Gear Geometry Table

2.7 Qualitative Discussion on Gear Ground Retraction

No loading relationships have been presented for the nose because it is known that the down and locked position does not go overcenter. Therefore if there is loss of the internal actuator lock function, the nose landing gear can be forcibly retracted. In this case, it is assumed that any delay in collapse of the nose gear was due to aerodynamic effects and crew efforts to keep the nose off the ground.

Main landing gear geometry is over center when down and locked, such that the side brace actuator is in tension. This design creates redundant safety so that loss of internal lock function does not result in gear collapse. Gear actuator retraction must continue for approximately one-half inch before the over center advantage is lost, unless ground loading results in additional side loads. It is expected that side loads induced by crosswinds tending to retract the LH gear would tend to extend the RH gear, and vice versa.

Alt Air data shows 560XL-5599 lost downlock indication 10 seconds before loosing indication of weight on wheels. During this time at least one gear was indicating unlock. If ground load conditions were such that collapse did not occur during those 10 seconds, it is likely that conditions would have existed where the ground loading and/or hydraulic system loading would have been able to restore an unlocked actuator to the fully down and locked position and restored lock without further incident.

It is expected that a partially retracted actuator can be held against further retraction by loads as calculated in Appendix K, but that additional loads would resist regaining down lock due to friction between the tires and the runway.

The landing gear control valve blocks gear extend system fluid from flowing freely to return when in the center position. The valve goes to the center position when unpowered. It also goes to the center position when both extend and retract solenoids are powered. The leakage from the gear extend volume is enough to control thermal expansion, approximately 60-300 cc/minute at 1500 psi. (3.7 to18.3 in^3/min at 1500 psi) If pressure verse flow relationship is quadratic, then the flow rate at 2250 psi is 4.53 to 22.4 in^3/min; and at 3750 psi is 5.85 to 28.9 in^3/min. In 10 seconds up to 4.8 in^3 of fluid could leak out of hydraulic lock allowing actuators to continue collapsing slowly before tube burst accelerated the collapse.

Left hand gear actuator volume is 1.22in^3 per inch of stroke. Static ground loads produce tube burst pressure at 2.8 inches of retract stroke as discussed above. Therefore, it is reasonable to conclude that landing gear plumbing hydraulic lock supported aircraft for 10 seconds with at least one actuator unlocked. In addition, it is most likely that all actuators were unlocked by the initial event, which is theorized in this assessment to be a hydraulically powered retract, possibly coincident with thrust reverser or speed brake deployment. Gradually increasing side brace loads due to both geometry and loss of lift provide the force to cause gear extend fluid to leak across thermal relief, and ultimately burst the gear extend tube. The landing gear extension system is depressurized allowing all gear that are not in over center position to collapse. Ground loads acting through landing gear doors and tire can push the gear into uplocks. Post incident test confirmed that the burst tube rendered the hydraulic system incapable of generating enough pressure to release gear uplocks for gear extension. This sequence of events matches the case for commanded gear retraction regardless of whether it is due to manifold fault or electrical fault.

If a gear retract command were present for 0.2 seconds with the hydraulic system already pressurized, the pumps would be capable of delivering 3.5 cubic inches of fluid. Approximately 0.6 inches of stroke from each main landing gear actuator would be required to increase the likelihood of ground loads not returning the actuators to the down and locked position. Given actuator retract area of 3.31in^2 each the volumetric requirement is 4.0 in^3. Since 0.2 seconds is only a rough estimate of the time required for the landing gear control valve to transition, it is seen as plausible that the gear control valve could deliver enough volume to partially retract the gear past the overcentered position.

2.8 Uplock Actuator

Uplock actuators operate to pull the uplock hook clear of the extending gear, prior to porting gear extend pressure to landing gear actuators. A spring pushes the hook into position. Gear retract pressure acts on the back side of the sequence piston to ensure the uplock hook is in position to receive the retracting gear. The retract connection includes an orifice. The job of the orifice is to dampen uplock actuator piston velocity, thus protecting the gear retract side from pressure spikes if gear extend is commanded when gear are already down and locked. All orifices were in place. If unlock occurred for this reason, normal system operation would try throughout the remainder of the incident to extend gear.

Review of the actuator force table above makes it evident that it is possible for the aircraft weight on the collapsing gear to create a pressure spike back through the uplock hook high enough in amplitude to cause a gear unlock. It is likely that the required pressure would also be high enough to cause a burst in the gear extend system.

Additional review of the actuator force table shows a trend of increasing force, and therefore actuator pressure. Given the 10 seconds between unlock indication and loss of weight on wheels it is reasonable to conclude that pressure built somewhat slowly in response to an impending overload. If this were the case, the first amount of gear retraction against hydraulic lock would tend to pull the uplock hooks. This would happen before pressure could rise to above normal operating levels. Field experience and post incident testing support the conclusion that the orifices in the uplock actuators are effective at preventing gear unlock at normal operating conditions, and likely beyond. Reference Appendix L – Hydraulic Schematic.

Additional check of the gradual pressure buildup hypothesis is as follows:

From actuator stroke 0.55 inches to 1.2 inches the gear goes from the on-center position of not requiring any load from the side brace actuator, to only requiring enough force that it can be generated with normal system pressure. With LH actuator extend area of 1.22 in^2, the volume of the hydraulically locked gear volume (except thermal relief) would decrease by 0.8 in^3. This is compared to uplock actuator stroked volume of 0.74 in^3. This is consistent with the hypothesis that the pressure in the gear extend could rise slow enough during a single gear collapse to avoid transmitting a retract pressure pulse capable of unlocking the other gears.

2.9 Single Gear Collapse – System Response

If the incident were initiated by single gear collapse, the hydraulic system would have attempted to extend the landing gear throughout the aircraft deceleration. At the time the thrust reversers were stowed, the gear could also have extended if they where not blocked by the ground. Additionally, the gear extend line rupture would have emptied the hydraulic reservoir before the end of the skid rail stop.

2.10 Flap Involvement

Report PR-560XL-008 indicated potential investigation regarding the flap system, and clues that may help identify root cause. The only finding with respect to the flap system is that the runway scars are consistent with crew statements regarding commanded flap position. The ground loads acting on the flaps overpowers the hydraulic pressure to put the flaps closer to the zero position than commanded. The aircraft system result is to continuously command flap extend and energize the hydraulic system by closing the loading valve. Therefore, it is concluded from this condition that the aircraft hydraulic system was pressurized from the time of secondary runway contact (after the period where only the LH wing tip was contacting the runway) until power was turned off due to flaps were out of commanded position condition. Thrust reverser deploy also results in the same finding for the hydraulic system pressurization, so no significant insight is gained due to this correlation. It is concluded that the flap system were operating properly and did not contribute to the incident.

2.11 Electrical System Interaction

There are electrical connectors which include both gear control and other system wiring. No evidence was found supporting theories of conduction between systems. Since erroneous command signal would need to have been present for the duration of the incident (to keep normal gear extension from happening), it seems unlikely that it would remain undetected during post test investigation. No additional data is available to prove or disprove this theory. The connectors, however, have wide fleet use with good service history.

Electrical retract voltage staying on is plausible to match aircraft data, so electrical wires as well as PCBs were replaced (as outlined in PR-560XL-008). No fault was replicated on removed hardware. All four landing gear and hydraulic printed circuit boards were removed from the aircraft. Each board was inspected and functionally tested. The boards were also subjected to environment tests including HIRF, Temperature, Vibration, and more. No anomalies were found on any of the boards.

2.12 Landing Gear PCB Test

The 6618735-1 Landing Gear PCB under went environmental and HIRF testing. These tests were preformed to RTCA/DO-160E and CSTI012 standards. The board was bombarded with radio and audio frequencies, Blackberry Cell Phone emissions, vibration test, and temperature tests. No anomalies were found during any of these tests. Reference Appendix F - Landing Gear PCB Test for the results from these tests.

2.13 Gear Control Handle

The gear control handle was partially disassembled to inspect for any visible damage either mechanical or electrical. The wires and electrical connectors were inspected for secure connections, chafing, or arcing. The mechanical portions were inspected for security and indications of wear or binding. Again, this was only for inspection purpose, no electrical tests were performed. No anomalies were found. Reference Appendix G - Gear Control Handle for pictures of the gear handle partially disassembled.

3. NON-CESSNA ACTIVITY

3.1 Honeywell Customer Return Investigation Report

The three down lock switches were sent back to Honeywell for further testing. The switches were photographed and x-rayed as part of the initial visual inspection and no anomalies were found. Reference Appendix C – Switch X-Rays. The switches underwent both mechanical and electrical tests. The mechanical test results indicated within design tolerance performance of all three switches. The switches passed all of the electrical test with the exception of the Insulation Resistance test. A modified version of this test was performed successfully. Cessna Electrical Engineers do not believe the Insulation Resistance could have caused the incident. Reference Appendix B – Honeywell Customer Return Investigation Report for the pictures and results.

3.2 Nabtesco Aerospace Inc. Teardown Report

The main landing gear actuators and the nose landing gear actuator were shipped back to Nabtesco for further testing. Nabtesco preformed the actuators ATP, a teardown inspection, and analysis. Other tests that were requested by Cessna were also preformed. No anomalies were found. Reference Appendix E: Nabtesco Aerospace Inc. Teardown Report for more information.

4. ELECTRICAL FAILURE MODE SUMMARY

Table 4-1 contains a summary of all practical failure paths that could have led to the landing gear collapse for 560XL-5999. Each potential failure mode has an explanation of expected results. The items listed in the table are the only components that can contribute to an uncommanded gear retraction.

TABLE 4-1: ELECTRICAL FAILURE MODE SUMMARY

Fault	Result
Up-Command to Control PCB	
Short to +28V	You would not be able to retract the gear.
Short to Gnd	Results in an Up-Command and Down-Command. The Control system would "Ignore" the Up-Command due to weight-on-wheels and a Down-Command. Once WOW is lost on the LH main landing gear the control system would still continue to "Ignore" the Up-Command because the control system still has a Down-Command. The control system would continue Extending the gear or not extending the gear depending on the state of the down locks (normal operation). Red Unlock light would turn on as soon as a gear wasn't down and locked (normal operation).
Open	You would not be able to retract the gear.
Down-Command to Control PCB	
Short to +28V	Results in neither an Up-Command or Down-Command. The control system would not command to retract or extend the gear. The Green down and locked lights would function normally. The Gear horn would function normally. The Red Unlock light would never come on (abnormal operation).
Short to Gnd	You would not be able to retract the gear.
Open	Results in neither an Up-Command or Down-Command. The control system would not command to retract or extend the gear. The Green down and locked lights would function normally. The Gear horn would function normally. The Red Unlock light would never come on (abnormal operation).
Down and Locked Indication	
Short to +28V	Control and Monitor system would never see a down and locked indication and would continue to command to Extend the gear. Gear horn would sound (normal operation). One or more green lights would not be on depending on which gear was shorted to 28V (Normal operation). The red unlock light would be on (normal operation).
Short to Gnd	A green light would always show that gear as down and locked. The gear horn would not sound and the red unlock light would not turn on. If the gear was down and locked nothing would happen until the gear was retracted. If the gear wasn't down and locked the extend system may turn off before the gear was down and locked.

Open	Control and Monitor system would never see a down and locked indication and would continue to command to Extend the gear. Gear horn would sound (normal operation). One or more green lights would not be on depending on which gear was open (Normal operation). The red unlock light would be on (normal operation).
Down and Locked Control	
Short to +28V	If all the gear is down and locked then this would either command the Control Valve to move to the Extend position or command the Loading Valve to turn on. If one or more gear is not down and locked then both the Control Valve and Loading Valve would command Extend and turn the Loading Valve on. The gear horn, green down and locked lights, and red unlock light would function normally.
Short to Gnd	If all the gear is down and locked then this would either prevent the command to the Control Valve to move to the Extend position or prevent the command to the Loading Valve to turn on. If one or more gear is not down and locked then neither the Control Valve or Loading Valve would command Extend or turn the Loading Valve on. The gear horn, green down and locked lights, and red unlock light would function normally.
Open	Depending on the location of the 'open' it would either cause a loss of control to Control Valve and Loading Valve, or a loss of control to just the Loading Valve. The gear horn, green down and locked lights, and red unlock light would function normally.
Up and Locked Indication	
Short to +28V	Red unlock light would not turn on. The gear horn, green down and locked lights, and control system would function normally.
Short to Gnd	Red unlock light would stay on while the gear was in Retract posisition.
Open	Depending on the location of the 'open' it would either prevent the red unlock light from turning on while the gear is extending or prevent the red unlock light from turning on while the gear was retracting.
Up and Locked Control	
Short to +28V	This would provide power to energize the Loading Valve and move the Control Valve to the Retract position. As soon as one gear becomes not down and locked the control system would command Extend and Loading Valve would stay on and the Control Valve would center. The gear horn, green down and locked lights, and red unlock lights would function normally.
Short to Gnd	You would not be able to retract the gear.
Open	You would not be able to retract the gear.
Ground In Air	
Short to +28V	Depending on where in the circuit this occurred it would either cancel the GIA to all systems in the aircraft or just to the landing gear handle solenoid. A loss of GIA to the Landing Gear solenoid would deactivate the safety preventing the landing gear handle from being moved into the retract position.
Short to Gnd	Depending on where in the circuit this occurred it would either always provide a GIA to all systems in the aircraft or just to the Landing Gear Handle solenoid. A constant GIA would prevent the landing gear handle from being moved into the retract position.
Open	Depending on where in the circuit this occurred it would either cancel the GIA to all systems in the aircraft or just to the landing gear handle solenoid. A loss of GIA to the Landing Gear solenoid would deactivate the safety preventing the landing gear handle from being moved into the retract position.

Ground On Ground	
Short to +28V	Ground on ground is not used by the Landing gear system. Only Ground in Air is used.
Short to Gnd	Ground on ground is not used by the Landing gear system. Only Ground in Air is used.
Open	Ground on ground is not used by the Landing gear system. Only Ground in Air is used.

5. CONCLUSIONS

No solid conclusions can be made regarding the cause of the multiple gear retract event on aircraft 560XL-5599. Reports PR-560XL-008 and PR-560XL-009 evaluate incident reports, post test aircraft data, post test component data, and system design without finding a cause or group of causes that are consistent with the data. No design flaw was identified which would indicate a fleet issue. All components associated with gear system mechanical and electrical control were replaced. It is therefore concluded that the incident is unique, and that the aircraft repairs were effective in returning the systems to a safe type design configuration.

APPENDIX A – RUPTURED 6627002-16 TUBE ANALYSIS

Photo 1 Overall view of the burst 6627002-16 Tube Assembly. Location of burst is circled.

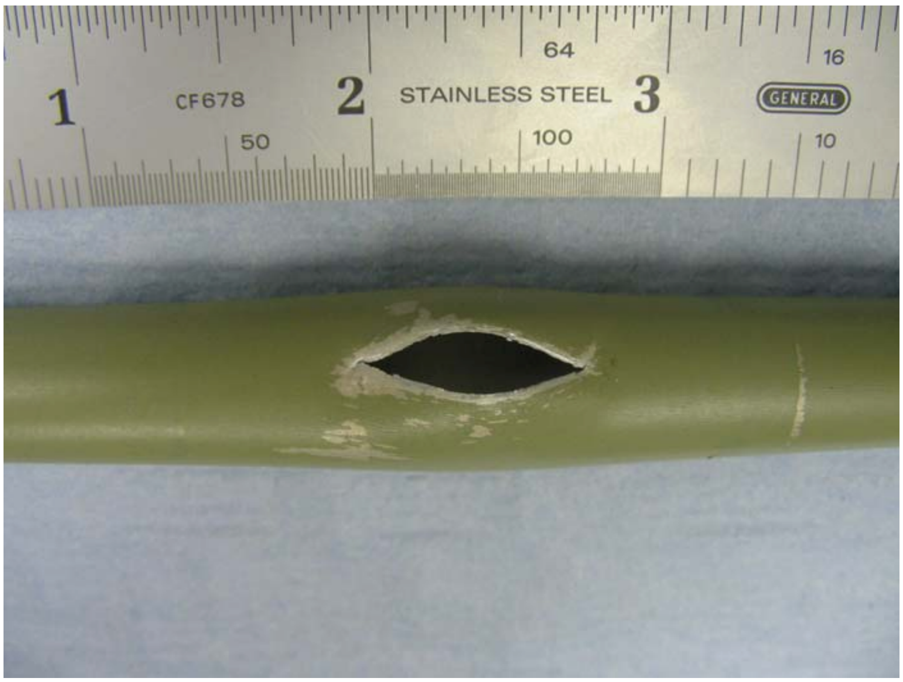

Photo 2 Close-up view of the tube burst. The shape and orientation of the burst was indicative of excessive internal pressure.

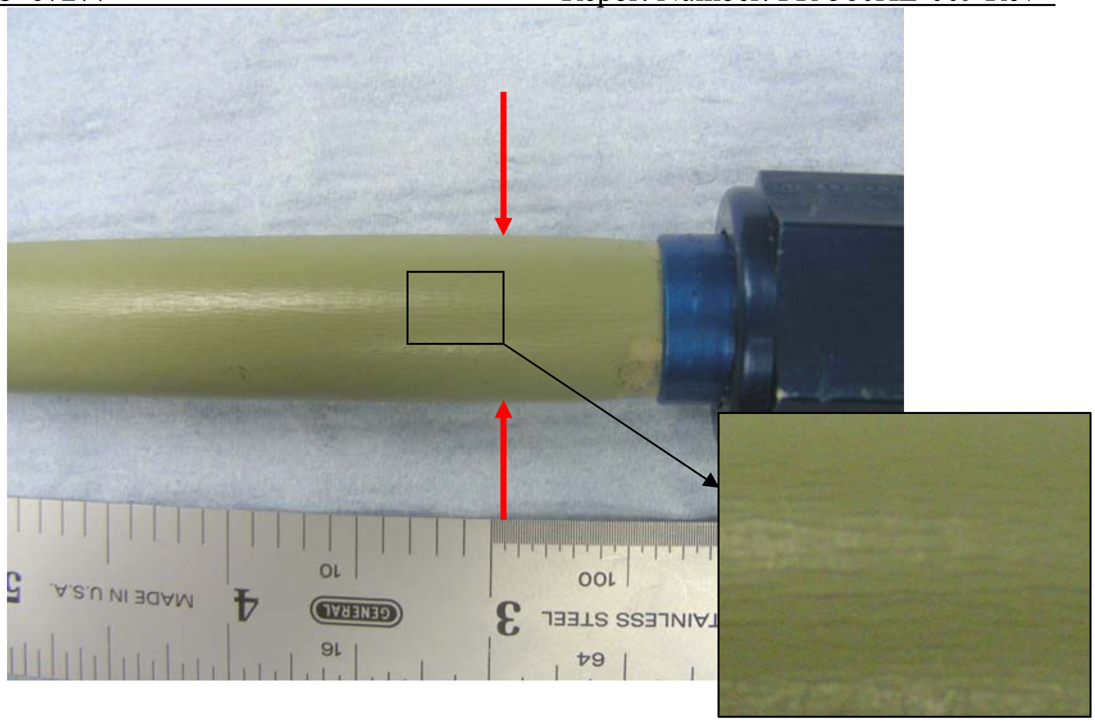

Photo 3 Close-up view of the tube near the aluminum sleeve, showing enlargement of the tube OD (red arrows) and longitudinal cracking of the primer (inset), indicative of excessive internal pressure.

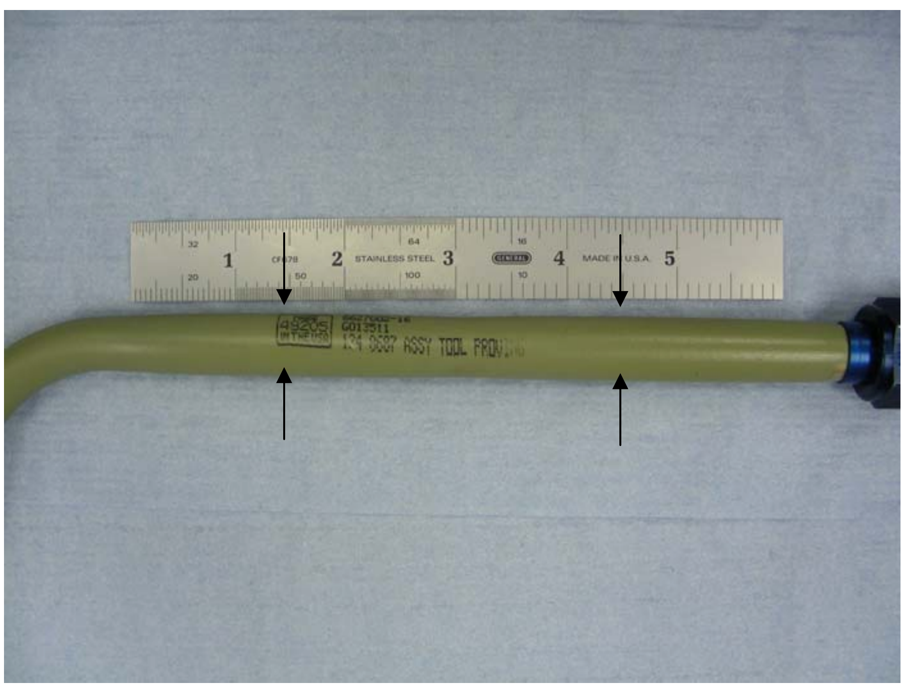

Photo 4 View showing enlargement of the tube OD (arrows).

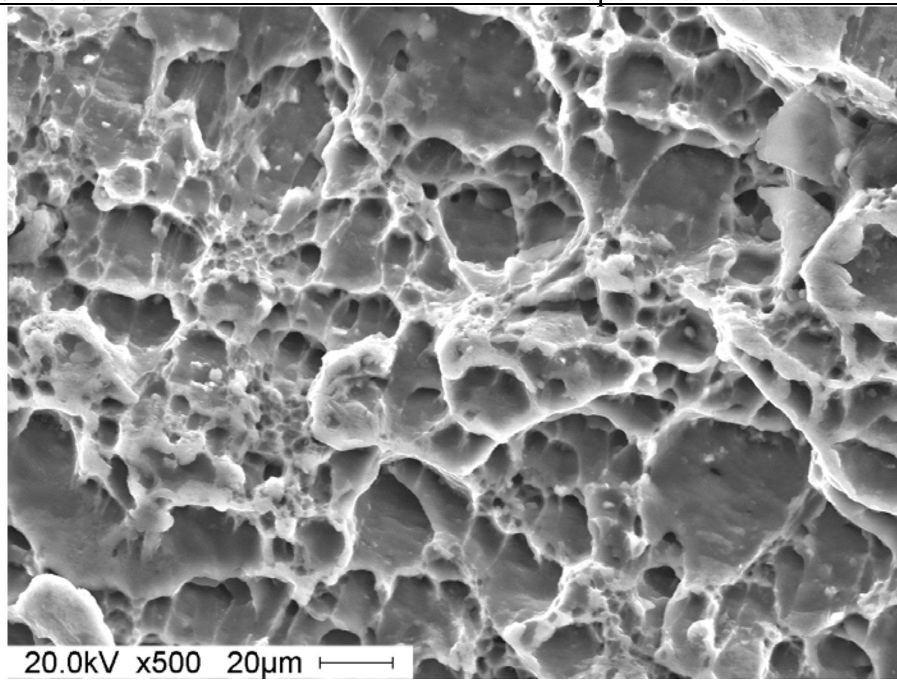

Photo 5 Scanning electron microscope view of the burst fracture surface, which was indicative of ductile overload. Magnification: x500.

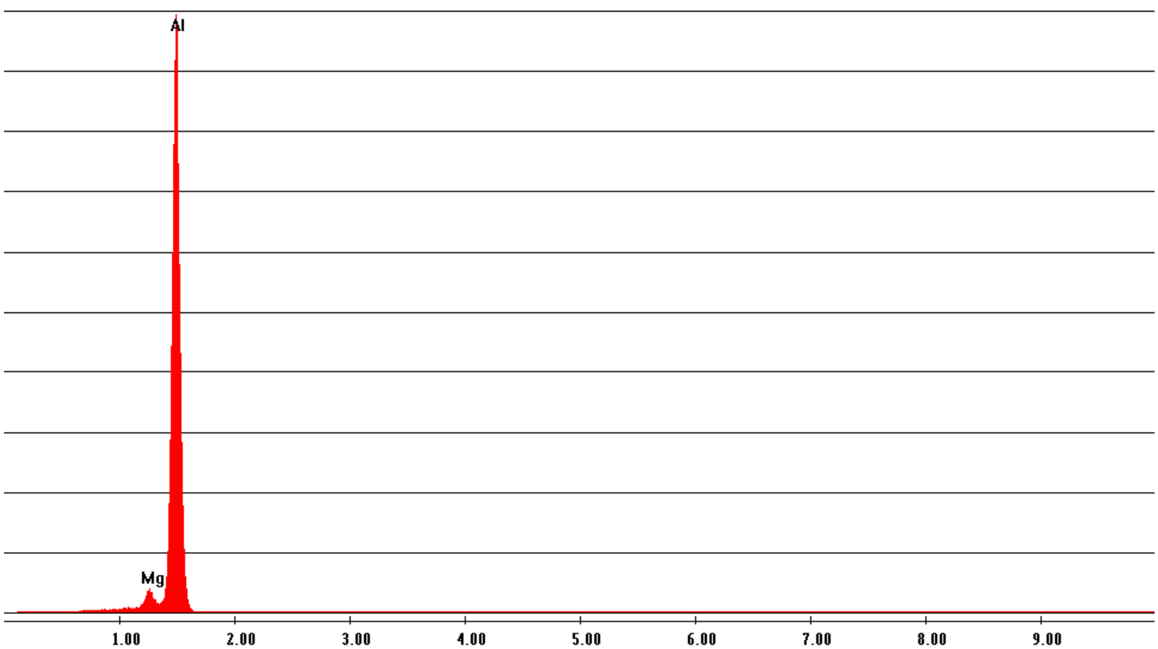

Photo 6 Chemical analysis spectrum of the burst tube metal. The chemical composition of the tube was consistent with 5052 aluminum alloy, containing mainly aluminum and magnesium. Note: 5052 should also contain chromium at 0.15-0.35 wt.%, which is below the detectable limits of this analysis technique.

APPENDIX B – HONEYWELL CUSTOMER RETURN INVESTIGATION REPORT

Honeywell

Honeywell

APPENDIX C – SWITCH X-RAYS

RMA# 066501
S/N 1011

X-ray examination:

S/N 1011- No abnormalities noted

1

2

3

RMA# 066501

S/N 0523

X-ray examination:

S/N 0523- No abnormalities noted

1

2

RMA# 066501
S/N 1003

X-ray examination:

S/N 1003- No abnormalities noted

1

APPENDIX D – HYDRAULIC FLUID ANALYSIS

LUBRICATION ENGINEERS®, Inc.

