APPROVAL SHEET FOR SUSPENDED LOAD OPERATIONS

SLO-KSC- 1991-019

CHANGE 2-JULY 1998

TITLE SSME ROTATING SLING MAINTENANCE/PREVENTIVE MAINTENANCE

DOCUMENT NUMBER/TITLE OMI V6G21 SSME ROTATING SLING MAINTENANCE/PREVENTIVE MAINTENANCE

PREPARED BY RAY SAMPLES, ROC SSME ENG.

DATE 6/95

REQUIRED APPROVAL

CONTRACTOR ____ DESIGN ____ R & QA ____ OPERATIONS ____ SAFETY

NASA ____ DESIGN ____ R & QA ____ OPERATIONS ____ SAFETY

TYPE OR PRINT NAME	SIGNATURE	ORGN.	DATE
J. LEWER, ROC SAFETY	J Lewer	ROC-SAF 7-30-98	7-30-98
K. HOSHSTRASSER, ROC MGR., R&QA	Ken Hoshstrasser	ROC S&M4	7/31/98
E. GARDZE, ROC MGR., SSME ENG	James W. Wobble for	ROC	7/31/98
D. EWERS, ROC MGR., SSME TECH OPS	D. Ewers	ROC	7-31-98
D. HAUSMAN, ROC SITE DIR.	D. Ewers FOR	ROC	7-31-98
J. JAMBA, USA SLAP COORD.	John W Jamba	USA-SAF	7-31-98
J. GARRETT, USA SAFETY ENG.	John W. Jamba	USA 5450	8/4/98
A. STEVENS, USA MGR., S&RE	A M Stevens	USA 5450	8/4/98
M. GLENN, NASA SR&QA	M. Glenn	EI-C-A	8/5/98

CONTRACTOR DIRECTOR OF SAFETY

M J Rapp 8/5/98

KSC FORM OT-4129 (11/91) (ONETIME FORM-REPRINT NOT AUTHORIZED)

NASA SUSPENDED LOAD OPERATION
ANALYSIS/APPROVAL

OPERATION - Preventive Maintenance/SSME Rotating Sling Maintenance

SUPPORTING DOCUMENTS - The associated operational procedures/system assurance analyses are as follows:

- OMI V6G21-Preventive Maintenance - SSME Rotating Sling Maintenance
- SAA09FY121-002-System Assurance Analysis of the 10-Ton Bridge Cranes at the VAB/Low Bay Areas K&L Checkout Cells 1, 2, and 4
- SAA09FT01-004-System Assurance Analysis of the Link Belt 250-Ton HC-268 Truck Crane
- SAA09FY12-006-System Assurance Analysis of the 175-Ton Bridge Crane at the VAB
- SAA05MH43-001-System Assurance Analysis of the 140-Ton Manitowoc Mobile Crane
- SAA09FT01-006-System Assurance Analysis of the Link Belt 40-Ton Mobile Crane HSP 8040
- SAA09FTOI-009-System Assurance Analysis of the 35-Ton Pettibone Mobile Crane
- SAA09CR00-001 - System Assurance Analysis of the 10 & 15-Ton Bridge Cranes at the SSMEPF

GENERAL DESCRIPTION - Permit designated personnel to be directly under the suspended sling during installation/removal of the lifting hardware as follows:

RGO000026 Adapter Panel Installation
Rotating Sling to 3G Engine Simulator Installation
Rotating Sling from 3G Engine Simulator Removal
Load Testing with 2G Configuration
Proof Test Securing

Maintenance and preventive maintenance on the RG00004 SSME Rotating Sling are performed using the SSMEPF 15-Ton Bridge Crane, one of the VAB 10-Ton Bridge Cranes, the VAB 175-Ton Bridge Crane, the Link Belt 250-Ton Truck Crane, the 140-Ton Manitowoc Mobile Crane, the 40-Ton Link Belt Mobile Crane HSP 8040, or the 35-Ton Pettibone Mobile Crane.

