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YALE FORKLIFT, MODEL ERC100HBN36SE096
FAILURE MODES AND EFFECTS ANALYSIS (FMEA)
AND CRITICAL ITEMS LIST (CIL)

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## LIST OF ATTACHMENTS


A- NPR 8715.3 Section 3.6 "Hazard Assessment"
B- NSI Document #40-06-303-1, "Periodic Inspection Report for YALE Forklift, S/N N411350.

# 1.0 SUMMARY OF FINDINGS

## 1.1 System Criticality

The YALE forklift, Model ERC100HBN36SE096, 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 BATTERY powered. Battery discharge or failure would result in loss 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 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:

- Inclusion of Category 1R Items IN inspection Procedure.
- Operator Certification per NASA STD 8719.9 para 12.6.4 and refresher on annual basis for critical lift operators.

### 1.11 Risk Assessment

Risk assessment was performed in accordance with NASA Standard 8719.9. The YALE forklift is considered safe to operate. The overall risk assessment is arrived as follows:

Hazard Severity Level: CRITICAL Class II
Likelihood: Improbable/Remote
Risk: RAC#5 Acceptable

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

## 2.0 SYSTEM SUMMARY

### 2.1 Specifications

See Section 2.2, item 1 below.

### 2.2 Documentation List

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

1. YALE MATERIALS HANDLING CORP. SERVICE AND PARTS MANUAL FOR BATTERY POWERED FORKLIFT, MODEL ERCH-B;
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. NASA Standard 8719.9, latest Revision "Standard for Lifting Devices and Equipment".
5. NPR 8715.3, latest Revision "NASA Safety Manual".

6. GMI 1710.6, "Certification and Re-certification of Lifting Devices and Equipment and Critical Lift Requirements", latest revision.
7. Maintenance History File.

