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CLARK FORKLIFT, MODEL C-500YS200PK
FAILURE MODES AND EFFECTS ANALYSIS (FMEA)
AND CRITICAL ITEMS LIST (CIL)

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1.0 SUMMARY OF FINDINGS

1.1 System Criticality

The Clark forklift, Model C-500YS200PK, is assessed as critical. A catastrophic failure of this forklift could cause loss of life and/or flight hardware.

1.2 Mechanical Critical Items

There are no Critical items identified by the Failure Modes and Effects Analysis (FMEA).

1.3 Electrical Critical Items

There are no electrical functions associated with the mechanical forklift system. The vehicle is powered with a PERKINS DIESEL, Model 4.236. (The engine drives the hydraulic pump. Engine failure would result in loss of movement forward or reverse and of lift capability. Controlled lowering would, however, be maintained.)

1.4 Critical Flex Hoses

The FMEA identifies all flex hoses to be Critical Category 1R items.

1.5 Critical Orifices

There are no orifices identified to be a Critical Item.

1.6 Critical Filters

There are no filters identified to be a Critical Item.

1.7 Criticality Category 1R Items

There are 16 Category 1R items identified during the analysis of the critical functions. The 1R items are summarized on the Criticality Category 1R Worksheets, Section 5.2. No single credible cause was identified to result in the loss of the redundant items.

1.8 Critical Control/Monitor Functions

There are no control/monitor functions associated with this system.

1.9 Sneak Circuits Identified

There is no Sneak Circuit Analysis performed for this forklift.

1.10 Areas of Concern and Recommendations

Several recommendations are presented in Section 7.0 to improve the level of protection and minimize or negate the uncertainties identified in the failure modes and effects analysis. In summary, the recommendations address:

- Inspection Procedures
  Inclusion of Category 1R Items
- Operator Certification and Biennial Operator Refresher Training and Daily, Frequent, and Periodic inspections.

1.11 Risk Assessment

Risk assessment was performed in accordance with RECERT-42-011. The Clark forklift is considered safe to operate. The overall risk assessment is arrived as follows:

Hazard Severity Level: Catastrophic
Likelihood: Remote
Risk: Acceptable (Uncertainties Controlled/Managed)

Implementation of the recommendations would further provide control measures to improve equipment reliability and minimize residual failure risks.

2.0 SYSTEM SUMMARY

2.1 Specifications

Clark Lift
Model No. C500YS200PK Type D
Clark Equipment
Industrial Truck Division
Battle Creek, Michigan

Side Shifter
Swing Shift Mfg., Inc.
Ridgefield, WA 98642
Model No. 21793-88/15
Serial No. 89120132

Swing Shift Mfg., Inc.
Ridgefield, WA 98642
Model No. 31753-151
Serial No. 89120131

Overhead Guard/Cab
Palm Industries, Inc.
Litchfield, MN 55355
Model No. 2394405 A9900A
Serial No. M8320A2 01 90

Tires: 10:00 x 20 16 ply Pneumatic
(4 - Front)
(2 - Rear)

Forks: 8" width; 6 ft. long
Maximum fork spread 88"

NOTE: Modification of the vehicle fork system to provide side shifting capability was completed by the local equipment dealer.

2.2 Documentation List

The following documents were used in the performance of this analysis:

1. Clark; Planned Maintenance and Adjustment Procedures;

2. ASME/ANSI B56.1-1988, "Safety Standard for Low Lift and High Lift Trucks";

3. NSTS 22206 Revision D, December 10, 1992, "Requirements for Preparation and Approval of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL)."

4. RECERT-42-011, "A Standard Operating Procedure for Preparation of a Request for a Waiver/Deviation to the Mandatory Requirements of NSS/GO-1740.9B," "NASA Safety Standard for Lifting Devices and Equipment."

5. NHB 1700.1(V1-B), "NASA Safety Policy and Requirements Document," June 1993.

3.0 DEFINITIONS AND GROUND RULES

3.1 Definitions

Definitions for the preparation and clarification of the Failure Modes and Effects Analysis are listed below.

Critical Item - A critical item is defined as any one of the following:

1. A Criticality Category 1, 1S or 2 Single Failure Point.

2. A redundant hardware item where the second failure results in loss of life or flight hardware (F/H) and the item is not capable of checkout during normal ground operations (i.e., a single fault tolerant item which fails Redundancy Screen A).