During attachment of the engine rotating sling to the RGO00026 interface panel adapter the sling is suspended from the crane while three (3) designated personnel initially position the panel and then position and install quick release pins in six supporting struts on the panel adapter . Attachment of the engine rotating sling to the RG000026 interface panel adapter requires approximately 15-20 minutes, during which time the designated personnel will be required to work beneath a suspended load.

In order to perform the 2 gravity (G) or 3G functional proof test, the previously connected engine rotating sling and interface panel adapter will be suspended and positioned over the 2G or 3G weight simulator by the crane. After initial alignment three (3) designated personnel will be required to work under the suspended load to perform final alignment and to level the interface plate, if required, to allow strut installation and then to install and secure the connecting bolts and quick release pins.

Disconnection from the 2G and 3G simulator and proof test securing will require that personnel work beneath suspended loads as described in the two immediately preceding paragraphs, but in reverse order, as the rotating sling is sequentially removed from the simulator and the interface panel adapter.

RATIONALE/ANALYSIS - The suspended load tasks comply with the NASA Alternate Safety Standard as follows:

Alternate Standard Requirement #1a - The operation cannot be conducted without personnel working beneath the hoist and sling during operations involving the connection and disconnection of the sling to the interface adapter panel and functional proof loads or during the performance of periodic maintenance operations. These operations have been evaluated and it has been determined that there are no procedural/operational means to eliminate personnel exposure to a suspended load that reduce the hazard level. In addition, it is not feasible to redesign the lifting/handling equipment in such a manner as to eliminate the requirement for personnel to work under a suspended load during these operations.

An analysis was performed to evaluate the potential redesign of the engine lifting and handling equipment in order to eliminate the requirement for personnel to work under a suspended load during rotating sling load testing operations. The analysis was performed by Lockheed Design Engineering, NASA and Boeing Robotics Engineers and the results were submitted to Rocketdyne System Engineering.

The principal design considered was to modify the rotating sling to enable it to be self -supporting. This would be accomplished by adding new struts and pneumatic screw jacks to the sling and by modifying the wheel base.

The redesign was considered by Lockheed Design Engineering to be unfeasible. The following are the principal reasons for rejection of the redesign:

1. The addition of struts to the rotating sling would require the installation and/or removal of wheels under a suspended load and would require additional workstands to abate the new suspended load.

2. The addition of struts to the rotating sling would restrict access to the work area by technicians and is considered to be a risk to critical flight hardware.

Alternate Standard Requirement #1b - The possible use of a secondary support system to catch the load in the event of a crane failure has been reviewed and determined not to be feasible. This conclusion was reached primarily due to the requirement to position the hoist and sling directly over the adapter and functional engine weight simulator in order to connect or disconnect before or after subsequent lifting operations.

Alternate Standard Requirement #1c - The maximum number of personnel permitted under the load at any time is three (3) .

Alternate Standard Requirement #1d - The designated personnel will accomplish their task as quickly and safely as possible in order to minimize exposure time. The maximum time that personnel are required to work beneath a suspended load is approximately 30 minutes during the 2G and 3G functional proof tests. All other operations described will require approximately 15-20 minutes of time in which personnel will be required to work beneath a suspended load.

Alternate Standard Requirement #4 - Operations and Maintenance Instruction (OMI) V6G21 has been revised to permit only the minimum required number of personnel under the suspended load during the installation/removal of the required hardware. The OMI is available on site during the operation for inspection.

Alternate Standard Requirement #6 - Suspended load operations associated with maintenance, preventative maintenance and proof load testing of the rotating sling involve the SSMEPF 15-Ton Bridge Crane, the VAB 10-Ton Bridge Crane, the VAB 175-Ton Bridge Crane, the 250-Ton Link Belt Truck Crane, the 140-Ton Manitowoc Mobile Crane, the 40-Ton Link Belt Mobile Crane HSP 8040, or the 35-Ton Pettibone Mobile Crane. The cranes are tested, inspected, maintained and operated in accordance with NSS/GO-1740.9.

The Space Shuttle Main Engine (SSME) rotating sling and the RGO00026 interface plate weigh 8,710 lbs. yielding an operational factor of safety of 11.5:1.