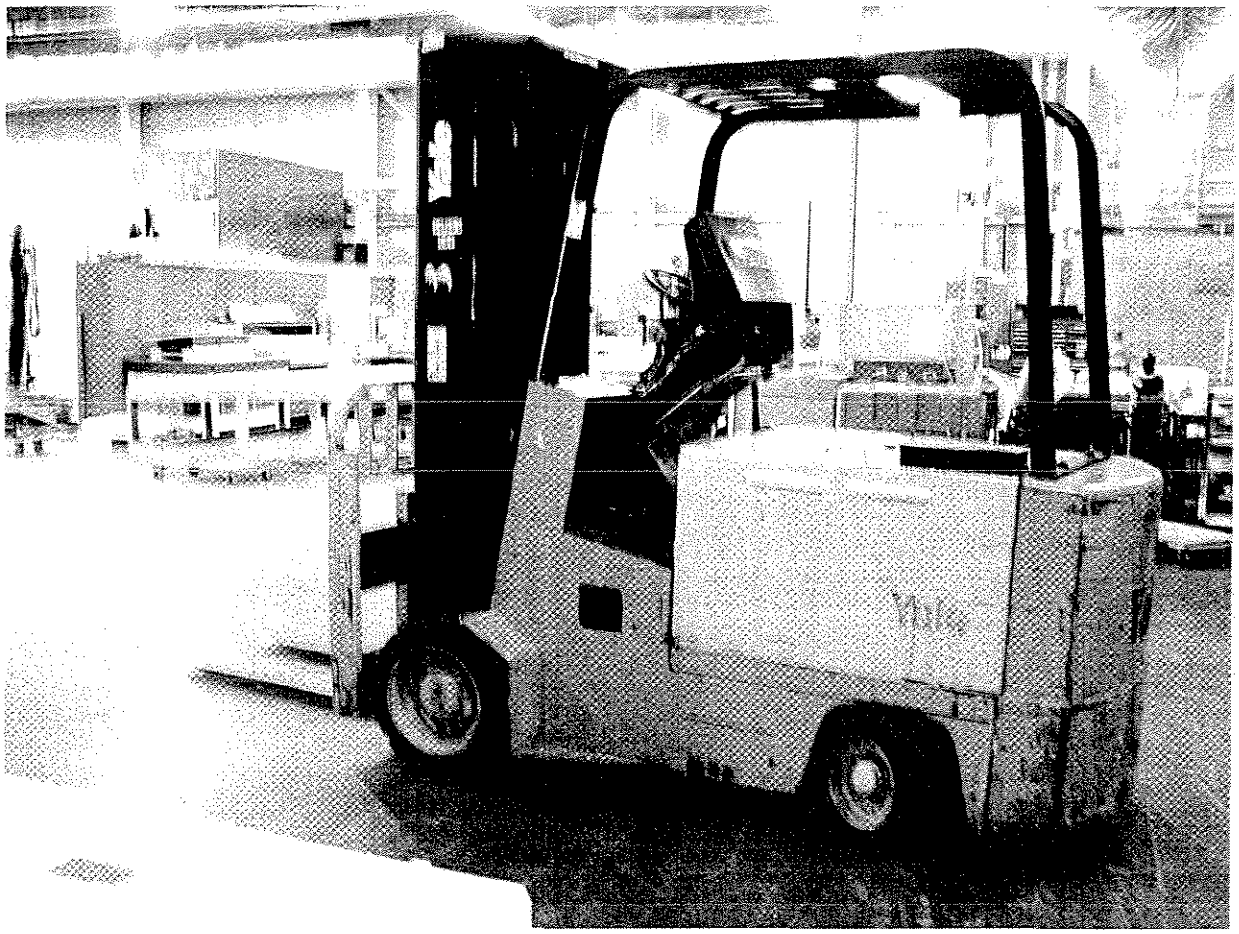

Figure 1

YALE FORKLIFT Model ERC100HBN36SE096

# 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 vehicle 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 vehicle (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 lifting device operators are trained and certified to operate this lift 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/lifting device.

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, if warranted, and developed by integration support personnel.

## 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 Non-critical 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<br>YALE Forklift<br>Model #<br>ERC100HBN36SE096 | Drawing<br>See Figure 1 ,<br>page 4 | Location<br>Building 7,10,15<br>and 29 | Prepared by E. Hemminger 9/16/04 | |
| INPUT/OUTPUT | FUNCTION | TIME PERIOD | EFFECT OF LOSS/FAILURE | CRIT. CAT. |
| Lift System | Provides ability to raise/lower loads up to 10K 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. 1 |
| 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 |
| 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. | Crit. 1 |

# 5.0 FAILURE MODES AND EFFECTS ANALYSIS AND CIL

## 5.1 Mechanical FMEA Worksheets

The mechanical components of the YALE forklift, Model ERC100HBN36SE096 are identified from documents referenced in the Documentation List and are analyzed on the following worksheets.

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: Service and Parts Manual for Model ERCH-B YALE Fork Lift, March 1986

DATE: September 2004
PREPARED BY: E. Hemminger

| 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 | Hoist Cylinder | Impeded movement of hoist 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 | Hoist 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. | ST | 1R |

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: Service and Parts Manual for Model ERCH-B YALE Fork Lift, March 1986

DATE: September 2004
PREPARED BY: E. Hemminger

| NO. | PART NAME | FAILURE CAUSE | FAILURE EFFECT ON SYSTEM PERFORMANCE | FAILURE EFFECT ON CRITICAL HARDWARE AND/OR PERSONNEL SAFETY | TIME TO EFFECT | CRIT CAT |
|---|---|---|---|---|---|---|
| 6 | Upper/lower carriage rollers, outer thrust rollers | Broken or misadjusted | Intermittent fork hang-up and resultant upright unloading. | Uncontrolled fork movement/dropping the load. | ST | 1R |
| 7 | Roller shaft | Misalignment | Premature wear. | Shortened life. Delay for repairs. | LT | 3 |
| 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. | 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 |

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: Service and Parts Manual for Model ERCH-B YALE Fork Lift, March 1986

DATE: September 2004
PREPARED BY: E. Hemminger

| NO. | PART NAME | FAILURE CAUSE | FAILURE EFFECT ON SYSTEM PERFORMANCE | FAILURE EFFECT ON CRITICAL HARDWARE AND/OR PERSONNEL SAFETY | TIME TO EFFECT | CRIT CAT |
|---|---|---|---|---|---|---|
| 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 |
| 16 | Cylinder base/bolts | Misalignment | Chain wear. | Delay for repair. | LT | 3 |

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: Service and Parts Manual for Model ERCH-B YALE Fork Lift, March 1986