Critical (Reliability Impact) - If loss or improper performance of any one of the system's functions, without regard to redundance, could result in loss of life or loss of flight hardware or damage to flight hardware, the total system is assessed as Critical. If loss or improper performance of all of the system's functions could not result if any of the aforementioned effects, the system will be considered Noncritical.

Criticality Category

Criticality	Potential Effect or Failure
1	Single failure which could result in loss of life or flight hardware.
1R	Two redundant hardware items, which if both failed, could result in loss of life or F/H (or loss of a safety or hazard monitoring system).
1S	Single failure in a safety or hazard monitoring system that could cause the system to fail to detect, combat, or operate when needed during the existence of a hazardous condition and could result in loss of life or flight hardware.
2	Single failure which could result in loss (damage) of flight hardware.
3	All others.

Failure Modes and Effects Analysis (FMEA) - A bottoms up systematic, inductive, methodical analysis performed to identify and document all identifiable failure modes at a prescribed level and to specify the resultant effect of

the modes of failure. It is usually performed to identify critical single failure point in hardware. The FMEA is subsidiary to a Hazard Analysis.

Hazard Analysis - A hazard analysis shall, as a minimum, determine potential sources of danger, identify most probable failure modes, and recommend resolutions for those conditions found in the hardware-facility-environment-human relationship that could cause loss of life, personal injury, or loss of lifting device, facility, or load.

Redundancy Screens - Redundancy screens must be addressed for all Criticality Category 1R items. Determination of "Pass," "Fail," or "N/A" (not applicable) must be documented in the summary list of 1R items. The GSE redundancy screens are defined as follows:

(a) Screen A - The redundant item is capable of being checked and verified during normal ground operations.

(b) Screen B - Loss of the redundant item is readily detectable by the operator. (This screen is not applicable to standby redundancy.)

(c) Screen C - Loss of all redundant items cannot result from a single credible cause, such as contamination. It is assumed here that loss of the redundant item(s) is not detectable by scheduled test, inspections, and maintenance nor operator's daily check prior to first use daily.

Time to Effect - The time for the failure effect to occur in this analysis is specified as follows:

ST	Short Term - Months
LT	Long Term - Years

3.2 Ground Rules

This analysis is developed in accordance with NSTS 22206, Revision D, "Requirements for Preparation and Approval of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL)."

The following ground rules and assumptions are established for this analysis:

a. For this analysis, it is assumed that forklift operators are trained and certified to operate this system.

b. This analysis assumes worst case scenario when analyzing Ground Support Equipment (GSE).

c. Passive components are not analyzed in this FMEA, but should be considered in a separate Hazard Analysis which is not part of this effort.

d. Failures of redundant items which meet the criteria described in 3.1.(a), (b) and (c) above are classified as Criticality Category 1R. Requirements for periodic test, inspection or functional validation of these items are invoked through the appropriate operation and maintenance requirements documentation. Single failure within the system controls which could cause loss of a 1R item is not be identified as 1R but is listed as a cause of the failure of the 1R items which it controls. Such system controls are included in the periodic test, inspection or functional validation requirement invoked on the 1R item.

e. Redundancy screens are addressed for all Criticality Category 1R items. Determination of "Pass," "Fail," or "N/A" (not applicable) are documented in the summary list of 1R items.

f. Failures due to human error in system setup (e.g., manual valves erroneously in the wrong position) are not considered in this FMEA.

g. This analysis assumes that all components, lubricants, and hydraulic fluids and fluid levels are as recommended by the original equipment manufacturer.

h. Fluids

1. Internal leakage is included in the assessment of the "fail open" failure mode.

2. External leakage is considered where leaks are detrimental to system operation or personnel safety.

3. All components located in the system downstream of the final filter are assessed for a possible source of contamination (e.g., transducers, temperature probes, component soft goods).

4. Filters, orifices and flex hoses are analyzed in the FMEA as part of the respective system.

i. The following classification of failure modes, as a minimum, is included in the CIL:

1. All Functional Criticality Category 1 and 2 items.

2. All Functional Criticality 1R items where (1) first failure could result in loss of life and/or flight hardware or (2) next failure of any redundant item could cause loss of operator/forklift.

3. All Functional Criticality Category 1R items that fail one or more redundancy screens.

j. This FMEA only analyzes the failure modes and effects of the forklift system and components. Other safety issues involving operating personnel qualifications, inherent hazards of a specific critical lift, and provisions for facility protection and emergency recovery during lift operations, etc., will be addressed in the specific Critical Lift Procedure. The Procedure is usually initiated and funded by the Project.

