

SYSTEM ASSURANCE ANALYSIS
OF THE
130 TON TADANO
MOBILE CRANE

AT

KSC

Baseline No.: 330.00

PMN: H72-1500

Revision Log

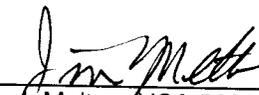
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Prepared By:

 7/11/01

M. Gross, USA 54530
Mission Assurance Engineer

Concurrence:

 7/11/01

J. Melton, USA 56220
System Design Engineer

Concurrence:

 10/25/01

J. Barnette USA 54530
First Line Manager,
Reliability Engineering

Concurrence:

 7/11/01

J. Blake, USA 56840
Systems Engineer

Approval:

 10/25/01

R. Harvey, USA 54500
Manager,
Mission Assurance

TABLE OF CONTENTS

1	SYSTEM ASSURANCE ANALYSIS SUMMARY	4
1.1	FINDINGS	4
1.2	AREAS OF CONCERN.....	4
2	SYSTEM DESCRIPTION.....	4
3	ANALYSIS GROUND RULES.....	5
4	FAILURE MODES AND EFFECTS ANALYSIS	5
4.1	CRITICALITY ASSESSMENT.....	5
4.2	FMEA WORKSHEETS	8
4.3	LPS/CLCS CONTROL/MONITOR REVIEW	64

Appendix A. FAULT TREE AND HAZARD ANALYSIS

Appendix B. CRITICAL ITEMS LIST

LIST OF ILLUSTRATIONS

Figure 1.	Tadano ATF 1300XL Mobile Crane.....	9
Figure 2.	Outrigger Cylinder Holding Valve	10
Figure 3.	Swing Gearbox	14
Figure 4.	Hoist Winch Gearbox	15
Figure 5.	P.A.T. SYSTEM	42

LIST OF TABLES

Table 1.	Finding Summary	4
Table 2.	Criticality Assessment Worksheet – H72-1500	6
Table 3.	Mechanical FMEA – Outrigger System.....	11
Table 4.	Mechanical FMEA – Mechanical and Hydraulic System	16
Table 5.	Electrical FMEA – Outrigger System	35
Table 6.	Electrical FMEA – Superstructure.....	43
Table 7.	Flexhose FMEA – Outrigger System	63
Table 8.	Hazard Analysis Worksheet – Tadano ATF 1300XL Mobile Crane.....	A-6

1 SYSTEM ASSURANCE ANALYSIS SUMMARY

1.1 FINDINGS

Table 1. Finding Summary

	<u>Assessment</u>	
Reliability Criticality	Critical	
Safety Criticality	Critical	
	<u>Type</u>	<u>Quantity</u>
Critical Items	1	2
	1S	-
	2	2
1R Non-CIL Items	1R	12
Critical Flexhoses	1S	-
	2	-
Critical Orifices	1S	-
	2	-
Critical Filters	1S	-
	2	-
Hazard Reports	Accepted Risk	-
	Controlled	-

1.2 AREAS OF CONCERN

There were no Areas of Concern identified with this system.

2 SYSTEM DESCRIPTION

The Tadano 130 Ton Hydraulic Crane, Model No. AFT 1300XL, (PMN H72-1500), is used at KSC for lifting APU and HPU carts, mounting the PPU and generators on the MLP for transporting the Shuttle to the Pads and various others lifting tasks requiring the unit to lift or be near flight hardware.

The crane consists of an undercarriage and uppercarriage. The uppercarriage is mounted on the undercarriage by means of a turntable. This allows the uppercarriage to rotate on a single axis above the undercarriage. A boom mounted on the uppercarriage may be raised, lowered, extended and retracted along with a load suspended from it. The load is positioned vertically by means of a hoisting system. There are two independent hoists one for the main boom and the other for the jib. Both have the same rated load capacity.

The cranes undercarriage and uppercarriage control system consists of a microprocessor based control and monitoring system similar to commercially available Programmable Logic Controllers (PLCs). The system consists of multiple CPU processing cards and associated I/O to provide supervised commanding and monitoring of multiple feedback inputs. The systems inherent safety provisions include an algorithm based out of limits monitor, detection and response system to mitigate potential of internal failures or operator error from putting the crane in an unsafe condition.

3 ANALYSIS GROUND RULES

This analysis has been developed in accordance with NSTS 22206 and NSTS 22254. The following additional groundrules and assumptions were used during this analysis:

- a. The Tadano Mobil Crane will not be used for suspended load operations.
- b. The upper cab CSS displays data associated with various functions of the lower carriage such as outrigger pressure and engine functions. The CSS has no capability for providing the operator with alarm or warning when an anomaly occurs. Therefore for purposes of this analysis the CSS will not be considered as capable of providing mitigation for critical failure modes.

4 FAILURE MODES AND EFFECTS ANALYSIS

4.1 CRITICALITY ASSESSMENT

Table 2. Criticality Assessment Worksheet – H72-1500					Pages 6 to 7
System/Subsystem: 130 Ton Tadano Mobile Crane Location: KSC				Baseline Number: 330.00	
Input / Output	Function	Time Period	Effect of Loss/Failure If Function Fails to Operate or Cease Operation on Time, Fails During Operation, and/or Prematurely Operates	Crit / Noncrit	Notes
Input Operator control	Operator provides the input to the unit to control all movements.	As required	Operator error could result in possible contact with flight hardware causing loss (damage) of a vehicle system.	C	Requires operator error. See Hazard analysis.
Output Boom extension, retraction, and holding	Position the load	As required	Failure of boom extension and retraction to cease operation on time, failure during operation, and/or premature operation could result in loss of life and/or loss (damage) of flight hardware. Failure to hold position could result in loss of life and/or loss (damage) of flight hardware.	C	See FMEA
Boom raising, lowering, and holding	Position the load	As required	Failure of boom raising and lowering to cease operation on time, failure during operation and/or premature operation could result in loss of life and/or loss (damage) of flight hardware. Failure to hold position could result in loss of life and/or loss (damage) of flight hardware.	C	See FMEA
Turret rotation and holding	Position the load	As required	Failure of turret rotation to cease operation on time, failure during operation, and/or premature operation could result in loss of life and/or loss (damage) of flight hardware. Failure to hold position could result in loss of life and/or loss (damage) of flight hardware.	C	See FMEA
Outrigger motion and support	Stabilize and level truck to prevent tipping	Before boom operations	Failure of an outrigger during operation could allow the crane to shift and/or topple. Could result in loss of life and/or loss (damage) of flight hardware.	C	See FMEA
Structural support	Provide support for personnel and equipment	As required	Failure of the machine to support personnel and/or equipment could result in loss life and/or loss (damage) of flight hardware.	C	No FMEA performed. Components associated with this function are considered passive (ref. NSTS 22206 paragraph 4.4.1.a.6).

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Undercarriage: cab, engine (including the monitoring system), hydraulic systems for steering and ride heights)	Provides for surface travel	As required	Failure of the undercarriage during operation will result in delay of operation.	NC	

4.2 FMEA WORKSHEETS

The Failure Modes and Effects Analysis follows.

The following components were considered passive in the analysis:

- Boom Structures
- Hydraulic Tubing
- Tires and Wheels
- Load Hook Block
- Boom Hoist Drums
- Boom Roller Pins and Guides
- Wire Rope

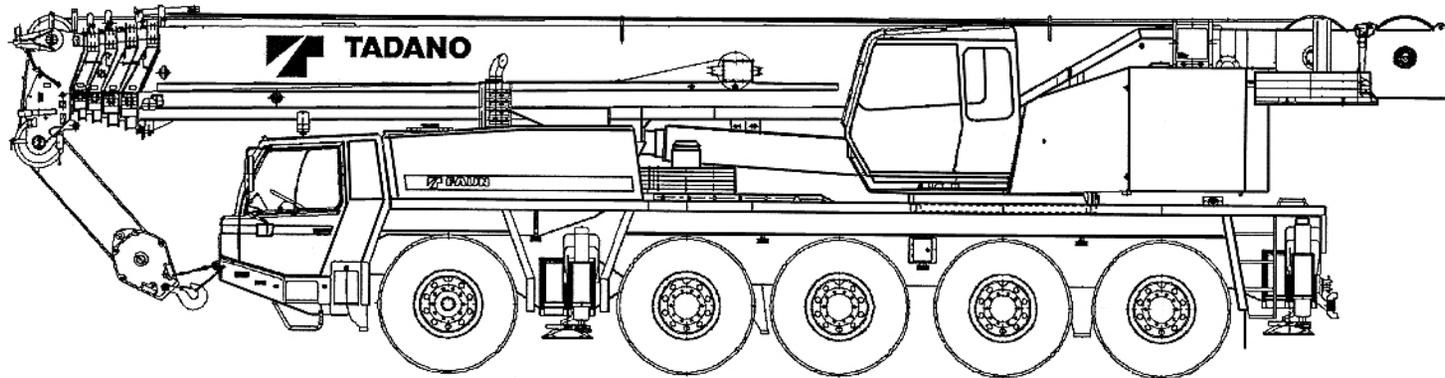


Figure 1. Tadano ATF 1300XL Mobile Crane

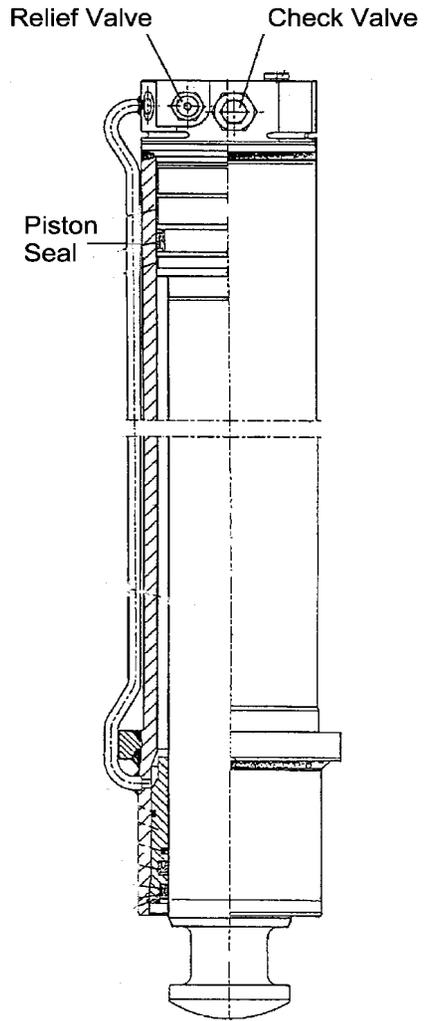


Figure 2. Outrigger Cylinder Holding Valve

Table 3. Mechanical FMEA – Outrigger System					Pages 11 to 13	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 59100 sht 1 & 2, 59149, 59151, 64103 sht 30 & 31, 0102-03 sht. 1, 0102-03 Reference: Fig. 1 and 2	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
A10V071/DFR1	Hydraulic pump	Supplies hydraulic pressure to move the outriggers.	Inoperable	Unable to move the outriggers. Aux pump is available.	No effect.	3
Y604/Y605, Y608/Y609, Y610/Y611, Y614/Y615	Support cylinder solenoid Valve (4)	Regulates hydraulic fluid to the front and rear outriggers to lift the truck for stabilization	Fails open (extend)	Outriggers would continue to extend to the maximum height.	No effect.	3
			Fails open (retract)	Outriggers would continue to retract until completely retracted.	No effect.	3
			Fails closed	Unable to supply fluid to extend the outrigger cylinder.	No effect.	3
Y602/Y603, Y607/Y606, Y612/Y613, Y616/Y617	Extend cylinder solenoid valve (4)	Directs the flow of fluid into the extend cylinder to deploy the support cylinder.	Fails open (outrigger cylinder valve)	The cylinder will extend the beam out to its furthest point. Possible damage to GSE.	No effect.	3
			Fails closed (outrigger cylinder valve)	Unable to extend the outrigger cylinder.	No effect.	3
			Fails open (extend cylinder valve)	The cylinder will retract the beam all the way in. Possible damage to GSE.	No effect.	3
			Fails closed (extend cylinder solenoid valve)	Unable to retract the cylinder.	No effect.	3