DATE: September 2004
PREPARED BY: E. Hemminger

| NO. | PART NAME | FAILURE CAUSE | FAILURE EFFECT ON SYSTEM PERFORMANCE | FAILURE EFFECT ON CRITICAL HARDWARE AND/OR PERSONNEL SAFETY | TIME TO EFFECT | CRIT CAT |
|---|---|---|---|---|---|---|
| 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: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Tilt
REFERENCE: Service and Parts Manual for Model ERCH-B YALE Fork Lift, March 1986

DATE: September 2004
PREPARED BY: E. Hemminger

| 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. | ST | 1R |

FAILURE MODE AND EFFECTS ANALYSIS (FMEA) WORKSHEET

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Hydraulic
REFERENCE: Service and Parts Manual for Model ERCH-B YALE Fork Lift, March 1986

DATE: September 2004
PREPARED BY: E. Hemminger

| 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: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: NSTS 22206, Revision D

DATE: September 2004
PREPARED BY: E. Hemminger

| 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: Uncontrolled lowering. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• 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<br>B<br>C | | • Operator inspection prior to first use daily.<br>• 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<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: NSTS 22206, Revision D

DATE: September 2004
PREPARED BY: E. Hemminger

| NO. | PART NAME | FAILURE CAUSE(S) | FAILURE EFFECT | REDUNDANCY SCREENS | | TEST AND INSPECTION REQUIREMENT(S) |
|---|---|---|---|---|---|---|
| | | | | PASS | FAIL | |
| 4 | Roller uprights | Clearance change | Intermittent fork hang-up and resultant unloading. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 5 | Roller uprights | Not adjusted | Intermittent fork hang-up and resultant unloading. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>•Periodic inspection annually. |
| 6 | Upper or lower carriage rollers, outer thrust rollers | Broken or misadjusted | Intermittent fork hang-up and resultant unloading. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 7 | Piston head | Surface debris, scratches | Hydraulic oil leakage.<br>Intermittent fork hang-up/upright | A<br>B<br>C | | • Operator inspection prior to first use daily. |

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: NSTS 22206, Revision D

DATE: September 2004
PREPARED BY: E. Hemminger

| NO. | PART NAME | FAILURE CAUSE(S) | FAILURE EFFECT | REDUNDANCY SCREENS PASS | REDUNDANCY SCREENS FAIL | TEST AND INSPECTION REQUIREMENT(S) |
|---|---|---|---|---|---|---|
| | | | unloading. Uncontrolled fork movement/could result in dropping the load. | | | • Periodic inspection annually. |
| 8 | Inner rails | Distance between inner rails narrow | Intermittent fork hang-up and resultant unloading. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 9 | Upright and tilt cylinder | Uneven test load distribution during setup or maintenance/ repair lead to improper adjustment | Unbalanced lift could drop load. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 10 | Uprights | Twisted | Intermittent fork hang-up and resultant unloading. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: NSTS 22206, Revision D

DATE: September 2004
PREPARED BY: E. Hemminger

| NO. | PART NAME | FAILURE CAUSE(S) | FAILURE EFFECT | REDUNDANCY SCREENS | | TEST AND INSPECTION REQUIREMENT(S) |
|---|---|---|---|---|---|---|
| | | | | PASS | FAIL | |
| 11 | Stop blocks | Misalignment | Unequal stop block loading. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 12 | Flex hoses | Leakage, rupture | Hydraulic oil leakage.<br>Intermittent fork hang-up/upright unloading.<br>Uncontrolled fork movement/could result in dropping the load. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 13 | Flex hose retainer | Overloading | Unrestrained hose.<br>Hydraulic oil leak.<br>Upright unloading. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 14 | Lift chains | Adjusted with upright forward of vertical | Intermittent fork hang-up/upright unloading.<br>Uncontrolled fork movement/could result | A<br>B<br>C | | • Operator inspection prior to first use daily. |

CRITICALITY CATEGORY 1R WORKSHEETS

SYSTEM: YALE Fork Lift Model No. ERC100HBN36SE096
SUBSYSTEM: Lift
REFERENCE: NSTS 22206, Revision D

DATE: September 2004
PREPARED BY: E. Hemminger

| NO. | PART NAME | FAILURE CAUSE(S) | FAILURE EFFECT | REDUNDANCY SCREENS PASS | REDUNDANCY SCREENS FAIL | TEST AND INSPECTION REQUIREMENT(S) |
|---|---|---|---|---|---|---|
| | | | in dropping the load. | | | • Periodic inspection annually. |
| 15 | 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<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 16 | Chain retainers | Overloading | Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |
| 17 | Flex hose - tilt | Leakage, rupture | Hydraulic oil leakage. Intermittent fork hang-up/upright unloading. Uncontrolled fork movement/could result in dropping the load. | A<br>B<br>C | | • Operator inspection prior to first use daily.<br>• Periodic inspection annually. |