4.0 CRITICALITY ASSESSMENT

4.1 Criticality Assessment Worksheets

This system input and output functions are assessed on the following Criticality Assessment Summary sheet.

The Criticality Assessment Worksheets are performed to determine whether the GSE is Critical or Noncritical in terms of reliability impact. If loss or improper performance of any one of the system's functions, without regard to redundancy, could result in loss of life or loss of flight hardware or damage to flight hardware, the total system is assessed as Critical. If loss or improper performance of all of the system's functions could not result in any of the aforementioned effects, the system is considered Noncritical.

SYSTEM CRITICALITY ASSESSMENT SUMMARY WORKSHEET				
System Clark Forklift Model C-500YS200PK	Drawing See Figures 1 and 2	Location Building M-16, WFF	Prepared by A. Zorn, 2/20/96	
INPUT/OUTPUT	FUNCTION	TIME PERIOD	EFFECT OF LOSS/FAILURE	CRIT. CAT.
Lift System	Provides ability to raise/lower loads up to 18.95K lbs.	Pick up, transport, and deposit of the load.	Failure of the overall lift system could cause the load to drop. Could cause loss of life and/or loss of flight hardware. Multiple failure is required.	Crit.
Tilt System	Provides ability to tilt the uprights/forks.	Pick up, transport, and deposit of the load.	Failure of the tilt system could cause delay for repairs. Multiple failure is required. Delay in operations.	3
Side shift system	Provides the ability to pick up and deposit a load laterally.	Pick up, transport, and deposit of the load.	Failure of the side shift system could cause delay for repairs. Multiple failure is required. Delay in operations.	3
Hydraulic	Provides hydraulic pressure to operate lift, tilt, side shift and steering functions.	Pick up, transport, and deposit of the load.	Failure of the hydraulic system could cause loss of critical flight hardware. Multiple failure is required.	Crit.

5.0 FAILURE MODES AND EFFECTS ANALYSIS AND CIL

5.1 Mechanical FMEA Worksheets

The mechanical components of the Clark forklift, Model C-500YS200PK are identified from documents referenced in the Documentation List and are analyzed on the following worksheets.

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: Clark Fork Lift Model No. C500YS200PK
SUBSYSTEM: Lift
PROGRAM: Side Shift Hose Damage
REFERENCE: Planned Maintenance and Adjustment Procedures: Clark, January 1981 Revision

DATE: February 20, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE	FAILURE EFFECT ON SYSTEM PERFORMANCE	FAILURE EFFECT ON CRITICAL HARDWARE AND/OR PERSONNEL SAFETY	TIME TO EFFECT	CRIT CAT
1	Lift cylinder	Impeded movement of lift cylinder due to debris, scratches on the cylinder rod surface causing leaks	Intermittent fork hang-up and resultant upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failure.	LT	1R
2	Lift cylinder rod	Surface debris or scratches	Intermittent fork hang-up and resultant upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failure.	LT	1R
3	Cylinder rod seals	Surface debris	Hydraulic oil leakage. Fork hang-up and resultant upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failure.	LT	1R
4	Roller, uprights	Clearance changed as a result of stress released in the welded areas.	Fork hang-up and resultant upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failure.	LT	1R
5	Roller, uprights	Not adjusted to the rails	Intermittent fork hang-up and resultant upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failure.	ST	1R
6	Upper or lower carriage rollers, outer thrust rollers	Broken or misadjusted	Intermittent fork hang-up and resultant upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failure.	ST	1R
7	Roller shaft	Misalignment	Premature wear.	Shortened life. Delay for repairs.	LT	3

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: Clark Fork Lift Model No. C500YS200PK
SUBSYSTEM: Lift
PROGRAM: Side Shift Hose Damage
REFERENCE: Planned Maintenance and Adjustment Procedures: Clark, January 1981 Revision