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Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
15 997-073-06735	Outrigger cylinder holding valves (4 valves head side, 4 valves rod side)	Blocks the flow of hydraulic fluid to secure the cylinder position.	a. Fails open (piston side)	The outrigger cylinder will bleed down at variable rates. However, the P.A.T. system LMB card would detect out of level (crane) and sound an alarm before tipping.	No effect. Subsequent failure of the P.A.T. system could result in loss of life.	1R
			b. Contamination, spring failure			
			c. 00004.001	Note: The ground operator will also observe the tilt of the machine to indicate that an outrigger is retracting.	No effect.	3
			d. Audible, visual			
e. NA	Unable to retract (if full of fluid) or extend (if empty of fluid) the outrigger cylinder.	No effect.	1R			
f. NA						
g. NA	Fluid pressure in the rod side has no effect in holding the load (crane and load).	No effect. Subsequent failure of the piston seal could cause the outrigger to come down resulting in loss of life.	3			
Fails closed (piston side)						
a. Fails open (cylinder rod side)	Unable to retract (if full of fluid) or extend (if empty of fluid) the outrigger cylinder.	No effect.	3			
b. Contamination, spring failure						
c. 00004.006	No effect.	3				
d. Audible, visual						
e. N/A	Unable to retract (if full of fluid) or extend (if empty of fluid) the outrigger cylinder.	No effect.	3			
f. N/A						
g. N/A	No effect.	3				
Fails closed (rod side)						

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Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
1 997-073-09304	Outrigger cylinder (4)	Provide the structural support to raise and hold up the Tadano.	External leak (rod seal failure)	Outrigger will not stay retracted (up position). May not be able to retract cylinder if the leak was large.	No effect.	3
			a. Internal leak (piston seal failure) b. Cut or broken seal c. 00004.005 d. Audible, visual e. N/A f. N/A g. N/A	The outrigger cylinder will bleed down at variable rates; the holding valve will prevent the fluid from coming out of the cylinder.	No effect. Subsequent failure of the holding valve could result in loss of life.	1R
None	Extension cylinder (2)	Extends the outrigger cylinder out and away from the truck to set up for the outriggers to go down.	External leak (rod seal failure)	May not be able to retract cylinder if the leak was large.	No effect.	3
			Internal leak (piston seal failure)	May extend slower.	No effect.	3
Y618	Solenoid valve	Opens to allow fluid into the outrigger hydraulic system when outriggers are in use. Diverts fluid to the coolers when outriggers are not being used.	Fails open	Oil will not be diverted to the coolers and could overheat.	No effect.	3
			Fails closed	Cannot perform outrigger functions.	No effect.	3

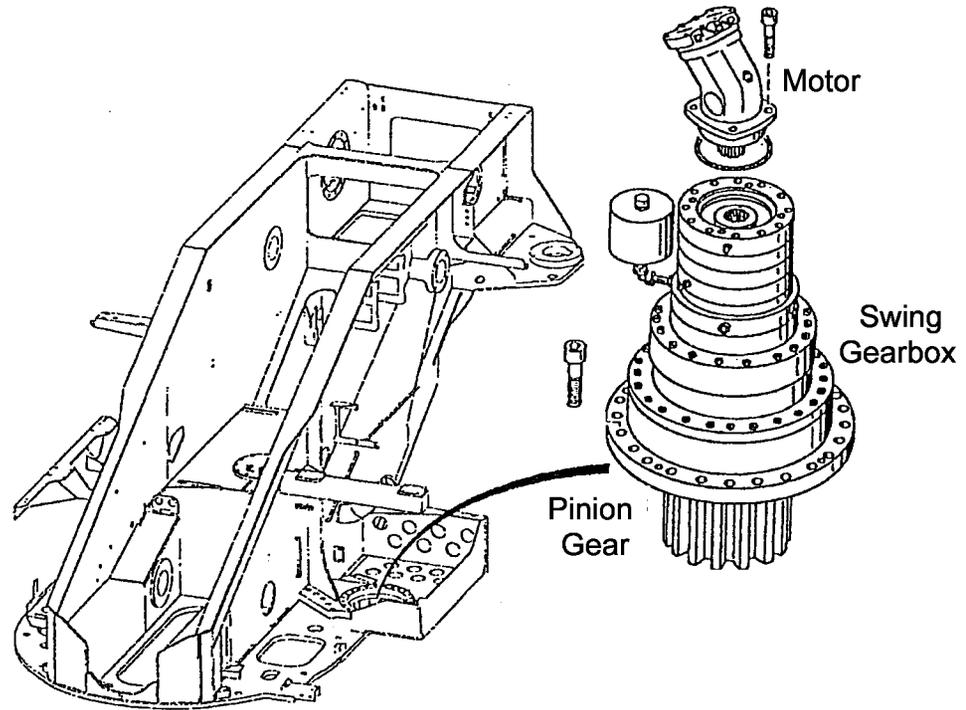


Figure 3. Swing Gearbox

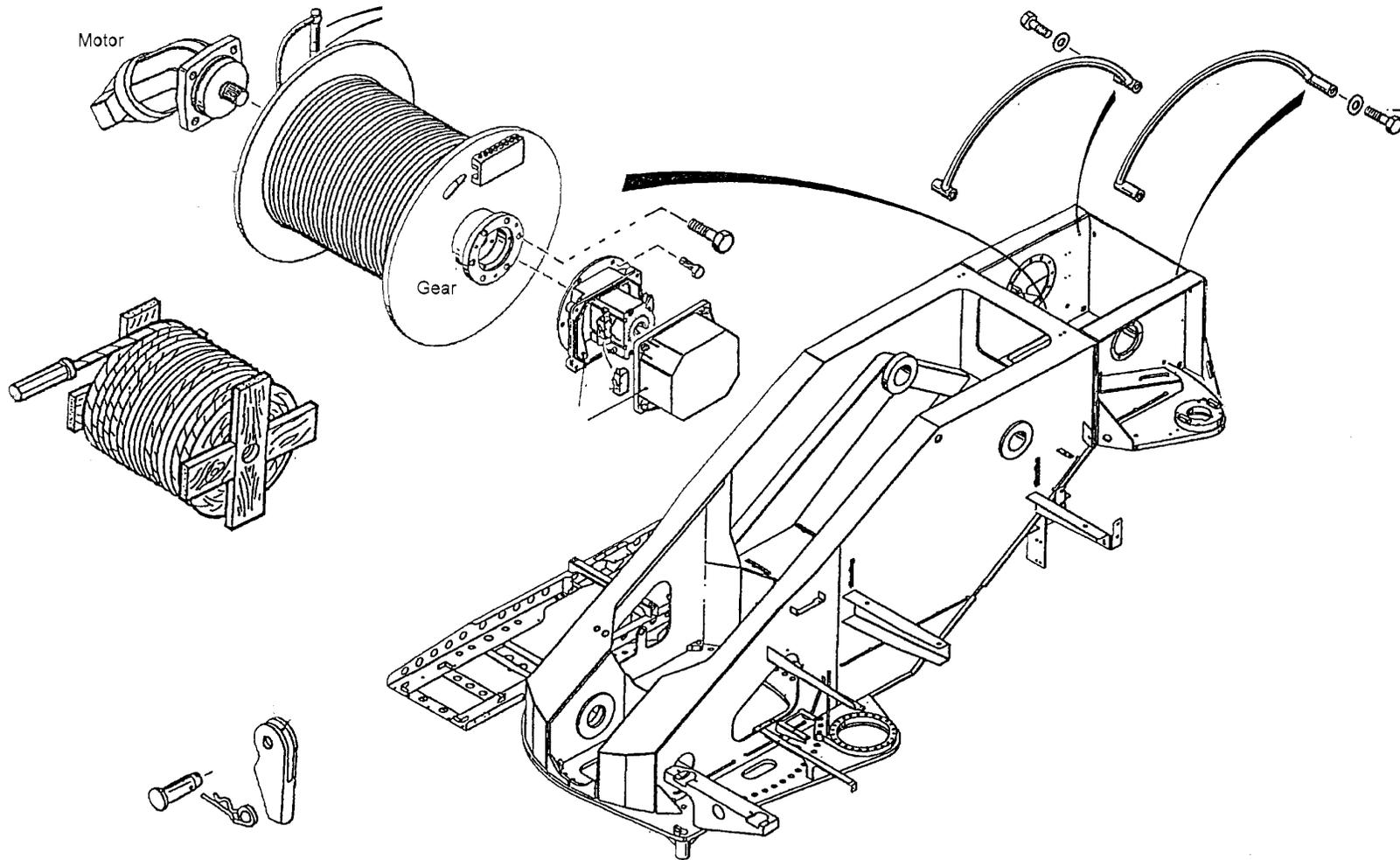


Figure 4. Hoist Winch Gearbox

Table 4. Mechanical FMEA – Mechanical and Hydraulic System						Pages 16 to 34
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
A20V095	Axial pump	Provide fluid pressure for boom telescoping, raising and load hoisting.	Inoperable	Unable to perform listed functions.	No effect.	3
37	Double gear pump	Provides fluid pressure for turret rotation, counterweight lifting and lowering.	Inoperable	Unable to perform listed functions.	No effect.	3
11	Pilot pressure pump	Provides fluid pressure to the pilot pressure valves.	Inoperable	Unable to perform any crane function.	No effect.	3
Y901	Solenoid valve	Controls the fluid out of the pilot pressure pump to either supply pilot pressure or shut the pressure off.	a. Fails open b. Broken spring, contamination c. N/A d. Audible alarm e. Operator will reposition the boom f. 5 seconds g. 3 seconds	When the pumps are turned off fluid may leak out of the pilot lines, when the pump is started this could cause damage to GSE through surge. In an overloaded condition this valve will not allow fluid into the lines that are not to be operated (hoist up, boom down and telescope out). If failed open the P.A.T. system will alarm the operator who would then take correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
			Fails closed	Pilot pressure will not be supplied to the system. Possible for functions not to operate.	No effect.	3

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Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	Pilot pressure valves (not shown)	All 3-position control valves have added pilot pressure supplied by these valves to aid them in opening and staying open. Normal electromechanical control valves are not strong enough to open and close by magnet only. These valves also supply pressure to the pumps to tell them to increase pressure when a function is selected.	Fails open position	Hydraulic pressure will not overcome the solenoid spring pressure to open the valve. Pilot pressure pump is continually pumping fluid into the system.	No effect.	3
			Fails closed position	Possible for the control valve to not open. Pressure compensation may not reach the pump. Possible loss of function selected.	No effect.	3
None	Manual isolation valve	Isolates the hydraulic oil tank from the main system for maintenance purposes.	Fails open	System fluid would continue to flow into the tank while trying to perform maintenance in it. Delay in operation.	No effect.	3
			Fails closed	Pumps would be unable to pull fluid from the tank. Unable to perform any uppercarriage operations.	No effect.	3
Y918/Y919	Turret rotation control valve.	Directs the flow of fluid into the turret rotation gear motor to rotate the turret right or left.	Fails neutral position	Unable to rotate the turret.	No effect.	3
			Fails left position	P.A.T. system will stop the movement or E-Stop is also available.	No effect.	3

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32	Turret rotation gear motor	Hydraulic motor that turns the pinion gear to rotate the turret.	Fails right position	P.A.T. system will stop the movement or E-Stop is also available.	No effect.	3
Y910	Turret brake control valve	Supplies fluid pressure to the turret brake to release and set the turret brake.	Inoperable	Unable to rotate the turret.	No effect.	3
			Fails open	Brake will be released. The brake is not the primary stopping device it aids in slowing the turrets rotation. Its primary function is to hold the turret in place when stopped. The hydraulics in the rotation motor stops the movement when rotation is complete.	No effect.	3
			Fails closed	Unable to release the brake. Brake may be prematurely worn out.	No effect.	3
1 997-070-00873	Swing Gearbox	Transfer torque from the hydraulic motor to the turret assembly.	a. Gear disengagement b. Structural failure of the gears. c. 00004.002 d. Audible, visual e. None f. Immediate g. Seconds	Torque for stopping horizontal rotation will be lost. Boom will continue to swing until the weight of the load or object stops it.	Possible loss (damage) to flight hardware.	2
			Gears seize	Unable to rotate platform. Delay of operations.	No effect.	3

