SECTION 41 22 13.14

BRIDGE CRANES, OVERHEAD ELECTRIC, TOP RUNNING
09/12

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 325	(2011) Steel Construction Manual

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M	(2010) Structural Welding Code - Steel
AWS D14.1/D14.1M	(2005) Specification for Welding Industrial and Mill Cranes and Other Material Handling Equipment

ASME INTERNATIONAL (ASME)

ASME B30.2	(2011) Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)

CRANE MANUFACTURERS ASSOCIATION OF AMERICA (CMAA)

CMAA 70	(2010) Top Running and Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes, No. 70

EUROPEAN COMMITTEE FOR ELECTROTECHNICAL STANDARDIZATION (CENELEC)

CENELEC EN 61800-3	(2005) Adjustable Speed Electrical Power Drive Systems - Part 3: EMC Product Standard Including Specific Test Methods

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 519	(1992) Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

INSTRUMENTATION SOCIETY OF AMERICA

ISA S84.00.01 Part 1	(2004) Functional Safety: Safety Instrumented Systems for the Process Industry Sector - Part 1: Framework, Definitions, System, Hardware and Software Requirements

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2008) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ICS 2	(2000; R 2005; Errata 2008) Standard for Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 6	(1993; R 2006) Enclosures
NEMA ICS 7	(2006) Adjustable-Speed Drives
NEMA ICS 8	(2000; R 2005) Crane and Hoist Controllers
NEMA MG 1	(2009) Motors and Generators

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2011; TIA 11-1; Errata 2011) National Electrical Code

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910	Occupational Safety and Health Standards
29 CFR 1910.147	Control of Hazardous Energy (Lock Out/Tag Out)
29 CFR 1910.179	Overhead and Gantry Cranes
29 CFR 1910.306B	Cranes and Hoists
47 CFR 15	Radio Frequency Devices

UNDERWRITERS LABORATORIES (UL)

UL 1004-1	(2008; Corrections 2008) Standard for Safety Rotating Electrical Machines
UL 1449	(2006; Reprint Feb 2011) Surge Protective Devices
UL 489	(2009; Reprint Jun 2011) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
UL 50	(2007) Enclosures for Electrical Equipment, Non-environmental Considerations
UL 508C	(2010) Power Conversion Equipment
UL 943	(2006; Reprint May 2010) Ground-Fault Circuit-Interrupters

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NASA-SPEC-5004A Welding of Aerospace Ground Support Equipment and Related Nonconventional Facilities

1.2 DEFINITIONS

a. Application Software: The commercially available development software used to write the user code.

b. Crane Bridge: That part of an overhead crane system consisting of girder(s), end trucks, end ties, walkway, and drive mechanism which carries the trolley(s) and travels along the runway rails parallel to the runway.

c. Crane Runway: The track system along which the crane operates horizontally, including track hangar rods, track connection devices, and runway structural supports.

d. Dead Loads: The loads on a structure which remain in a fixed position relative to the structure.

e. Fail-safe: Any failure of an individual component shall result in the safe and normal shutdown of the crane. The safe state of the crane is "power off."

f. Girder: The principal horizontal beam of the crane bridge. It is supported by the crane end trucks.

g. Live Load: A load which moves relative to the structure under consideration.

h. Programmable Logic Controller (PLC) or Programmable Electronic System (PES): A system for control, protection or monitoring based on one or more programmable electronic devices, including all elements of the system such as power supplies, sensors, and other input devices, data highways and other communication paths, and actuators and other input devices.

i. Rated Load: For the purpose of this specification the rated load is defined as the maximum working load suspended under the load hook.

j. Speed, Hoisting: The velocity in feet per minute (fpm) at which the hoisting mechanism will lift the rated load.

k. Speed, Bridge: The velocity in feet per minute (fpm) at which a motor-driven bridge with trolley and hoisting mechanism will carry the rated load in horizontal travel along the crane runway.

l. Speed, Trolley: The velocity in feet per minute (fpm) at which a motor-driven trolley and hoisting mechanism will carry the rated load in horizontal travel across the crane bridge.

m. Standard Commercial Cataloged Product: A product which is currently being sold, or previously has been sold, in substantial quantities to the general public, industry or Government in the course of normal

business operations. Models, samples, prototypes or experimental units do not meet this definition. The term "cataloged" as specified in this section is defined as "appearing" on the manufacturer's published product data sheets. These data sheets must have been published or copyrighted prior to the issue date of this solicitation and have a document identification number or bulletin number.

n. Top Running Crane: An electric overhead traveling crane that runs on rails on top of support girders.

o. Trolley Mounted Hoist: A combined unit consisting of a wheeled trolley that provides horizontal motion along the bridge girder, and a hoist supported by the trolley, that provides lifting and lowering of a freely suspended load.

p. User code: The software written by the installer that is utilized by a programmable device for its specific application.

q. Watchdog processor: The independent microprocessor based, user programmable device employed to monitor the function of the PES (see above).