DATE: February 20, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE	FAILURE EFFECT ON SYSTEM PERFORMANCE	FAILURE EFFECT ON CRITICAL HARDWARE AND/OR PERSONNEL SAFETY	TIME TO EFFECT	CRIT CAT
8	Piston head	Surface debris, paint, or scratches	Hydraulic oil leakage. Fork hang-up and resultant unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failure.	LT	1R
9	Inner rails	Distance between inner rails narrow	Intermittent fork hang-up and resultant upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failure.	LT	1R
10	Upright and tilt cylinder	Uneven test load distribution during test	Intermittent fork hang-up and resultant upright unloading.	Requires multiple failures.	ST	1R
11	Uprights	Twisted	Intermittent fork hang-up and resultant upright unloading.	Requires multiple failures.	LT	1R
12	Stop blocks	Misalignment	Unequal stop block loading.	Uncontrolled fork movement. Requires multiple failure.	LT	1R
13	Flex hoses	Leakage/rupture	Upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failures.	LT	1R
14	Flex hose retainer	Overloading	Unrestrained hose. Hydraulic oil leakage. Upright unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failures.	ST	3
15	Load back rest	Damage due to load	Premature replacement.	Shortened life. Delay for repairs.	LT	3

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: Clark Fork Lift Model No. C500YS200PK
SUBSYSTEM: Lift
PROGRAM: Side Shift Hose Damage
REFERENCE: Planned Maintenance and Adjustment Procedures: Clark, January 1981 Revision

DATE: February 20, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE	FAILURE EFFECT ON SYSTEM PERFORMANCE	FAILURE EFFECT ON CRITICAL HARDWARE AND/OR PERSONNEL SAFETY	TIME TO EFFECT	CRIT CAT
16	Cylinder base/ anchor bolts	Misalignment	Chain wear.	Delay for repair.	LT	3
17	Lift chains	Adjusting with upright forward of vertical	Intermittent fork hang-up and resultant unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failures.	ST	1R
18	Lift chain	Uneven wear/tension	Intermittent fork hang-up and resultant unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failures.	LT	1R
19	Chain anchor	Wear, damage, misalignment	Chain twisting or poor alignment.	Unbalanced load. Delay for repairs.	LT	3
20	Chain sheaves	Worn flanges	Chain side wear.	Delay for repairs.	LT	3
21	Chain retainers	Overloading	Chain unloading.	Uncontrolled fork movement/dropping the load. Requires multiple failures.	LT	1R
22	Flow control valve	Restricted flow due to debris	System inoperative.	Delay for repairs.	ST	3

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: Clark Fork Lift Model No. C500YS200PK
SUBSYSTEM: Tilt
PROGRAM: Side Shift Hose Damage
REFERENCE: Planned Maintenance and Adjustment Procedures: Clark, January 1981 Revision

DATE: February 20, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE	FAILURE EFFECT ON SYSTEM PERFORMANCE	FAILURE EFFECT ON CRITICAL HARDWARE AND/OR PERSONNEL SAFETY	TIME TO EFFECT	CRIT CAT
1	Tilt cylinder	Inadequate maintenance of cylinder and hydraulic valves	Stability determined by load weight/ distribution subsequent to failure.	Delay for repairs. Requires multiple failures.	LT	3
2	Tilt cylinder rod	Unequal adjustment	Stability determined by load weight/ distribution subsequent to failure.	Delay for repairs. Requires multiple failures.	ST	3
3	Flex hose	Leakage, rupture	Upright unloading.	Uncontrolled fork movement/dropping the load. Require multiple failure.	ST	1R

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: Clark Fork Lift Model No. C500YS200PK
SUBSYSTEM: Hydraulic
PROGRAM: Side Shift Hose Damage
REFERENCE: Planned Maintenance and Adjustment Procedures: Clark, January 1981 Revision

DATE: February 20, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE	FAILURE EFFECT ON SYSTEM PERFORMANCE	FAILURE EFFECT ON CRITICAL HARDWARE AND/OR PERSONNEL SAFETY	TIME TO EFFECT	CRIT CAT
1	Hydraulic relief valve	External leakage	Capacity limited.	Delay in operation.	ST	3
		Fail to relieve	System pressure exceeded.	System leaks. Delay in operation.	ST	3
		Fail to close	System inoperative.	Delay in operation.	ST	3
2	Sump tank filter, 10 micron, return line	Clogged sump tank filter element	Bypasses fluid flow. Unable to lower forks. Load transfer required.	Delay for repairs.	LT	3
3	Hydraulic pump	External leakage	Capacity limited.	Delay in operation.	ST	3
		Fail to operate	System inoperative.	Delay in operation.	ST	3

5.2 Criticality Category 1R Worksheets

There are sixteen (16) Category 1R items identified during the analysis of the critical output functions. The 1R items are summarized on the following Criticality Category 1R Worksheets.