Laboratory Analysis

Fluids

File No.: Test1904
Cessna
Date Received: September 23, 2008

Samples: Oil from Main Gear Actuator

Number of Samples: 2

Sample #	Sample Name
1	560XC-5599 N613QS RH MAIN GEAR ACTUATOR
2	560XC-5599 N613QS LN MAIN GEAR ACTUATOR

Particle Size and Distribution per NAS 1638

Sample No. 1
Particle Counts/100 ml

NAS Class	Out of Range
5 µ-15 µ	1849800
15 µ-25 µ	380470
25 µ-50 µ	112860
50 µ-100 µ	6411.1
>100 µ	155.6

Particle Size and Distribution per NAS 1638

Sample No. 2
Particle Counts/100 ml

NAS Class	Out of Range
5 µ-15 µ	2138000
15 µ-25 µ	348230
25 µ-50 µ	76589
50 µ-100 µ	4700.0
>100 µ	411.1

COMMENTS:

The maximum range our particle count will detect is an NAS 12. Both samples are >12.

THS
September 23, 2008

APPENDIX E– NABTESCO AEROSPACE INC. TEARDOWN REPORT

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QC09-040 Rev. A
2009/6/9

TEARDOWN REPORT

EXCEL MLG ACTUATOR (P/N 1550000-5/-6)

EXCEL NLG ACTUATOR (P/N 1549300-9)

1. Scope

This report provides teardown inspection results for the following MLG Actuators and NLG Actuator that were returned from Cessna for investigation following an incident on April 15, 2008 in White Plains, NY where all the landing gear collapsed.

The three (3) units below were shipped from Cessna to Nabtesco America (NTA) where they were secured while waiting for preparation of shipment to Nabtesco Japan (NTS). The units were subsequently shipped under NTA PO# P12150 with instructions directed by Cessna to perform an ATP, conduct a teardown inspection and analysis, and prepare a report for submittal to Cessna and the NTSB.

Part name	MLG Actuator		NLG Actuator
Nabtesco Part No. (Cessna P/N)	1550000-5, LH (9912537-3)	1550000-6, RH (9912537-4)	1549300-9 (9912491-5)
Serial No.	1011	1003	0523
MFG Date	Aug. 2005	Aug. 2005	Sep. 2005
Reported Discrepancy	Involved in incident April 15, 2008 White Plains, NY. All gears collapsed.		

2. Receiving Inspection

The following was noted for three actuators upon receipt at NTS Receiving Inspection department.

- Top Coat and primer has been removed.
- Packings, Backup Rings and Teflon Seals were in a plastic bag, which was attached to each actuator.
- Switch, P/N 1EN329-R, used on each actuator and were not with the actuators. (The switches remained at Cessna per their direction).
- Ball, P/N MS19060-4815, for the NLG actuator was not with the unit.

Following the teardown and dimensional inspection and with Cessna's concurrence NTS replaced all packings, backup rings and Teflon seals, replaced the ball for the NLG unit and installed new switches prior to conducting the ATP's on each unit.

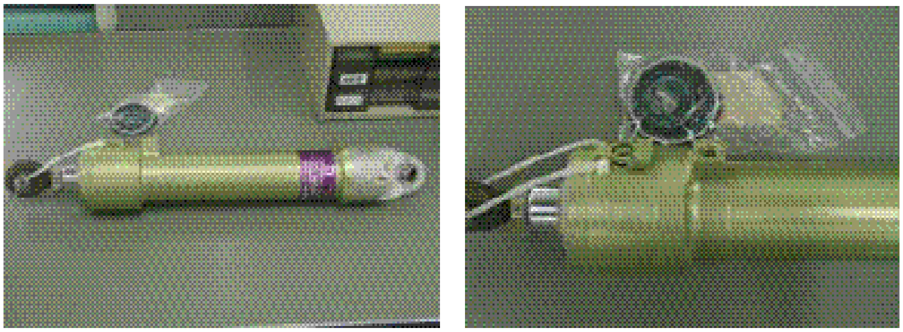
3. Teardown, Dimensional Inspection, Acceptance Test

1) Dimensional Inspection
All dimensions that are related to lock mechanism were measured.
All dimensions met the requirements.
Details are shown in Attachment A.

2) Acceptance Test
All actuators were re-assembled with new seals and stocked switches per Cessna's request and conducted functional test.
All functional tests met the requirements.
Details are shown in Attachment A.

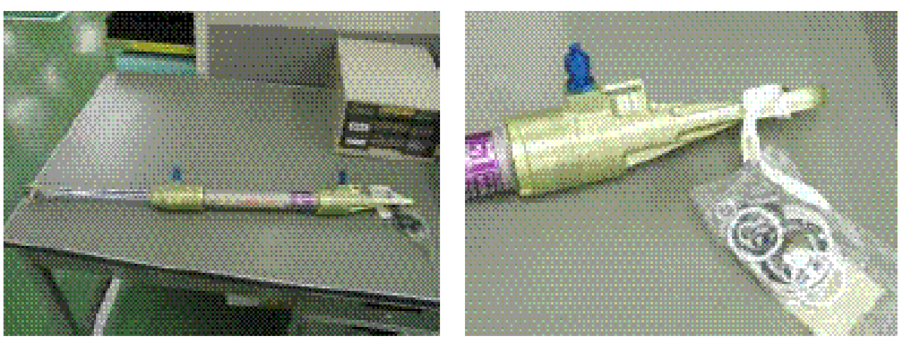
4. Additional Test requirement

Additional Test requested by Cessna was conducted.
Details are shown in Attachment B.



P/N 1550000-5 (S/N 1011)

P/N 1550000-6 (S/N 1003)



P/N 1549300-9 (S/N 0523)

Photo 1 - Returned Actuators

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QC09-040 Rev. A
2009/6/9

3. Conclusion

As a result of the teardown inspection, there were no findings that could be considered as contributing to the unlocking of the actuators experienced the White Plains incident.

As a result of the additional tests requested by Cessna, Nabtesco confirmed that the actuators tested under either a tension or compression load resulted in unlocking pressures above the minimum design unlocking pressure specified in Cessna specifications. The margin above the minimum requirement was always positive and its magnitude was determined by whether or not the load was compression or tension.

Prepared by: ____________
Y.Otani, Quality Control

Checked by: ____________
K. Fujii, QC Manager

Concurred by: ____________
N. Tanaka, Engineering Manager

Approved by: ____________
T. Kado, QA General Manager

Attachment A

Teardown Inspection Results

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QC09-040 Rev. A
2009/6/9

1. Dimensional Inspection

1.1. Dimensional Inspection for MLG Actuators

Part name	MLG Actuator	
Nabtesco Part No. (Cessna P/N)	1550000-5, LH (9912537-3)	1550000-6, RH (9912537-4)
Serial No.	1011	1003

All dimensions that are related to lock mechanism were measured.

- Barrel (P/N 1550001)
- Piston (P/N 1550002)
- Plug (P/N 1550006)
- Guide (P/N 1550007)
- Plunger (P/N 1550008)
- Key-Lock (P/N 1550009)
- Spring (P/N 1550010)

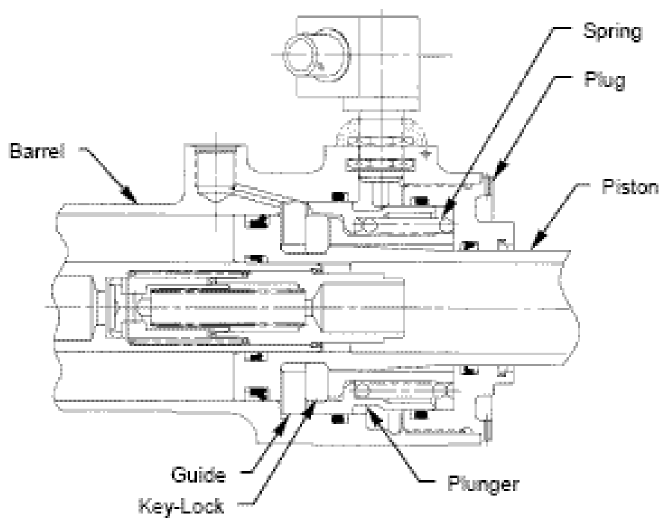
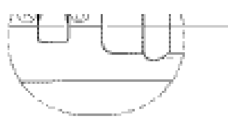


Figure 1 – Sections for MLG Actuators

A-2

1) Barrel (P/N 1550001)



No.	Requirement (mm)	Actual (mm)	
		P/N 1550000-5, LH S/N 1011	P/N 1550000-6, RH S/N 1003
1		ϕ 89.240	ϕ 89.230
2		0.013	0.018
3		72.030 – 72.035	72.030 – 72.035
4		R0.15	R0.20
		R0.15	R0.20
5		ϕ 76.240	ϕ 76.230
6		0.010	0.008

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QC09-040 Rev. A
2009/6/9

2) Piston (P/N 1550002)

No.	Requirement (mm)	Actual (mm)	
		P/N 1550000-5, LH S/N 1011	P/N 1550000-6, RH S/N 1003
1		ϕ 66.389 – 66.392	ϕ 66.388 – 66.389
		ϕ 66.395	ϕ 66.394 – 66.395
2		0.010	0.010
3		ϕ 38.850 – 38.880	ϕ 38.860 – 38.875
4		0.010	0.010
5		16.46	16.46
6		16.050	16.050
7		32° 51'	32° 46'
		32° 49'	32° 47'
		32° 48'	32° 46'
8		0.010	0.010
9		ϕ 44.474	ϕ 44.465
10		ϕ 41.208 – 41.210	ϕ 41.204 – 41.206
11		R0.46	R0.48
		R0.50	R0.48
		R0.48	R0.47
12		R0.52	R0.51
		R0.52	R0.52
		R0.55	R0.54

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QC09-040 Rev. A
2009/6/9

3) Plug (P/N 1550006)

No.	Requirement (mm)	Actual (mm)	
		P/N 1550000-5, LH S/N 1011	P/N 1550000-6, RH S/N 1003
1		ϕ 89.178 – 89.179	ϕ 89.185 – 89.186
2		0.006	0.012
3		ϕ 73.085	ϕ 73.085
4		0.012	0.020
5		R0.25	R0.25
		R0.20	R0.20
6		9.987 – 9.998	9.989 – 9.998

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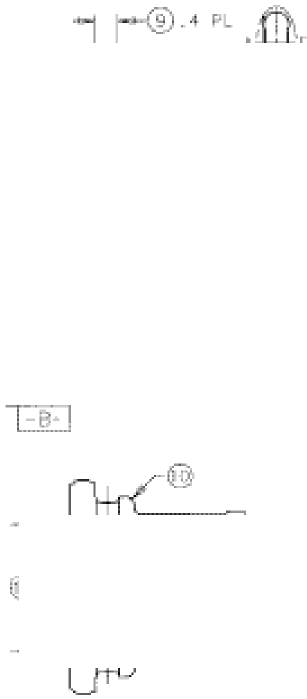
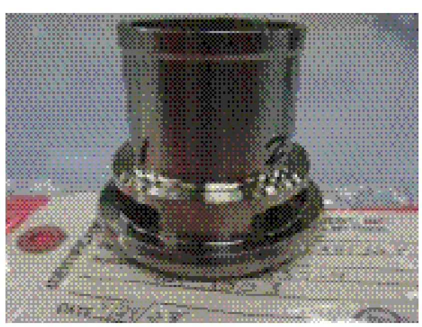
QC09-040 Rev. A
2009/6/9

4) Guide (P/N 1550007)





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QC09-040 Rev. A
2009/6/9

P/N 1550000-5, LH, S/N 1011

No.	Requirement (mm)	Actual (mm)			
1		ϕ 76.162 – 76.164			
2		ϕ 53.38			
3		ϕ 63.99			
4		8.89			
5		0.017			
6		61.989 – 61.994			
7		25.24	25.26	25.25	25.26
8		0.025	0.021	0.025	0.013
9		8.095 – 8.100	8.090 – 8.097	8.093 – 8.100	8.095 – 8.105
10		C1.76			
11		ϕ 44.99			
		1	2	3	4
		Position			

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2009/6/9

P/N 1560000-6, RH, S/N 1003

No.	Requirement (mm)	Actual (mm)			
1		ϕ 76.160 – 76.164			
2		ϕ 53.38			
3		ϕ 63.99			
4		8.89			
5		0.020			
6		61.983 – 61.986			
7		25.24	25.25	25.25	25.26
8		0.012	0.006	0.012	0.010
9		8.094 – 8.100	8.091 – 8.097	8.094 – 8.100	8.097 – 8.104
10		C1.77			
11		ϕ 44.99			
		1	2	3	4
		Position			

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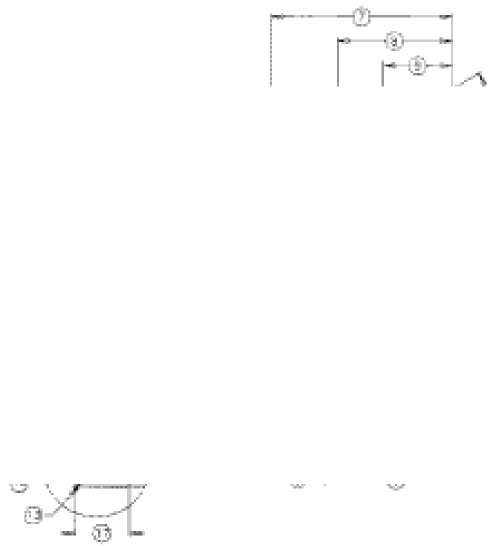
2009/6/9

5) Plunger (P/N1550008)



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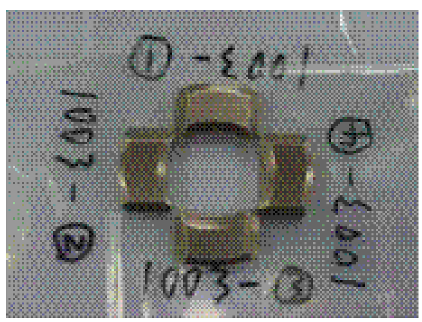
2009/6/9

No.	Requirement (mm)	Actual (mm)	
		P/N 1550000-5, LH S/N 1011	P/N 1550000-6, RH S/N 1003
1		ϕ 76.115 – 76.119	ϕ 76.110 – 76.112
2		ϕ 69.38 – 69.41	ϕ 69.38 – 69.41
3		30° 30' - 30° 31'	30° 29' - 30° 30'
4		R0.38 – 0.41	R0.48 – 0.50
5		13.56 - 13.57	13.55 - 13.57
6		28.50	28.51
7		46.111	46.109
8		29.49	29.49
9		17.34	17.34
10		29.75°	29.62°
11		ϕ 72.959 – 72.965	ϕ 72.947 – 72.952
12		0.008	0.008
13		R0.49 - 0.52	R0.47 - 0.51
14		2° 15' - 2° 18'	2° 14' - 2° 20'
15		---	---
16		0.005	0.004
17		8.09	8.10

6) Key-Lock (P/N 1550009)

SECT A-A A



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QC09-040 Rev. A
2009/6/9

P/N 1550000-5, LH, S/N 1011

No.	Requirement (mm)	Actual (mm)			
		Key-Lock 1	Key-Lock 2	Key-Lock 3	Key-Lock 4
1		6.462	6.486	6.469	6.496
2		30.02°	30.07°	30.05°	30.02°
3		8.023 – 8.025	8.024 – 8.025	8.022 – 8.024	8.022 – 8.024
4		6.82	6.82	6.82	6.82
5		R0.47	R0.50	R0.46	R0.50
6		R0.65	R0.66	R0.66	R0.73
7		R0.59	R0.66	R0.60	R0.63
8		R0.57	R0.57	R0.61	R0.65
9		30° 9'	30° 11'	30° 15'	30° 13'
10		R1.49	R1.45	R1.42	R1.48
		R1.54	R1.52	R1.51	R1.49
11		24.93	24.92	24.92	24.92
12		13.898	13.900	13.895	13.889
13		R33.41	R33.42	R33.44	R33.44
14		R0.52	R0.53	R0.52	R0.56
		R0.52	R0.50	R0.53	R0.55
15		R0.50	R0.51	R0.53	R0.53
		R0.50	R0.52	R0.52	R0.53

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QC09-040 Rev. A
2009/6/9

P/N 1550000-6, RH, S/N 1003

No.	Requirement (mm)	Actual (mm)			
		Key-Lock 1	Key-Lock 2	Key-Lock 3	Key-Lock 4
1		6.479	6.493	6.490	6.475
2		29.95°	29.93°	29.92°	29.93°
3		8.016 – 8.018	8.016 – 8.019	8.016 – 8.019	8.017 – 8.020
4		6.81	6.81	6.81	6.81
5		R0.45	R0.45	R0.46	R0.49
6		R0.64	R0.63	R0.68	R0.67
7		R0.57	R0.55	R0.60	R0.59
8		R0.50	R0.61	R0.66	R0.71
9		30° 12'	30° 12'	30° 13'	30° 12'
10		R1.49	R1.44	R1.48	R1.41
		R1.53	R1.53	R1.49	R1.42
11		24.92	24.92	24.92	24.92
12		13.900	13.900	13.886	13.893
13		R33.42	R33.43	R33.43	R33.43
14		R0.52	R0.50	R0.51	R0.53
		R0.51	R0.50	R0.52	R0.54
15		R0.51	R0.51	R0.53	R0.55
		R0.52	R0.52	R0.52	R0.53

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QC09-040 Rev. A
2009/6/9

7) Spring (P/N 1550010)

No.	Requirement (mm)	Actual (mm)	
		P/N 1550000-5, LH S/N 1011	P/N 1550000-6, RH S/N 1003
1		58.6kg	55.9kg
2		51.8kg	49.7kg
3		4.980	5.000
4		5.0	5.0

1.2. Dimensional Inspection for NLG Actuator

Part name	NLG Actuator
Nabtesco Part No. (Cessna P/N)	1549300-9 (9912491-5)
Serial No.	0523

All dimensions that are related to lock mechanism were measured.

- Cylinder Barrel (P/N 1549301-3)
- Piston (P/N 1549302-3)
- Cylinder Head Assy (P/N 1549303-3)
- Ram-Lock (P/N 1549308-1)
- Key-Lock (P/N 1549309-3)
- Spring (P/N 1549313)
- Retainer (P/N 1523222)
- Piston (P/N 1523225)
- Stopper (P/N 1524708)
- Spring (P/N 1524717)

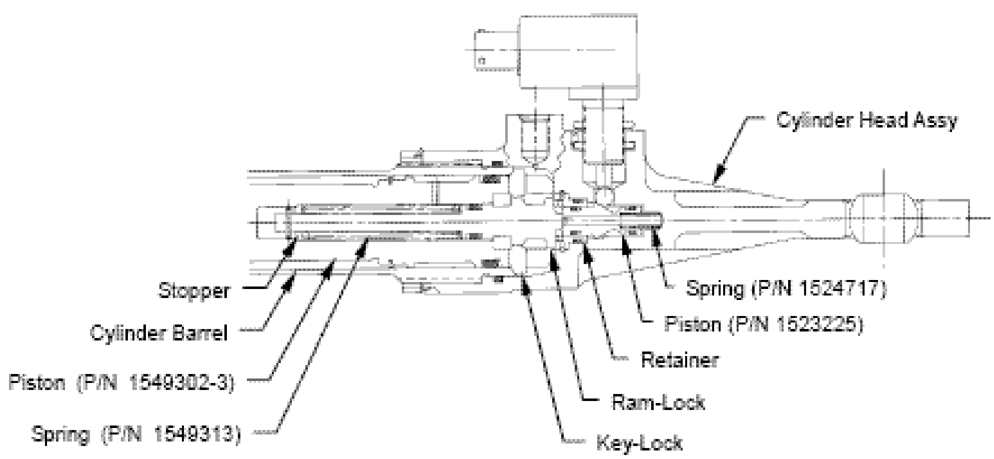

Figure 2 – Sections for NLG Actuator

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QC09-040 Rev. A
2009/6/9

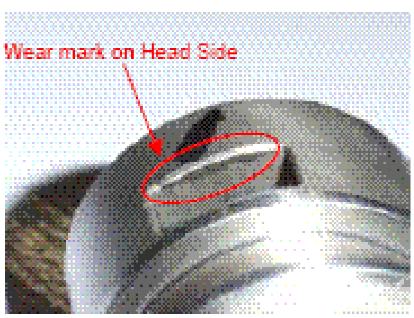
1) Cylinder Barrel (P/N 1549301-3)

No.	Requirement (mm)	Actual (mm)
1		12.590 – 12.596
2*		φ 36.296 – 36.302
3*		36° 12′
4		R 0.75
5		φ 40.86

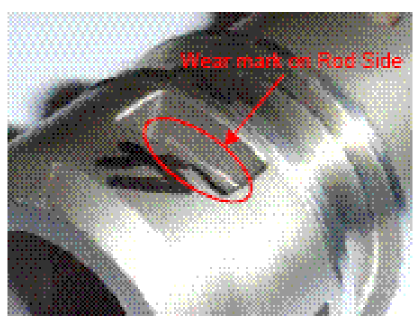
* There are no depths of contact mark to be measured by instruments.

A-16

2) Piston (P/N 1549302-3)



#13-1 (Surface 1-2)



#13-2 (Surface 3-4)

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QC09-040 Rev. A
2009/6/9

No.	Requirement (mm)	Actual (mm)			
1		14.625	14.633	14.635	14.641
2		0			
3		ϕ 36.232 – 32.234			
4		ϕ 21.52			
5		ϕ 15.03			
6		100.03			
7		29.98°			
8		ϕ 13.996 – 14.003			
9		0.025			
10		ϕ 13.875 – 13.885			
11^{x}		6.525 – 6.530	6.528 – 6.535	6.525 – 6.533	6.527 – 6.533
11-1		0.032	0.028	0.031	0.046
11-2		0.005	0.005	0.005	0.010
12		3.269	3.265	3.263	3.257
13		12.62	12.62	12.62	12.62
14		0.028	0.004	0.004	0.006
15		R0.40	R0.35	R0.35	R0.35
		R0.35	R0.40	R0.35	R0.35
		R0.35	R0.35	R0.35	R0.35
		R0.35	R0.35	R0.35	R0.35
16		ϕ 35.45			
		1	2	3	4
		Position			

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QC09-040 Rev. A
2009/6/9

3) Cylinder Head Assy (P/N 1549303-3)

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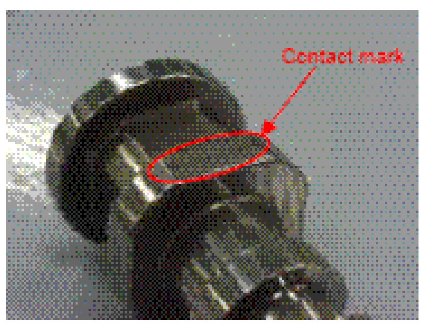
QC09-040 Rev. A
2009/6/9

No.	Requirement (mm)	Actual (mm)
1		ϕ 7.24
2		ϕ 17.170
3		0.013
4		ϕ 22.26
5		ϕ 14.11
6		28.512
7		51.81
8		3.22
9		5.54
10		18.95
11		34.98
12		6.46
13		7.55
14		1.21
15		ϕ 11.585 – 11.592
16		0.019
17		ϕ 6.52
18		ϕ 42.875 – 42.885
19		ϕ 18.03
20		60°

4) Ram-Lock (P/N 1549308-1)



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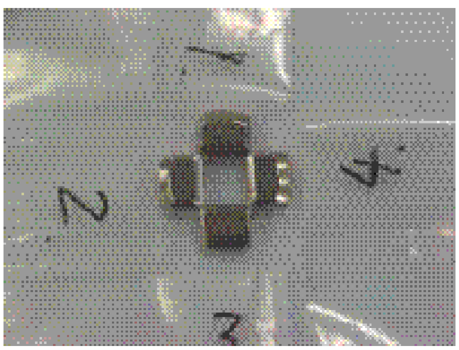
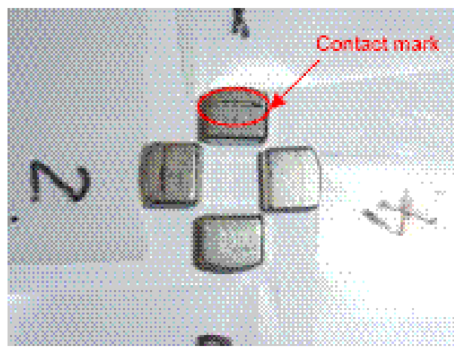
2009/6/9

No.	Requirement (mm)	Actual (mm)			
1		109.37			
2		36.51			
3		17.20			
4		2.99			
5		ϕ 13.958			
6		R0.39			
7		5.02			
8		ϕ 6.97 – 6.98			
9		ϕ 2.04			
10		30.25°	30.10°	30.09°	30.25°
11		12.76	12.76	12.75	12.76
12*		18.960		18.967 – 18.970	
13		0.015		0.007	
14		30° 03'	29° 51'	30° 02'	29° 51'
15		12.82	12.83	12.83	12.83
16		R0.87	R0.91	R0.86	R0.84
17		R0.38	R0.37	R0.38	R0.38
18		13.58		13.59	
		1	2	3	4
		Position			

* There are no depths of contact mark to be measured by instruments.

5) Key-Lock (P/N1549309-3)





Nabtesco
QC09-040 Rev. A
2009/6/9

No.	Requirement (mm)	Actual (mm)			
		Key-Lock 1	Key-Lock 2	Key-Lock 3	Key-Lock 4
1*		34° 5'	34° 0'	33° 57'	34° 2'
2		4.36	4.37	4.40	4.36
3		R1.12	R1.25	R1.25	R1.25
4		R0.59	R0.59	R0.62	R0.59
5*		6.449 – 6.451	6.455 – 6.457	6.462 – 6.463	6.458 – 6.467
6		R17.89	R17.88	R17.89	R17.90
7		10.975	10.975	10.975	10.995
8		12.28	12.28	12.28	12.29
9		C0.75	C0.72	C0.73	C0.74
		C0.74	C0.76	C0.72	C0.73
		C0.82	C0.82	C0.79	C0.82
		C0.81	C0.82	C0.80	C0.83
10		R1.24	R1.17	R1.16	R1.15
11		1.48	1.45	1.48	1.46
12		1.87	1.88	1.86	1.88
13		R1.00	R1.02	R1.02	R1.02
14		R0.95	R0.99	R0.91	R1.06

* There are no depths of contact mark to be measured by instruments.