1.3 REQUIREMENTS

The requirements structural steel are specified in Section 05 12 00, STRUCTURAL STEEL, and must conform to AISC 325.

1.4 VERIFICATION OF DIMENSIONS

The Contractor is responsible for the coordination and proper relation of his work to the building and existing crane structure and to the work of all trades. The Contractor shall verify all dimensions of the building that relate to the installation of walkways, control panels, and control cab and notify the Contracting Officer of any discrepancy before finalizing the crane design.

1.5 SUBMITTALS

Government approval is required for all submittals. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Design and Installation Drawings shall be submitted in accordance with paragraph titled "Preproduction Design Data" of this section.

Submit shop drawings showing the general arrangement of all new and modified components in plan, elevation, and end views as needed. Provide clearances and principal dimensions, assemblies of hoist, trolley and bridge drives, motor nameplate data, overcurrent protective device ratings, other components and electrical schematic drawings. Shop drawings shall include controls schematics, inner connection diagrams, panel layouts, etc. Include weights of components.

Shop drawing quality must be equivalent to the contract drawings accompanying this solicitation.

SD-03 Product Data

Product data shall be provided for all assemblies and subassemblies including but not limited to the following:

Control PES

Supervisory PES

Watchdog Processor

Application software

User Code

Position Display System

Drive Controllers

Control Parameter Settings

Control Components

Electrification

AC Motors

Brakes

Couplings

Data Recorder

UPS

Weighing System

OIT

Capacity Overload Protective Device

Limit Switches

Master Switches

Crane Operator's Cab Air Conditioning

Enclosure Cooling Units

Batteries - The contractor shall submit a list of devices that contain batteries. This list shall indicate the estimated life of each individual battery, location of each battery, and the

procedure for replacement of each battery. This can be supplied by the devices cut sheet.

SD-05 Design Data

Load and sizing calculations

Cooling load and sizing calculations

Heating load and sizing calculations

SD-06 Test Reports

Acceptance Tests

No-load Testing

Load Tests

SD-07 Certificates

Loss of Power (Panic Test) Certificate

Hazardous Material Certificate

Certificate of the Coupling Alignment Verification Record

Overload Test Certificate

Certificate of Compliance with Listed Standards

Qualification of Professional Engineers

Special Engineering Assessment, Single Motor Operation

Certificates of EMI compliance of enclosures

Certificates of EMI compliance of drives

SD-10 Operation and Maintenance Data

Overhead electric crane, Data Package 4

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA, including weekly, monthly, semi-annual, and annual required maintenance items.

1.6 QUALITY ASSURANCE

1.6.1 Contractor Qualifications

Overhead electric crane system modifications, including sub-system components manufactured by vendors, must be designed and manufactured by a company with a minimum of 10 years of specialized experience that is regularly engaged in designing and manufacturing the enhanced safety

overhead crane systems for material handling of hazardous materials or high dollar items for the aerospace, nuclear, chemical or steel mill industries.

The crane control systems and operator position display systems required herein include special enhanced safety features that exceed normal industry safety practices. As such, only companies experienced in this type of control system development and their applications will be considered qualified to meet requirements of the Contract Documents.

All software developed specifically for this project shall be done by personnel with a minimum of three years experience in writing and interfacing software on the development platforms chosen. The Contractor shall supply the credentials and experience levels of individual(s) performing software development for this project for approval by the Contracting Officer.

1.6.2 Certificates

Submit an Overload Test Certificate stating that the new crane control system and its new installed mechanical items is capable of and can be periodically tested to 125% of rated load.

Submit a Loss of Power (Panic Test) Certificate stating that a test may be performed in which power is removed from the crane while the hoist, bridge, and trolley are in operation at full load to simulate a loss of power.

Submit a Hazardous Material Certificate that the new control system, parts and materials installed on the crane does not contain hazardous material, asbestos, lead, cadmium, chromium, PCBs or elemental mercury.

Submit a Certificate of Compliance with Listed Standards.

Submit a Certificate of the Coupling Alignment Verification Record for couplings installed and tested during the performance of this contract.

Submit a certificate for qualification of professional engineers.