The SSMEPF 15-Ton Bridge Crane is equipped with a hoist motor brake and a load hold/halt drum brake, each capable of stopping and holding the load at the crane's rated capacity. The motor brake provides retarding torque to hold the load when no power is being transmitted. It is an electrically released disc brake set by spring compression to apply load holding torque to the motor shaft. The load hold/halt drum brake provides retarding torque to hold the load when no power is being transmitted if the load moves down after stopping. This electrically released brake applies load holding torque directly to the hoist drum.

The VAB 10-Ton Bridge Crane is equipped with mechanical and magnetic braking systems with overspeed braking, each of which is capable of stopping and holding the load at the crane's rated capacity. The mechanical load brake controls the lowering speed of the hoist motor. If the speed of the load begins to exceed that of the motor, the brake begins to set, slowing the rate of descent. The magnetic load brake provides braking torque to the hoist motor pinion shaft. Whenever the hoist motor is energized the solenoid in the magnetic load brake is also energized causing the magnetic load brake to release. Therefore whenever power is removed from the hoist motor, the magnetic brake will set.

The 250-Ton Link Belt crane main hoist brake system is comprised of three fixed position calipers and one disc mounted on each of the two independent rotating drums which transfer the power from the torque converter and diesel motor to the hoisting system. Each drum also has a spring applied planetary brake. The operator can also effectively lower or brake a load through clutch operation to a "controlled" slippage or lowering of the load. The main hoist has five methods of holding or lowering a load.

The VAB 175-Ton Bridge Crane is equipped with redundant hoist drive systems (including hoist wire ropes and holding brakes) each capable of lifting and holding the load up to the crane's rated capacity. The crane has a dual braking system with overspeed braking.

The 140-Ton Manitowoc Mobile Crane hoist has two independent rotating drums each with its own brake, capable of lifting and holding the load up to the crane's rated capacity.

The 40-Ton Link Belt HSP 8040 Mobile Crane Hoist is driven by a two speed bi-directional gear type hydraulic motor equipped with an automatic disc brake.

The 35-Ton Pettibone Mobile Crane Hoist is driven by a vane type hydraulic motor through a gear drive with control valves to move and hold the load.

The cranes are load tested annually at 100% of the rated load and the Operational Maintenance Requirements and Specifications Document (OMRSD) , File VI, requires verification of the load test prior to any critical lift. Detailed preventive maintenance is performed monthly, quarterly and annually on each crane to ensure proper operation.

Alternate Standard Requirement #7 - System Assurance Analyses (SAAS) have been completed on the cranes to perform SSME rotating sling maintenance/preventive maintenance. The analyses include a failure modes and effects analysis/critical items list (FMEA/CIL) and a hazard analysis (see supporting document). No single failure points were identified for the 250-Ton Link Belt Truck Crane or the 140-Ton Manitowoc Mobile Crane.

The SAA for the SSMEPF 10 & 15-Ton Bridge Cranes identifies one SFP, the Programmable Logic Controller (PLC). The PLC controls motion for the hoist, bridge and trolley. The identified failure mode is erroneous input or output which could cause the load to travel in an uncommanded direction. The PLC is designed to industry standard and is UL listed. Internal diagnostics verify all crane controls each time the crane is used and crane control functional checks are performed before each use. The PLC is electrically isolated from external voltages/currents.

The SAA for the VAB 10-Ton Bridge Crane identifies one single failure point (SFP) in the hoist gear drive when the system is hoisting or lowering. The identified failure mode f or the ten ton overhead crane is disengagement of the drive gear as a result of structural failure of the teeth, shafts or keys which will allow the load to drop. There is no history of failure with the SFP in the critical failure mode. The use of high quality components and a comprehensive maintenance, inspection and test program including pre-operational checks ensure that the crane system operates properly. The gears and shafts are designed in accordance with American Gear Manufacturers Association and Crane Manufacturers Association of America standards and all load bearing parts are designed so that the static stress, calculated for rated load, does not exceed 20 percent of the average ultimate material strength.