6) Spring (P/N 1549313)

No.	Requirement (mm)	Actual (mm)
1		2.635 – 2.640
2		47.50 kg
3		29.20 kg
4		20

7) Retainer (P/N 1523222)

No.	Requirement (mm)	Actual (mm)
1		1.950
2		5.475
3		12.885
4		ϕ 11.165 – 11.171
5		ϕ 17.105
6		0.002

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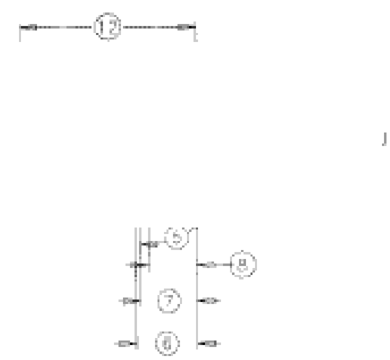
QC09-040 Rev. A
2009/6/9

8) Piston (P/N 1523225)



No.	Requirement (mm)	Actual (mm)
1		ϕ 13.54
2		ϕ 11.067
3		ϕ 5.94
4		59.9°
5		45.0°
6		10.79
7		9.96
8		8.59
9		ϕ 6.25
10		ϕ 11.485
11		0.010
12		30.91
13		18.31

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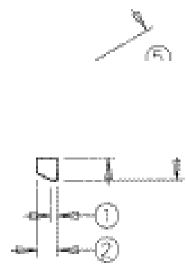
QC09-040 Rev. A
2009/6/9

9) Stopper (P/N 1524708)



No.	Requirement (mm)	Actual (mm)
1		1.00
2		2.99
3		ϕ 7.41
4		ϕ 13.71
5		30.3°

10) Spring (P/N 1524717)

No.	Requirement (mm)	Actual (mm)
1		10.33
2		0.91
3		2.920 kg

Nabtesco
QC09-040 Rev. A
2009/6/9

2. Acceptance Test

Acceptance Test Result for P/N 1550000-5 (S/N 1011), 1550000-6 (S/N 1003)

Test	Requirement	Result	
		P/N 1550000-5, LH S/N 1011	P/N 1550000-6, RH S/N 1003
Proof Pressure Test		Pass	Pass
Locking and Unlocking Test		60 psid	60 psid
		290 psid	264 psid
		Pass	Pass
		Pass	Pass
Retract Test		Pass	Pass
		2.94	2.98
		1.3 in/sec 0.83 in	1.3 in/sec 0.83 in
Leakage Test		Pass	Pass
		Pass	Pass
		Pass	Pass
		Pass	Pass
		0 drop	0 drop
		0 drop /25cycles	0 drop /25cycles
		Pass	Pass
Axial Lash Test		.017in	.017in

A-28

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QC09-040 Rev. A
2009/6/9

Acceptance Test Result for 1549300-9 (S/N 0523)

Test	Requirement	Result
Proof Pressure Test	T o	Pass
Locking and Unlocking Test	T e	60 psid
	T p	380 psid
	T	Pass
	D st	Pass
Timed Extension, Retraction & Snubbing test	T se	2.1 sec
	T se	2.5 sec
	T 1.	1.2 in
	T	1.3 in/sec
Leakage Test	N	Pass
	N	Pass
	N	Pass
	N	Pass
	P d	0 drop
	P d	0 drop/25cycles
	T	Pass
Axial Lash Test	T	.010 in

A-29

Attachment B

Additional Test Results per Cessna's Request

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QC09-040 Rev. A
2009/6/9

Test Results for Special Test Procedure per Cessna's Request

Cessna's revised PO # JM061554 dated 3/24/09 requested the following test procedure be conducted after the completion of all other inspections and ATPs of the units.

Test Procedure as requested by Cessna in their PO#JM061554:
"Determine unlock pressure when external load is applied over a series of external loads in the 100 to 500 lb range with just pressure to unlock. The load should be both aiding and opposing. Test all three actuators in tension and compression at +100, +200, +300, +500 lbs and at -100, -200, -300, -400, -500 lbs where (+) loads are tension and (-) loads are compression loads."

Detail Test Procedures:
a) Aiding Direction (Unlock Direction)

1. Installed MLG (NLG) actuator at the locked position into the test setup.
2. Applied pressure equivalent to aiding 100 lbs to the MLG (NLG) actuator into the load cylinder and held the pressure.
3. Applied unlock pressure to the MLG (NLG) actuator until piston unlocked.
4. Recorded the unlock pressure which piston just unlocked.
5. Repeated step 2 through 4 by applying 200, 300, 400 and 500 lbs to the MLG (NLG) actuator.

b) Opposing Direction (Lock Direction)

1. Installed MLG (NLG) actuator at the locked position into the test setup.
2. Applied pressure equivalent to opposing 100 lbs to the MLG (NLG) actuator into the load cylinder and held the pressure.
3. Applied unlock pressure to the MLG (NLG) actuator until piston unlocked.
4. Recorded the unlock pressure which piston unlocked while pressure to the load cylinder was kept.
5. Repeated step 2 through 4 to apply 200, 300, 400 and 500 lbs to the MLG (NLG) actuator.

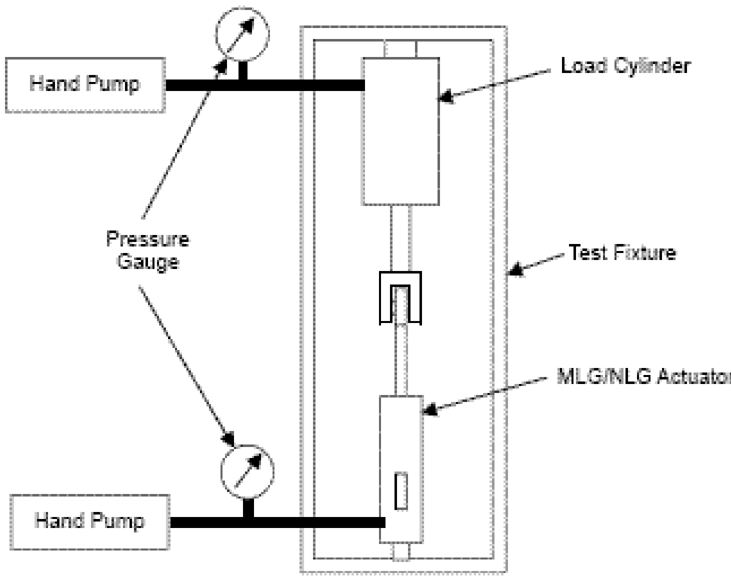


Figure A-1 – Test Setup

Discussion:

Back pressure at actuator locked position is 5 to 15 psig since those are specified as leakage test pressure at locked position in Cessna SDs 9912491 and 9912537. The additional tests requested by Cessna show that piston unlock pressures remained virtually unchanged or increased slightly under loads in both the unlock and opposing directions. In both cases the piston never unlocked at pressures below the minimum unlocking pressure specified in the Cessna specifications

Table A-1: Piston Unlock Pressure under External Tension Load

APPENDIX F – LANDING GEAR PCB TEST

CESSNA AIRCRAFT COMPANY
P.O. BOX 7704
WICHITA, KANSAS 67277

MODEL XLS

LANDING GEAR CONTROL PCB TEST RESULTS

DATE:	1/5/09
WRITTEN BY:	Chris Hellman
CHECKED BY:	J. Mowry

REVISIONS

Rev	Date	By:	Approved By:
-	12/15/08	See Title Page	See Title Page
ECR No:			

Section	Description
All	Initial Release

TABLE OF CONTENTS

REFERENCES

The following documents form a part of this specification. Unless a specific revision of one of these documents is specified, the revision in effect at the time of original issue of this document shall apply. If components or specification documents are added to this document by revision, the revision level of the specific applicable specification document at the time of issue of the revision to this document shall apply to those components unless otherwise specified.

Cessna Drawings

Pilot Side Console logic module:	
Part Number:	**Description:**
6618735-1	Printed Circuit Board Assy – Landing Gear Control – (NZ009)
Additional Drawings:	
Drawing Number:	**Description:**
6618114	Module Isntl - LH Side Console
9912507-1	Electronic module enclosures (LH Console)
9912550-1	XL Landing Gear Control
T6728800	Module Assembly Test Box
Landing Gear Handle:	
Part Number:	**Description:**
9912550-1	Landing Gear Handle

Cessna Reports

Document No.	**Description**
560XL-96-030	High Intensity Radiated Fields, Indirect Effects Of Lightning

Specifications and Standards

Document No.	Description
RTCA/DO-160D	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA/DO-160E	Environmental Conditions and Test Procedures for Airborne Equipment
CSTI012	Electromagnetic Environmental Testing Specification
CSAM030	Electrical Bonding And Verification

LIST OF TABLES

LIST OF FIGURES

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

Amps, A	Amperes (measure of electrical current)
Assy	Assembly
CES	Cessna Engineering Standard
DC, dc	Direct Current
ESD	Electro-Static Discharge
Hz	Hertz (measure of frequency)
IO	Input / Output
KHz	Kilohertz
LISN	Line Impedance Stabilization Network
m	Meter(s)
MHz	Megahertz
ms	Milliseconds
PCB	Printed Circuit Board
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
SMT	Surface Mount Technology
Vdc	Volts Direct Current
V/m	Volts per Meter
VSWR	Voltage Standing Wave Ratio

1 SCOPE

This document contains the test results for the environmental and HIRF testing of the 6618735-1 Landing Gear Control PCB of XL-5599. The tests conducted were to discover if the board had any susceptibilities that could be identified . The tests performed were to RTCA/DO-160E and CSTI012 standards.

1.1 Results Summary

Table 1-1 below lists the overall results of the testing that was performed on the Landing Gear Control PCB logic module.

Item:	RTCA/DO-160E or CSTI012 Section:	RTCA/DO-160E or CSTI012 Category:	Pass / Fail
Radio Frequency Susceptibility	CSTI012 9.0	R	Passed
Audio Frequency Conducted Susceptibility	CSTI012 7.0	Z	Passed
Blackberry Cell Phone	N/A	N/A	Passed
Power Input	CSTI012 5.6.1.3	Z	Passed
Vibration	DO-160E Section 8.0	H (Curve R)	Passed
Temperature Variation	DO-160E Section 5.0	B	Passed
Logic of Retract Command	N/A	N/A	Passed
Power Input	CSTI012 5.0	Z	Passed
Voltage Spike	CSTI012 6.0	A	Passed
Lightning Induced Transient Susceptibility	CSTI012 11.0	XXC3	Passed

Table 1-1 Logic Module Test Results

2 GENERAL REQUIREMENTS

This document defines the setup and procedures for testing of the 6618735-1 Landing Gear PCB.

2.1 Test Setups

2.1.1 General

Test bundles and components defined by the Landing Gear Control PCB Test Plan were used for tests that required the logic module to be in an operating state. The tests were conducted per the requirements stated in the Test Plan. Details on each of the tests can be found in Section 3. Deviations from the test plan are covered in the following sections. A single wire bundle was used for the entirety of the testing.

In addition to the instrumentation defined in the test plan, a recording oscilloscope was placed on the extend and retract line to catch any abnormal signals induced by testing. The oscilloscope was set to display 2sec/div which if a signal appeared, it would remain on the display for 20 seconds

2.1.2 Functional Test

The logic module was functionally tested per the functional tests detailed in Appendix A of the Test Plan. A full functional test was performed at the beginning, end and between each test phase as required. The logic module passed all functional testing.

2.1.3 Test Witnessing

All environmental testing was witnessed by Mark Nye, NetJets Flight Operations Pilot, Jason Profio, NetJets Maintenance Technical Services Manager, and Jan Smith, Cessna Air Safety Investigations.

3 TEST RESULTS

This section contains a summary of the test results of the 6618735-1 Landing Gear Control PCB.

3.1 Radio Frequency Susceptibility

Radio Frequency Susceptibility testing was successfully performed at Cat R levels as stated in section 3.2.1 of the Test Plan. The Landing Gear Control PCB was exposed to 400 MHz – 2 GHz signals at 150 V/m. The chamber was stirred which resulted in radiated fields hitting the board at all angles. The board functioned as intended and no anomalies were found.

3.2 Audio Frequency Conducted Susceptibility

Audio Frequency Susceptibility testing was successfully performed at Cat Z levels as stated in section 3.2.2 of the Test Plan. The wire bundle was exposed to 10 HZ – 150 KHz signals conducting onto the wire bundle. The board functioned as intended and no anomalies were found.

3.3 Blackberry Cell Phone

Testing of the Landing Gear Control PCB with the Blackberry cell phone was successfully performed. The cell phone was placed in various orientations facing the PCB and wire bundle. During testing the cell phone was called to verify the antenna was transmitting. Emissions tests were first run on the Blackberry cell phone to see what frequencies the antenna transmitted at. The cell phone operated at two different frequencies, one at 700 MHz and another at 1.9 GHz. Both of these frequencies were also covered in the radiated susceptibility tests. Testing was repeated twice; once with the HIRF chamber door closed and once with the door open. Testing with the doors closed removed all background noise and only fields emitted from the Blackberry would affect the Landing Gear Control PCB. Testing with the doors open exposed the chamber and PCB to all noise in the environment (i.e. Radio Towers). With the doors open, the spectrum analyzer showed fields from the environment much stronger than emissions from the Blackberry cell phone. First the cell phone was placed about 6.2 inches away perpendicular to the PCB as seen in Figure 3-1. 6.2 inches is about one wavelength of 1.9 GHz. Next the cell phone was placed 2" above, parallel to the wire bundle as seen in Figure 3-2. Lastly, the cell phone was placed parallel to the PCB on top of the enclosure as seen in Figure 3-3. All three tests passed with no anomalous signals seen on the extend or retract line.

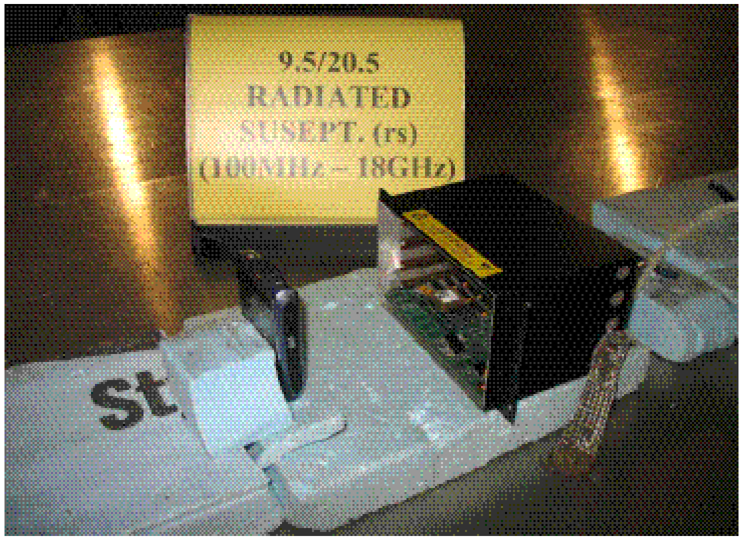


Figure 3-1: Blackberry Placed Perpendicular to the PCB

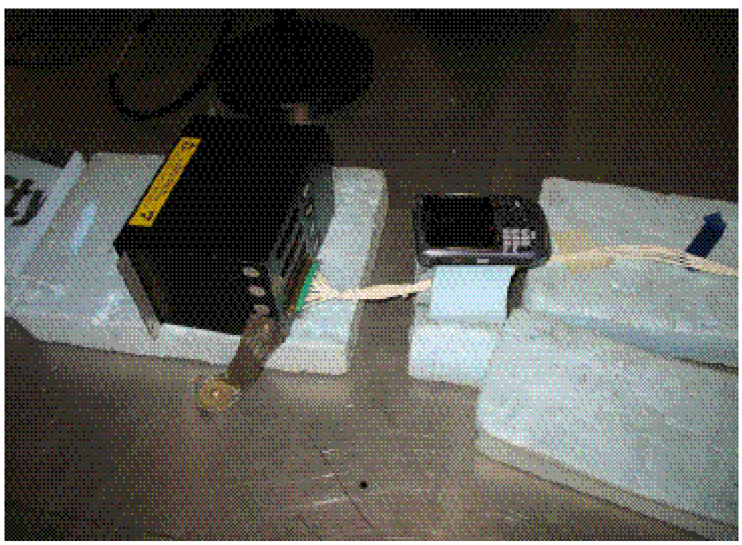


Figure 3-2: Blackberry Placed Above Wire Bundle

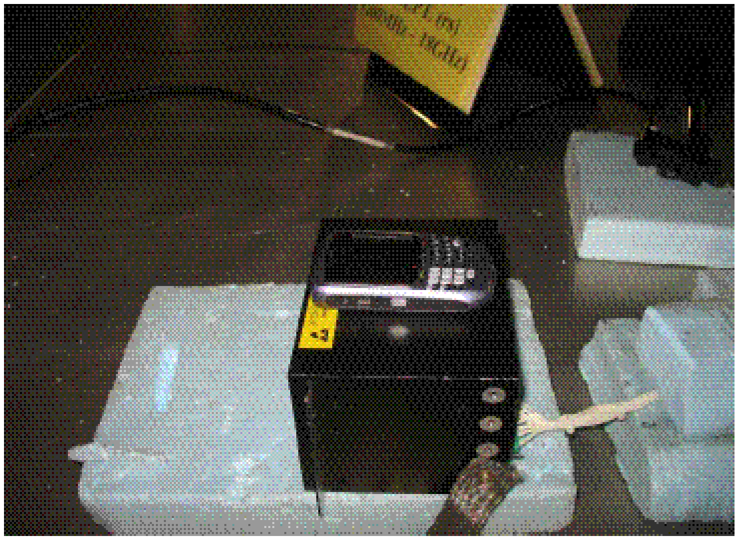


Figure 3-3: Blackberry Placed on PCB Enclosure

3.4 **Vibration**

Vibration testing was successfully performed as specified in section 3.1.2 of the Test Plan. The specified curve, curve R, can be seen in Figure 3-4 from RTCA/DO-160E. Test Results are located in Appendix A, Section 1.1, 1.2, and 1.3. The board performed as intended and no anomalies were found.

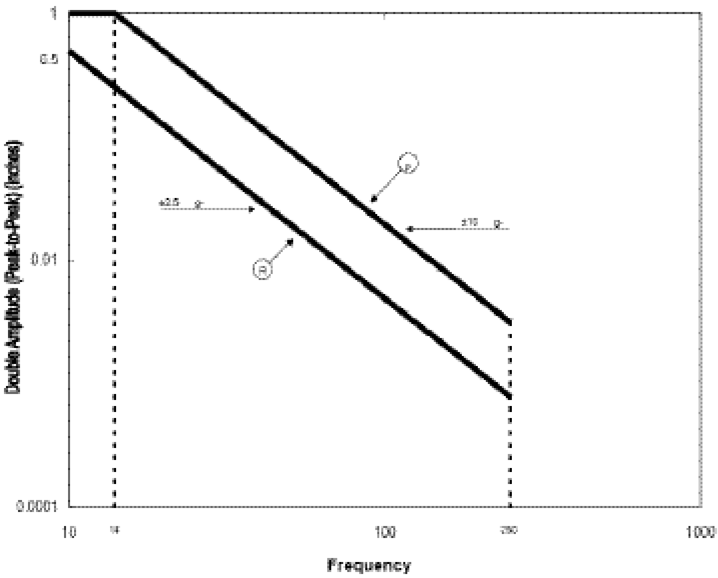


Figure 3-4: High-Level Short Duration Sinusoidal Vibration Test Curves

3.5 Temperature Variation

Temperature Variation testing was successfully performed as specified in section 3.1.1 of the Test Plan. Note 2 seen in Figure 3-5 was set to 30 minutes for equipment temperature stabilization time. 30 minutes gave the PCB adequate time to stabilize. Note 1 seen in Figure 3-5 deviated from the specification of 5°C/Min by having a significantly higher rate of change. This was due to the HALT chamber used being equipped with liquid nitrogen. The rate of change going from -40°C to 110°C ranged from 67.3°C/Min to 110°C/Min. The rate of change going from 110°C to -40°C was about -20°C/Min. The rate of change was very rapid compared to the specification which can be seen below in Appendix A, Section 1.4. Having a greater rate of change in temperature provided a more stringent test for the PCB. The Landing Gear Control PCB performed as intended and no anomalies were found.

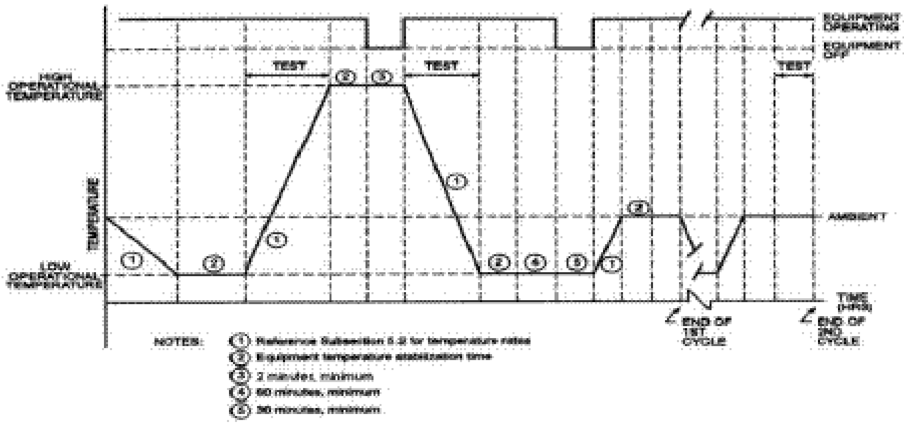


Figure 3-5: Temperature Variation Test

3.6 Logic of Retract Command

This test was not called out in the Test Plan. The retract command was requested to be tested to verify the code in the file was the same programmed onto the logic chip. This was tested by exercising all possible combinations of inputs that are contained in the retract command logic. The logic of the retract command was successfully tested and performed as intended.

3.7 Power Input

Power Input testing was successfully performed as specified in section 3.2.3 of the Test Plan. The PCB was exposed to power dropouts defined by CSTI012 section 16.6.1.3. This test drops out power supplied to the PCB at various rates and levels. The test is defined to verify the PCB will recover and be in the correct logic state on power up. The board functioned as intended and no anomalies were found.

3.8 Voltage Spike

Voltage Spike testing was successfully performed as specified in section 3.2.4 of the Test Plan. The Landing Gear Control PCB was exposed to voltage spikes induced onto the power line in an attempt to upset the PCB. The board functioned as intended and no anomalies were found.

3.9 Lightning Induced Transient Susceptibility

Lightning Induced Transient Susceptibility was successfully performed but deviated from what was specified in section 3.2.5 of the Test Plan. The level to test to in the Test Plan was XXC3. XXC3 level were well beyond the design limitations of the PCB and this would have exceeded pin injection voltage levels which would have damaged the PCB. The level we tested to was

XXC2 which is the next step down. XXC2 levels were coordinated through and agreed upon by Cessna Aircraft's EME DER, Billy Martin, as well all witnesses of testing. This induced 125 VDC with a current limit of 25 A on waveform 2 and 250 VDC with a current limit of 10 A on waveform 3 onto the wire bundle (see CSTI012 Section 11.5.2 for waveform definition). The board functioned as intended and no anomalies were found.

4 CONCLUSION

All tests that were planned from the Landing Gear Control PCB Test Plan were successfully completed as well as other tests that were not stated in the test plan. The Landing Gear Control PCB 6618735-1 off of XL-5599 passed all tests and no anomalies or failures were found.