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: Clark Forklift Model No. C500YS200PK
SUBSYSTEM: Lift
PROGRAM: Side Shift Hose Damage
REFERENCE: NSTS 22206, Revision D

DATE: February 21, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE(S)	FAILURE EFFECT	REDUNDANCY SCREENS		TEST AND INSPECTION REQUIREMENT(S)
				PASS	FAIL	
1	Lift cylinder	Impeded movement due to surface debris	Up-mode: Unable to operate. Down-mode: Uncommanded lowering.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
2	Lift cylinder rod	Surface debris, scratches	Hydraulic oil leakage. Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
3	Cylinder rod seals	Surface debris	Hydraulic oil leakage. Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
4	Roller uprights	Clearance change	Intermittent fork hang-up and resultant unloading.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: Clark Forklift Model No. C500YS200PK
SUBSYSTEM: Lift
PROGRAM: Side Shift Hose Damage
REFERENCE: NSTS 22206, Revision D

DATE: February 21, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE(S)	FAILURE EFFECT	REDUNDANCY SCREENS		TEST AND INSPECTION REQUIREMENT(S)
				PASS	FAIL	
5	Roller uprights	Not adjusted	Intermittent fork hang-up and resultant unloading.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
6	Upper or lower carriage rollers, outer thrust rollers	Broken or misadjusted	Intermittent fork hang-up and resultant unloading.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
8	Piston head	Surface debris, scratches	Hydraulic oil leakage. Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
9	Inner rails	Distance between inner rails narrow	Intermittent fork hang-up and resultant unloading.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: Clark Forklift Model No. C500YS200PK
SUBSYSTEM: Lift
PROGRAM: Side Shift Hose Damage
REFERENCE: NSTS 22206, Revision D

DATE: February 21, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE(S)	FAILURE EFFECT	REDUNDANCY SCREENS		TEST AND INSPECTION REQUIREMENT(S)
				PASS	FAIL	
10	Upright and tilt cylinder	Uneven test load distribution during setup or maintenance/ repair lead to improper adjustment	Unbalanced lift could drop load.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
11	Uprights	Twisted	Intermittent fork hang-up and resultant unloading.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
12	Stop blocks	Misalignment	Unequal stop block loading.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
13	Flex hoses	Leakage, rupture	Hydraulic oil leakage. Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: Clark Forklift Model No. C500YS200PK
SUBSYSTEM: Lift
PROGRAM: Side Shift Hose Damage
REFERENCE: NSTS 22206, Revision D

DATE: February 21, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE(S)	FAILURE EFFECT	REDUNDANCY SCREENS		TEST AND INSPECTION REQUIREMENT(S)
				PASS	FAIL	
14	Flex hose retainer	Overloading	Unrestrained hose. Hydraulic oil leak. Upright unloading.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
17	Lift chains	Adjusted with upright forward of vertical	Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
18	Lift chains wear	Uneven wear, tension	Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load. Requires multiple failures.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.
21	Chain retainers	Overloading	Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: Clark Forklift Model No. C500YS200PK
SUBSYSTEM: Tilt
PROGRAM: Side Shift Hose Damage
REFERENCE: NSTS 22206, Revision D

DATE: February 21, 1996
PREPARED BY: A. Zorn

NO.	PART NAME	FAILURE CAUSE(S)	FAILURE EFFECT	REDUNDANCY SCREENS		TEST AND INSPECTION REQUIREMENT(S)
				PASS	FAIL	
3	Flex hose -tilt	Leakage, rupture	Hydraulic oil leakage. Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load.	A B C		• Operator inspection prior to first use daily. • Frequent inspection monthly. • Periodic inspection annually.

6.0 RATIONALE FOR ACCEPTABILITY

No mechanical critical items were identified by the FMEA. Note that the Criticality 1R items are acceptable in that each item is capable of checkout during normal ground operations. Documentation of the following data elements: Design, Test and Inspection, Failure History and Operational Use are provided to categorize the analysis for risk assessment.

6.1 Design

Forklift design is in accordance with ASME/ANSI B56.1-1988, "Safety Standard for Low Lift and High Lift Trucks," to minimize the probability of occurrence of the critical failure modes and causes.

6.2 Test and Inspection

- Operator inspection prior to first use daily.
- Frequent inspection monthly.
- Periodic inspection annually.

6.3 Failure History

No significant failure history to impact FMEA.