The SAA for the 175-Ton Bridge Crane identifies 3 SFP's in the main hoist system when the hoist is lifting or lowering. Failure of the motor-generator set (one each) or the main hoist motors (two each) would allow the load to lower without regenerative braking. There are no SFP's when the hoist is static. There is no history of failure with the SFP's in the critical failure mode. The use of high quality, reliable components and a comprehensive maintenance, inspection, and test program, including pre-operational checks ensures that the crane systems operate properly. If a failure were to occur, it can be recognized by a brake set light, ammeter, or selsyn position indicator (depending on the failure) which are in view of both crane operators. The crane operators would secure the load by applying the brakes. The estimated operator and system reaction time, i.e., without regenerative braking, to recognize the failure and set the brakes is 3 seconds and the load would have descended an estimated 12 inches. This estimate assumes a solid rocket booster segment being lowered at 10 feet/minute and failure occurring. In addition, Emergency Stop operators, remote from the crane operator's cab, can stop the crane if a failure indication is observed. In summary, there should be sufficient time to observe a failure and stop the crane before injuring personnel working under the suspended load.

The SAA for the 40-Ton Link Belt Mobile Crane identifies two SFPs in the hoist. The identified failure modes are the gears disengage in the gear reducer and the brake slips or fails to engage. There is no history of failure with the SFPs in the critical failure mode. The use of high quality components and a comprehensive maintenance, inspection and test program including pre-operational checks ensure the crane system operates properly. The gears are designed in accordance with American Gear Manufacturers Association Standards and all load bearing parts are designed so that the static stress, calculated for rated loads, does not exceed twenty (20) percent of the average ultimate material strength. The brake is an off-the-shelf item with rotating discs splined to the motor output shaft, stationary discs grooved to fit and retained in place by shoulders within the brake housing.

The SAA for the 35-Ton Pettibone Mobile Crane identifies one SFP in the hoist. The identified failure mode is structural failure of the gears, couplings, keys and gearbox housing. The gearbox is an off-the-shelf item manufactured by Pettibone Corporation. The design complies with the American Gear Manufacturers Association. Load bearing members, such as the gear case and shafts are designed to a 5 to 1 safety factor. Gear case oil sample testing is performed annually.

The associated SAA CIL Sheets identify the rationale f or accepting the risk of the SFP, including design information, failure history and the operational controls in effect to minimize the risks associated with crane operation.

Alternate Standard Requirement #8 - Visual inspections for cracks or other signs of damage or anomalies are performed on the cranes, hooks and lifting assemblies and crane functional checks are performed before each operation per NSS/GO-1740.9.

Alternate Standard Requirement #9 - Trained and licensed crane operators shall remain at the crane controls while personnel are under the load.

Alternate Standard Requirement #10 - Appropriate safety clear areas are established areas are established before initiating operations. only the minimum number of personnel will be permitted in this area.

Alternate Standard Requirement #11 - A pretask briefing and a safety walkdown of the area are conducted prior to the lift to ensure that all systems and personnel are ready to support. All participants are instructed on their specific tasks and warned of the hazards involved. Following any crew change, the new personnel are instructed by the task leader on their specific tasks and warned of hazards involved.

Alternate Standard Requirement #12 - Personnel beneath the suspended load will be in voice contact with the crane controller/signal person. Upon loss of communication, the operation shall stop immediately, personnel shall clear the hazardous area and the load shall be safed. Operations shall not resume until communications are restored.

Alternate Standard Requirement #13 - Ground controllers and E-stop operators are properly positioned during all phases of the lifting operation in full view of the load block, lifting fixtures and attach points. Personnel working beneath the load shall remain in continuous sight of the operator/signal person.

APPROVAL: DATE:

Joel R. Reynolds 8/5/98

Joel R. Reynolds
Director
Safety Assurance (EI)
Kennedy Space Center

APPROVAL: DATE

8/6/98

James D. Lloyd
Director
Safety and Risk Management (QS)
NASA Headquarters