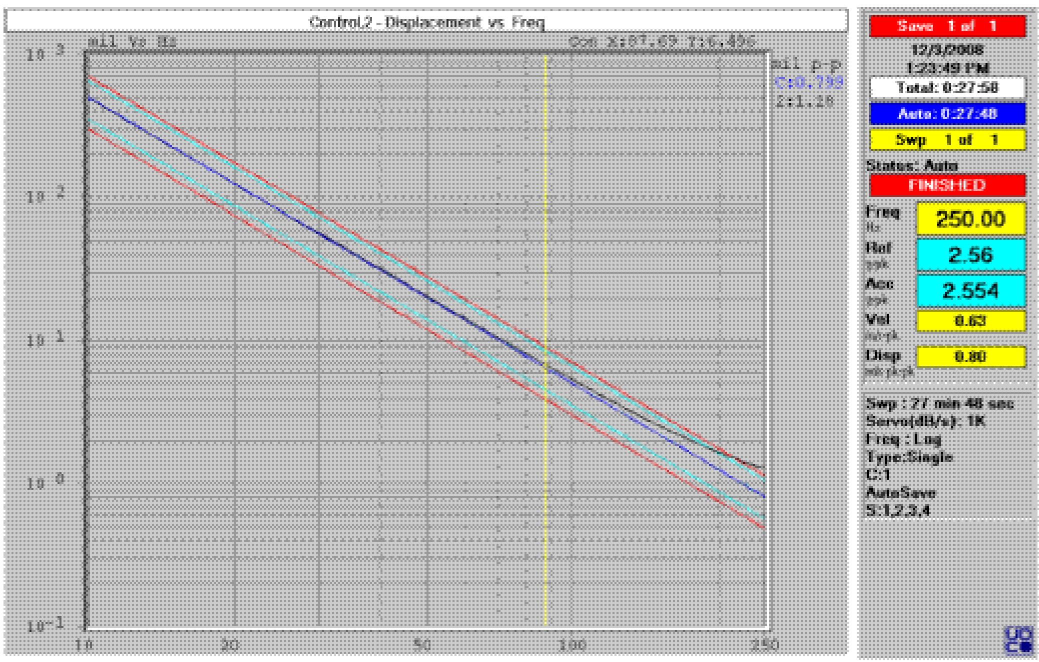
APPENDIX A – Environmental Test Data

1 ENVIRONMENTAL TESTS

1.1 Vibration – X Axis

Cessna Aircraft Physical Test Laboratory
Swept Sine Test Report

SETUP NAME: Curve R
SETUP DESC: Landing Gear PCB Vibration Test
SETUP COMMENTS: XL-5599 P/N 6618735-1
RUN NAME: X-AxisPCB1
USER/PROJECT FOLDER: H560B Large Shaker
SAVE NUMBER: 1



CONTROL PARAMETERS

CONTROL CHANNEL(S): 1
CONTROL TYPE: SINGLE
SWEEP TIME: 27 min, 48 sec
SWEEP TYPE: LOG
STARTING SWEEP DIRECTION: UP
STARTING FREQUENCY: 10.00 Hz
LOWER FREQUENCY: 10.00 Hz
UPPER FREQUENCY: 250.00 Hz
SERVO SPEED: 1K dB/s

INPUT CHANNEL PARAMETERS

Chan (#)	Sensitivity (mV/g)	Coupling (AC/DC)	Max.Range (g pk)
1	97.90	AC	100.00
2	9.83	AC	100.00
3	9.82	AC	100.00
4	9.66	AC	100.00

INPUT CHANNEL DESCRIPTION

Chan #	Description
1	Control 352C65 S/N 82548
2	Response #1 352C15 S/N 79778 SN159
3	Response #2 352C15 S/N 79779 SN155
4	Response #3 352C15 S/N 79781

REFERENCE SEGMENT TABLE

Seg #	Freq Hz	Type DAVS	Disp mil pp	Accel g pk	Vel in/s pk	Alarm- (-%)	Alarm+ (+%)	Abort- (-%)	Abort+ (+%)
1	10.00	A	500.000	2.556	15.708	30.00	30.00	40.00	40.00
2	250.00	A	0.782	2.500	0.614	30.00	30.00	40.00	40.00

ALARM/ABORT PARAMETERS

MAXIMUM DRIVE OUTPUT PEAK VOLTAGE (+/-): 5.00 volts

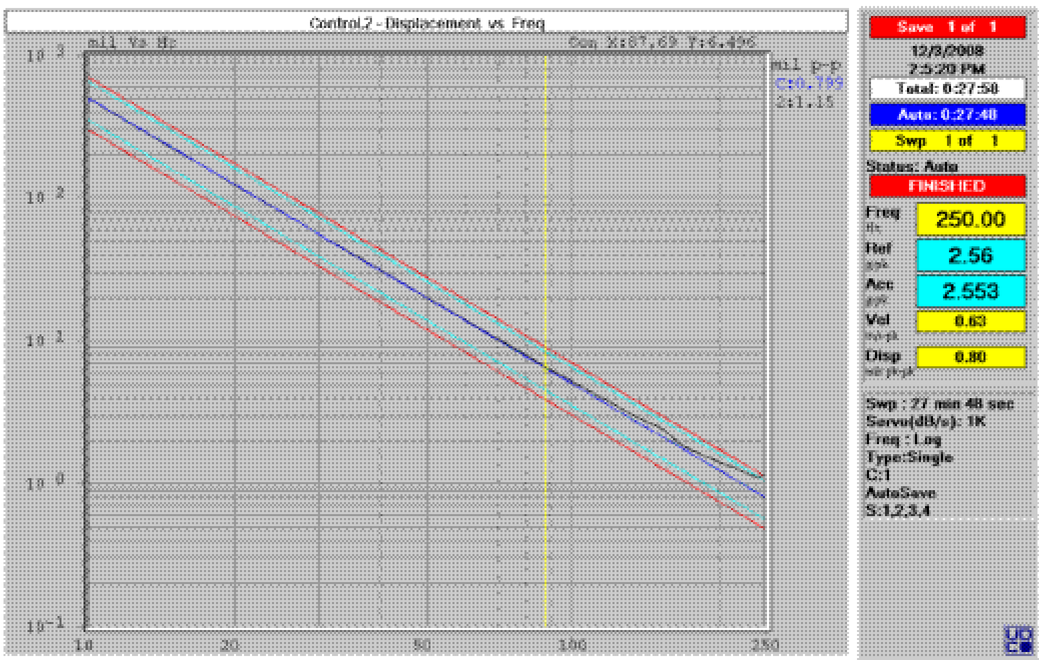
TEST STARTUP & SCHEDULE PARAMETERS

START LEVEL: -12.00 dB
NUMBER OF SWEEPS: 1

1.2 Vibration – Y Axis

Cessna Aircraft Physical Test Laboratory
Swept Sine Test Report

SETUP NAME: Curve R
SETUP DESC: Landing Gear PCB Vibration Test
SETUP COMMENTS: XL-5599 P/N 6618735-1
RUN NAME: Y-AxisPCB1
USER/PROJECT FOLDER: H560B Large Shaker
SAVE NUMBER: 1



CONTROL PARAMETERS

CONTROL CHANNEL(S): 1
CONTROL TYPE: SINGLE
SWEEP TIME: 27 min, 48 sec
SWEEP TYPE: LOG
STARTING SWEEP DIRECTION: UP
STARTING FREQUENCY: 10.00 Hz
LOWER FREQUENCY: 10.00 Hz
UPPER FREQUENCY: 250.00 Hz
SERVO SPEED: 1K dB/s

INPUT CHANNEL PARAMETERS

Chan (#)	Sensitivity (mV/g)	Coupling (AC/DC)	Max.Range (g pk)
1	97.90	AC	100.00
2	9.83	AC	100.00
3	9.82	AC	100.00
4	9.66	AC	100.00

INPUT CHANNEL DESCRIPTION

Chan #	Description
1	Control 352C65 S/N 82548
2	Response #1 352C15 S/N 79778 SN159
3	Response #2 352C15 S/N 79779 SN155
4	Response #3 352C15 S/N 79781

REFERENCE SEGMENT TABLE

Seg #	Freq Hz	Type DAVS	Disp mil pp	Accel g pk	Vel in/s pk	Alarm- (-%)	Alarm+ (+%)	Abort- (-%)	Abort+ (+%)
1	10.00	A	500.000	2.556	15.708	30.00	30.00	40.00	40.00
2	250.00	A	0.782	2.500	0.614	30.00	30.00	40.00	40.00

ALARM/ABORT PARAMETERS

MAXIMUM DRIVE OUTPUT PEAK VOLTAGE (+/-): 5.00 volts

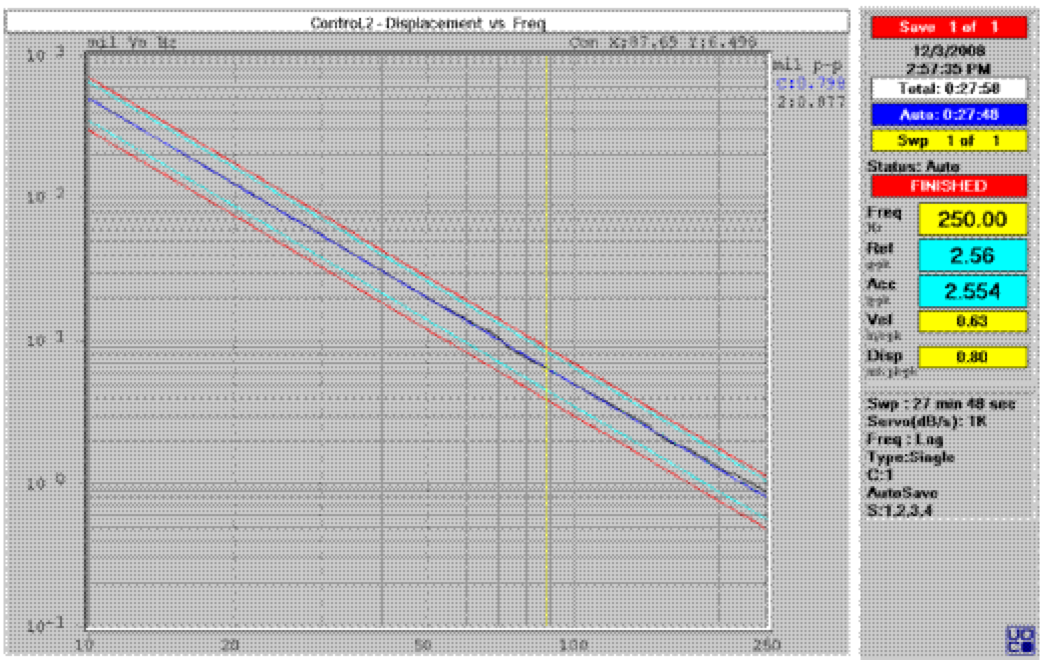
TEST STARTUP & SCHEDULE PARAMETERS

START LEVEL: -12.00 dB
NUMBER OF SWEEPS: 1

1.3 Vibration – Z Axis

Cessna Aircraft Physical Test Laboratory
Swept Sine Test Report

SETUP NAME: Curve R
SETUP DESC: Landing Gear PCB Vibration Test
SETUP COMMENTS: XL-5599 P/N 6618735-1
RUN NAME: Z-AxisPCB1
USER/PROJECT FOLDER: H560B Large Shaker
SAVE NUMBER: 1



CONTROL PARAMETERS

CONTROL CHANNEL(S): 1
CONTROL TYPE: SINGLE
SWEEP TIME: 27 min, 48 sec
SWEEP TYPE: LOG
STARTING SWEEP DIRECTION: UP
STARTING FREQUENCY: 10.00 Hz
LOWER FREQUENCY: 10.00 Hz
UPPER FREQUENCY: 250.00 Hz
SERVO SPEED: 1K dB/s

INPUT CHANNEL PARAMETERS

Chan (#)	Sensitivity (mV/g)	Coupling (AC/DC)	Max Range (g pk)
1	97.90	AC	100.00
2	9.83	AC	100.00
3	9.82	AC	100.00
4	9.66	AC	100.00

INPUT CHANNEL DESCRIPTION

Chan #	Description
1	Control 352C65 S/N 82548
2	Response #1 352C15 S/N 79778 SN159
3	Response #2 352C15 S/N 79779 SN155
4	Response #3 352C15 S/N 79781

REFERENCE SEGMENT TABLE

Seg #	Freq Hz	Type DAVS	Disp mil pp	Accel g pk	Vel in/s pk	Alarm- (-%)	Alarm+ (+%)	Abort- (-%)	Abort+ (+%)
1	10.00	A	500.000	2.556	15.708	30.00	30.00	40.00	40.00
2	250.00	A	0.782	2.500	0.614	30.00	30.00	40.00	40.00

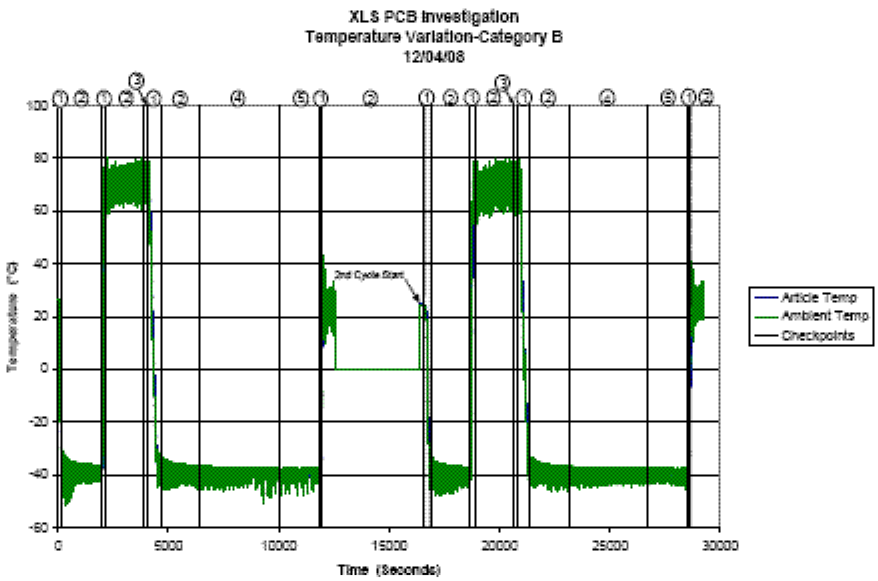
ALARM/ABORT PARAMETERS

MAXIMUM DRIVE OUTPUT PEAK VOLTAGE (+/-): 5.00 volts

TEST STARTUP & SCHEDULE PARAMETERS

START LEVEL: -12.00 dB
NUMBER OF SWEEPS: 1

1.4 Temperature Variation



APPENDIX B – HIRF Test Report

THE CESSNA AIRCRAFT COMPANY
ELECTROMAGNETIC EFFECTS GROUP
P.O. BOX 7704
WICHITA, KANSAS 67277

XLS Landing Gear Control PCB
ENGINEERING EVALUATION

Cessna's Electromagnetic Effects Group Mission Statement:

To provide Cessna Aircraft Company and it's customers, a cost effective, world class engineering test and analysis capability, which ensures the safe and reliable operation of our aircraft and associated systems against all forms of electromagnetic effects

1.0 SUBJECT

The purpose of this testing was to verify EUT operation during various CSTI-012 tests.

This document describes the CSTI-012, evaluation testing performed on the Landing Gear Control PCB. This testing was accomplished in accordance with CSTI-012 to the following sections and categories:

Section 5	Category Z
Section 6	Category A
Section 7	Category Z
Section 9	Category R
Section 10	Category M
Section 11	Category XXC2 (Wfms 2 & 3)

In addition, radiated susceptibility testing was also conducted utilizing a customer-supplied cell phone (Blackberry) in order to approximate a possible transmitted signal scenario. This was performed at the request of Chris Hellman.

All testing was performed at the Cessna EMI facility during 12/1/08-12/05/08.

Data graphs, pictures, and test log scans are provided in the pages that follow.

2.0 TESTING SUMMARY

Testing showed that the EUT was not susceptible during any Section 10 tests.

3.0 CONCLUSIONS

The results of the testing show that the unit was not susceptible to any of the tests performed during this time.