## 6.0 RATIONALE FOR ACCEPTABILITY

No mechanical critical items were identified by the FMEA. Justification for retaining any of the items analyzed is, therefore, not required in accordance with the instructions provided in NSTS 22206, Revision D. 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

- Required operator inspection prior to use.
- Periodic inspection annually per NSI Document #40-06-300, "Periodic Inspection Procedure for 10,000#, YALE, SN/ N411350".

### 6.3 Failure History

No Failures have been experienced.

### 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 careful operators, physically and mentally fit, 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 All Criticality Category 1R items identified in this analysis should be included in the Periodic inspection.

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

7.2 No critical items were identified as a result of this analysis. Numerous redundant hardware items were identified and all are capable of checkout during normal operations. The time for failure to occur for 13 of the 31 components analyzed herein was determined to be "Short Term," i.e., months. Implementation of the aforementioned scheduled test and inspections are recommended to mitigate these 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. Present operator certification training is performed per NASA STD 8719.9 para 12.6.4. Certification training is required every three years with refresher training annually for critical lift operators.

It is recommended that forklift operators, performing critical lifts, continue to receive re-certification training on an annual basis.

7.3 The act of stacking loads or setting forks on other surfaces has been identified as the cause of upright reverse loading which can result in hydraulic hose damage. It is recommended that, means of detecting reverse fork loading, be included in operator training and certification.

## 8.0 RISK ASSESSMENT

Risk assessment was performed in accordance with NPR 8715.3 Figure 3.2, "Risk Assessment Matrix".

Definitions of the "Hazard Severity Levels" and "Likelihood of Occurrence" are defined in the above reference document.

Hazard Severity Level: Class II Critical
Likelihood: Improbable/Remote
Risk: RAC #5 Acceptable (Uncertainties Controlled/Managed)

# ATTACHMENT- A

## NPR 8715.3 Section 3.6 "Hazard Assessment"

The hazard assessment process is a principal factor in the understanding and management of technical risk. Hazards are identified and resultant risks are assessed by considering probability of occurrence and severity of consequence. Risk may be assessed qualitatively or quantitatively. System safety is an integral part of the overall program risk management decision process. A sample format to document the risk process is provided in Appendix E.

3.6.1 Risk Assessment Code (RAC). The RAC is a numerical expression of comparative risk determined by an evaluation of both the potential severity of a condition and the probability of its occurrence. RAC`s are assigned a number from 1 to 7 in a risk matrix (see figure 3.2.). The RAC number will serve as a means to prioritize corrective actions, e.g., RAC 1 is unacceptable and mitigation actions must be taken immediately or operations terminated, RAC 2`s must be addressed before RAC 3`s, etc. (Requirement 25246). Differences between higher number RAC`s (beyond 4) probably cannot be discerned due to low risk levels. The cognizant safety and program officials may approve variations to the matrix.

3.6.1.1 Severity is an assessment of the worst potential consequence, defined by degree of injury or property damage, which could occur. The severity classifications are defined as follows:

Class I - Catastrophic - A condition that may cause death or permanently disabling injury, facility destruction on the ground, or loss of crew, major systems, or vehicle during the mission.

Class II - Critical - A condition that may cause severe injury or occupational illness, or major property damage to facilities, systems, equipment, or flight hardware.

Class III - Moderate - A condition that may cause minor injury or occupational illness, or minor property damage to facilities, systems, equipment, or flight hardware.

Class IV - Negligible - A condition that could cause the need for minor first aid treatment though would not adversely affect personal safety or health. A condition that subjects facilities, equipment, or flight hardware to more than normal wear and tear.