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Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	Check valves (swing motor)	When the turret is in free swing mode the motor will continue to rotate when the control valve goes back to neutral. There is no oil being supplied through the control valve therefore the vacuum created in the line opens the check valve sucking oil out of the tank and into the motor to keeping it from cavitating and destroying the motor.	Fails open (any one)	The motor would not run due to the oil returning to the tank.	No effect.	3
			Fails closed	Possible to burn up the motor and stop all swing motion. Damage to GSE.	No effect.	3
Y929/Y930	Telescope locking control valve	Supplies pressure to the locking cylinder to lock the boom into place once it is reached its proper position.	Fails neutral position	Unable to move the cylinder to set the lock.	No effect.	3
			Fails locking position	Cylinder will extend to its furthest position. This could cause overpressurization in the system damaging seals.	No effect.	3
			Fails unlock position	Cylinder will retract until it can retract no further. This could cause overpressurization in the system damaging seals.	No effect.	3

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Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	Holding valves (lock pin cylinder)	Prevents pressure from leaving the cylinder to hold the cylinder in place.	Fails open extended position	Possible for the lock pin cylinder to retract, unable to keep the 1 st boom locked in place. 1 st Boom holding valves will prevent boom movement.	No effect.	3
			Fails open retracted position	Possible for the rod to drift out of the cylinder. This may allow the rod to strike the boom. Possible damage to GSE.	No effect.	3
None	Telescope locking cylinder	Lock the boom into place once it is reached its proper position. The first cylinder is a sequencing cylinder for the other boom cylinders it has to be held in place for the pressure to build up to move the other cylinder. This lock holds the boom in place to allow the other booms to extend before the first boom is extended all the way.	Internal leak	Internal leak will cause hydraulic fluid to flow into an already filled cylinder. This will cause hydraulic lockup. No effect. It would have to also have an external leak to cause drifting of the platform.	No effect.	3
			External leak	May not be able to set the lock due to lost pressure.	No effect.	3
Y948	Control valve	Switches hydraulics pressure from the turret rotation gear hydraulic system to the cab tilt hydraulic system and back.	Fails cab position	Unable to rotate the turret	No effect.	3

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Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
Y933/Y934	Counterweight control valve (motor)	Supplies fluid pressure to the counterweight motors.	Fails turret rotation position	Unable to tilt the cab.	No effect.	3
			Fails turn right position	Locks will continue to turn right until it can go no further. This could cause overpressurization in the system damaging seals.	No effect.	3
			Fails turn left position	Locks will continue to turn left until it can go no further. This could cause overpressurization in the system damaging seals.	No effect.	3
			Fails neutral	Unable to rotate the locking pin. Unable to lift the weights.	No effect.	3
None	Counterweight motor (2)	The motors will turn a lock (attached to the end of the cylinder) to hold the counterweights in place before raising the counterweight.	Inoperable (one)	Loss of one motor would cause the counterweight to not be locked properly and could not be lifted.	No effect.	3
Y931/Y932	Counterweight cylinder (2)	Lowers and raises the counterweights.	Internal leak	Internal leak will cause hydraulic fluid to flow into an already filled cylinder. This will cause hydraulic lockup. No effect. It would have to also have an external leak to cause drifting of the platform.	No effect.	3
			External leak	Dual cylinders are used. May not be able to lift the load due to lost pressure.	No effect.	3

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None	Counterweight control valve (cylinder)	Supplies fluid pressure to the counterweight cylinders	Fails open down position	Motors will lower the counterweights until it extends as far as it could. This could cause overpressurization in the system damaging seals.	No effect.	3
			Fails open up position	Cylinders will lift the counterweights until it bottoms out. This could cause overpressurization in the system damaging seals.	No effect.	3
			Fails neutral position	Unable to lift or lower the counterweights.	No effect.	3
None	Counterweight flow divider	Used to flow fluid into the cylinders for lowering them. Divides the flow of fluid equally to the two cylinders. (Restricts the flow for more control similar to an orifice).	Fails clogged one cylinder	Cannot raise the affected cylinder. Cannot lower the affected cylinder due to hyd. lock.	No effect.	3
None	Counterweight holding valve	Holds the cylinder in place once it has raised the counterweights.	Fails open	Dual holding valves prevent the counterweights from coming down.	No effect.	3
			Fails closed	Cannot raise or lower the counterweights.	No effect.	3
125	Hoist winch axial piston motor (2, aux and main)	Hydraulic motor that turns the wire rope spool to raise and lower the load.	Inoperable	Unable to raise or lower the load.	No effect.	3

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1 997-073-07- 188	Hoist winch gearbox (aux and main)	Transfers torque from the hydraulic motor to rotate the cable drum.	a. Gear disengagement b. Structural failure of the gears. c. 00004.003 d. Audible, visual e. None f. Immediate g. N/A	Torque for stopping drum rotation will be lost. Load will continue to drop until an object stops it.	Possible loss of life or loss (damage) of a vehicle system.	1
None	Hoist motor solenoid valve (2)	Used to keep fluid pressure in the system when the control valve goes to neutral. Open when the motor is running.	Fails closed	Cannot run the hoist.	No effect.	3
			Fails open	Unable to keep fluid in the system. Possible damage to the motor when started due to cavitation.	No effect.	3
None	Hoist motor relief valve (2)	Relives pressure in the system. Due to the system being closed pressure could build up due to heat.	Fails open	Unable to keep fluid in the system. Possible damage to the motor when started due to cavitation.	No effect.	3
			Fails to relieve	Overpressurization of the system. Possible damage to GSE.	No effect.	3
			Fails prematurely	Loss of fluid pressure in the system. Possible damage to the motor due to cavitation.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System						Pages 16 to 34
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	Hoist motor check valve (2)	Used to keep fluid pressure in the system when the control valve goes to neutral.	Fails closed	Cannot run the hoist.	No effect.	3
			Fails open	Unable to keep fluid in the system. Possible damage to the motor when started due to cavitation.	No effect.	3
Y903/Y904, Y906/Y907	Hoist motor control valve	Supplies fluid pressure to the hoist motors.	Fails up position	P.A.T. system will stop the movement or E-Stop is also available.	No effect.	3
			Fails down position	P.A.T. system will stop the movement or E-Stop is also available.	No effect.	3
			Fails neutral	Unable to raise or lower the load.		
Y905/Y908	Telescope control valve	Supplies fluid pressure to the telescope cylinders to extend/retract the boom.	Fails extend position	P.A.T. system will stop the movement or E-Stop is also available.	No effect.	3
			Fails retract position	P.A.T. system will stop the movement or E-Stop is also available.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System					Pages 16 to 34	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	First section telescope cylinder	Extends and retracts the first section of boom.	Internal leak	Internal leak will cause hydraulic fluid to flow into an already filled cylinder. This will cause hydraulic lockup. No effect. It would have to also have an external leak to cause drifting of the platform.	No effect.	3
			External leak	Loss of pressure, possible for the boom not to extend or retract.	No effect.	3
None	Second boom cylinder	Extends and retracts the next 3 sections of boom section of boom	Internal leak	Internal leak will cause hydraulic fluid to flow into an already filled cylinder. This will cause hydraulic lockup. No effect. It would have to also have an external leak to cause drifting of the platform.	No effect.	3
			External leak	Loss of pressure, possible for the boom not to extend or retract.	No effect.	3
None	Pilot operated control valve (inlet first boom)	Allows fluid into the cylinder for extending. When retracting 1 st section pilot will open the valve allowing fluid to be metered out of the cylinder.	Fails closed	Fluid will not be released from section I during retraction. Unable to retract section I.	No effect.	3
			Fails open	Boom will be pinned but fluid is allowed to leak out of the cylinder. The pin is capable of holding the load.	No effect.	3
None	Relief valve (inlet first boom)	Relieves overpressure in the cylinder, due to heat build up.	Fails to relieve	If the system were to overpressurize there could be damage to valve and cylinder seals.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System					Pages 16 to 34	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
Y955	Solenoid valve (inlet first boom)	Opens during extension of the booms. Closes when all booms are extended to act as a holding valve for section I. The valve is opened until section II, III and IV are retracted, then closes to meter the fluid out of section I.	Fails open	Cannot extend any section, or at least run slower. All or most system fluid will be returned to tank.	No effect.	3
			Relieves prematurely	Cannot extend any section, or at least run slower. All or most system fluid will be returned to tank.	No effect.	3
			Fails open	Boom will be pinned but fluid is allowed to leak out of the cylinder. The pin is capable of holding the load.	No effect.	3
			Fails closed	Fluid would enter the cylinder at a much slower rate than normal causing slow extension of the boom.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System					Pages 16 to 34	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
Y951	Solenoid valve	Closed during extension until section I is extended. It keeps pressure on the spring of shuttle valve I to shift it to keep fluid out of section II. P.A.T. system will shift the valve over to allow fluid into section II to extend (takes pressure off the spring). Closes again when section II is extended allowing fluid to go to section III/IV. Note: Y954 is also shut not allowing fluid into section III/IV. Y951 valve remains closed during retraction.	Fails open	Section II would extend with section I, P.A.T. system will shut down the crane.	No effect.	3
			Fails closed	Cannot extend section II.	No effect.	3
Y953	Solenoid valve	Remains closed during extension of sections. P.A.T. system will open valve to put pressure on shuttle valve I to shift it to allow fluid out of section II.	Fails open	Shuttle valve I will be shifted. Fluid will be trying to enter section II as well as leave. Section II would not move.	No effect.	3
			Fails closed	Cannot retract section II.	No effect.	3
None	Check valve	When filling it does not allow fluid into Shuttle valve I so it will not have an open line to fill section II. Allows fluid out of section II.	Fails open	Fluid will be trying to enter section II as well as leave. Section II would not move	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System						Pages 16 to 34
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	Shuttle valve	When extending section I, this allows fluid into the shuttle valve I to push the spring down and close it to keep fluid out of section II.	Fails closed	Cannot retract section II.	No effect.	3
			Fails closed to the left	Section II would extend with section I, P.A.T. system will shut down the crane or E-Stop is available.	No effect.	3
			Fails closed to the right	Section II will start to retract along with section III/IV P.A.T. system will shut down the crane or E-Stop is available.	No effect.	3
None	Shuttle valve I	Shuttle valve that shifts to allow fluid either into or out of section II.	Fails open extend position	Cannot extend section III/IV. P.A.T. system will shut down the system or E-Stop is available if III/IV needed to be extended.	No effect.	3
			Fails open retract position	Cannot retract section III/IV. P.A.T. system will shut down the system or E-Stop is available if III/IV needed to be retracted.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System					Pages 16 to 34	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
Y952	Solenoid valve	Closed during extension until section II is extended. It keeps pressure on the spring of the shuttle valve II to shift it to keep fluid out of section III. P.A.T. system will shift the valve over to allow fluid into section III to extend (takes pressure off the spring). Closes again when section III is extended. Valve remains closed during retraction.	Fails open	Section II would extend with section I, P.A.T. system will shut down the crane or E-Stop is available.	No effect.	3
			Fails closed	Cannot extend section II.	No effect.	3
Y954	Solenoid valve	Remains closed during extension of sections. P.A.T. system will open valve to put pressure on shuttle valve II to shift it to allow fluid out of section III.	Fails open	Shuttle valve II will be shifted. Fluid will be trying to enter section III as well as leave. Section III would not move.	No effect.	3
			Fails closed	Cannot extend section III.	No effect.	3
None	Check valve	When filling, it does not allow fluid into shuttle valve II so it will not have an open line to fill section III. Allows fluid out of section III.	Fails open	Fluid will be trying to enter section III as well as leave. Section III would not move.	No effect.	3
			Fails closed	Cannot retract section III.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System						Pages 16 to 34
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	Shuttle valve	When extending section II, this allows fluid into shuttle valve II to push the spring down and close it to keep fluid out of section III/IV.	Fails closed to the left	Section III/IV would extend with section II, P.A.T. system will shut down the crane or E-Stop is available.	No effect.	3
			Fails closed to the right	Section III/IV will start to retract along with section II P.A.T. system will shut down the crane or E-Stop is available.	No effect.	3
None	Relief valve	Relieves overpressure in the cylinder, due to heat build up.	Fails to relieve	If the system were to overpressurize there could be damage to valve and cylinder seals.	No effect.	3
			Fails open	Cannot extend any section, or at least run slower. All or most system fluid will be returned to tank.	No effect.	3
			Relieves prematurely	Cannot extend any section, or at least run slower. All or most system fluid will be returned to tank.	No effect.	3
None	Shuttle valve II	Shuttle valve that shifts to allow fluid either into section III or out.	Fails open extend position	Cannot retract section III.	No effect.	3
			Fails open retract position	Cannot extend section III.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System						Pages 16 to 34
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
Y939	Pilot operated valve	P.A.T. system controlled valve. Opens and closes main solenoid valve to allow fluid into or out of the boom cylinder to extend or retract the boom cylinder.	a. Fails open b. Contamination on the seat, broken return spring c. NA d. Visual e. Operator will reposition the boom f. 5 seconds g. 3 seconds	The boom would not be held in place and could drift down possibly contacting flight hardware unless the operator takes correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
None	Pilot operated control valve	Opens and closes to allow fluid into or out of the boom cylinder to extend or retract the cylinder.	Fails closed	Unable to raise or lower the boom.	No effect.	3
			Fails check valve side	Unable to raise or lower the boom.	No effect.	3
			a. Fails flow control valve side b. Contamination on the seat, broken return spring c. NA d. Visual e. Operator will reposition the boom f. 5 seconds g. 3 seconds	The boom would not be held in place and could drift down possibly contacting flight hardware unless the operator takes correcting action.	No effect. Correcting action prevents damage to flight hardware.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System						Pages 16 to 34
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	Check valve	Thermal relief valve. Whenever fluid temp rises to an unacceptable level the valve opens to relieve fluid from the cylinder.	a. Fails open b. Contamination on the seat, broken return spring c. NA d. Visual e. Operator will reposition the boom f. 5 seconds g. 3 seconds	The boom would not be held in place and could drift down possibly contacting flight hardware unless the operator takes correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
			Fails closed	Unable to raise or lower the boom. Possible for heat (pressure) build-up causing damage to the seals. Damage to GSE.	No effect.	3
None	Telescoping cables	Moves Section IV out simultaneously with section III by these cables. Section IV is not an independent telescoped boom.	Cable breaks	The boom could bind up and stop if one were to fail. The boom has two groups of 5 cables each capable of holding the boom in place. There is a guide cable on top of the boom that will also aid in supporting the boom. Triple failure required.	No effect.	3
Y902/Y909	Boom control valve	Supplies fluid pressure to the boom cylinders to raise or lower the boom.	Fails raise position	P.A.T. system will stop the movement once the hand controller is shifted to neutral.	No effect.	3
			Fails lower position	P.A.T. system will stop the movement once the hand controller is shifted to neutral.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System						Pages 16 to 34
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Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
Y925	Solenoid valve	N O valve. Opens and closes to control the fluid out of pump I. Pump I supplies fluid for boom lift and telescope.	Fails open	Pump I would not operate. Cannot operate boom lift and telescope.	No effect.	3
			Fails closed	Fluid would continuously be supplied to the solenoid valves of the boom functions and reducing the reliability of the pumps.	No effect.	3
Y926	Solenoid valve	N O valve. Opens and closes to control the fluid out of pump II. Pump II supplies fluid to the aux and main winches.	Fails open	Pump II would not operate. Cannot operate aux and main winches.	No effect.	3
			Fails closed	Fluid would continuously be supplied to the solenoid valves of the aux and main winch functions reducing the reliability of the pumps.	No effect.	3
Y914	Solenoid valve	When shifted, both pumps I & II are operating to supply twice the amount of volume for fast speed.	Fails open	The P.A.T. system has not turned on pump II therefore the operation will be normal, speed will be normal speed.	No effect.	3
			Fails closed	Functions will always be operated at normal speed. Cannot go to high speed.	No effect.	3

