APPROVAL SHEET FOR SUSPENDED LOAD OPERATIONS

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TITLE ENGINE PROWERHEAD/NOZZLE SEPARATION IN THE VERTICAL ASSEMBLY BUILDING (VAB) ENGINE SHOP & SSMEPF

DOCUMENT NUMBER/TITLE OMI V5E28.001/SSME NOZZLE REMOVAL AND INSTALLATION IN ENGINE SHOP

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REQUIRED APPROVAL

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NASA SUSPENDED LOAD OPERATION
ANALYSIS/APPROVAL

OPERATION - Engine Powerhead/Nozzle Separation in the Vehicle Assembly Building (VAB) engine shop.

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

- ONH V5E28.001 - SSNM Nozzle Removal and Installation in Engine Shop
- SAA09FY121-003 - System Assurance Analysis of the 10-Ton Bridge Crane at the Space Shuttle Main Engine Assembly Area in the VAB Low Bay
- SAA09CR00-001 - System Assurance Analysis of the 10 & 15-Ton Bridge Cranes at the SSMEPF

GENERAL DESCRIPTION - Permit a maximum of four (4) designated personnel to be directly under the suspended sling/powerhead during installation/removal of the lifting hardware as follows:

- Powerhead/MCC Removal from Nozzle to Horizontal Handler
- Powerhead/MCC Removal from Nozzle to Pedestal
- Move Powerhead/MCC from Horizontal Handler to Pedestal
- Move Powerhead/MCC from Pedestal to Horizontal Handler
- Install Powerhead/MCC from Pedestal on to Nozzle
- Install Powerhead/MCC from Handler on to Nozzle
- Install Powerhead from Powerhead Stand to Nozzle MCC

Powerhead/Main Combustion Chamber (MCC) separations from the nozzle and subsequent remates are performed in the SSMEPF using the 10-Ton Bridge Crane or in the VAB engine shop using the 10-Ton Bridge Crane located in the VAB low bay checkout cell #5. The crane is used with the RGO00004 engine rotating sling or RGO00478 Vertical Engine Support & Lift Set (VESALS) to hoist, move or rotate the Space Shuttle Main Engine (SSME) powerhead/MCC in the main engine shop.

The engine rotating sling is attached to the RGO00026 engine interface panel adapter and to the crane at the hoist load hook for mate or demate operations as well as transfer of the powerhead/MCC to the engine handler or pedestal until preparations are complete for their subsequent remate with the same, or replacement nozzle. Similarly, the VESALS is attached to the SSME gimbal block and to the crane at the hoist hook.

The engine handler sling is connected to the interface panel adapter, pinned to the RG000001 horizontal engine handler at the handler barrel. Access to the interface panel adapter is from the shop floor surface on either side of the engine handler. Three technicians are located to align the sling with the panel adapter and to attach the struts to the interface panel adapter clevises. Upon connection of the struts, and the removal of three (3) quick release pins securing the interface panel adapter to the barrel of the engine handler, the interface panel is ready for lift and rotation. After the panel has been rotated and positioned over the powerhead/MCC, technicians will again be required to work under a suspended load to align and attach the interface panel adapter to the powerhead for removal. Attachment of the interface panel to the powerhead is accomplished by slowly lowering the interface panel adapter utilizing the sling jackscrew until four captive screws can be connected to secure the interface panel adapter to the powerhead at the interface support panel. The screws are torqued and verified and two (2) heavyweight strut quick release pins are installed that connect the powerhead to the interface panel adapter. Six (6) bolts are then installed and torqued that connect the engine gimbal block to the interface panel adapter completing the mating of the powerhead to the handier sling. With mating operations completed, four (4) technicians will be required to work under a suspended load during the separation of the powerhead/MCC from the nozzle in order to verify and assist in a smooth separation. The powerhead/MCC is then hoisted and rotated to be positioned for installation onto the horizontal engine handler or pedestal. Three (3) technicians will be required to work under a suspended load to align and remate the engine interface panel adapter to the horizontal handier by installing the three quick release pins to connect the interface panel to the handler barrel. If the powerhead/MCC is going to be installed on a pedestal, two (2) personnel are required to work under a suspended load to clean, inspect and photograph joint G15. The MCC/powerhead will then be rotated vertical for mating to the pedestal. Four (4) personnel are required under a suspended load to align and mate the powerhead/MCC to the pedestal. The procedure is reversed for the remate of the powerhead/MCC to the nozzle.