6.4 Operational Use

6.4.1 Failures due to human error are not considered in the performance of a failure modes and effects analysis.

The inclusion here of the following paragraph reproduced from ASME/ANSI B56.1-1988 is considered most appropriate:

> The use of powered industrial trucks is subject to certain hazards that cannot be completely eliminated by mechanical means, but the risks can be minimized by the exercise of intelligence, care, and common sense. It is therefore essential to have competent and qualified operators, thoroughly trained in the safe operation of the equipment and the handling of the loads. Serious hazards are overloading, instability of the load, obstruction to the free passage of the load, poor maintenance, and using equipment for a purpose for which it was not intended or designed.

7.0 AREAS OF CONCERN AND RECOMMENDATIONS

The following recommendations are provided to further improve operational safety and reliability of this equipment for flight project support.

7.1 It is recommended that:

7.1.1 critical forklift inspections be performed by qualified, designated personnel;

7.1.2 the sixteen (16) Criticality Category 1R items identified during this analysis be included in the Periodic inspection annually; and,

7.1.3 such inspections should be performed according to approved technical operating procedures.

7.2 No critical items were identified as a result of this analysis. There are numerous redundant hardware items. All are capable of checkout during normal operations. The time for failure to occur for 11 of the 29 components analyzed herein was, however, determined to be "Short Term," i.e., months. Implementation of the aforementioned scheduled test and inspections will mitigate the respective failure modes. Certain hazards cannot be eliminated by mechanical means. Operators thoroughly trained in the safe operation of the equipment can minimize the risk of human error. The present forklift operator refresher course interval is two years, based on the recommendations of both the forklift manufacturer and the National Safety Council.

7.3 It is recommended that appropriate, pertinent portions of this analysis pertaining to:

- operator training and biennial refresher training; and
- the significance of operator inspections prior to first use daily, Frequent monthly inspection and Periodic inspection annually.

be included in the next revision of the Engineering Services Division Safety Manual.

7.4 The act of stacking loads or setting forks on other surfaces has been identified as a potential cause of sudden upright unloading and could result in hose damage. It is recommended that means of detecting reverse fork loading be considered to alert the operator as to possible unloading of the uprights.

8.0 RISK ASSESSMENT

Risk assessment was performed in accordance with Figure 2, reproduced from RECERT-42-011, see Section 2.2, Documentation List, No. 8. The rationale for retaining the critical systems was developed based on:

- Consideration of the aforementioned parameters: Design, Test, Inspection, Failure History and Operational Use.

Definitions of the "Hazard Severity Levels" and "Likelihood of Occurrence" are self-explanatory (see Figure 2).

Hazard Severity Level : Catastrophic
Likelihood : Remote
Risk : Acceptable (Uncertainties Controlled/Managed)

GSFC RECERTIFICATION
HAZARD SEVERITY LEVELS VERSUS LIKELIHOOD OF OCCURRENCE FOR RISK ASSESSMENT*

		HAZARD* SEVERITY LEVELS		
		MARGINAL (COULD RESULT IN MINOR INJURY OR MINOR FLIGHT HARDWARE DAMAGE)	CRITICAL (COULD RESULT IN SERIOUS INJURY OR SIGNIFICANT FLIGHT HARDWARE DAMAGE)	CATASTROPHIC (COULD RESULT IN FATALITY OR LOSS OF FLIGHT HARDWARE)
LIKELIHOOD	*PROBABLE (EXPECTED TO HAPPEN)*	UNACCEPTABLE RISK (UNCERTAINTIES EXIST)	UNACCEPTABLE RISK (UNCERTAINTIES EXIST)	UNACCEPTABLE RISK (UNCERTAINTIES EXIST)
	OCCASIONAL (COULD HAPPEN)	ACCEPTABLE RISK (MINOR UNCERTAINTIES EXIST)	UNACCEPTABLE RISK (MINOR UNCERTAINTIES EXIST)	UNACCEPTABLE RISK (MINOR UNCERTAINTIES EXIST)
	REMOTE (NOT EXPECTED TO HAPPEN)	ACCEPTABLE RISK (UNCERTAINTIES CONTROLLED/ MANAGED)	ACCEPTABLE RISK (UNCERTAINTIES CONTROLLED/ MANAGED)	ACCEPTABLE RISK (UNCERTAINTIES CONTROLLED/ MANAGED)

* THIS GSFC RECERT RISK ASSESSMENT MATRIX IS A MODIFIED VERSION OF FIGURE G-1, APPENDIX G, IN NHB 1700.1(V1-B), "NASA SAFETY POLICY AND REQUIREMENTS DOCUMENT," JUNE 1993.

Figure 1