APPENDIX A

TEST DATA

INDEX

SECTION 5
DATA GRAPHS

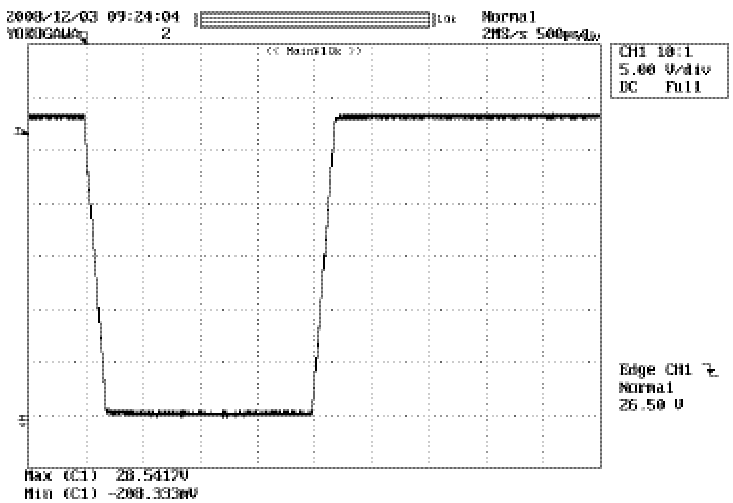


Figure A - 1: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 1

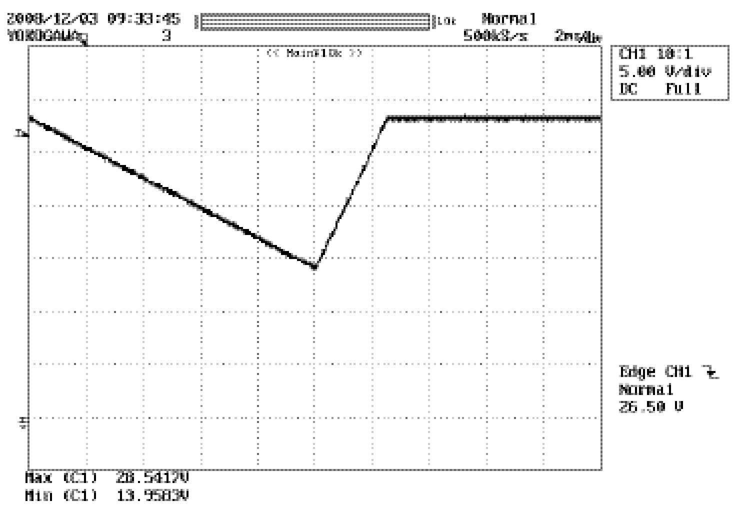


Figure A - 2: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 2

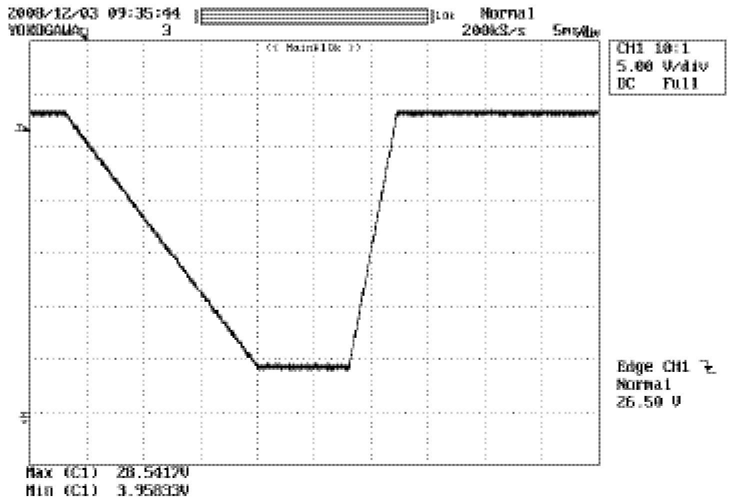


Figure A - 3: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 3

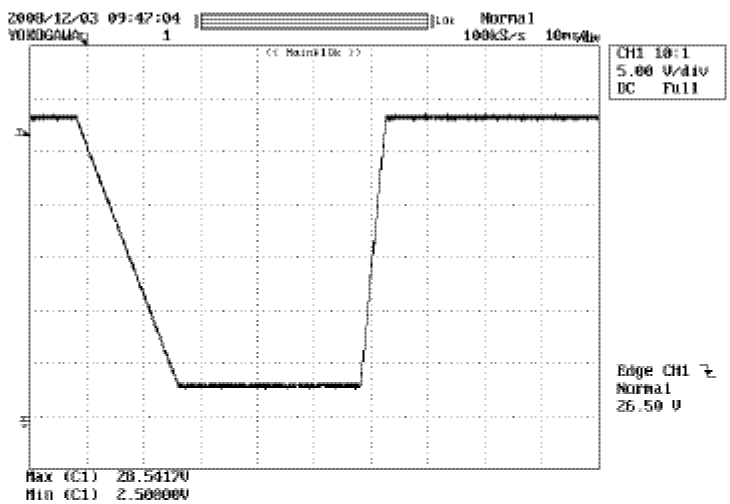


Figure A - 4: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 4

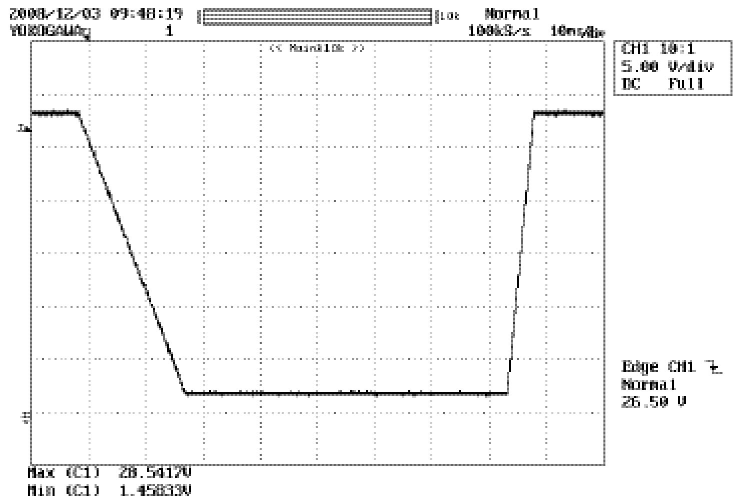


Figure A - 5: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 5

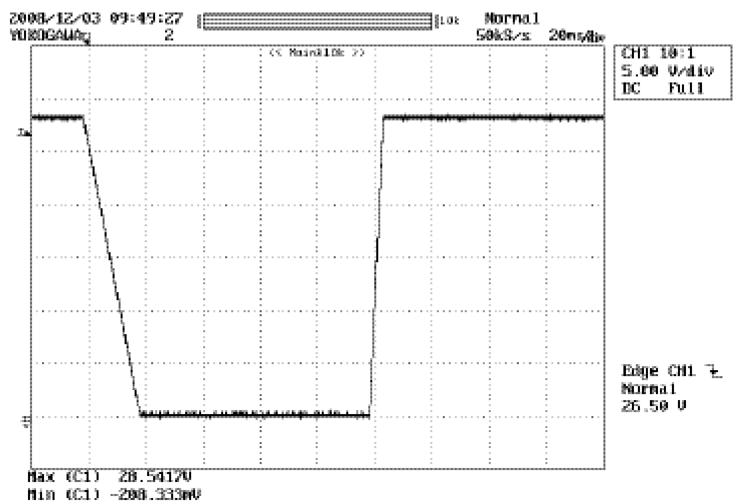


Figure A - 6: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 6

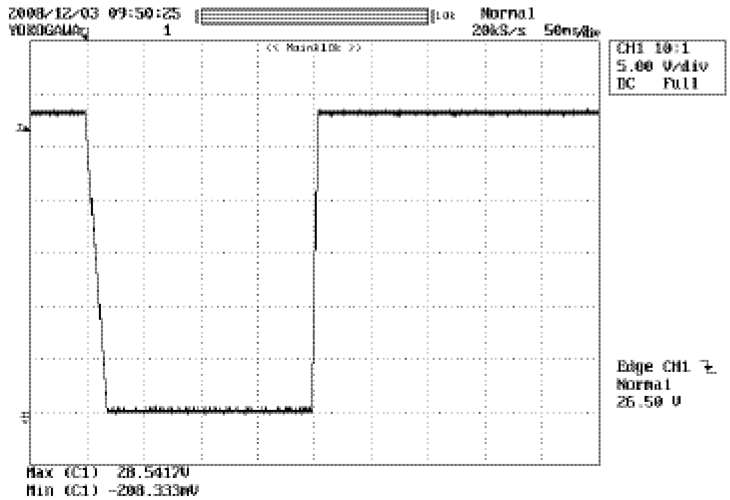


Figure A - 7: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 7

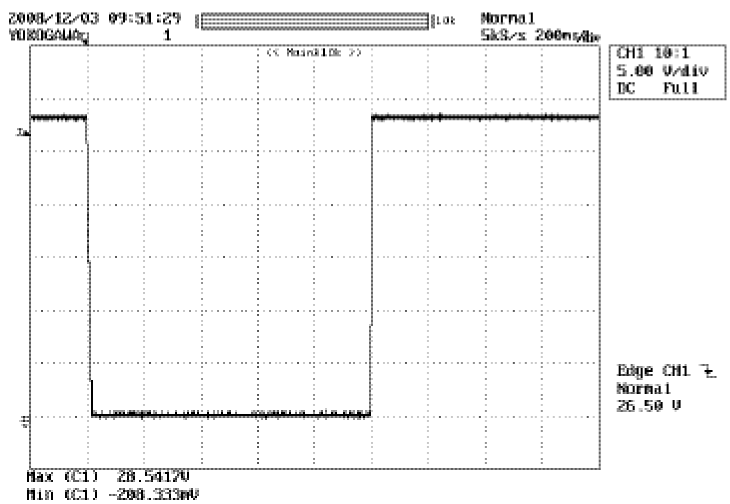


Figure A - 8: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 8

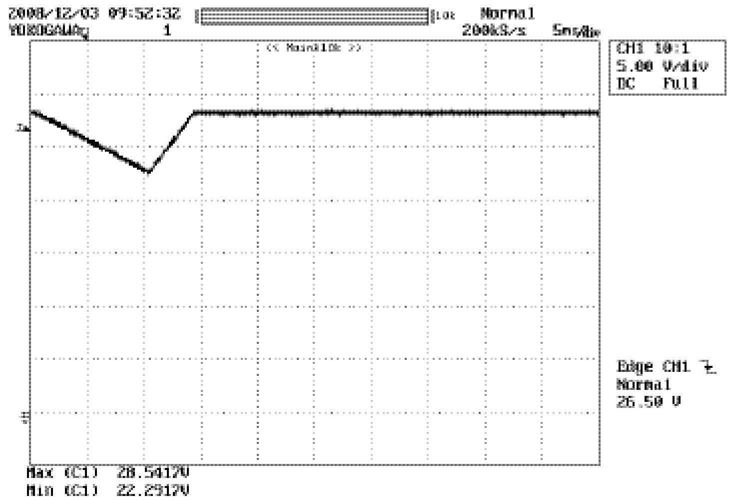


Figure A - 9: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 9

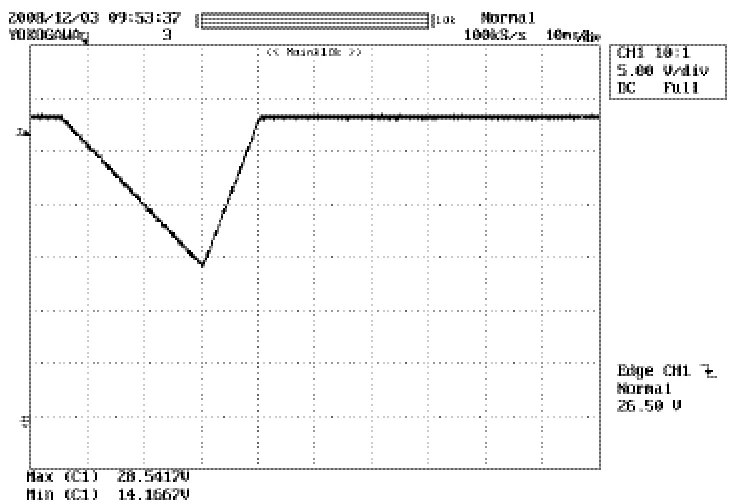


Figure A - 10: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 10

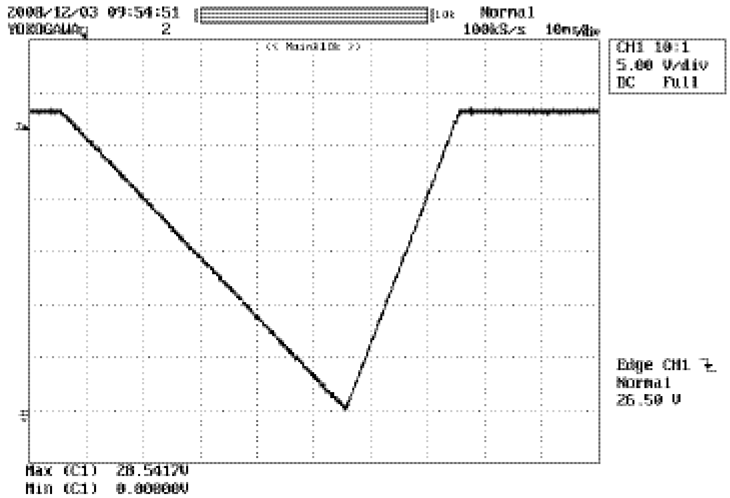


Figure A - 11: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 11

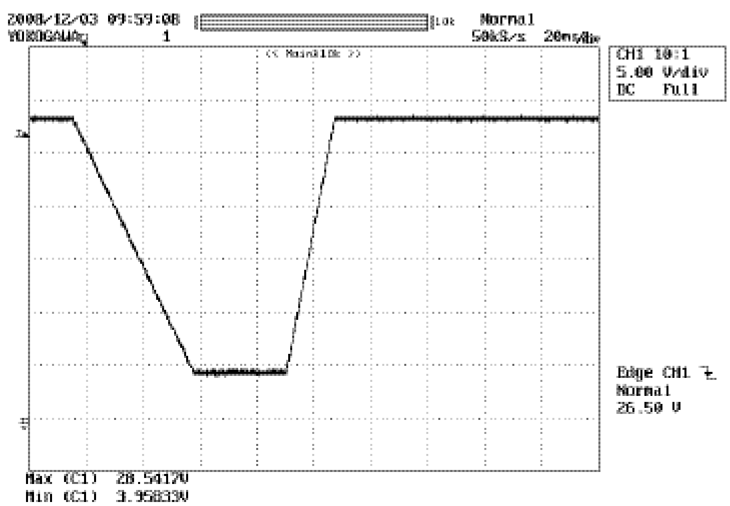


Figure A - 12: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 12

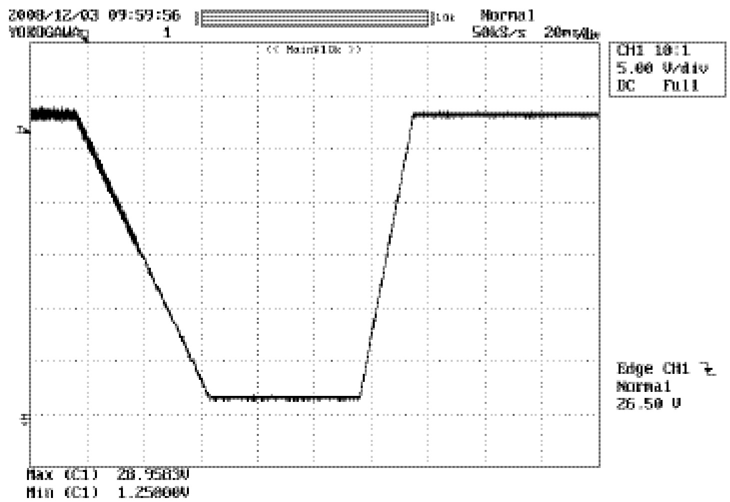


Figure A - 13: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 13

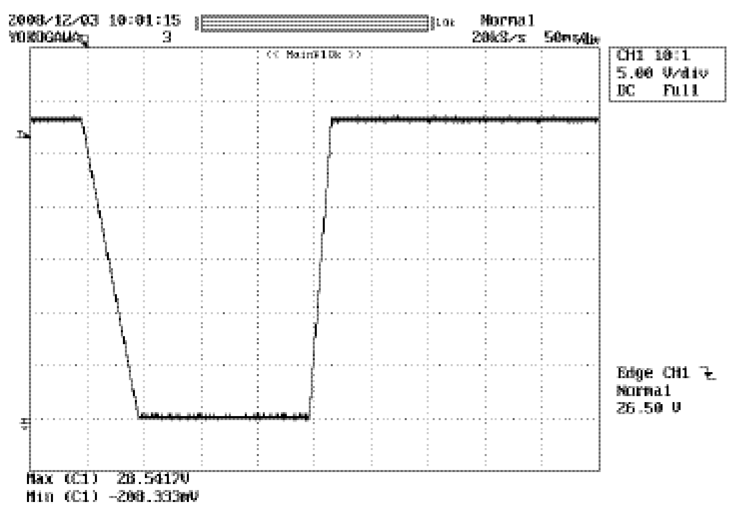


Figure A - 14: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 14

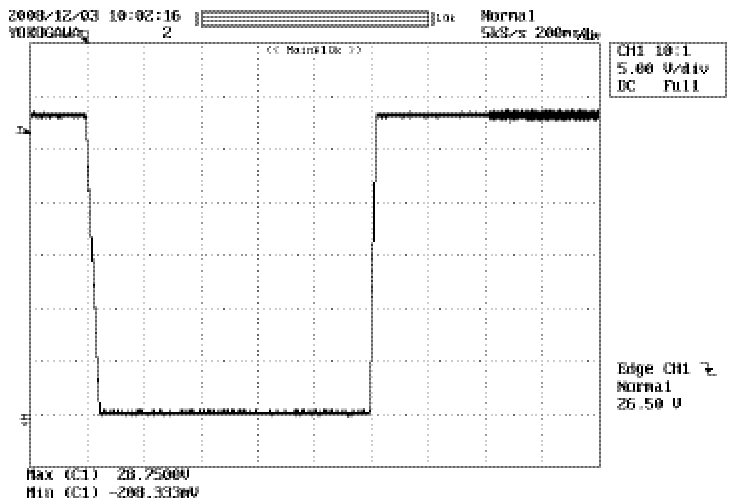


Figure A - 15: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 15

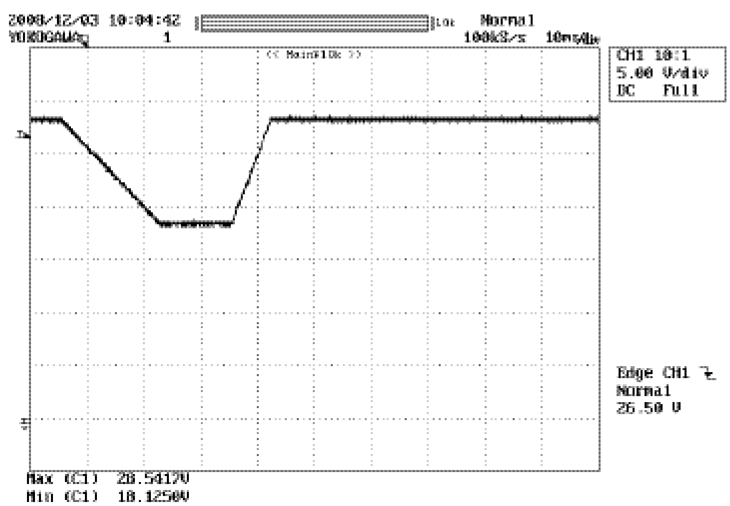


Figure A - 16: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 16

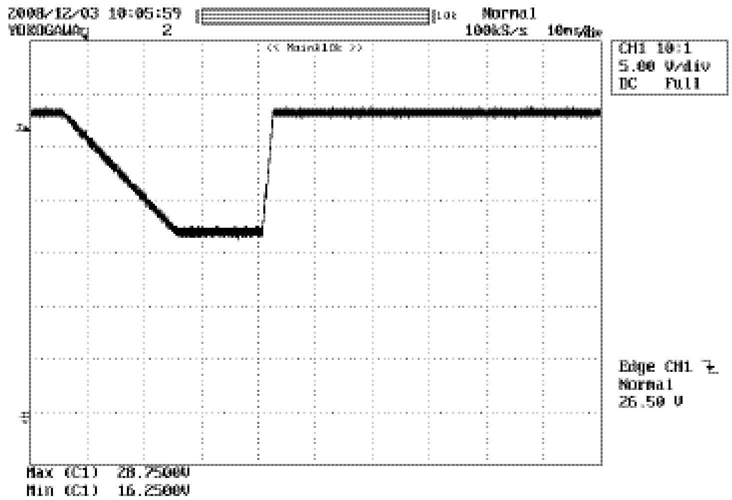


Figure A - 17: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 17

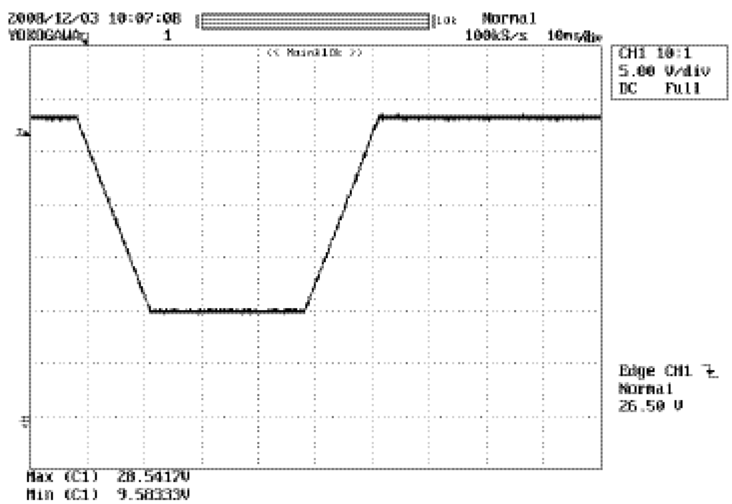


Figure A - 18: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 18

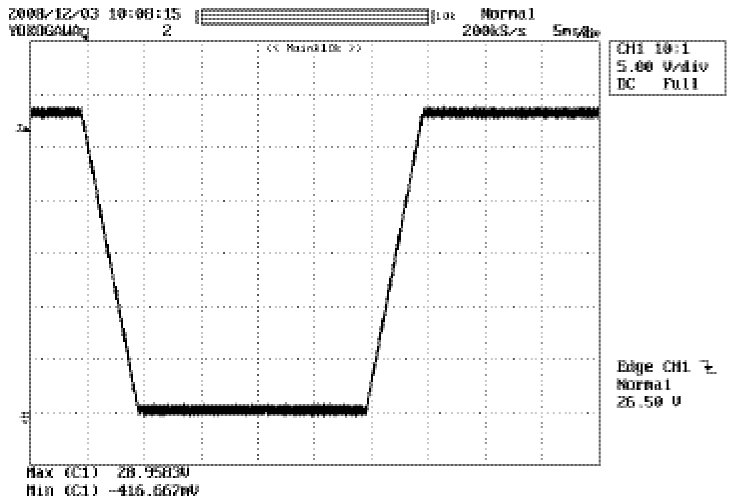


Figure A - 19: Section 5.6.1.3 Momentary Power Interruptions Cat Z Cond 19

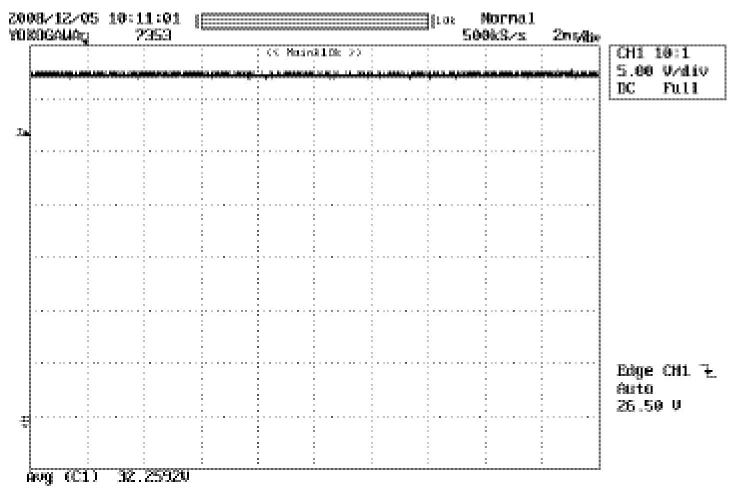


Figure A - 20: Section 5.6.2.1 Voltage Steady State Cat Z

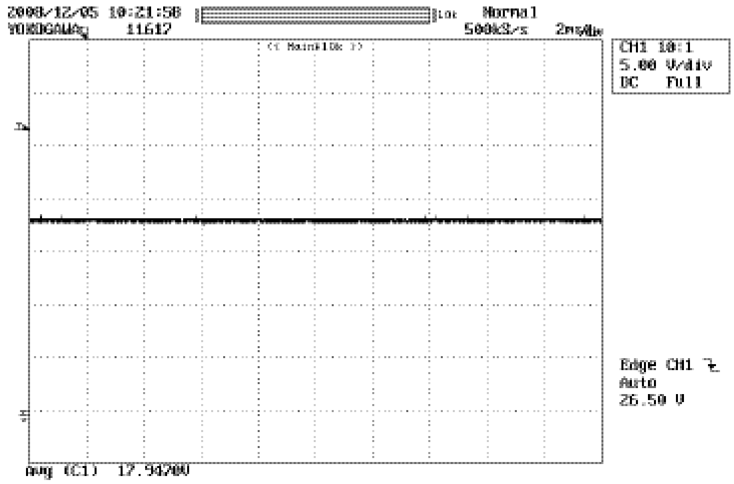


Figure A - 21: Section 5.6.2.2 Low Voltage Conditions Cat Z

SECTION 6
DATA GRAPHS

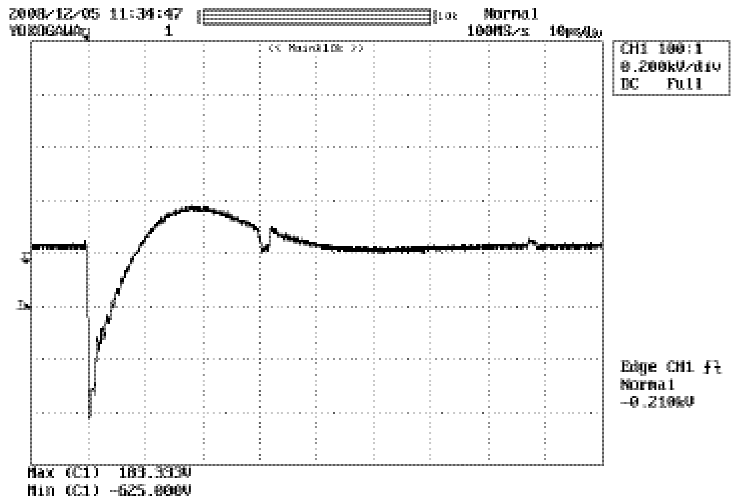


Figure A - 22: Section 6.4 Voltage Spike Calibration 600V Negative Polarity

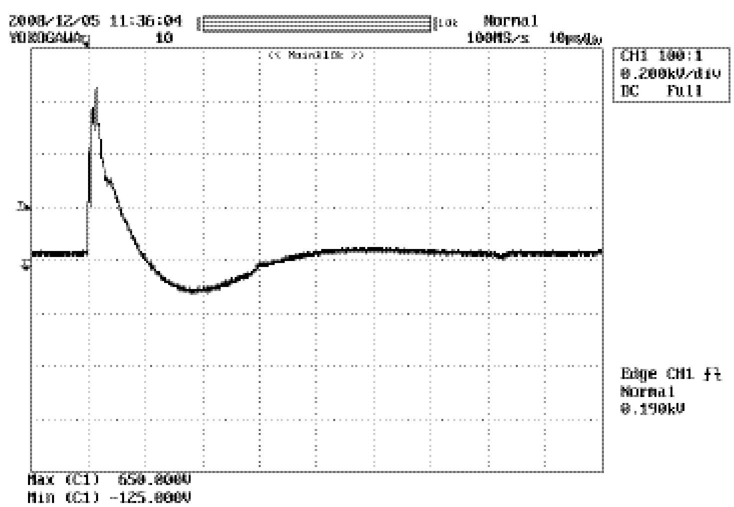


Figure A - 23: Section 6.4 Voltage Spike Calibration 600V Positive Polarity

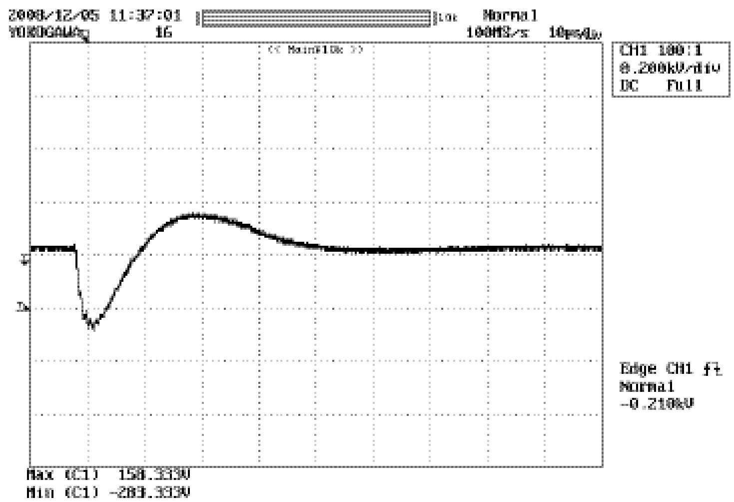


Figure A - 24: Section 6.4 Voltage Spike Calibration 50Ohm Negative Polarity

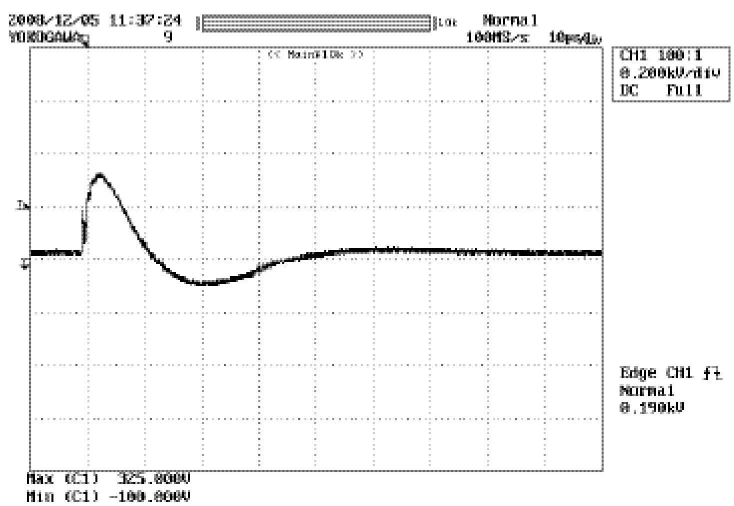


Figure A - 25: Section 6.4 Voltage Spike Calibration 50Ohm Positive Polarity

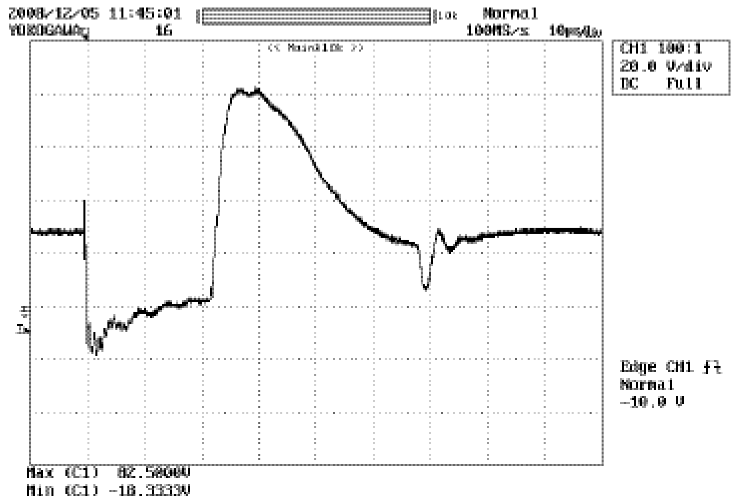


Figure A - 26: Section 6.4 Voltage Spike Negative Polarity

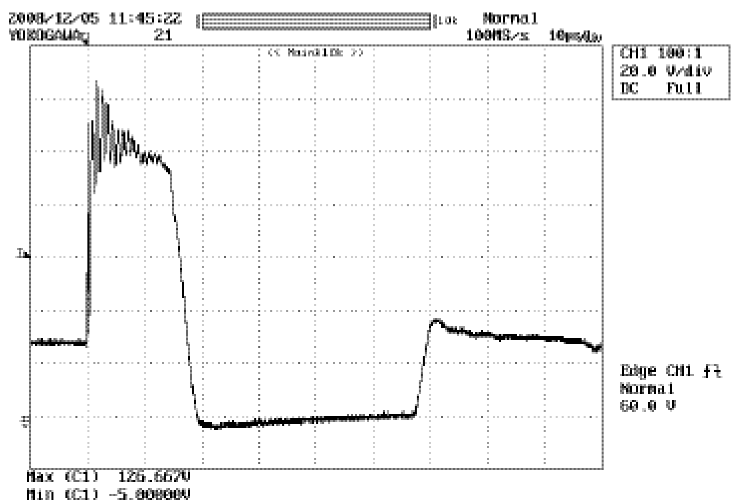


Figure A - 27: Section 6.4 Voltage Spike Positive Polarity

SECTION 7
DATA GRAPHS

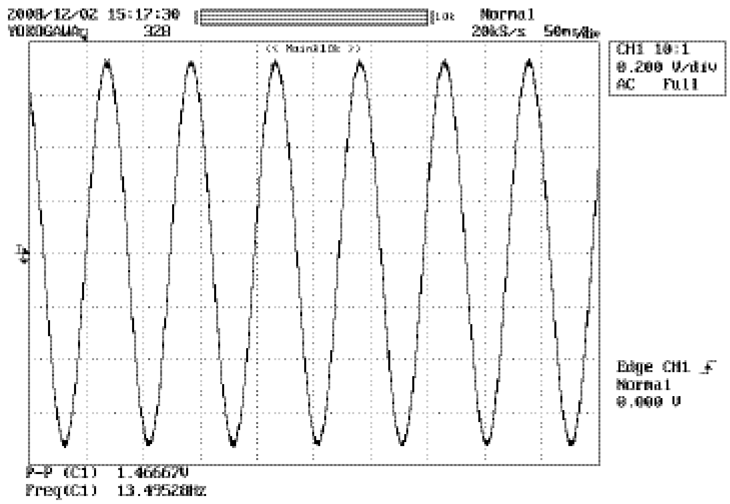


Figure A - 28: Section 7.3.1 Audio Frequency Susceptibility 10-200Hz Cat Z

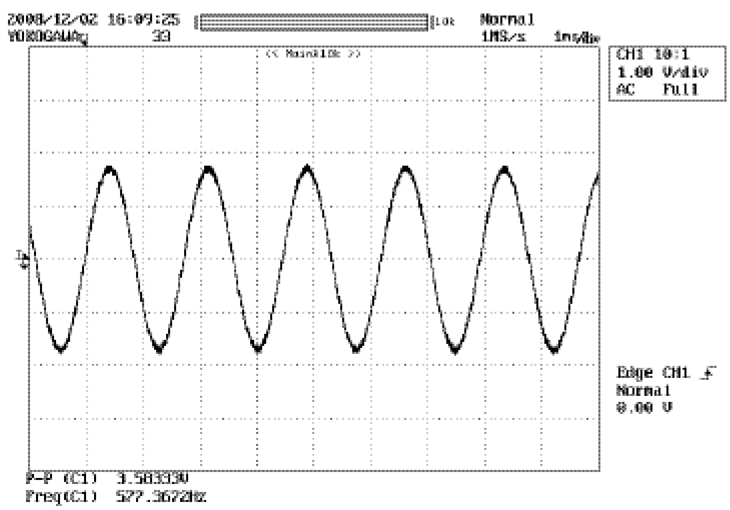


Figure A - 29: Section 7.3.1 Audio Frequency Susceptibility 200Hz-1KHz Cat Z

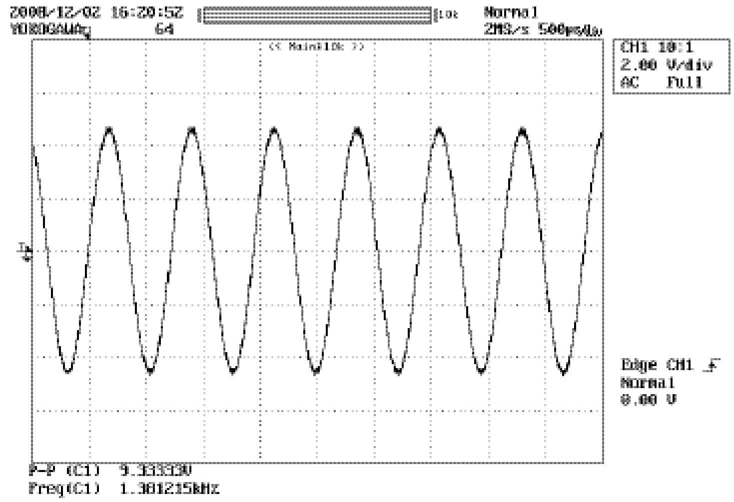


Figure A - 30: Section 7.3.1 Audio Frequency Susceptibility 1-15KHz Cat Z

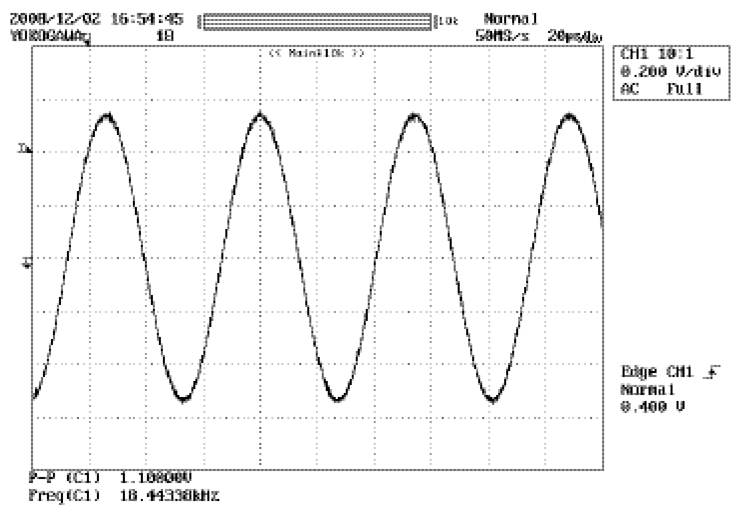


Figure A - 31: Section 7.3.1 Audio Frequency Susceptibility 15-150KHz I Cat Z

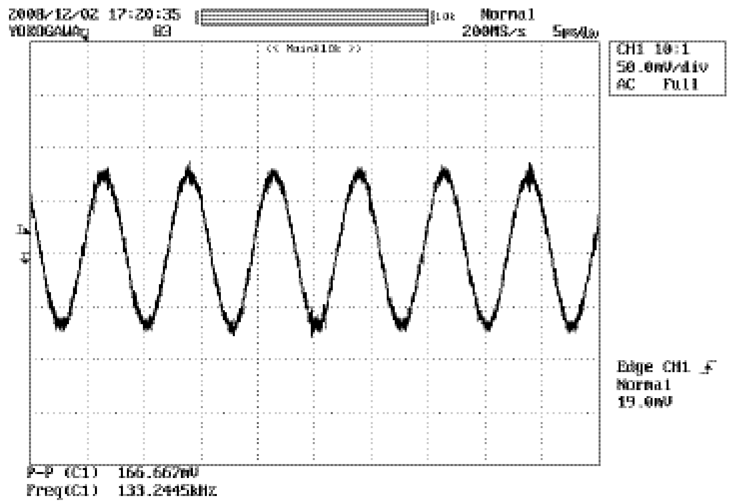


Figure A - 32: Section 7.3.1 Audio Frequency Susceptibility 15-150KHz II Cat Z

SECTION 8
DATA GRAPHS

SECTION 9
DATA GRAPHS

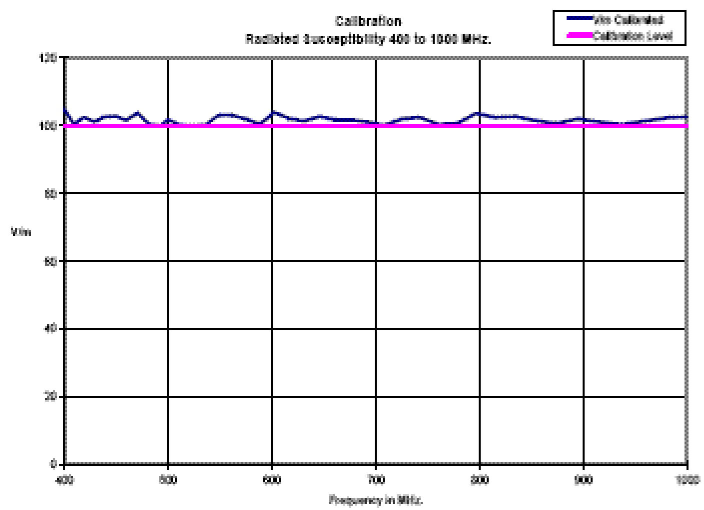


Figure A - 33: Section 9.5 Radiated Susceptibility Calibration 400-1000MHz 100V/m