Table 4. Mechanical FMEA – Mechanical and Hydraulic System						Pages 16 to 34
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 45268 sht 1 & 2, 45009 5905-01 sht. 1, 6020-01 sht. 1 Reference: Fig. 1, 3 and 4	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
Y915	Solenoid valve	When the pressure in the system increases above 320 bar this valve shifts to relieve the pressure in the system so that fast speed does not become super fast speed.	a. Fails shifted fast speed b. Contamination on the seat, broken return spring c. N/A d. Visual e. Move the control lever back f. 5 seconds g. 3 seconds Fails shifted to normal speed.	The crane will slowly begin to run to a very fast speed. Operator will notice functions are faster than normal and slow the movement by easing back on the control lever. Corrective action prevents the fast speed condition. Cannot run in fast speed.	No effect. Correcting action prevents fast speed. No effect.	3 3

Table 5. Electrical FMEA – Outrigger System						Pages 35 to 41
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 99707764175, 1505-01 sht. 1 Reference: None	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	CSS	Control and Service System that controls the undercarriage functions including the outrigger system.	Unsolicited command	CSS could initiate or continue a crane motion (outriggers) in an uncommanded direction. The superstructure is in stowed position and any unsolicited command will not tip the machine over. Once the outriggers are set the engine is turned off preventing any outrigger motion via the hyd. pump.	No effect.	3
			Loss of output	Loss of monitoring capability of the outriggers. Delay in operation.	No effect.	3
None	Outrigger pressure sensor (4)	Supplies pressure inputs to the CSS for monitoring of the outrigger hydraulic pressure.	Erroneous output	Input to the CSS that shows the pressure in the cylinders greater than actual could lead to toppling the crane. See groundrule 3b.	No effect	3
			No output	Loss of monitoring capability of the outriggers. Delay in operation.	No effect.	3
None	Change over switch	Selects either ground or superstructure operation.	Fails closed ground position	Can only run ground functions.	No effect.	3
			Fails closed superstructure position	Can only run any superstructure function along with driving and outrigger operation from the cab.	No effect.	3
			Fails open	Unable to operate any superstructure or ground function.	No effect.	3

Table 5. Electrical FMEA – Outrigger System					Pages 35 to 41	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 99707764175, 1505-01 sht. 1 Reference: None	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S611	Rocker switch	Right side of vehicle. Selects outriggers, or outriggers beams. Selects one or the other.	Fails closed (outrigger beams)	Cannot deploy the outriggers.	No effect.	3
			Fails closed (outriggers)	Cannot deploy the outrigger beams.	No effect.	3
			Fails open position	Cannot deploy the outriggers or outrigger beams.	No effect.	3
S616	Rocker switch	Right side of vehicle. Selects all outriggers and outrigger beams on the right side for automatic deployment or retraction of both simultaneously for automatic level control.	Fails closed (extend)	Outriggers would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed (retract)	Beams and outriggers would retract, unable to extend the beams using this switch.	No effect.	3
			Fails open	Unable to deploy the outriggers and beams simultaneously.	No effect.	3
S658	Rocker switch	Right side of vehicle Engine stop/start switch. Also provides E-Stop capability.	Fails closed start position	Possible to damage the starter.	No effect.	3
			Fails closed stop position	Unable to start the engine.	No effect.	3
			Fails open	Unable to stop or start the engine.	No effect.	3
S618	Rocker switch	Right side of vehicle Engine speed adjustment	Fails closed high engine speed position	Engine will always run at a high RPM.	No effect.	3

Table 5. Electrical FMEA – Outrigger System					Pages 35 to 41	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 99707764175, 1505-01 sht. 1 Reference: None	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/OR Personnel Safety	Crit Cat
S615	Rocker switch	Right side of vehicle Left hand front outrigger extend/retract	Fails closed low engine speed position	Engine will always run at a low RPM	No effect.	3
			Fails open	Cannot run in high or low RPM.	No effect.	3
			Fails closed extend position	Outriggers and beams would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed retract position	Beams and outriggers would retract, unable to extend the beams using this switch.	No effect.	3
			Fails open	Unable to extend or retract the outrigger cylinder.	No effect.	3
S614	Rocker switch	Right side of vehicle Left hand rear outrigger extend/retract	Fails closed extend position	Outriggers and beams would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed retract position	Beams and outriggers would retract, unable to extend the beams using this switch.	No effect.	3
			Fails open	Unable to extend or retract the outrigger cylinder.	No effect.	3
S612	Rocker switch	Right side of vehicle Right hand front extend/retract outrigger beam or outrigger, whichever was selected by S611.	Fails closed extend position	Outriggers would extend to their furthest position. Possible damage to GSE.	No effect.	3

Table 5. Electrical FMEA – Outrigger System				Pages 35 to 41		
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 99707764175, 1505-01 sht. 1 Reference: None		
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S613	Rocker switch	Right side of vehicle. Right hand rear extend/retract outrigger beam or outrigger. Whichever was selected by S611.	Fails closed retract position	Outriggers would retract, unable to extend the outriggers using this switch.	No effect.	3
			Fails open	Unable to extend or retract outrigger beam.	No effect.	3
			Fails closed extend position	Outriggers would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed retract position	Outriggers would retract, unable to extend the outriggers using this switch.	No effect.	3
S621	Rocker switch	Left side of vehicle Selects outriggers, or outriggers beams. Selects one or the other.	Fails open	Unable to extend or retract the outrigger beams.	No effect.	3
			Fails closed (outrigger beams)	Cannot deploy the outriggers.	No effect.	3
			Fails closed (outriggers)	Cannot deploy the outrigger beams.	No effect.	3
			Fails open position	Cannot deploy the outriggers or outrigger beams.	No effect.	3

Table 5. Electrical FMEA – Outrigger System				Pages 35 to 41		
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 99707764175, 1505-01 sht. 1 Reference: None		
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S626	Rocker switch	Left side of vehicle Selects all outriggers and outrigger beams on the left side for automatic deployment or retraction of both simultaneously for automatic level control.	Fails closed (extend)	Outriggers and beams would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed (retract)	Beams and outriggers would retract, unable to extend the beams using this switch.	No effect.	3
			Fails open	Unable to deploy the outriggers and outrigger beams.	No effect.	3
S659	Rocker switch	Left side of vehicle Engine stop/start switch. Also provides E-Stop capability.	Fails closed start position.	Possible to damage the starter.	No effect.	3
			Fails closed stop position	Unable to start the engine.	No effect.	3
			Fails open	Unable to stop or start the engine.	No effect.	3
S628	Rocker switch	Left side of vehicle Engine speed adjustment	Fails closed high engine speed position	Engine will always run at a high RPM.	No effect.	3
			Fails closed low engine speed position	Engine will always run at a high RPM	No effect.	3
			Fails open	Unable to run engine in high or low speed.	No effect.	3

Table 5. Electrical FMEA – Outrigger System						Pages 35 to 41
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 99707764175, 1505-01 sht. 1 Reference: None	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S625	Rocker switch	Left side of vehicle Left hand front outrigger beam or outrigger extend/retract whichever was selected by S621.	Fails closed extend position	Outriggers and beams would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed retract position	Beams and outriggers would retract, unable to extend the beams using this switch.	No effect.	3
			Fails open	Unable to extend or retract the outrigger beams.	No effect.	3
S624	Rocker switch	Left side of vehicle Left hand rear outrigger or beam outrigger extend/retract whichever was selected by S621.	Fails closed extend position	Outriggers and beams would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed retract position	Beams and outriggers would retract, unable to extend the beams using this switch.	No effect.	3
			Fails open	Unable to extend or retract the outrigger beams.	No effect.	3
S622	Rocker switch	Left side of vehicle Right hand front extend/retract outrigger.	Fails closed extend position	Outriggers would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed retract position	Outriggers would retract, unable to extend the outriggers using this switch.	No effect.	3

Table 5. Electrical FMEA – Outrigger System				Pages 35 to 41		
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 99707764175, 1505-01 sht. 1 Reference: None		
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S623	Rocker switch	Left side of vehicle. Right hand rear extend/retract outrigger.	Fails open	Unable to extend or retract the outrigger cylinder.	No effect.	3
			Fails closed extend position	Outriggers would extend to their furthest position. Possible damage to GSE.	No effect.	3
			Fails closed retract position	Outriggers would retract, unable to extend the outriggers using this switch.	No effect.	3
			Fails open	Unable to extend or retract the outrigger cylinder.	No effect.	3

PAT-GmbH
BME
Hertzstraße 32-34
D-76275 Ettlingen
Tel.: 07243-709-113
Fax.: 07243-709-495
e-mail: PAT.Service@pat-gmbh.de