VESALS - With Gimbal locks or I/F panel installed to hold the gimbal block up right the VESALS is connected to the gimbal block by 6 bolts. The powerhead is lifted off its pedestal and aligned over the MCC. Three (3) technicians will be required to work under a suspended load during installation of 3 guide pins which facilitate mating of the powerhead to the MCC.

RATIONALE/ANALYSLS - 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 engine interface panel adapter or the powerhead/MCC prior to and post separation/installation. Operations to separate the nozzle and powerhead/MCC in the VAB engine shop 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 powerhead lifting and handling equipment in order to eliminate the requirement for personnel to work under a suspended load. It was determined that due to the nature of the operation that requires personnel to be under the suspended load to monitor the precise positioning of the main combustion chamber to the nozzle during mating that no modification could be made that would alleviate the requirement for personnel to work under the suspended load. In addition, engine configuration and weight requirements preclude design enhancements that would modify the powerhead or nozzle in an attempt to reduce the hazard.

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 SSME in order to connect or disconnect before or after separation operations.

Alternate Standard Requirement #1c - The maximum number of personnel permitted under the load at any time is four (4).

Alternate Standard Requirement #1d - The minimum number of technicians will be used to accomplish their tasks as quickly and safely as possible in order to minimize exposure time. During the procedures to connect the sling with the adapter, the technicians will be working directly beneath the suspended rotating sling for approximately 15-20 minutes.

The mating process in preparation for separation of the powerhead/MCC from the nozzle or pedestal requires three (3) technicians to work under a suspended load for approximately 20 - 30 minutes, while the separation of the MCC/powerhead from the nozzle or pedestal will require three (3) technicians and one (1) quality assurance representative to work under the suspended load for approximately 20 minutes. Powerhead installation on to a nozzle/MCC using the Vertical Engine Support Lift Set will require three (3) technicians to work under suspended load for approximately 5 minutes.

Alternate Standard Requirement #4 - Operations and Maintenance Instruction (OMI) V5E28.001 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 nozzle and powerhead/MCC separation use the SSMEPF 10-Ton Bridge Crane or the VAB Engine Shop 10-Ton Bridge Crane. The crane is designed, tested, inspected, maintained and operated in accordance with NSS/GO-1740.9. The crane is designed with a minimum safety factor of 5:1, based on ultimate material strength of the hoist load carrying components. The heaviest load to be lifted is approximately 15,410 lbs; powerhead, MCC, rotating sling and associated GSE.

The SSMEPF 10-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 over-speed 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 cranes are load tested annually at 100% of rated load and the Operational Maintenance Requirements and Specification Document (OMRSD), File VI, requires verification of the load test prior to any critical lift. Detailed preventative maintenance is performed on the crane monthly, quarterly and annually to ensure proper operation.

Alternate Standard Requirement #7 - A System Assurance Analysis (SAA) has been completed on the 10-Ton crane. The analysis includes a failure modes and effects analysis/critical items list (FMEA/CIL) and a hazard analysis (see supporting documents).

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 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 of America and Crane Manufacturers Association of America standards and all load bearing parts designed so that the static stress, calculated for rated load, does not exceed 20 percent of the average ultimate material strength.

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CIL

The associated SAA ~~CIL~~ Sheets identify all rationale for 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 crane, hook and lifting assembly and crane functional checks are performed daily 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 before initiating operations. Only the minimum number of personnel will be permitted in this area.

Alternate Standard Requirement #11 - A pre-task 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 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 have been 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.

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