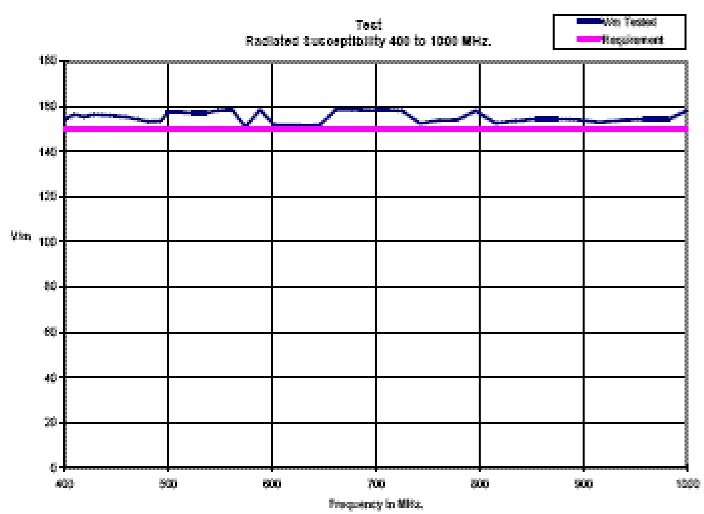


Figure A - 34: Section 9.5 Radiated Susceptibility Pulse 400-1000MHz 150V/m

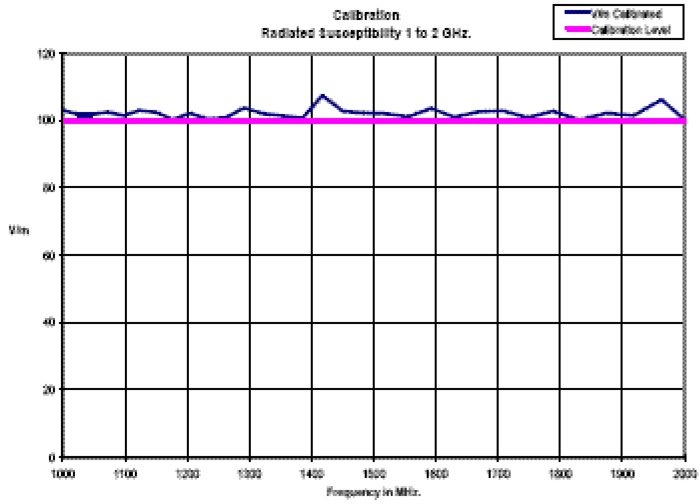


Figure A - 35: Section 9.5 Radiated Susceptibility Calibration 1-2GHz 100V/m

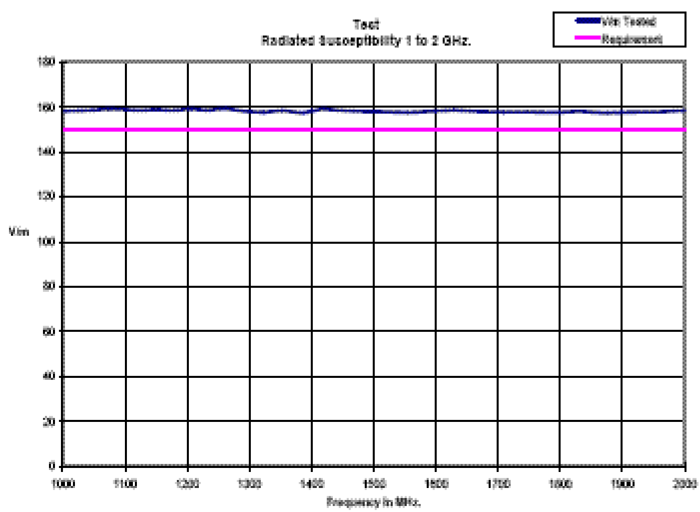


Figure A - 36: Section 9.5 Radiated Susceptibility Pulse 1-2GHz 150V/m

SECTION 10
DATA GRAPHS

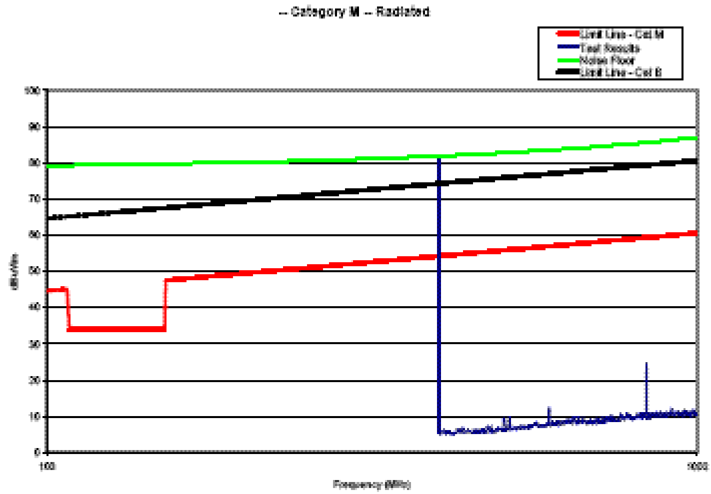


Figure A - 37: Section 10.4 Mode Stirred Emission 100-1000MHz Cat M Baseline

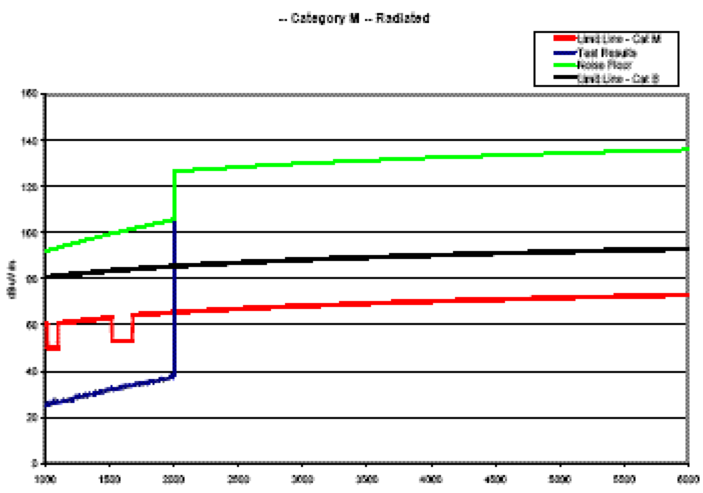


Figure A - 38: Section 10.4 Mode Stirred Emission 1-6GHz Cat M Baseline

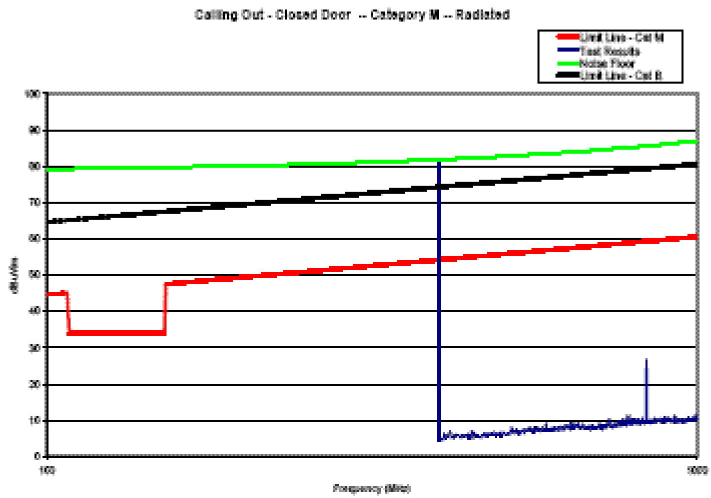


Figure A - 39: Section 10.4 Mode Stirred Emission 100-1000MHz Cat M Closed Door

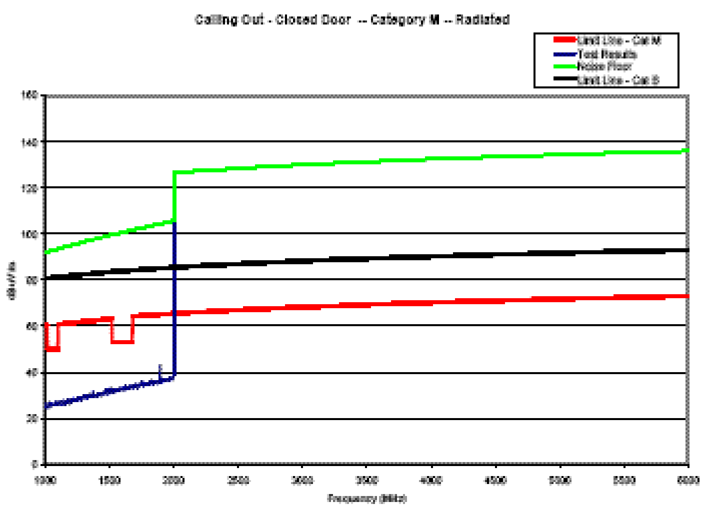


Figure A - 40: Section 10.4 Mode Stirred Emission 1-6GHz Cat M Closed Door

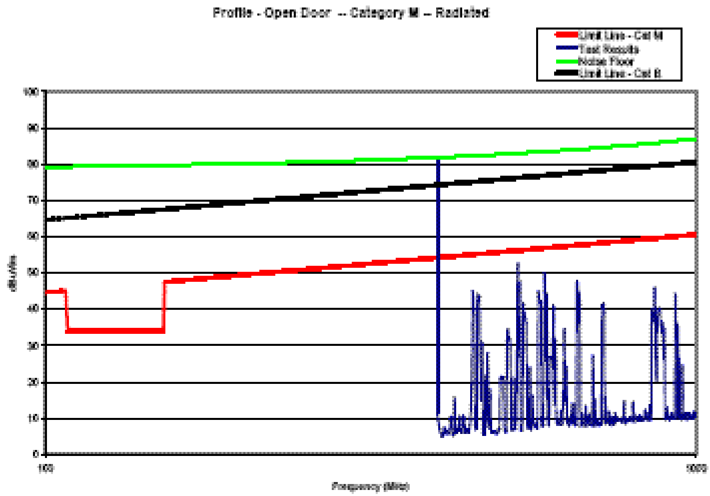


Figure A - 41: Section 10.4 Mode Stirred Emission 100-1000MHz Cat M Open Door

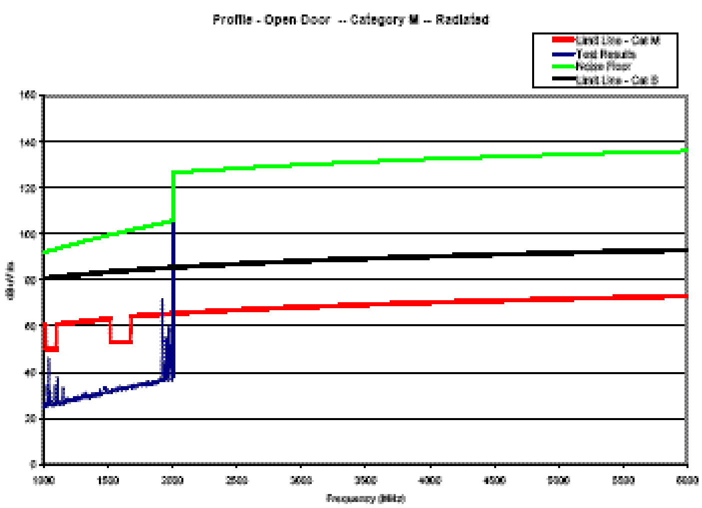


Figure A - 42: Section 10.4 Mode Stirred Emission 1-6GHz Cat M Open Door

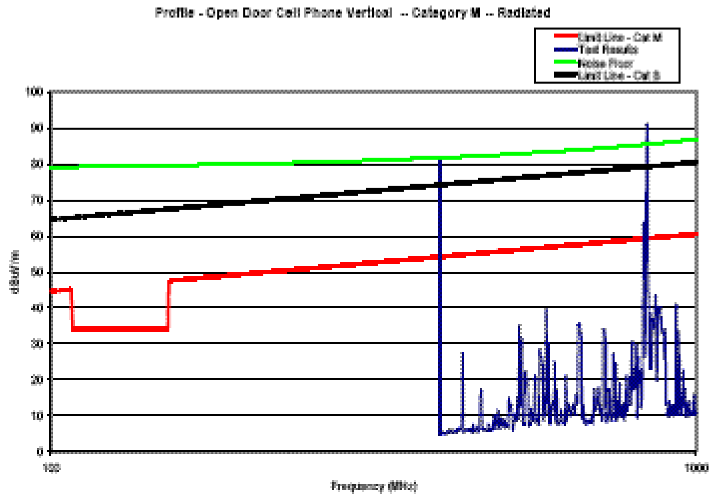


Figure A - 43: Section 10.4 Mode Stirred Emission 100-1000MHz Cat M Open Door Cell Phone Horizontal Above Wire Bundle

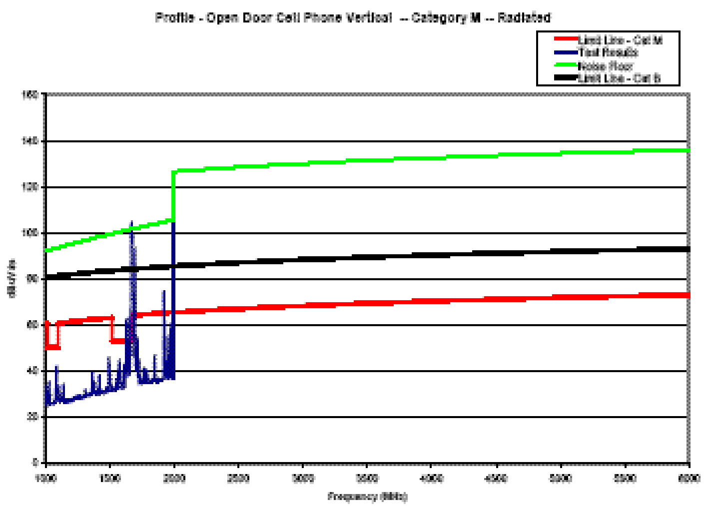


Figure A - 44: Section 10.4 Mode Stirred Emission 1-6GHz Cat M Open Door Cell Phone Horizontal Above Wire Bundle

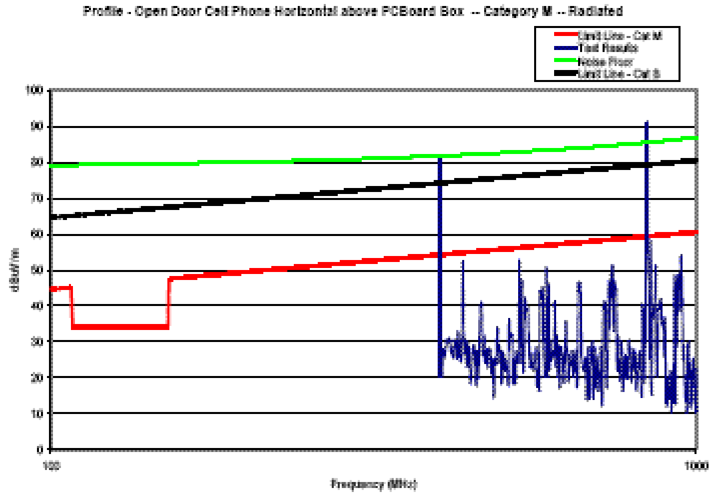


Figure A - 45: Section 10.4 Mode Stirred Emission 100-1000MHz Cat M Open Door Cell Phone Horizontal Above PC Board Box

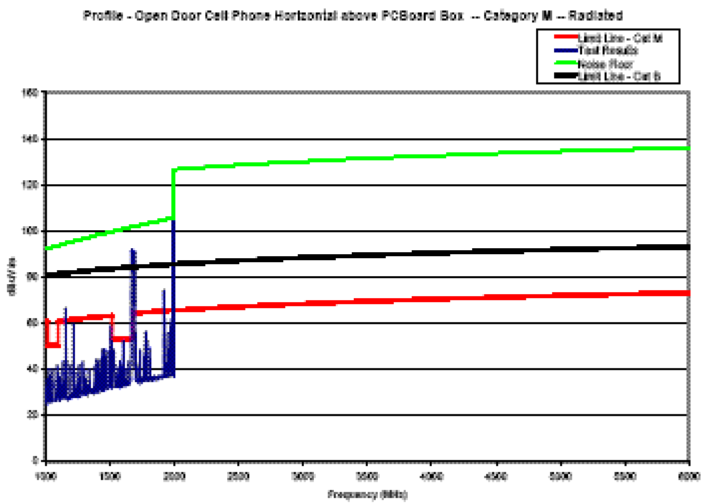


Figure A - 46: Section 10.4 Mode Stirred Emission 1-6GHz Cat M Open Door Cell Phone Horizontal Above PC Board Box

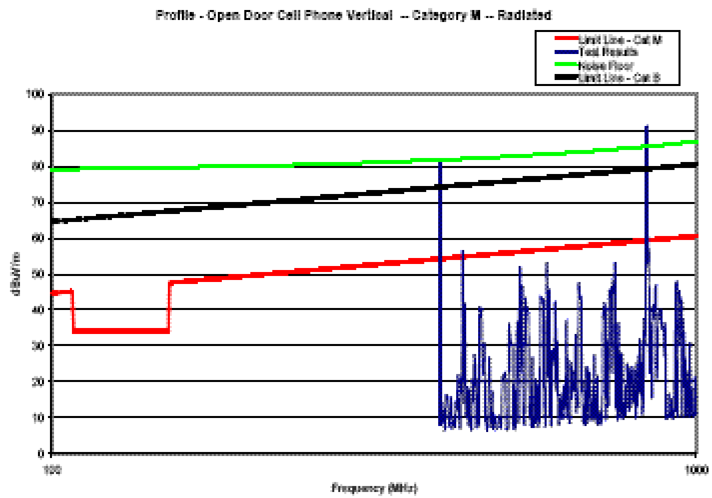


Figure A - 47: Section 10.4 Mode Stirred Emission 100-1000MHz Cat M Open Door Cell Phone Vertical

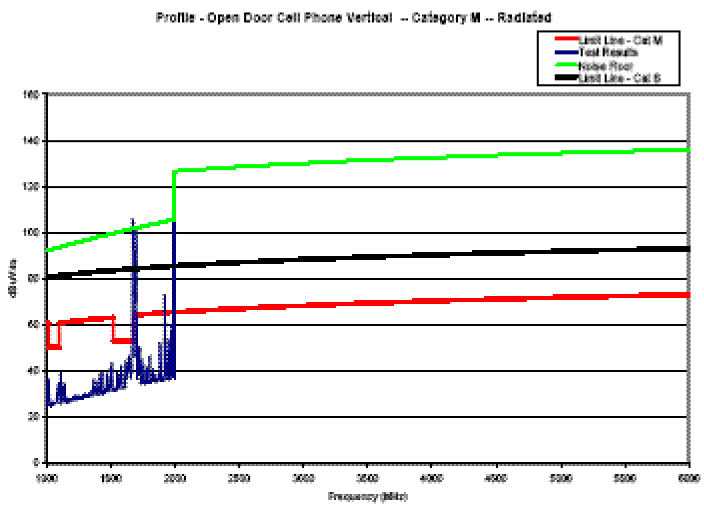


Figure A - 48: Section 10.4 Mode Stirred Emission 1-6GHz Cat M Open Door Cell Phone Vertical