SERVICE MANUAL PDC



2. SYSTEM LAYOUT

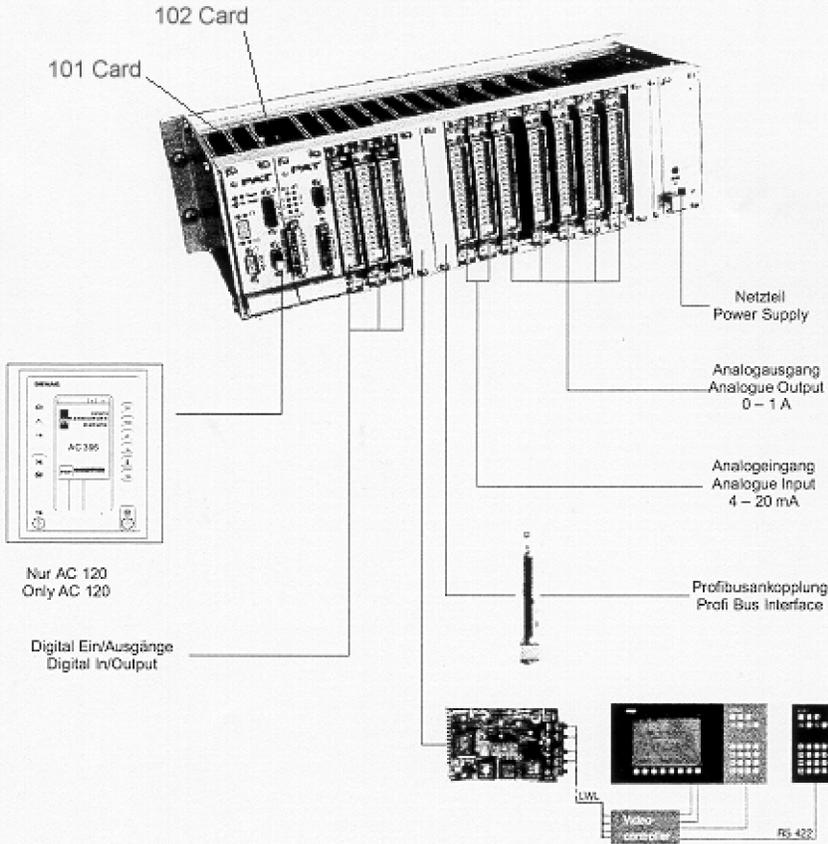


Figure 5. P.A.T. SYSTEM

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
P810	CGC	Cockpit graphic control system. Displays crane functions in the display.	Inoperable	Unable to operate the crane. Cannot input the initial crane configuration to the P.A.T. system without this system.	No effect.	3
S904	Key switch	Automatic safe load indicator (ASLI) override. Switch will cut out the safety cutouts (safety card in P.A.T. system).	Fails closed	This is a momentary switch which the key has to be held over at all times, a stuck switch will be immediately noticed when turning the key off. When the key is over an alarm also sounds, if stuck the alarm will continue to sound.	No effect.	3
			Fails open	Cannot override the ASLI. Delay in operation.	No effect.	3
B905	Buzzer	When the S904 switch is activated the buzzer will sound as long as the key is held over.	Fails off	Loss of audible alarm. Second alarm will sound E901.	No effect.	3
E901	Visual/audible alarm	When the S904 switch is activated the alarm will sound and a light in the cab will come on as long as the key is held over.	Fails off	Loss of audible alarm. Second alarm will sound B905.	No effect.	3
V907	Diodes	Restricts the current flow to the E901.	Diode No. 1 fails open	Diode No. 2 will supply power to the alarm. Still have alarm capability.	No effect.	3

Table 6. Electrical FMEA – Superstructure						Pages 43 to 62
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
A905	Pressure sensor piston end	Safety sensor providing input to the P.A.T. system The pressure is compared to data stored in the P.A.T. system so that when an overloaded condition occurs the P.A.T. system shuts down boom down, telescope out and hoist up.	a. Diode no. 1 fails short b. Internal failure c. N/A d. Visual, audible alarm e. Safe the crane f. 5 seconds g. 3 seconds	X2/3 only is powered when in an overloaded condition. Possible for the X3/2 and X3/6 to be powered. This would disable the ASLI system. The visual and acoustical alarm from E901 and B905 will operate indicating to the operator that he is in an overloaded condition. Continued operation on the crane could lead loss of load and or life unless corrective action is taken. Possible that the fuse in the CPU would blow.	No effect. Corrective action prevents loss of load and or life.	3
			Diode No. 2 fails open	Diode No. 2 will supply power to the alarm. Still have alarm capability.	No effect.	3
			Diode No. 2 fails short	When S904 is powered the crane will in ASLI override. Power will also be supplied to X2/3 which trips the ASLI relay for overloaded condition. Possible the crane cannot be put into override. Delay in operation.	No effect.	3
			Erroneous/no output	Possible for input to the P.A.T. system that shows the load weight lower than actual. Other sensors (proximity switches, boom angle and boom percent) will show if it was in an overload condition.	No effect.	3

Table 6. Electrical FMEA – Superstructure				Pages 43 to 62		
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5		
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
A906	Pressure sensor rod end	Safety sensor providing input to the P.A.T. system When booming up or down the pressure in the piston side becomes very high. This would be interpreted by the P.A.T. system as an overloaded condition. The rod side sensor is used to compensate for this and the P.A.T. system compares the two inputs and does not shut the machine down.	Erroneous/no output	The P.A.T. system could possibly interpret the data as having an overload condition and shut down the critical functions. Delay in operation.	No effect.	3
A907	Hydraulic pressure sensor	Provides the main hydraulic pressure indication to the P.A.T. system	Erroneous/no output	Pressure will not be read correctly. If low pressure were observed, the operator would shut down the crane. Delay in operation.	No effect.	3
None	Boom length sensor	Safety sensor providing input to the P.A.T. system The length out is compared to stored data in the P.A.T. system so that when an overload condition occurs the P.A.T. system shuts down boom down, telescope out and hoist up.	Erroneous/no output	Possible that input to the P.A.T. system shows the boom to be further in than actual. Other sensors (pressure sensor piston end, boom angle and boom percent) will show if it was in an overload condition.	No effect.	3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
None	Boom angle sensor	Safety sensor providing input to the P.A.T. system The angle is compared to stored data in the P.A.T. system so that when an overload condition occurs the P.A.T. system shuts down and prevents boom down, telescope out and hoist up.	Erroneous/no output	Input to the P.A.T. system that shows the boom angle greater than actual. Other sensors (proximity switches, pressure sensor piston end, boom length and boom percent) will show if it was in an overload condition.	No effect.	3
None	Boom percent sensor	Safety sensor providing input to the P.A.T. system The percent out is compared to stored data in the P.A.T. system so that when an overload condition occurs the P.A.T. system shuts down prevent boom down, telescope out and hoist up.	Erroneous/no output	Input to the P.A.T. system that shows boom to be further in than actual. Other sensors (proximity switches, pressure sensor piston end, boom angle and boom percent) will show if it was in an overload condition.	No effect.	3
A921 P.A.T. system DC 350 (PLC).	P.A.T. system	Process commands from the operator inputs through the joystick or switches and sends the command to the corresponding solenoid valve.	a. Unsolicited command b. Internal component failure or software failure of any microprocessor card. c. 00004.004 d. Visual e. If the load was near an object he can shut down the crane. f. Seconds to minutes g. Seconds to minutes	P.A.T. system could initiate or continue a crane motion in an uncommanded direction or speed possibly lowering or moving a load into an object resulting in loss (damage) to flight hardware.	Loss (damage) to flight hardware.	2

Table 6. Electrical FMEA – Superstructure				Pages 43 to 62		
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5		
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
		Detect overloaded condition (LMB card)	a. Fails to detect b. Out of calibration, erroneous output c. 00004.007 d. Visual, audible e. NA f. NA g. NA	Load indication system will be enabled, possible to go outside the load chart. Operator error.	No effect. Subsequent failure of the outrigger cylinder holding valve could result in loss of life.	1R
S903	Key actuated switch	Hoist limit switch override (cable out limit switch)	Fails open	Per NSS/GO 1740.9, there must be at least two wraps of rope (Tadano requires three) on the drum when the hook is in its extreme low position to prevent the wire rope from coming off the drum. Requires operator error.	No effect.	3
			Fails closed	Drum would stop rotating when less than 3 wraps were left on the drum. Only time you would need this off is when you're replacing the cable.	No effect.	3
A922	Swing angle transmitter	Transmits the degree of swing of the turret. Angle is shown on the cockpit graphic control display (CGC).	Erroneous/no output	Improper degree is shown on display.	No effect.	3
S701	Key switch	Changes control from the chassis to the cab.	Fails cab position	Cannot operate from the ground.	No effect.	3
			Fails ground position	Cannot operate from the cab.	No effect.	3

Table 6. Electrical FMEA – Superstructure				Pages 43 to 62		
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5		
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
V701	Diodes	Restricts the current flow to the GCG.	Fails open (any one)	There are three other diodes to restrict the current. Still have monitoring capability.	No effect.	3
			Fails short (any one)	Possible for power from the other diodes to enter the CGC through this one and damage it. May lose the CGC. Delay in operation.	No effect.	3
K812	CGC relay	Closes to provide power for the CGC display.	Coil fails open/short	Display will not be operable.	No effect.	3
			Contact fails open	Display will not be operable.	No effect.	3
			Contact fails closed	Whenever power is supplied to the cab the display will come on which is normal.	No effect.	3
	• Suppression diode	Used to dissipate the coil's energy when deenergized. Used for added reliability to the relay.	Fails open	No effect. Relay will operate normally.	No effect.	3
			Fails short	Relay coil will not energize. GCG will not work. Delay in operation.	No effect.	3
V803	Diodes	Restricts the current flow to the GCG relay K812.	No. 1 fails open	Redundant No. 2 diode will power K812.	No effect.	3
			No. 1 fails short	Possible for power from No. 2 diode to enter the CGC through No. 1 and damage it. May lose the CGC. Delay in operation.	No effect.	3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
V802	Diodes	Restricts the current flow to the GCG.	No. 2 fails open	Redundant No. 1 diode will power K812.	No effect.	3
			No. 2 fails short	Possible for power from No. 1 diode to enter the CGC through No. 2 and damage it. May lose the CGC. Delay in operation.	No effect.	3
			Fails open (any one)	There are three other diodes to restrict the current. Still have the CGC operational.	No effect.	3
			Fails short (any one)	Possible for power from the other diodes to enter the CGC through this one and damage it. May lose the CGC. Delay in operation.	No effect.	3
S810	Ignition starter switch	Starts the upper engine to run the hydraulic pumps and power the battery.	Fails open	Cannot start the engine. No hydraulic functions can be run.	No effect.	3
			Fails closed	It would burn up the starter. Damage to GSE.	No effect.	3
S823	E-Stop	Cuts power to the engine in event of an emergency.	Fails open	Cannot run the engine. No hydraulic functions can be run.	No effect.	3
			Fails closed	Cannot cut power in an emergency. Triple failure required (component failure, P.A.T. system and E-Stop).	No effect.	3