3.6.1.2 Probability is the likelihood that an identified hazard will result in a mishap, based on an assessment of such factors as location, exposure in terms of cycles or hours of operation, and affected population. The following is an example of Probability Estimation:

A - Likely to occur immediately. ($X > 10^{-1}$)

B - Probably will occur in time. ($10^{-1} \geq X > 10^{-2}$)

C - May occur in time. ($10^{-2} \geq X > 10^{-3}$)

D - Unlikely to occur. ($10^{-3} \geq X > 10^{-6}$)

E - Improbable to occur. ($10^{-6} \geq X$)

(derived from Mil Std 882-System Safety Program Requirements)

| | Probability Estimate | | | | |
|---|---|---|---|---|---|
| Severity Class | A | B | C | D | E |
| I | 1 | 1 | 2 | 3 | 4 |
| II | 1 | 2 | 3 | 4 | 5 |
| III | 2 | 3 | 4 | 5 | 6 |
| IV | 3 | 4 | 5 | 6 | 7 |

Figure 3.2 Risk Assessment Code Matrix

Attachment B

APPENDIX

# PERIODIC INSPECTION/MAINTENANCE REPORT FOR CERTIFICATION OF 10,000#, YALE, S/N N411350

ManTech Document No.

40-06-300-1

July 1997

INSPECTED BY: _____

☐R. Gayo, ☐D. Burtis, ☐G. Bell, ☐J. Selba, Date
Lifting Device Inspector, Recertification

INSPECTED BY: _____

☐R. Gayo, ☐D. Burtis, ☐G. Bell, ☐J. Selba, Date
Lifting Device Inspector, Recertification

APPROVED BY: _____

Warren Thomas, Manager, Recertification Date
Function, ManTech

Recertification Function
ManTech Aerospace Technology Applications Center
Goddard Space Flight Center
Greenbelt, Maryland 20771

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REVISION SHEET

ManTech International Corporation
Aerospace Technology Applications Center
Goddard Space Flight Center
Greenbelt, Maryland 20771

| Type of Document<br>Report | Function<br>Recertification Support | Release Date<br>July 1997 |
|---|---|---|
| Title: Periodic Inspection/Maintenance Report for certification of 10,000#, YALE, S/N N411350 | | |
| Prepared by:<br>G. Miller | Approved by:<br>A. Zorn | |

| Symbol | Page | Line | Description of Change | Date | Approval |
|---|---|---|---|---|---|
| -1 | | | Revised from checklist to formal procedure. | 7/97 | |
| | | | Document 40-06-300-1 | Revision Symbol<br>-1 | |

# FORKLIFT DATA SHEET

GSFC Forklift No.: 399855

Location: Building 15

Manufacturer: Yale

Serial No.: N411350

Capacity: 10,000 lbs.

Type: Riding type

INSPECTION REPORT
FOR 10,000#, YALE, S/N N411350

INSPECTOR(S) _____ DATE _____

| ITEM | DESCRIPTION | ACTION |
|---|---|---|

The complete report is available for review. It is filed with Lifting Devices Equipment and Inspection Section of ManTech.

This crane has been inspected and load tested to 10,000 lbs. and is/is not liftworthy for recertification.

Inspector _____ Inspector _____

# PERIODIC INSPECTION AND MAINTENANCE REPORT

When this inspection is performed, the rated load test must also be completed.

The inspector should refer to the "Parts, Care and Operations Manual" located in the files, for a more complete discussion of maintenance, troubleshooting, parts, and schematics, if necessary.

Conditions: (✓) - Satisfactory, (x) - Unsatisfactory, (*) - Corrected

| Initial | Date | Condition | | |
|---|---|---|---|---|
| | | | 1.0 | GENERAL IDENTIFICATION AND MARKINGS |
| _____ | _____ | _____ | 1.1 | Fill out blank requesting the forklift's make, model, and serial number. |
| | | | 2.0 | CARRIAGE INSPECTION |
| _____ | _____ | _____ | 2.1 | Determine if the Load Back Rest is attached. |
| _____ | _____ | _____ | 2.2 | Check to see if either of the Hoist Cylinders or Tilt Cylinders are broken, fractured, or leaking. |
| _____ | _____ | _____ | 2.3 | Visually inspect the Mast Flanges for worn spots. |
| _____ | _____ | _____ | 2.4 | Determine if the Mast Rollers and Thrust Buttons are functional. |
| _____ | _____ | _____ | 2.5 | Check if any of the Tension Rods are broken. |
| _____ | _____ | _____ | 2.6 | Fork Inspection. Check for the following: |
| | | _____ | 2.6.1 | Determine if the top clip, pin, and heel are attached. |