SECTION 11
DATA GRAPHS

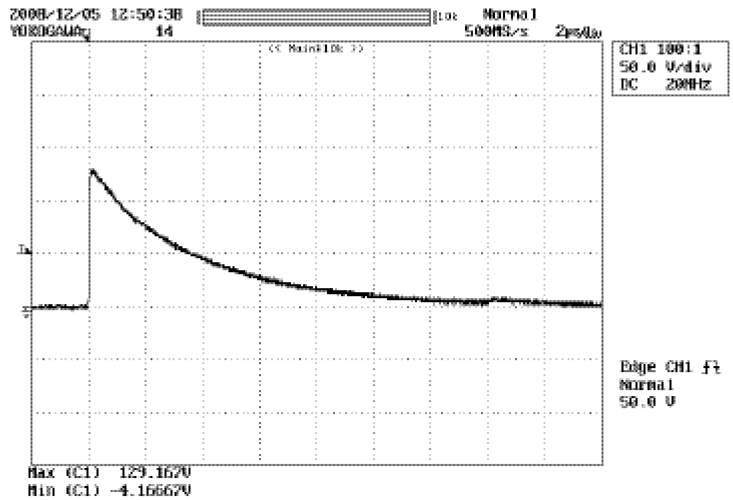


Figure A - 49: Section 11.5.2.1.1 Voltage Calibration WFM 2 Level 2

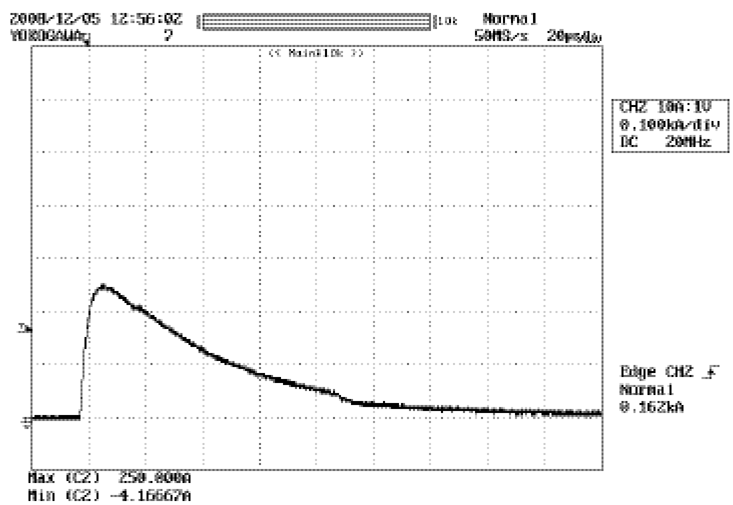


Figure A - 50: Section 11.5.2.1.1 Current Calibration WFM 2 Level 2

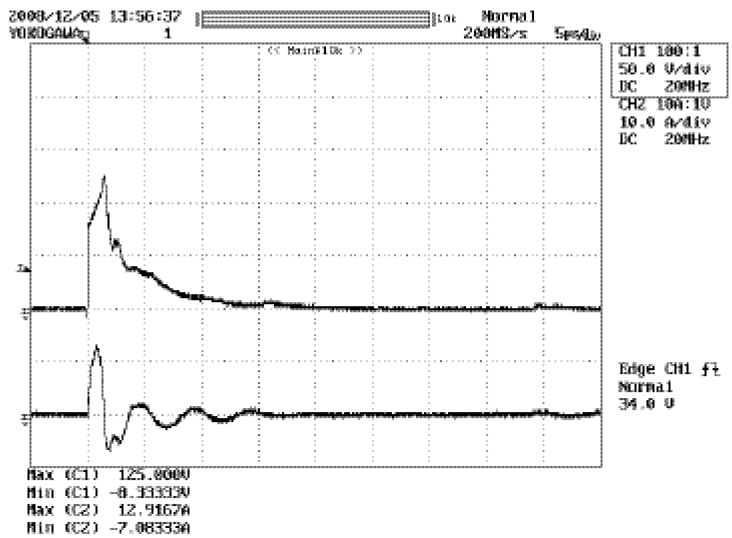


Figure A - 51: Section 11.5.2.1.2 Positive Polarity WFM 2 Level 2

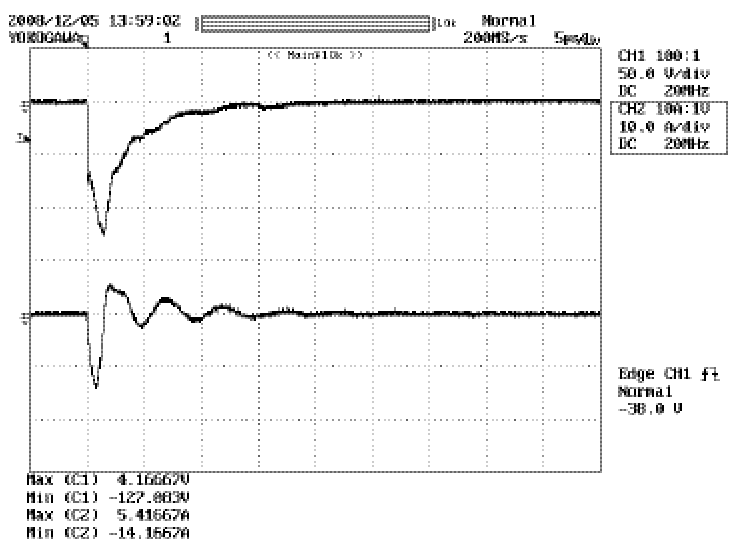


Figure A - 52: Section 11.5.2.1.2 Negative Polarity WFM 2 Level 2

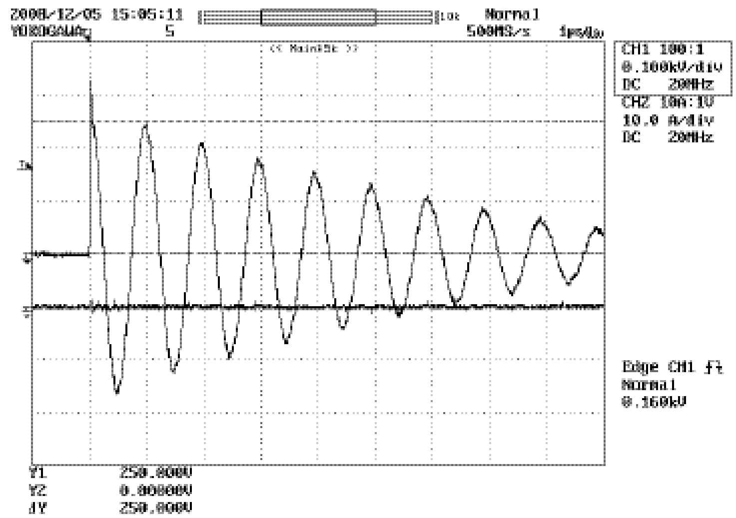


Figure A - 53: Section 11.5.2.1.1 Voltage Calibration WFM 3 Level 2 1MHz

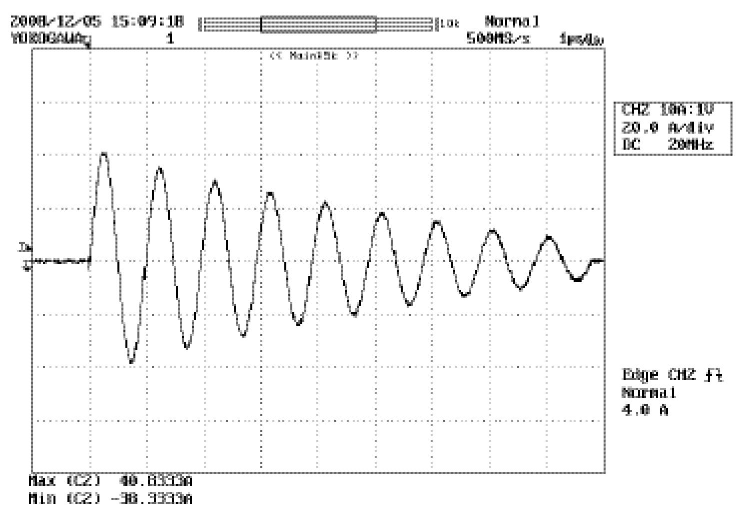


Figure A - 54: Section 11.5.2.1.1 Current Calibration WFM 3 Level 2 1MHz

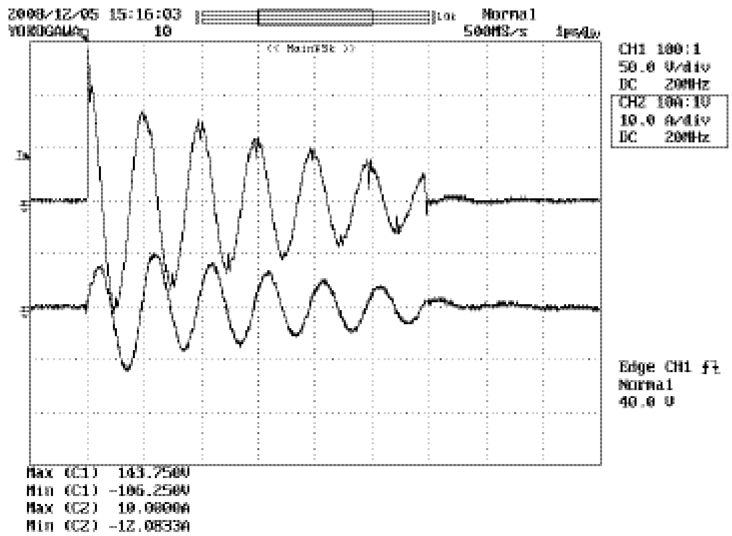


Figure A - 55: Section 11.5.2.1.2 Positive Polarity WFM 3 Level 2 1MHz

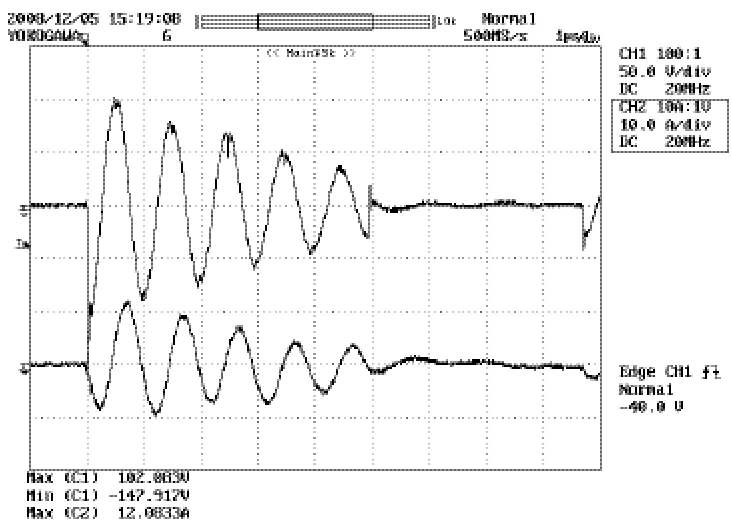


Figure A - 56: Section 11.5.2.1.2 Negative Polarity WFM 3 Level 2 1MHz

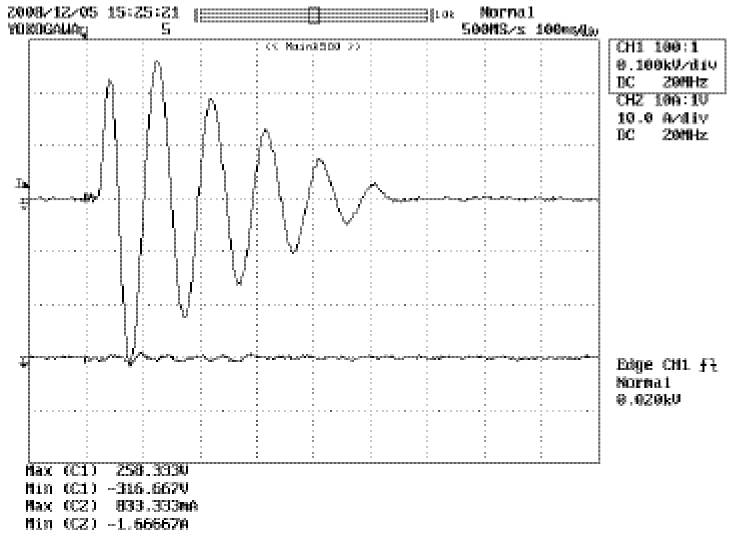


Figure A - 57: Section 11.5.2.1.1 Voltage Calibration WFM 3 Level 2 10MHz

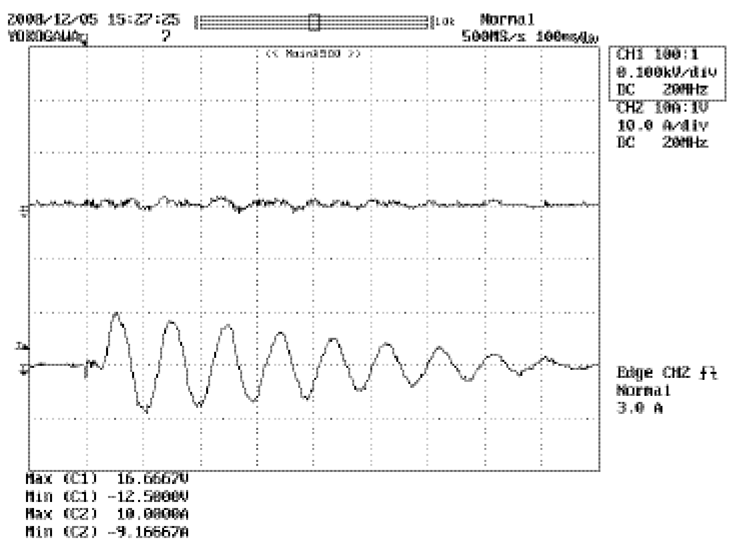


Figure A - 58: Section 11.5.2.1.1 Current Calibration WFM 3 Level 2 10MHz

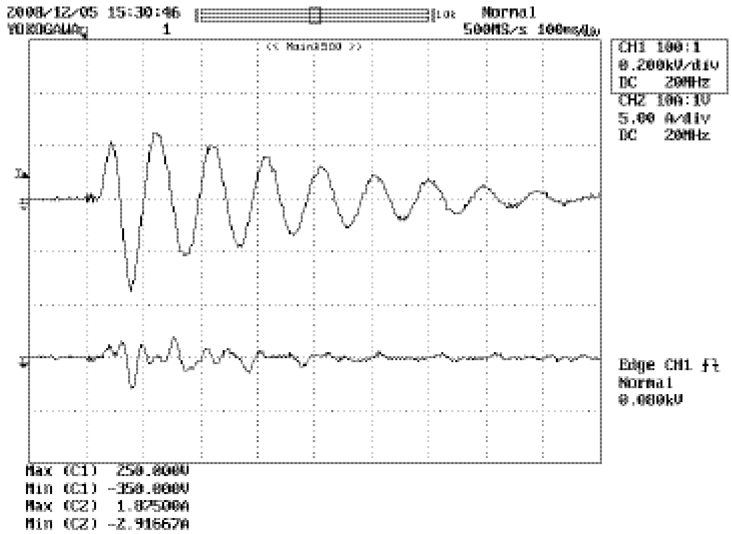


Figure A - 59: Section 11.5.2.1.2 Positive Polarity WFM 3 Level 2 10MHz

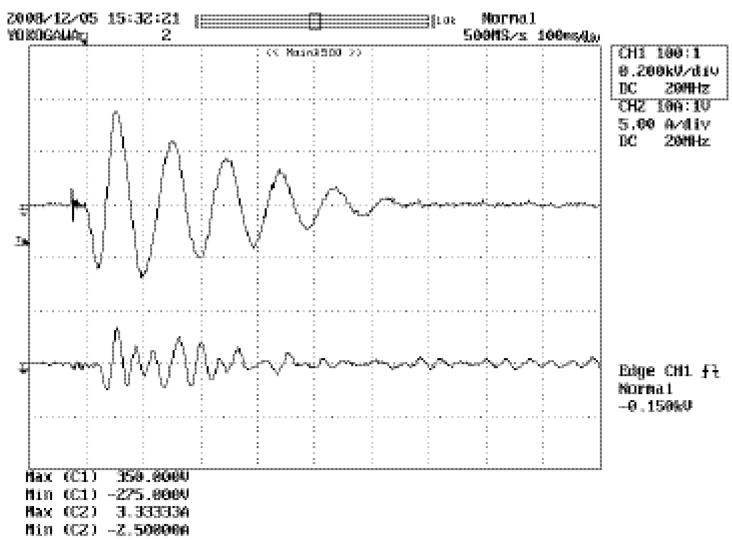


Figure A - 60: Section 11.5.2.1.2 Negative Polarity WFM 3 Level 2 10MHz

APPENDIX B

PICTURES

INDEX

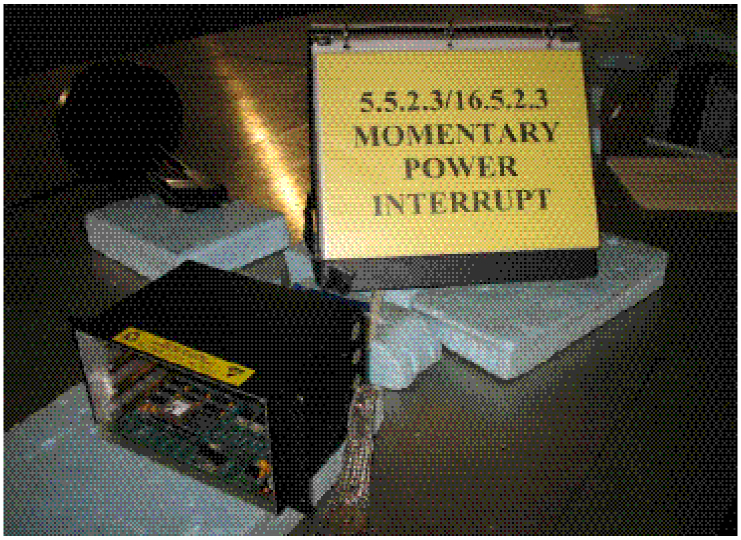


Figure B - 1: Typical Section 5 Test Set Up

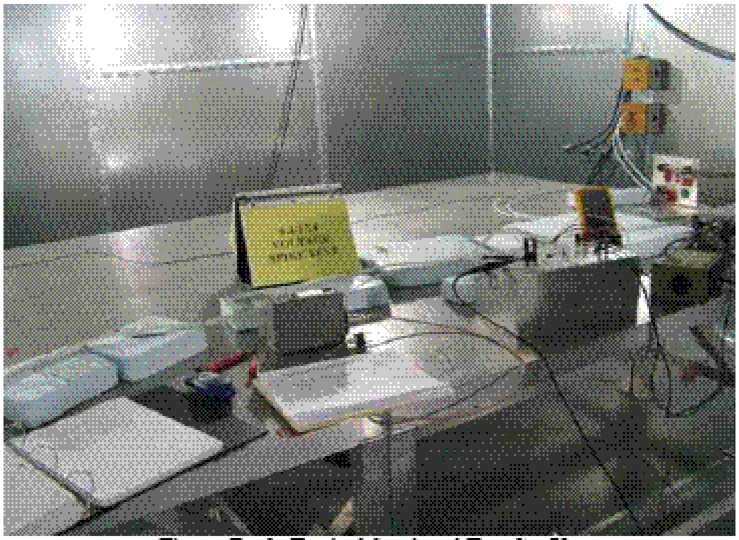


Figure B - 2: Typical Section 6 Test Set Up

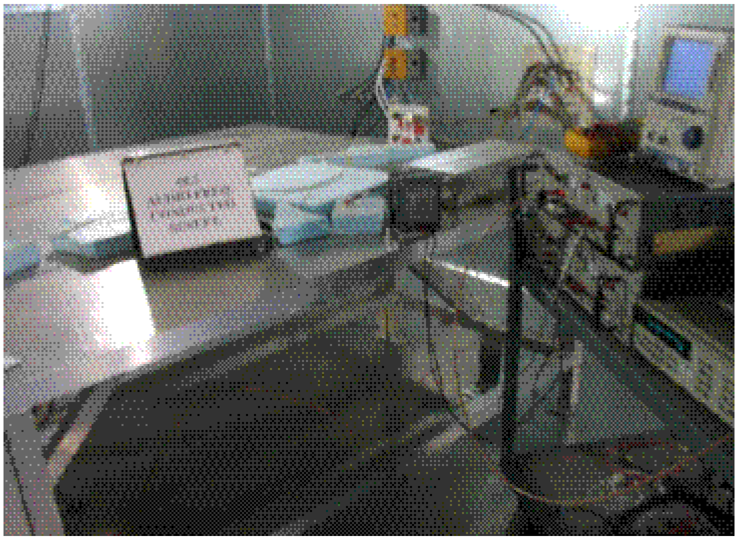


Figure B - 3: Typical Section 7 Test Set Up

Figure B - 4: Typical Section 9 Test Set Up

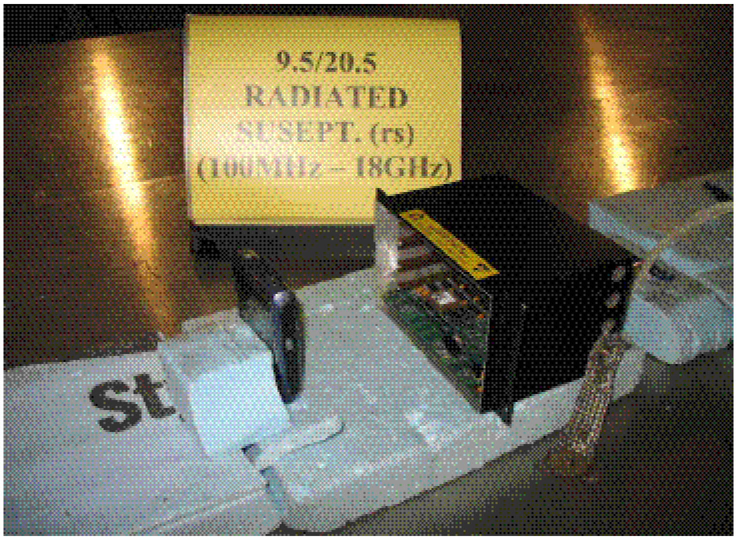


Figure B - 5: Typical Section 9 Test Set Up

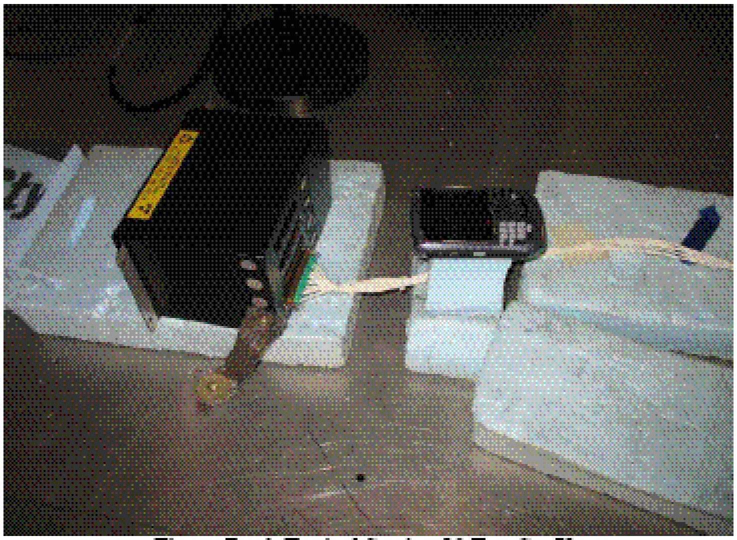


Figure B - 6: Typical Section 10 Test Set Up

Figure B - 7: Typical Section 10 Test Set Up

APPENDIX C

TEST LOG SCANS

INDEX

DO160E SECTION 16 TEST LOG

Page 1 of 2

EUT Description: Landing Gear Control PCB | P/N: 6618735 -1 | S/N: 198 | Test Engineer: MAG

Date	Filename	Test Section	Category A	Category B	Category Z	Suscept Y/N	Auto Rcvr Y/N	Waveform correct & backed up	Comments / Susceptibility Description	
		16.6.1.1-Voltage (Average Value DC)								
		Test 1	☐	☐	☒					
		Test 2	☐	☐	☒					
		16.6.1.3-Momentary Power Interruptions (DC)								
11/3/08	✓ 05	Condition 1	☐	☐	☒	N	—	✓		
	✓ 06	Condition 2	☐	☐	☒	* Y	— Y		Flicker	
	✓ 07	Condition 3	☐	☐	☒	* Y	Y		Flicker	
	✓ 08	Condition 4	☐	☐	☒	Y	Y		* Flicker	[illegible]
	✓ 09	Condition 5	☐	☐	☒	Y	Y		* "	
	✓ 10	Condition 6	☐	☐	☒	Y	Y		* "	
	✓ 11	Condition 7	☐	☐	☒	Y	Y		* "	
	✓ 12	Condition 8	☐	☐	☒	Y	Y		* "	
	✓ 13	Condition 9	☐	☐	☒	N	—			
	✓ 14	Condition 10	☐	☐	☒	Y	Y		Flicker	
	✓ 15	Condition 11	☐	☐	☒	Y	Y		Flicker	
	✓ 16	Condition 12	☐	☐	☒	Y	Y		* Flicker	[illegible]
	✓ 17	Condition 13	☐	☐	☒	Y	Y		"	
	✓ 19 18	Condition 14	☐	☐	☒	Y	Y		"	
	✓ 20	Condition 15	☐	☐	☒	Y	Y		"	
	✓ 21	Condition 16	☐	☐	☒	Y	Y		Flicker	
	22	Condition 17	☐	☐	☒	Y	Y		"	
	23	Condition 18	☐	☐	☒	Y	Y		"	
	24	Condition 19	☐	☐	☒	Y	Y		* Flicker	[illegible]

NOTES: * Gear handle solenoid in "AIR" mode (pulled)

EXLOW00

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Figure C - 1: Pg 1

DO160E SECTION 16 TEST LOG

Page 2of 2

						Susceptible	AutoRecover	w/FM	Notes
		16.6.1.4-Normal Surge Voltage(DC)							
		Test 1	[ ]	[ ]	[X]				
		16.6.1.5-Engine Starting Undervoltage Operation (DC)							
		Test 1		[ ]	[X]				
		16.6.2.1-Voltage Steady State (DC)							
12/05	0029	Test 1	[ ]	[ ]	[X]	No	NA		
		16.6.2.2-Low Voltage Conditions (DC)							
12/05	0031	Test 1		[ ]		NO	NA		
		16.6.2.3-Momentary Undervoltage Operation (DC)							
		Test 1	[ ]	[ ]	[X]				
		16.6.2.4-Abnormal Surge Voltage (DC)							
		Test 1	[ ]	[ ]	[X]				

NOTES:

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Figure C - 2: Pg 2

DO-160 SECTION 17/CSTI012 SECTION 6 & DO-160 SECTION18/CSTI012 SECTION 7 TEST LOG

Page 1 of 1

EUT Description: P/N: S/N: Test Engineer:

Date	Filename	Test Section	Category A	Category B	Category Z	Suscept Y/N	Auto Rcr Y/N	Waveform correct & backed up	Comments / Susceptibility Description
		17.4-Voltage Spike							
[illegible]	0032	Calibration-600V Negative Polarity	☐	☐				[illegible]	
	0033	Calibration-600V Positive Polarity	☐	☐				[illegible]	
	0034	Calibration-50 Ohm Negative Polarity	☐	☐				[illegible]	
	0035	Calibration-50 Ohm Positive Polarity	☐	☐				[illegible]	
	0037	Negative Polarity	☐	☐		Y	Y	[illegible]	[illegible]
[illegible]	0038	Positive Polarity	☐	☐		Y	Y		[illegible]
		18.3.1-Audio Frequency Susceptibility, Power Inputs							
[illegible]	0000.hif	10Hz-200Hz	☐	☐	☒	No	N/A	[illegible]	
	0001.hif	200Hz-1KHz	☐	☐	☒	No	N/A	[illegible]	
	0002.hif	1KHz-15KHz	☐	☐	☒	No	N/A	[illegible]	
	0003.hif	15KHz-150KHz (I)	☐	☐	☒	No	N/A	[illegible]	
[illegible]	0004.hif	15KHz-150KHz (II)	☐	☐	☒	No	N/A	[illegible]	

NOTES:

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Figure C - 3: Pg 3

DO-160 CSTI012 SECTION 11 CABLE BUNDLE TEST LOG

EUT Description: Landing Gear Control PCB | P/N: 6618735 | S/N: | Test Engineer:

Cable Induction ☒ (22.5.2.1/11.5.2.1) | Ground Injection ☐ (22.5.2.2/11.5.2.2)

Date	Filename	Polarity	Level 1	Level 2	Level 3	Level 4	WFM	Suscept Y/N	Auto Rcr Y/N	Waveform correct & backed up	Comments / Susceptibility Description
12/5	0040	Pos		X			2	NA	—	[illegible]	[illegible]
12/5	0041	Pos		X			2	NA	—	[illegible]	[illegible]
	0042	Pos		2			2	NO	NA	[illegible]	[illegible]
	0043	Neg		2			2	NO	NA	[illegible]	[illegible]
				7							
	0044	Pos		2			3	N/A	—	[illegible]	[illegible]
	0045	Pos		2			3	N/A	—	[illegible]	1.7
	0046	Pos		2			3	No	N/A	[illegible]	[illegible]
	0047	Neg		2			3	No	N/A	[illegible]	5a (+12a)
	0048	Pos		2			3	N/A	—	[illegible]	[illegible]
	0049	Pos		2			3	N/A	—	[illegible]	[illegible]
	0050	Pos		2			3	No	N/A	[illegible]	
	0051	Neg		2			3	No	N/A	[illegible]	

NOTES: WFM 2 125VT / 25 IL
WFM 3 250VT / 10 IL

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Figure C - 4: Pg 4

1

12/1/08

12/02/08

Figure C - 5: Pg 5

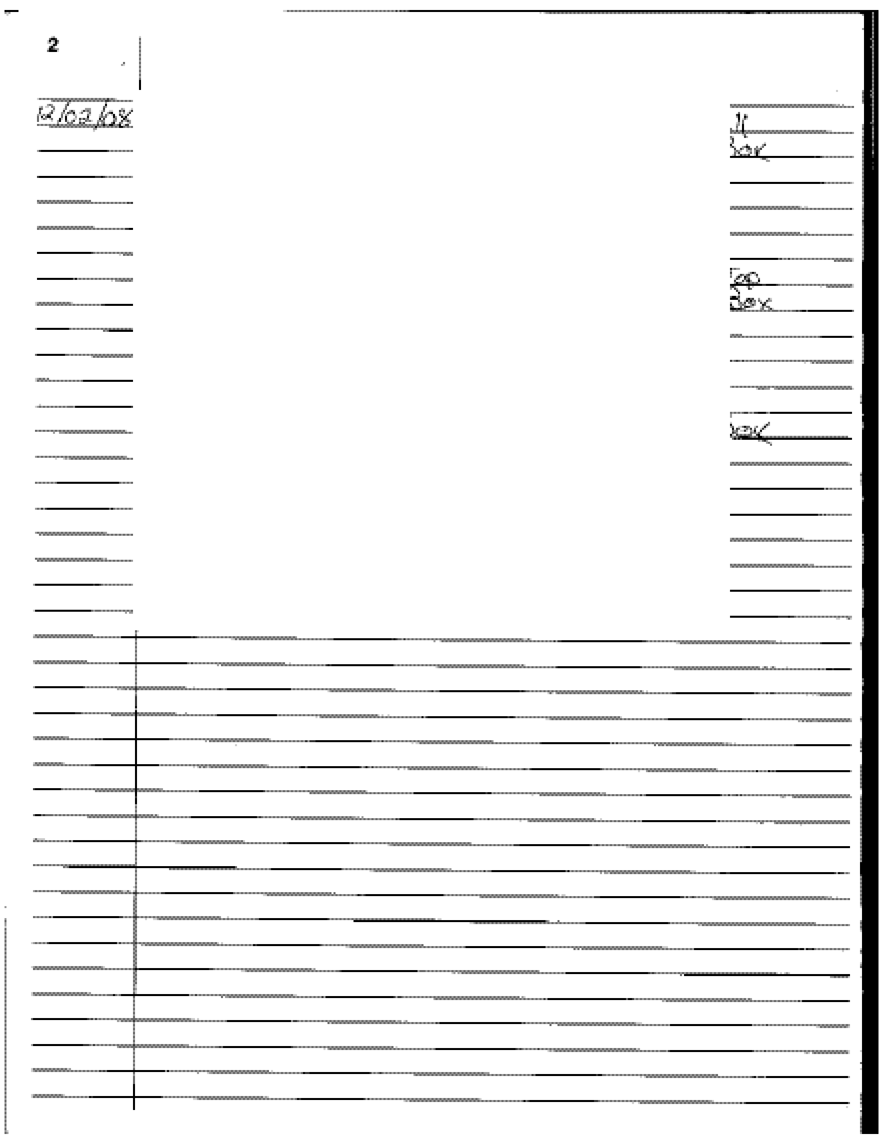
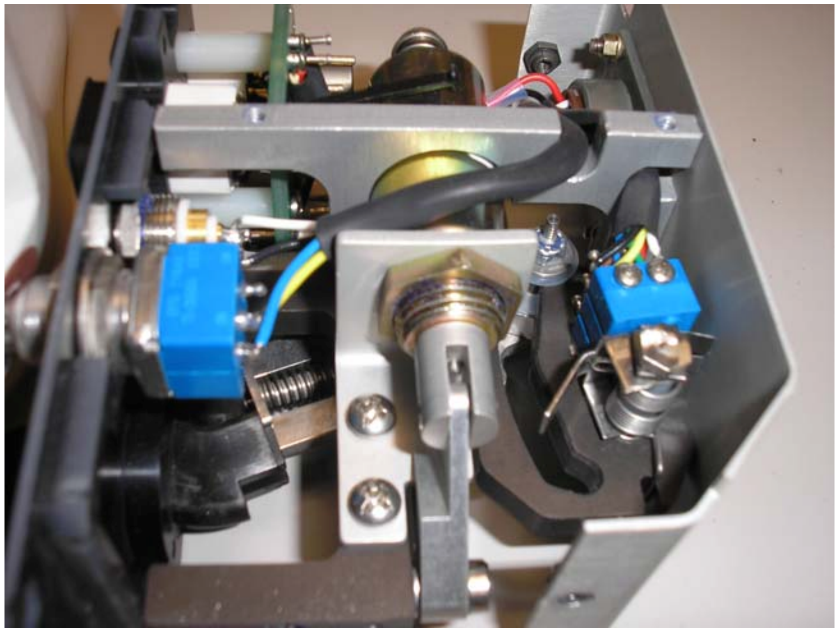
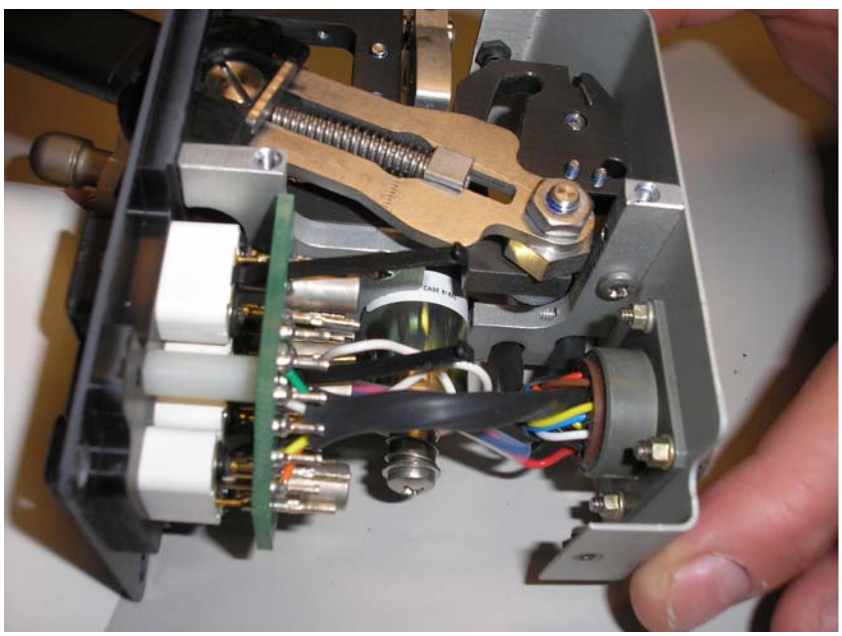