Table 6. Electrical FMEA – Superstructure				Pages 43 to 62		
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5		
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
K813	Relay	Supplies power to the A804 and A805 control engine modules to run and manage the engine.	Coil fails open/short	Cannot run the engine. No hydraulic functions can be operated.	No effect.	3
			Contact fails open	Cannot run the engine. No hydraulic functions can be operated.	No effect.	3
			Contact fails closed	When the battery switch is opened power will still be supplied to the control modules prematurely degraded their reliability.	No effect.	3
	• Suppression diode	Used to dissipate the coil's energy when deenergized. Used for added reliability to the relay.	Fails open	No effect. Relay will operate normally.	No effect.	3
			Fails short	Relay coil will not energize. Engine will not run. Delay in operation.	No effect.	3
S808	Main battery switch	Closes to provide power for the all crane controls.	Fails open	Cannot operate any function.	No effect.	3
			Fails closed	Battery will run down when the undercarriage engine is shut off.	No effect.	3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S970	Proximity switch	When the section II of the boom is fully retracted or being extended the switch will file this data into the P.A.T. system to detect overload conditions.	Fails closed	P.A.T. system will detect an irregularity and shut the system down.	No effect.	3
			Fails open	With no input into the P.A.T. system when a motion is activated the P.A.T. system will shut the system down.	No effect.	3
A917	Left hand control lever	Operate the boom extend/retract, aux winch and slewing left/right. All inputs from the controller are feed to the P.A.T. system for proper operation of the solenoid valves. Note: Rocker switch to place the controller in aux winch, telescoping or counterweight mode is located on the right hand controller.	Extend/retract controller fails high	Can only extend or retract the boom in the highest controller range. When setting or picking up the load, the crane is operated at idle speed. The highest controller speed allows the operator to continue to control the load since the accelerator will also be used to control speed.	No effect.	3
			Extend/retract controller fails low	Can only extend or retract the boom in the lowest controller range. When setting or picking up the load, the crane is operated at idle speed. The highest controller speed allows the operator to continue to control the load since the accelerator will also be used to control speed.	No effect.	3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
			Aux winch controller fails high	Can only raise or lower the rope in the highest controller range. When setting or picking up the load, the crane is operated at idle speed. The highest controller speed allows the operator to continue to control the load since the accelerator will also be used to control speed.	No effect.	3
			Aux winch controller fails low	Can only raise or lower the rope in the lowest controller range.	No effect.	3
			Swing controller fails high	Can only rotate the turret in highest controller range. When setting or picking up the load, the crane is operated at idle speed. The highest controller speed allows the operator to continue to control the load since the accelerator will also be used to control speed.	No effect.	3
			Swing controller fails low	Can only rotate the turret and boom in lowest controller range.	No effect.	3
		Fast speed pushbutton	Fails on	Can only run the selected function in high speed.	No effect.	3
			Fails off	Can only run the selected function in normal speed.	No effect.	3
		Slewing gear brake pushbutton	Fails on	Turret brake will always be engaged. Premature wear out of brake.	No effect.	3

Table 6. Electrical FMEA – Superstructure				Pages 43 to 62			
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5			
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat	
A918	Right hand control lever	Deadman switch (seat). Disables the control functions when the operator is off the seat.	Fails off	Cannot set the brake using this button, must use the footpedal brake to hold the turret.	No effect.	3	
			Fails closed	No effect. The armrest deadman is a redundant deadman switch, which will disable all controls when the operator leaves the cab.	No effect.	3	
			Fails open	Unable to perform any function.	No effect.	3	
		Deadman switch (left hand armrest). Disables the control functions when the operator lifts up the armrest to get out when he leaves the cab.	Fails closed	No effect. The seat deadman is a redundant deadman switch, which will disable all controls when the operator leaves the cab.	No effect.	3	
			Rotation transmitter B904 & B908 (vibrates the controller whenever the aux or main winch drum is turning)	Fails on	Controller will continually vibrate.	No effect.	3
				Fails off	Controller will not vibrate when the drum is turning.	No effect.	3
		Operate the main winch and boom raise/lower. All inputs from the controller are feed to the P.A.T. system for proper operation of the solenoid valves.	Main winch controller fails high	Can only raise or lower the rope in the highest controller range. When setting or picking up the load, the crane is operated at idle speed. The highest controller speed allows the operator to continue to control the load since the accelerator will also be used to control speed.	No effect.	3	

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
			Main winch controller fails low	Can only raise or lower the rope in the lowest controller range.	No effect.	3
			Boom raise/lower fails high	Can only raise or lower the boom in highest controller range. When setting or picking up the load, the crane is operated at idle speed. The highest controller speed allows the operator to continue to control the load since the accelerator will also be used to control speed.	No effect.	3
			Boom raise/lower fails low	Can only raise or lower the boom in lowest controller range.	No effect.	3
		Fast speed pushbutton	Fails closed	Can only run the selected function in high speed.	No effect.	3
			Fails open	Can only run the selected function in normal speed	No effect.	3
		Aux winch, boom extend/retract and counterweight lifting/lowering selector rocker switch	Fails winch position	Can only operate the winch.	No effect.	3
			Fails boom extend/retract position	Can only operate the boom extend/retract.	No effect.	3
			Fails counterweight position	Can only operate the counterweights.	No effect.	3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S957	Proximity switch	Deadman switch (seat). Disables the control functions when the operator is off the seat.	Fails closed	No effect. The arm rest deadman is a redundant deadman switch, which will disable all controls when the operator leaves the cab.	No effect.	3
			Fails open	Unable to perform any function.	No effect.	3
		Deadman switch (left hand armrest). Disables the control functions when the operator lifts up the armrest to get out when he leaves the cab.	Fails closed	No effect. The seat deadman is a redundant deadman switch, which will disable all controls when the operator leaves the cab.	No effect.	3
			Fails open	Unable to perform any function.	No effect.	3
		Rotation transmitter (vibrates the controller whenever the winch drum is turning)	Fails on	Controller will continually vibrate.	No effect.	3
			Fails off	Controller will not vibrate when the drum is turning.	No effect.	3
S958	Proximity switch	Indicates when the locking piston is unlocked from the 1 st boom.	Fails closed	Indication in CGC that the 1 st boom is always unlocked.	No effect.	3
			Fails open	No indication the 1 st boom is unlocked.	No effect.	3
S958	Proximity switch	Indicates when the locking piston is locked into the 1 st boom.	Fails closed	Indication in CGC that the 1 st boom is always locked.	No effect.	3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S959	Proximity switch	Indicates the position of the 1 st boom. This will send a signal to the P.A.T. system then to the CGC indicating the position of the 1 st boom. The 1 st boom has only 3 positions 0, 50 and 100 percent extended.	Fails open	No indication the 1 st boom is locked.	No effect.	3
			Fails closed one of the 3 positions	Indication in CGC that the 1 st boom is in the wrong position.	No effect.	3
S969	Proximity switch	Indicates the 3 rd and 4 th booms are retracted.	Fails open	No indication of the 1 st boom position.	No effect.	3
			Fails closed	Indication in CGC that the 3 rd and 4 th booms are always retracted.	No effect.	3
			Fails open	No indication that the 3 rd and 4 th booms have been retracted.	No effect.	3
K913	Relay	Controlled by the LMB card. When overloaded condition occurs it cuts out “hoist up” operations for both main winch.	Coil fails open/short	Unable to “hoist up”.	No effect.	3
			Contact fails open	Unable to “hoist up”.	No effect.	3
			Contact fails closed	Loss of safety device. Y901 valve will prevent hoist movement.	No effect.	3
	• Suppression diode	Used to dissipate the coil's energy when deenergized. Used for added reliability to the relay.	Fails open	No effect. Relay will operate normally.	No effect.	3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
K965	Relay	Controlled by the LMB card. When overloaded condition occurs it cuts out “hoist up” operations for the aux winch.	Fails short	Relay coil will not energize. Unable to cut out “hoist up” when in an overloaded condition. P.A.T. system will indicate in an overloaded condition and the operator will control the load.	No effect.	3
			Coil fails open/short	Unable to “hoist up”.	No effect.	3
			Contact fails open	Unable to “hoist up”.	No effect.	3
			Contact fails closed	Loss of safety device. Y901 valve will prevent hoist movement.	No effect.	3
			Fails open	No effect. Relay will operate normally.	No effect.	3
	Fails short	Relay coil will not energize. Unable to cut out “hoist up” when in an overloaded condition. P.A.T. system will indicate in an overloaded condition and the operator will control the load.	No effect.	3		
S938	Limit switch	Prevents the rope of the main hoist from unwinding off the drum.	Fails closed	Main drum would not rotate.	No effect.	3
	• Suppression diode	Used to dissipate the coil's energy when deenergized. Used for added reliability to the relay.	Fails open	No effect. Relay will operate normally.	No effect.	3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S939	Limit switch	Prevents the rope of the aux hoist from unwinding off the drum.	Fails open	Per NSS/GO 1740.9, there must be at least two wraps of rope (Tadano requires three) on the drum when the hook is in its extreme low position to prevent the wire rope from coming off the drum. Requires operator error.	No effect.	3
			Fails closed	Aux drum would not rotate.	No effect.	3
			Fails open	Per NSS/GO 1740.9, there must be at least two wraps of rope (Tadano requires three) on the drum when the hook is in its extreme low position to prevent the wire rope from coming off the drum. Requires operator error.	No effect.	3
S925	Rocker switch	Telescope emergency enable switch. Sets the controls for manually telescoping the individual boom sections.	Fails closed	The system will continually be setup to allow manual boom telescoping.	No effect.	3
			Fails open	Cannot move the booms manually.	No effect.	3
S934	Rocker switch	Used with S909, S910 and S911 when extending or retracting boom sections in emergency mode.	Fails closed	Boom functions will be enabled. Must have two switches on to move a boom section.	No effect.	3
			Fails open	Unable to move any boom section.	No effect.	3

Table 6. Electrical FMEA – Superstructure						Pages 43 to 62
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S909	Rocker switch (emergency control)	Moves the 1 st boom section	a. Fails closed b. Welded contacts c. N/A d. Visual e. Release the rocker switch S934 f. 5 seconds g. 3 seconds	Boom function will be enabled. Whenever S934 is depressed boom 1 will move as well as the other selected boom section. Boom will continue to be raised possibly damaging flight hardware unless the operator takes correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
V903	Diodes	Prevents power entering the lines VI-SW and BR-WS-RT when using switches S910 and S911.	Fails open No. 1 diode fails open No. 1 diode fails short No. 2 diode fails open	Unable to move the boom section. Losses of telescoping control of section I from switch S909. When retracting section II (S910) power would be supplied to BR-WS- RT line which shifts valve Y953. Power would also be supplied to Y954 causing section III/IV to retract as well. Since these switches are in emergency use the operation would be stopped. Loss of telescoping control of section I from switch S909.	No effect. No effect. No effect.	3 3 3

Table 6. Electrical FMEA – Superstructure					Pages 43 to 62	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
S910	Rocker switch (emergency control)	Moves the 2 nd boom section	No. 2 diode fails short	When retracting section III/IV (S911) power would be supplied to VI-SW line which shifts valve Y954. Power would also be supplied to Y953 causing section II to retract as well. Since these switches are in emergency use the operation would be stopped.	No effect.	3
			a. Fails closed b. Welded contacts c. N/A d. Visual e. Release the rocker Switch S934 f. 5 seconds g. 3 seconds	Boom function will be enabled. Whenever S934 is depressed boom 2 will move as well as the other selected boom section Boom will continue to be raised possibly damaging flight hardware unless the operator takes correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
S911	Rocker switch (emergency control)	Moves the 3 rd and 4th boom sections	Fails open	Unable to move the boom section.	No effect.	3
			a. Fails closed b. Welded contacts c. N/A d. Visual e. Release the rocker switch S934 f. 5 seconds g. 3 seconds	Boom function will be enabled. Whenever S934 is depressed boom 2 will move as well as the other selected boom section Boom will continue to be raised possibly damaging flight hardware unless the operator takes correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
S962	Anti two blocking limit switch main winch.	Stops the winch from two blocking.	Fails open	Unable to move the boom section.	No effect.	3
			Fails closed	Boom out, hoist up and boom down will be inoperable. Delay in operation.	No effect.	3

Table 6. Electrical FMEA – Superstructure				Pages 43 to 62		
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500				Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5		
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
R910	Resistor	Resistance for S962 switch	a. Fails open b. Broken contact c. N/A d. Audible e. Release the joystick f. 5 seconds g. 3 seconds	The load could fall if the wire rope broke. An audible alarm will sound alerting the operator to take correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
S963	Anti two blocking limit switch aux winch jib.	Stops the winch from two blocking.	Fails open	Improper reading in the P.A.T. system critical functions will be stopped.	No effect.	3
			Fails closed	Boom out, hoist up and boom down will be inoperable. Delay in operation.	No effect.	3
			a. Fails open b. Broken contact c. N/A d. Audible e. Release the joystick f. 5 seconds g. 3 seconds	The load could fall if the wire rope broke. An audible alarm will sound alerting the operator to take correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
R912	Resistor	Resistance for S963 switch	Fails open	Improper reading in the P.A.T. system critical functions will be stopped.	No effect.	3
S979	Anti two blocking limit switch aux winch top jib.	Stops the winch from two blocking.	Fails closed	Boom out, hoist up and boom down will be inoperable. Delay in operation.	No effect.	3