| | | | | |
|---|---|---|---|---|
| | | _____ | 2.6.2 | Check to see if the forks are bent or twisted in any way. |
| | | _____ | 2.6.3 | Test for fatigue cracks using the Dye Penetrant inspection method. |
| _____ | _____ | _____ | 2.7 | Check the condition of the Tires. Check for cuts or other deficiencies. |
| | | 3.0 | INTERNAL TESTS | |
| _____ | _____ | _____ | 3.1 | Check that the Capacity and Battery Capacity Plate are in place and clearly marked. |
| _____ | _____ | _____ | 3.2 | Make sure the Hour Meter is functioning. |
| _____ | _____ | _____ | 3.3 | Verify that the Horn is working properly. |
| _____ | _____ | _____ | 3.4 | Operate the Shifting and Accelerator Control Linkages. Verify that they are functioning correctly. |
| _____ | _____ | _____ | 3.5 | Determine if the steering wheel is easily moveable and does not bind or stick. |
| _____ | _____ | _____ | 3.6 | Run the Hoist full up and full down. Look to see if the operation of hoisting and lowering moves smoothly. |
| _____ | _____ | _____ | 3.7 | Check the Mast and Carriage Safety Stops. Determine if they stop when they are supposed to. Make sure that welds are not cracked. |
| _____ | _____ | _____ | 3.8 | Tilt the Carriage. Determine if the Carriage moves forward and backward smoothly. Check in ON and OFF positions. |

_____ _____ _____ 3.9 Determine if the Parking/Seat Switch works correctly.

_____ _____ _____ 3.10 Check if the Seat Belt is in good repair.

_____ _____ _____ 3.11 Test if the Reverse Motion Notification Beeper is functioning properly.

_____ _____ _____ 3.12 Test the Service Brake and the Parking Brake. Make sure they work correctly.

4.0 UNDER-CHASSIS

_____ _____ _____ 4.1 Determine if the Main Relief Valve Setting is correct.

_____ _____ _____ 4.2 Look for leaks. Watch for cuts or abrasions on any hoses or their fittings.

_____ _____ _____ 4.3 Make sure that the hydraulic fluid is at a sufficient level.

_____ _____ _____ 4.4 Check all Valve Hoist and Tilt Switches. Check that they are in proper positions.

_____ _____ _____ 4.5 Check all Wire Connectors. Test for good connections at all junctions. Look for frayed or broken wires.

5.0 OVER-CHASSIS

_____ _____ _____ 5.1 Examine the Overhead Guard for bends or breaks. Make sure that all welds are intact. Check bolts. Make sure guard is secure.

_____ _____ _____ 5.2 Visually inspect the Finger Guards. Make sure they are in place and in good repair.

_____ _____ _____ 5.3 Battery Inspection. Check the battery for the following:

_____ 5.3.1 Look to see if the box and its connectors are clean.

_____ 5.3.2 Determine if the box and its connectors are in good repair.

_____ 5.3.3 Check if the battery itself is clean.

_____ 5.3.4 Make sure the water level is at a sufficient height.

6.0 LOAD TEST

_____ _____ _____ 6.1 Lift a load of the rated capacity of the forklift to the maximum height of the forklift and let it sit for 3 minutes. Then lower forks and remove the weight.

_____ _____ _____ 6.2 Test for cracks by surface NDT.

7.0 TIRES

_____ _____ _____ 7.1 Check tires for tread wear, cuts, and abrasions.

7.2 Check tires for proper air pressure as shown in the manufacturer's manual.

CERTIFICATION FOR YALE FORKLIFT, S/N N411350

_____
(Date)

The Periodic Inspection and original equipment manufacturer's recommended maintenance as required were successfully completed and documented in ManTech Report 40-06-300-1. This work was performed in accordance with ManTech Procedure 40-06-300-1.

It is recommended that Yale Forklift, S/N N411350 be certified, commencing _____, expiring _____.

_____ _____
☐R. Gayo, ☐D. Burtis, ☐G. Bell, ☐J. Selba, Date
LDE Inspector, Recertification Function, ManTech

_____ _____
☐R. Gayo, ☐D. Burtis, ☐G. Bell, ☐J. Selba, Date
LDE Inspector, Recertification Function, ManTech

Approval:

_____ _____
W. Thomas, Manager, Recertification Function Date
ManTech

Certification:

_____ _____
S. Chan, RECERT Manager, Code 540, NASA/GSFC Date