Figure C - 6: Pg 6

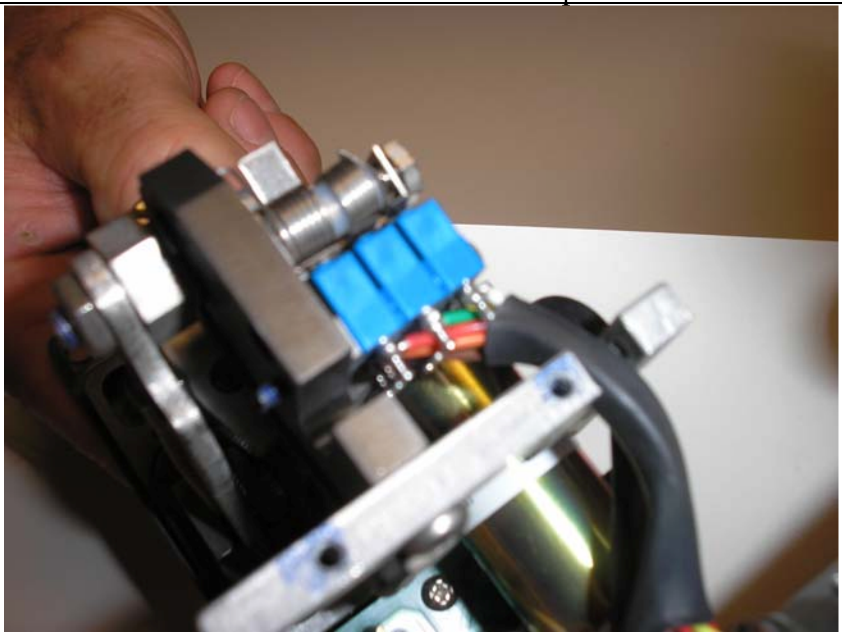
APPENDIX G – LANDING GEAR HANDLE TEAR DOWN PICTURES



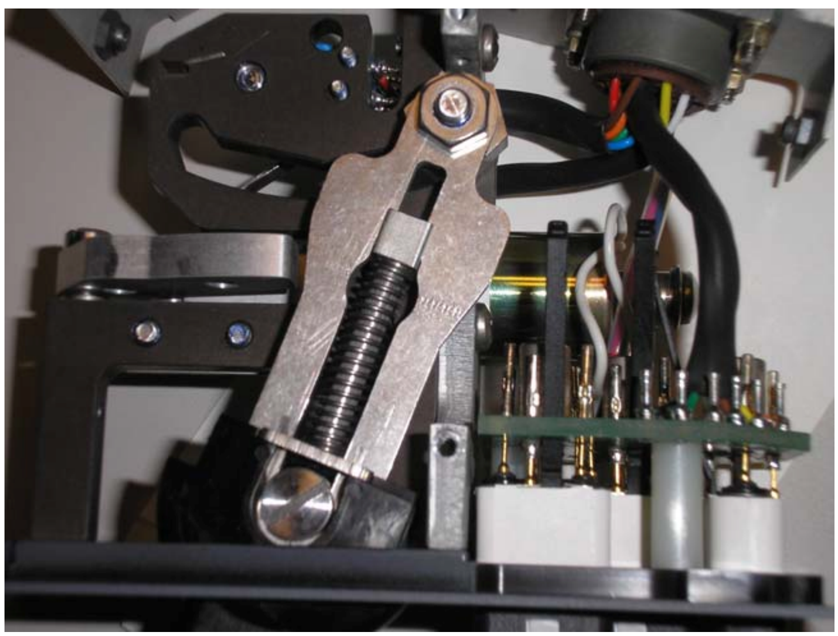
View of the Lockout Solenoid.



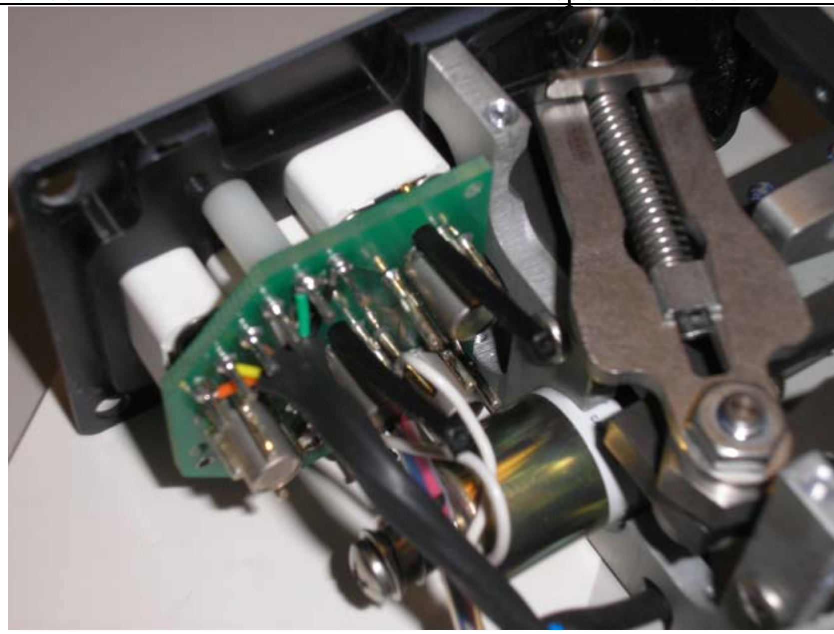
View of the Wire Routing.



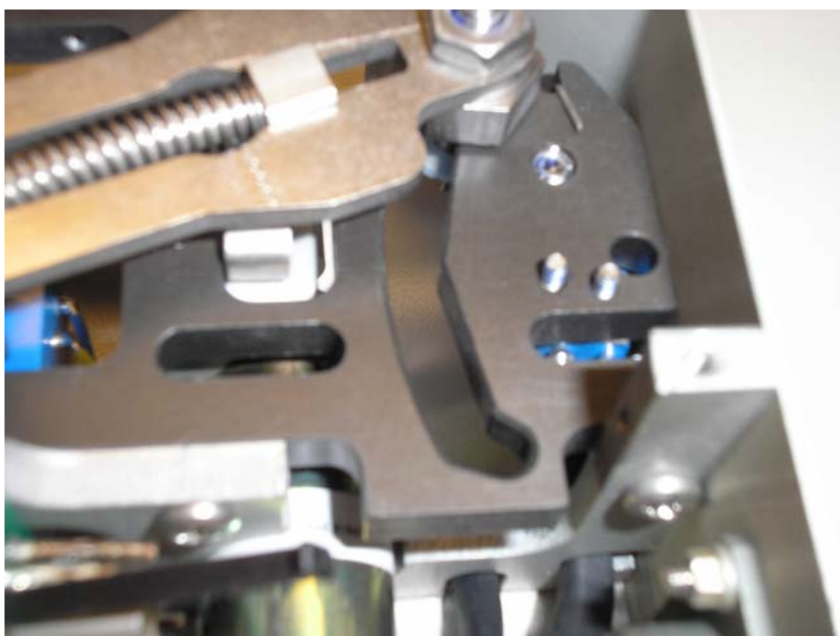
View looking at the back of Gear Handle.



View Looking Down from Side of Gear Handle.



Close-Up View of the Wire Connectors to the Board.



Close-up view of the Gear Handle Track.

APPENDIX H – HYDRAULIC MANIFOLD DIMENSIONAL REPORT

Part Number	Part Name	Zone	Dim.	Actual Dim. 1	Actual Dim. 2	Notes
4219-1	Valve, Solenoid Oper.					
37276	Lap Assembly		[redacted]	[redacted]		
36689	Sleeve	B6	[redacted]	3.109		
37277	Spool	D3 D3 C3 D3 D2 C3 D2	[redacted]	.2865 1.383 .925 3.1068 1.382 1.065 .287		
4235	Valve, Sol. Operated		[redacted]			
36596-10	Solenoid Assy.		[redacted]			
36596-3	Bobbin	C6 B5	[redacted]	1.6745 .329	1.675 .329	Both dimensions are pre-plate dim's. Actual includes plating.
36596-2	Pole Piece	C4 B4 C2	[redacted]	.049 .832 .1265	.049 .8315 .127	
36596-1	Armature	D4 C5	[redacted]	.5575 .3255	.557 .3255	This Dim. Is trimmed at next Assy. This Dim. Is trimmed at next Assy.
36704	Housing	B6 A5	[redacted]	.0294 .1885	.0294 .1885	
36605	Pin	B3 C1	[redacted]	1.374 .1225	1.374 .1230	This Dim. Is trimmed at next Assy.
36577-1	Pintle	D3 C2	[redacted]	.182 .0274	.182 .0274	This Dim. Is trimmed at next Assy.

APPENDIX I – FLUID LOSS ADDENDUM

Addendum

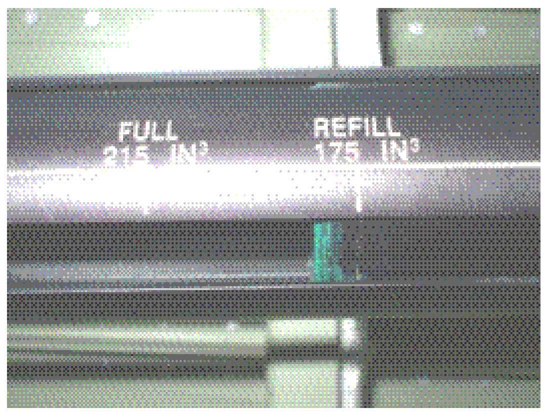
April 22, 2008

Joel,

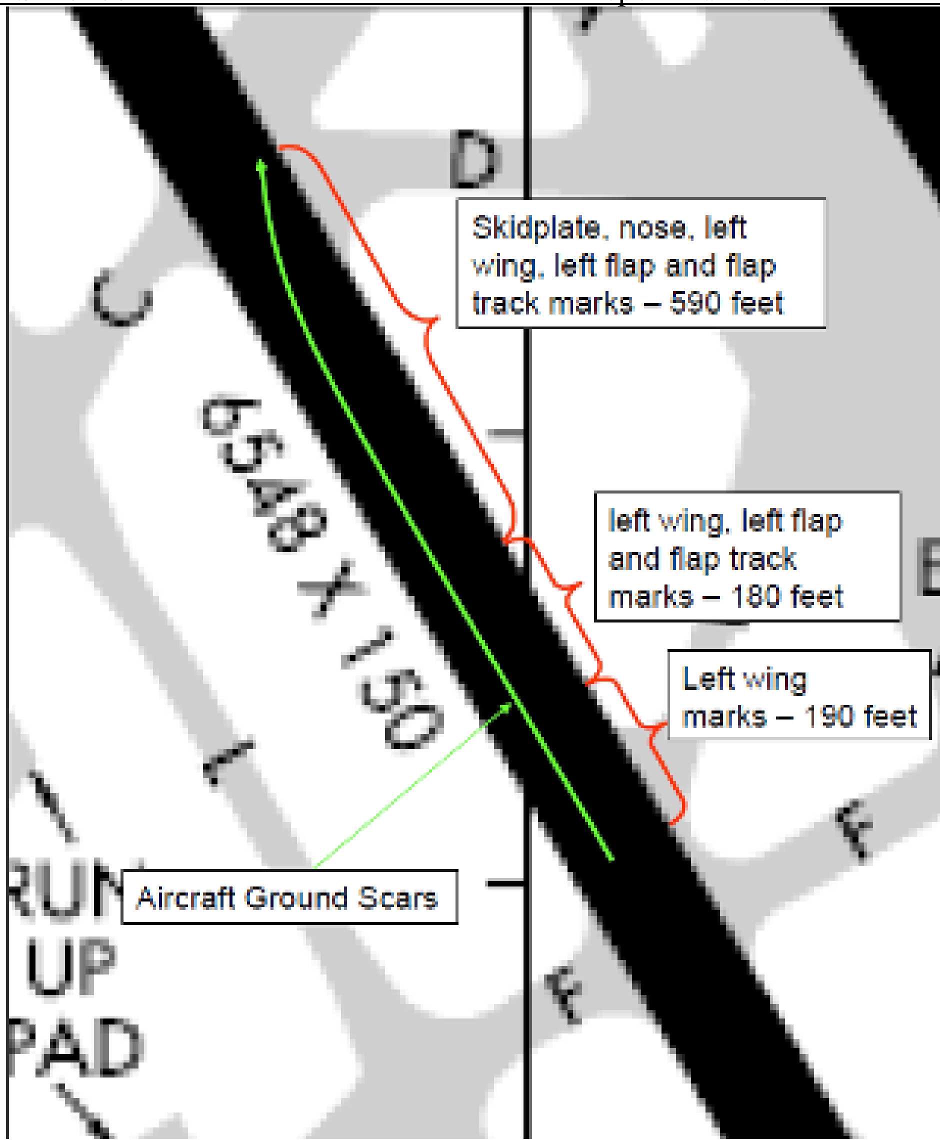
Larry Gase here in White Plains on N613QS. I was asked to provide you with information on the status of the hydraulic system reservoir level. I have asked the guys here on site that worked on the plane after the incident and nobody recalls looking at or recording the fluid system level. Attached is a photo of the current reservoir level. The hydraulic system has not been touched except that the gear were blown down. The speed brakes are extended and the flaps are currently between 17 and 25 deg and the TRs are stowed. Sorry I cannot provide anymore information.

Larry Gase

Lead Mechanic WCSC



APPENDIX J – RUNWAY SCARS



Runway Scars

APPENDIX K – WEIGHT VS. GEAR GEOMETRY TABLE

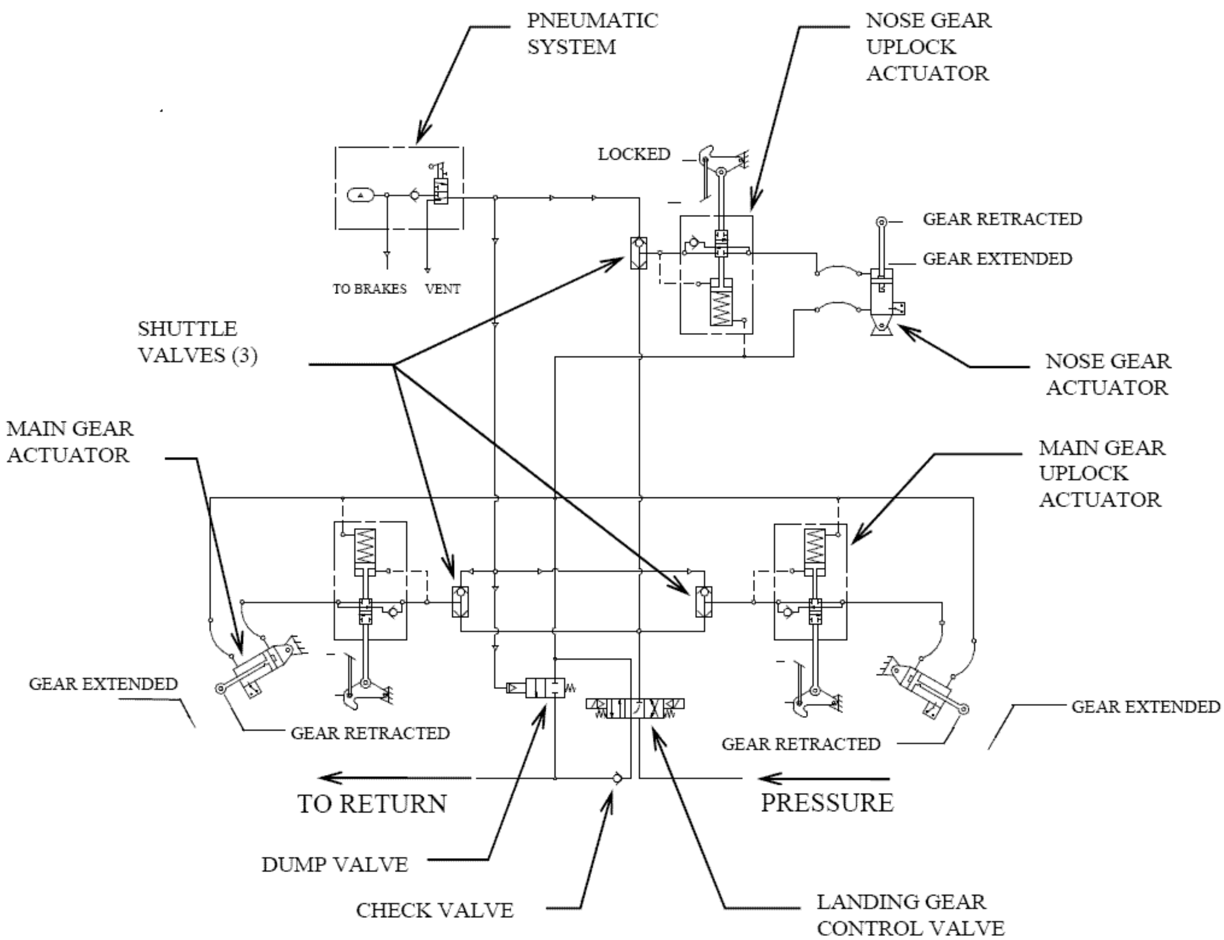
Weight of aircraft							
							Typical NetJets
Weight on LH main =	5941	lb	Typical scale reading for a NetJet configured aircraft				5941
Weight on RH main =	5908	lb					5908
Weight on nose =	588	lb					588
Actuator Compression Stroke (S)	Moment Arm Actuator	Moment Arm Aircraft Weight	Moment about Gear Pivot point	Force Acting on Actuator	This column is check to original data from A. Heiman	Where LH main weight=5941 lb	
Inches	inches	inches	lb*in	lb			
0	9.797	-2.086	-12392.9	-1265	-1265	Negative force values on actuator are tensile	
0.1	9.852	-1.721	-10224.5	-1038	-1038		
0.2	9.906	-1.354	-8044.1	-812	-812		
0.3	9.959	-0.987	-5863.8	-589	-589		
0.4	10.011	-0.619	-3677.5	-367	-367		
0.5	10.062	-0.251	-1491.2	-148	-148	Gear moves over center with about .55 inches of actuator travel	
0.6	10.113	0.118	701.0	69	69	Positive force values on actuator are compressive	
0.7	10.162	0.488	2899.2	285	285		
0.8	10.211	0.858	5097.4	499	499		
0.9	10.259	1.229	7301.5	712	712		
1	10.305	1.601	9511.5	923	923		
1.1	10.351	1.974	11727.5	1133	1133		
1.2	10.397	2.347	13943.5	1341	1341		
1.3	10.441	2.72	16159.5	1548	1548		
1.4	10.484	3.095	18387.4	1754	1754		
1.5	10.527	3.47	20615.3	1958	1958		
1.6	10.569	3.845	22843.1	2161	2161		
1.7	10.61	4.22	25071.0	2363	2363		
1.8	10.65	4.599	27322.7	2566	2566		
1.9	10.689	4.976	29562.4	2766	2766		
2	10.728	5.355	31814.1	2966	2966		

2.1	10.766	5.733	34059.8	3164	3164		
2.2	10.802	6.113	36317.3	3362	3362		
2.3	10.839	6.493	38574.9	3559	3559		
2.4	10.874	6.873	40832.5	3755	3755		
2.5	10.908	7.255	43102.0	3951	3951		
2.6	10.942	7.636	45365.5	4146	4146		
2.7	10.975	8.019	47640.9	4341	4341		
2.8	11.007	8.402	49916.3	4535	4535		
2.9	11.038	8.785	52191.7	4728	4728		
3	11.068	9.17	54479.0	4922	4922		
3.1	11.097	9.553	56754.4	5114	5114		
3.2	11.126	9.938	59041.7	5307	5307		
3.3	11.154	10.324	61334.9	5499	5499		
3.4	11.181	10.71	63628.1	5691	5691		
3.5	11.207	11.096	65921.3	5882	5882		
3.6	11.232	11.483	68220.5	6074	6074		
3.7	11.257	11.87	70519.7	6265	6265		
3.8	11.281	12.258	72824.8	6456	6456		
3.9	11.303	12.646	75129.9	6647	5596		
4	11.325	13.034	77435.0	6838	6838		
4.1	11.346	13.423	79746.0	7029	7029		
4.2	11.367	13.812	82057.1	7219	7219		
4.3	11.386	14.202	84374.1	7410	7410		
4.4	11.404	14.591	86685.1	7601	7601		
4.5	11.422	14.981	89002.1	7792	7792		
4.6	11.437	15.371	91319.1	7985	7985		
4.7	11.454	15.762	93642.0	8175	8175		
4.8	11.469	16.153	95965.0	8367	8367		
4.9	11.483	16.543	98282.0	8559	8559		
5	11.496	16.935	100610.8	8752	8752		
5.1	11.508	17.326	102933.8	8945	8945		
5.2	11.519	17.717	105256.7	9138	4674		
5.3	11.529	18.108	107579.6	9331	9331		
5.4	11.539	18.5	109908.5	9525	9525		
5.5	11.548	18.891	112231.4	9719	9719		
5.6	11.554	19.283	114560.3	9915	9915		
5.7	11.56	19.674	116883.2	10111	10111		
5.8	11.565	20.065	119206.2	10307	10307		
5.9	11.569	20.457	121535.0	10505	10505		
6	11.572	20.848	123858.0	10703	10703		
6.1	11.574	21.239	126180.9	10902	10902		
6.2	11.575	21.629	128497.9	11101	11101		
6.3	11.575	22.02	130820.8	11302	11302		
6.4	11.574	22.41	133137.8	11503	11503		
6.5	11.571	22.8	135454.8	11706	11706		
6.6	11.567	23.19	137771.8	11911	11911		
6.7	11.562	23.579	140082.8	12116	12116		

6.8	11.556	23.968	142393.9	12322	12322		
6.9	11.549	24.357	144704.9	12530	12530		
7	11.54	24.744	147004.1	12739	12739		
7.1	11.531	25.132	149309.2	12949	12949		
7.2	11.519	25.519	151608.4	13162	13162		
7.3	11.507	25.905	153901.6	13375	13375		
7.4	11.493	26.29	156188.9	13590	13590		
7.5	11.478	26.675	158476.2	13807	13807		
7.6	11.461	27.059	160757.5	14026	14026		
7.7	11.443	27.442	163032.9	14247	14247		
7.8	11.423	27.824	165302.4	14471	14471		
7.9	11.402	28.205	167565.9	14696	14696		
8	11.38	28.585	169823.5	14923	14923		
8.1	11.355	28.964	172075.1	15154	15154		
8.2	11.329	29.294	174035.7	15362	15362		
8.3	11.302	29.719	176560.6	15622	15622		
8.4	11.272	30.095	178794.4	15862	15862		
8.5	11.241	30.469	181016.3	16103	16103		
8.6	11.208	30.841	183226.4	16348	16348		
8.7	11.173	31.213	185436.4	16597	16597		
8.8	11.137	31.582	187628.7	16847	16847		
8.9	11.098	31.95	189815.0	17104	17104		
9	11.057	32.316	191989.4	17364	17364	Gear door comes in contact with ground	
9.1	11.014	32.681	194157.8	17628	17628		
9.2	10.969	33.043	196308.5	17897	17897		
9.3	10.921	33.404	198453.2	18172	18172		
9.4	10.871	33.762	200580.0	18451	18451		
9.5	10.819	34.118	202695.0	18735	18735		
9.6	10.764	34.472	204798.2	19026	19026		
9.7	10.707	34.823	206883.4	19322	19322		
9.8	10.647	35.172	208956.9	19626	19626		
9.9	10.584	35.518	211012.4	19937	19937		
10	10.518	35.861	213050.2	20256	20256		
10.1	10.45	36.201	215070.1	20581	20581		
10.2	10.378	36.538	217072.3	20917	20917		
10.3	10.302	36.872	219056.6	21263	21263		
10.4	10.224	37.202	221017.1	21617	21617		
10.5	10.141	37.529	222959.8	21986	21986		
10.6	10.055	37.852	224878.7	22365	22365		
10.7	9.966	38.17	226768.0	22754	22754		
10.8	9.871	38.485	228639.4	23163	23163		
10.9	9.773	38.795	230481.1	23583	23583		
11	9.67	39.1	232293.1	24022	24022		
11.1	9.562	39.4	234075.4	24480	24480		

11.2	9.45	39.695	235828.0	24955	24955		
11.3	9.331	39.985	237550.9	25458	25458		
11.4	9.208	40.268	239232.2	25981	25981	Wing tip comes in contact with ground	
11.5	9.078	40.545	240877.8	26534	26534		
11.6	8.941	40.816	242487.9	27121	27121		
11.7	8.798	41.079	244050.3	27739	27739		
11.8	8.648	41.334	245565.3	28396	28396		
11.9	8.489	41.581	247032.7	29100	29100		
12	8.323	41.82	248452.6	29851	29851		

APPENDIX L – HYDAULIC SCHEMATIC



Landing Gear Hydraulic System Schematic