Table 6. Electrical FMEA – Superstructure						Pages 43 to 62
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500					Drawing No.: 64175 sht 1-24, 64226, 22-001-38-0046D sht1 to 9 Reference: Fig. 5	
Find No. Part No.	Part Name	Part Function	a. Failure Mode b. Cause c. FMN d. Detection Method e. Correcting Action f. Time to Effect g. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems And/Or Personnel Safety	Crit Cat
R914	Resistor	Resistance for S979 switch	a. Fails open b. Broken contact c. N/A d. Audible e. Release the joystick f. 5 seconds g. 3 seconds	The load could fall if the wire rope broke. An audible alarm will sound alerting the operator to take correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
F803	Fuse	Opens when current is above 10 amps. Protects the P.A.T. system from overcurrent.	Fails open	Improper reading in the P.A.T. system critical functions will be stopped.	No effect.	3
			Premature operation	P.A.T. system will cut off. No functions can be performed.	No effect.	3
			Fails to operate	Overcurrent could enter the P.A.T. system causing a failure of the P.A.T. system leading to loss of some or all functions.	No effect.	3
S981	Anti two blocking limit switch winch single top jib.	Stops the winch from two blocking.	Fails closed	Boom out, hoist up and boom down will be inoperable. Delay in operation.	No effect.	3
			a. Fails open b. Broken contact c. N/A d. Audible e. Release the joystick f. 5 seconds g. 3 seconds	The load could fall if the wire rope broke. An audible alarm will sound alerting the operator to take correcting action.	No effect. Correcting action prevents damage to flight hardware.	3
	Resistor	Resistance for S981 switch	Fails open	Improper reading in the P.A.T. system, critical functions will be stopped.	No effect.	3

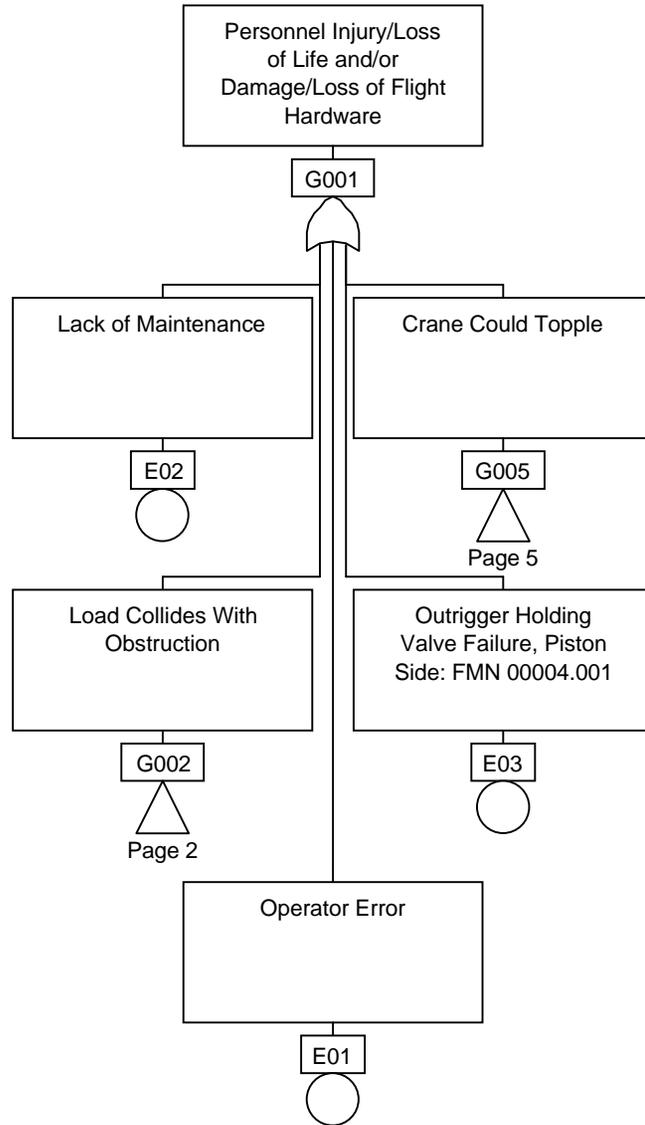
Table 7. Flexhose FMEA – Outrigger System							Pages 63 to 63	
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500							Drawing No.: 7759159 Reference: Fig. 6	
Find No. Qty NASA Part No.	MFG Name MFG Part No.	Material	Fluid Media	Inside Dia. (in.)	Max Oper/Proof/ Burst Pressure (psig)	Bend Radius (in.)	Failure Effect On System Performance, Vehicle Systems, And/Or Personnel Safety	Crit Cat
450							No effect. The holding valve will prevent the fluid from coming out of the cylinder.	3
451							No effect. The holding valve will prevent the fluid from coming out of the cylinder.	3
452							No effect. The holding valve will prevent the fluid from coming out of the cylinder.	3

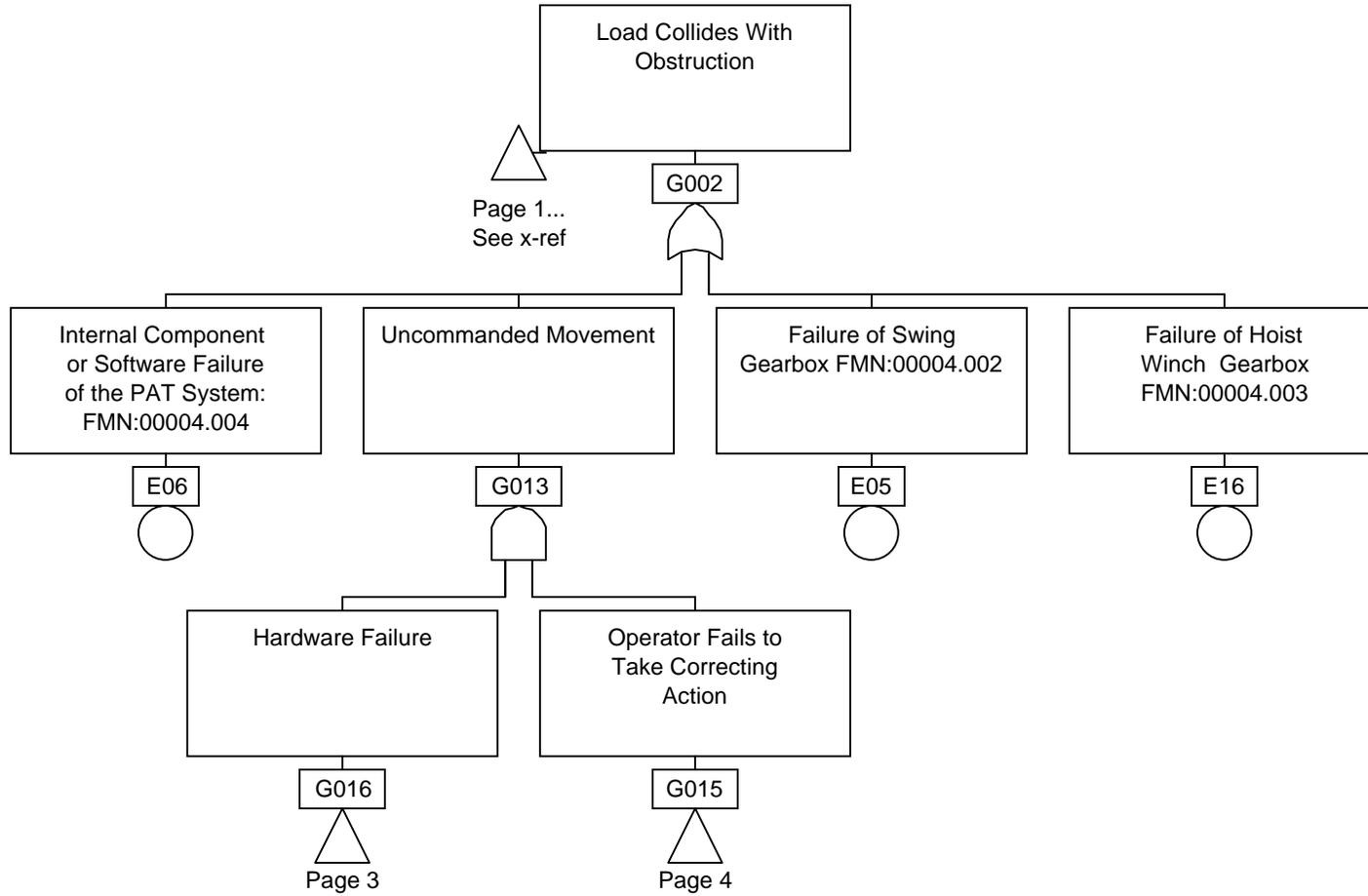
4.3 LPS/CLCS CONTROL/MONITOR REVIEW

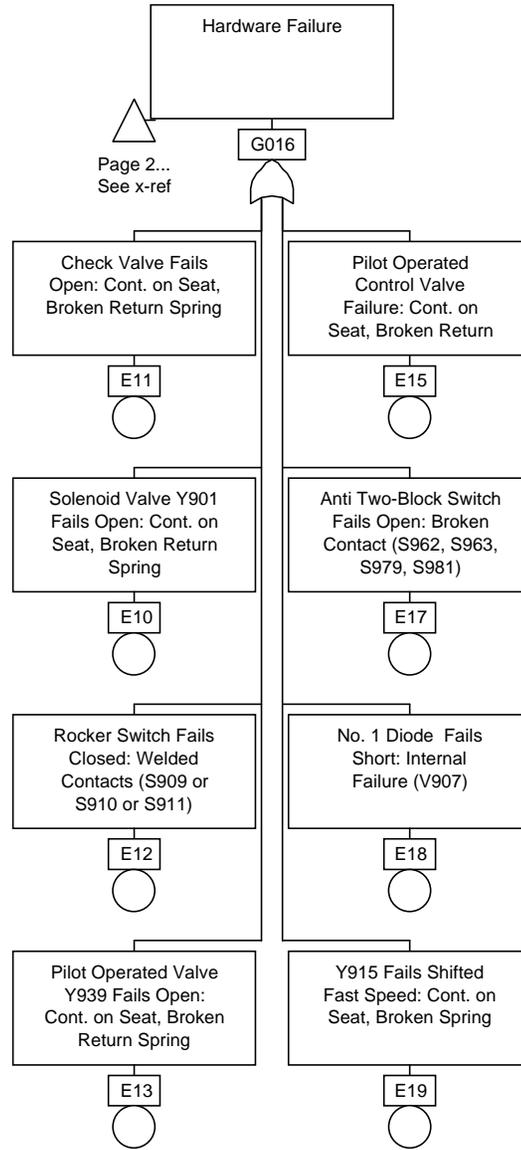
There is no LPS control/monitor interface associated with this system.

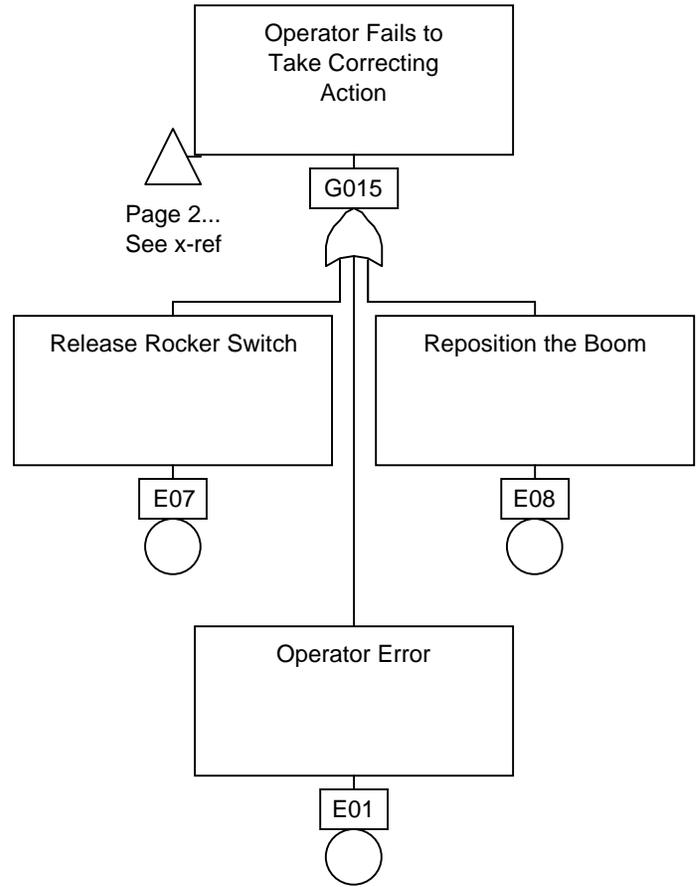
Appendix A. FAULT TREE AND HAZARD ANALYSIS

The Fault Tree Analysis, Hazard Analysis Worksheets, and Hazard Reports follow.









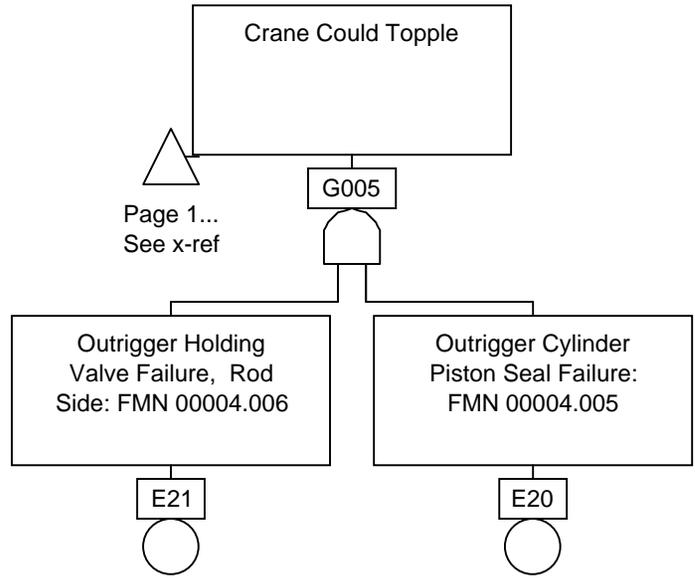


Table 8. Hazard Analysis Worksheet – Tadano ATF 1300XL Mobile Crane		Pages A-6 to A-7
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500		Location: KSC
Event No.	Event Nomenclature (Hazard Cause)	Hazard Elimination / Control Verification
E01	Operator error	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency lowering functions designed into the Tadano and any correcting action that has to be taken in the event the booms were to drift downward.
E02	Lack of maintenance	Job plan 10213 requires monthly maintenance.
E03	Outrigger holding valve failure	Initial load tests per Job Plan 11722 specifies a rated drift under rated load rated load. See CIL sheet.
E05	Failure of swing gearbox	Job Plan 10213 requires that the bolts on the turret be checked monthly for tightness. The oil level is checked semiannually. File VI requires rotation of the gearbox annually. See CIL sheet.
E06	Internal component or software failure of the PAT system	The system runs through a series of self diagnostics to detect any fault in the system. See CIL sheet.
E07	Release rocker switch	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E08	Reposition the boom	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E10	Solenoid valve Y901 fails open	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E11	Check valve fails open	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E12	Rocker switch fails closed	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.

Table 8. Hazard Analysis Worksheet – Tadano ATF 1300XL Mobile Crane		Pages A-6 to A-7
System/Subsystem: 130 Ton Tadano Mobile Crane PMN: H72-1500		Location: KSC
Event No.	Event Nomenclature (Hazard Cause)	Hazard Elimination / Control Verification
E13	Pilot operated valve Y939 fails open	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E15	Pilot operated control valve failure	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E16	Failure of the hoist winch gearbox	Job Plan 10213 requires that the winches be checked monthly for any degradation. See CIL sheet.
E17	Anti two-block switch fails open	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E18	No. 1 diode (V907) fails short	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E19	Y915 fails shifted fast speed	All operators are trained and certified (CSR-342 and 343) in the operation of the Tadano. The certs require the operator to be familiar with the E-Stop and emergency operations of the Tadano. These requirements include familiarity of the emergency functions designed into the Tadano and any correcting action that has to be taken in the event the any alarms are activated.
E20	Outrigger cylinder piston seal failure	Initial load tests per Job Plan 11722 specifies a rated drift under rated load.
E21	Outrigger holding valve failure, rod side	Initial load tests per Job Plan 11722 specifies a rated drift under rated load.

Appendix B. CRITICAL ITEMS LIST

USA Ground Operations CIL Sheet

Critical Item: Swing Gearbox
NASA Part No: None
Mfg/Part No: Tadano / 997-070-00873
System: 130 Ton Tadano Mobile Crane

Criticality Category: 2
Total Quantity: 1

Find No.	Qty	Area	PMN	Baseline	Drawing / Sheet
1	1	KSC	H72-1500	330.00	5905-01 / 1

Function:

Transfer torque from the hydraulic motor to the turret assembly.

Failure Mode No. Failure Mode	Failure Cause Failure Effect	Detection Method Time to Effect	Crit Cat
00004.002 Gear disengagement	Structural failure of the gears. Torque for stopping horizontal rotation will be lost. Boom will continue to swing until the weight of the load or object stops it. Possible loss (damage) to flight hardware.	Audible, Visual Immediate	2

ACCEPTANCE RATIONALE**Design:**

- The gears in the motor, pinion and ring gear are designed to DIN 3990 standard. The DIN standard has been verified to be equivalent to AGMA-2001.
- The design is in accordance with NSS/GO 1740.9.

Test:

- Operational check of the turret rotation is performed before use per "Pre-Operational Maintenance Mobile Equipment Checklist" KSC form 28-528 or Startup procedures as outlined in the Vendor's Operators Manual.
- OMRSD File VI requires annual operational test of turret rotation.

Inspection:

- OMRSD File VI requires annual inspection of the ring and pinion gear.

Failure History:

- Current data on test failures, unexplained anomalies, and other failures experienced during ground processing activities can be found in the PRACA database. The PRACA database was researched and the following data was found on a similar component in the critical failure mode.
- One problem report, PV-6-177113, was written against aerial manlift HE-907-287 (Condor 68) for swing gearbox failure (broken teeth) The failure was caused by operator error when the turret was rotated while the boom was restrained. No problems have occurred since this incident.

Operational Use:

Correcting Action	Timeframe
There is no action which can be taken to mitigate the failure effect.	Since no correcting action is available, timeframe does not apply.

USA Ground Operations CIL Sheet

Critical Item: Hoist Gearbox
NASA Part No: None
Mfg/Part No: Tadano / 997-073-07-188
System: 130 Ton Tadano Mobile Crane

Criticality Category: 1
Total Quantity: 2

Find No.	Qty	Area	PMN	Baseline	Drawing / Sheet
1	2	KSC	H72-1500	330.00	6020-01 / 1

Function:

Transfer torque from the hydraulic motor to rotate the cable drum. There are two hoist, one main and one auxiliary.

Failure Mode No. Failure Mode	Failure Cause Failure Effect	Detection Method Time to Effect	Crit Cat
00004.003 Gear disengagement	Structural failure of the gears. Torque for stopping drum rotation will be lost. Load will continue to drop until an object stops it. Possible loss of life or loss (damage) of a vehicle system.	Audible, Visual Immediate	1

ACCEPTANCE RATIONALE**Design:**

- Each hoist system is rated at 130 Tons.
- The gears in the motor, pinion and ring gear are designed to DIN 3990 standard. The DIN standard has been verified to be equivalent to AGMA-2001.
- The design is in accordance with NSS/GO 1740.9.

Test:

- Operational check of the winches is performed before use per "Pre-Operational Maintenance Mobile Equipment Checklist" KSC form 28-528 or Startup procedures as outlined in the Vendor's Operators Manual.
- OMRSD File VI requires performance of an annual rated load test.

Inspection:

- None

Failure History:

- Current data on test failures, unexplained anomalies, and other failures experienced during ground processing activities can be found in the PRACA database. The PRACA database was researched and no data was found on this component in the critical failure mode.

Operational Use:

Correcting Action	Timeframe
There is no action which can be taken to mitigate the failure effect.	Since no correcting action is available, timeframe does not apply.

USA Ground Operations CIL Sheet

Critical Item: P.A.T. System
NASA Part No: None
Mfg/Part No: Piech Automotive Design / DC 350
System: 130 Ton Tadano Mobile Crane

Criticality Category: 2
Total Quantity: 1

Find No.	Qty	Area	PMN	Baseline	Drawing / Sheet
A921	1	KSC	H72-1500	330.00	22-001-38-0046D / 1 TO 9

Function:

Processes commands from the operator inputs through the joystick or switches and sends the command to the corresponding solenoid valve.

Failure Mode No. Failure Mode	Failure Cause Failure Effect	Detection Method Time to Effect	Crit Cat
00004.004 Unsolicited command	Internal component failure or software failure of any microprocessor card P.A.T. could initiate or continue a crane motion in an uncommanded direction or speed possibly lowering or moving a load into an object resulting in loss (damage) to flight hardware.	Visual Seconds	2

ACCEPTANCE RATIONALE**Design:**

- The design of the overload safety devices (including the 102 card in the P.A.T. system) is subject to the directives of the Association of German Engineers (VDI) standard 3750.
- Overloads are detected by a separate card (102) that will prevent crane movements leading to instability.

Test:

- Before crane operation the system goes through a series of self diagnostics to detect any fault in the system.
- OMRSD File VI requires the performance of an annual operational test to verify proper operation of all crane controls.

Inspection:

- None

Failure History:

- Current data on test failures, unexplained anomalies, and other failures experienced during ground processing activities can be found in the PRACA database. The PRACA database was researched and no data was found on this component in the critical failure mode.

Operational Use:

Correcting Action	Timeframe
If the load was not in close proximity to an object, the operator can take correcting action by shutting down the crane.	Seconds to minutes.

USA Ground Operations 1R Non-CIL Sheet**1R Non-CIL Item:** Outrigger Cylinder Holding Valves**Criticality Category:** 1R**NASA Part No:** None**Total Quantity:** 4**Mfg/Part No:** Tadano / 997-073-06735**System:** 130 Ton Tadano Mobile Crane

Find No.	Qty	Area	PMN	Baseline	Drawing / Sheet
15	4	KSC	H72-1500	330.00	0102-03 / 1

Function:

Blocks the flow of hydraulic fluid to secure the cylinder position.

Failure Mode No. Failure Mode	Failure Cause Failure Effect	Detection Method Time to Effect	Crit Cat
00004.001 Outrigger Cylinder Holding Valves	Contamination, spring failure The outrigger cylinder will bleed down at variable rates. However, the P.A.T. system LMB card would detect out of level (crane) before tipping. Subsequent failure of the P.A.T. system could result in loss of life.	Audible, Visual Seconds	1R

ACCEPTANCE RATIONALE**Redundancy Screens:****Pass/Fail**

A Item is verifiable during normal ground operations	Pass
B Item loss is readily detectable by the ground crew	Pass
C Loss of all redundant items cannot result from a single cause	Pass

Conforms to NSTS 08080-1: Yes**Test and Inspection:**

OMRS File VI requires an annual load test.

USA Ground Operations 1R Non-CIL Sheet**1R Non-CIL Item:** Outrigger Cylinder**Criticality Category:** 1R**NASA Part No:** None**Total Quantity:** 4**Mfg/Part No:** Tadano / 997-073-09304**System:** 130 Ton Tadano Mobile Crane

Find No.	Qty	Area	PMN	Baseline	Drawing / Sheet
1	4	KSC	H72-1500	330.00	0102-03 / 1

Function:

Provide the structural support to raise and hold up the Tadano.

Failure Mode No. Failure Mode	Failure Cause Failure Effect	Detection Method Time to Effect	Crit Cat
00004.005 Internal leak (piston seal failure)	Cut or broken seal The outrigger cylinder will bleed down at variable rates; the holding valve will prevent the fluid from coming out of the cylinder. Subsequent failure of the holding valve could result in loss of life.	N/A N/A	1R

ACCEPTANCE RATIONALE**Redundancy Screens:****Pass/Fail**

A Item is verifiable during normal ground operations	Pass
B Item loss is readily detectable by the ground crew	Pass
C Loss of all redundant items cannot result from a single cause	Pass

Conforms to NSTS 08080-1: Yes**Test and Inspection:**

OMRS File VI requires annual load test.