Submit a certificate on Special Engineering Assessment, Single Motor Operation.

Submit certificates of EMI compliance of enclosures with 47 CFR 15 Class A.

Submit certificates of EMI compliance of drives with CENELEC EN 61800-3.

Submit a certificate on Special Engineering Assessments, Single Motor Operation and Main and Auxiliary Hoist Holding Brake Capacity.

1.6.3 Drawings: Overhead Electric Crane

Submit shop drawings showing the general arrangement of all new and modified components in plan, elevation, and end views as needed. Provide clearances and principal dimensions, assemblies of hoist, trolley and bridge drives, motor nameplate data, overcurrent protective device ratings, other components and electrical schematic drawings. Shop drawings shall include controls schematics, inner connection diagrams, panel layouts, etc. Include weights of components.

Shop drawing quality must be equivalent to the contract drawings accompanying this solicitation.

1.6.4 Design Data: Load and Sizing Calculations

The crane structure shall be analyzed by a registered professional structural engineer to determine the effects of the new crane cab and other modifications made to the crane on the existing crane structure. The analysis shall consider the net change in weight of the crane due to the replacement or modification of electrical components and other modifications made to the crane. The analysis shall also include the wheel loads on the existing end trucks due to the crane modifications to compare with the existing cranes published wheel loads. The engineer shall obtain information regarding the existing crane including modifications made since the original installation by way of field measurements, shop drawings, etc. by others.

The crane structure framing modifications required to support the crane modifications shall be included in the analysis. A submittal of analysis calculations bearing the seal and signature of the professional engineer performing the analysis shall be furnished prior to making crane modifications. The crane structure shall be stiffened as necessary based on the analysis for the support of the new crane cab and other modifications indicated.

Submit calculations, signed and sealed by a registered professional engineer verifying the travel drives, and overcurrent protection for motors, controllers and branch circuits. Calculations shall be reviewed and approved by the Contracting Officer before any modifications can commence.

1.6.5 Welding Qualifications and Procedures

Welding must be in accordance with qualified procedures using AWS D14.1/D14.1M as modified and NASA-SPEC-5004A. Welders and welding operators must be qualified in accordance with AWS D1.1/D1.1M or AWS D14.1/D14.1M. Allowable stress values must comply with CMAA 70.

1.7 CRANE SAFETY

Comply with the mandatory and advisory safety requirements of NFPA 70. Submit data on Capacity Overload Protective Device.

Comply with the mandatory and advisory safety requirements of ASME B30.2, CMAA 70, 29 CFR 1910.147, 29 CFR 1910.179, 29 CFR 1910.306B, and all applicable provisions of 29 CFR 1910, ISA S84.00.01 Part 1 and NFPA 70.

1.8 STANDARD PRODUCTS

Drives, PES, Displays, parts and accessories shall be of size, design, and quality to meet requirements specified herein and shall be the standard, fabricated products of the manufacturer or his supplier, so that prompt and continuing service and the delivery of repair parts and replacement components may be ensured. Parts, assemblies, and components shall be new and shall have a minimum service life of 20 years.

1.9 PRECONSTRUCTION DESIGN DATA

Contractor shall provide design and installation drawings and supporting design data before any crane modification. A reliability engineering support group under a separate NASA contract will perform a reliability analysis on the crane electrical control system. This reliability analysis will involve a step by step component failure analysis of the crane control system including the user code.

Before modification occurs, the reliability analysis should be submitted in draft form. It should be completed in the Design/Build Phase and should be functionally complete before shop testing.

The failure of a single component shall not cause a resulting effect on the crane performance and control, based on the criteria set forth in section titled "Reliability Engineering Analysis."

PART 2 PRODUCTS

2.1 TOP RUNNING CRANE SYSTEM MODIFICATIONS

The VAB 175-ton crane was put in service 1966, controls replacement will be compatible with performance requirements specified herein and reused equipment.

2.1.1 Existing 175 Ton Crane

The existing crane has the following specifications:

1. 480 volt, 3 phase, 3 wire via existing power rails 1200 amp single feed to crane. The crane is fed from a substation breaker that is currently set at 720 amps.

2. 175 ton main hoist, using two 100HP compound DC motors 500/1500 RPM with a gear box rated for 155 HP.

3. 25 ton aux hoist, using two 40HP compound DC motors 500/1500 RPM

4. Trolley using two 15HP compound DC motors 1150 RPM.

5. Bridge using four 10HP compound DC motors 1150 RPM one on each truck.

6. 2 (1/2) HP, 2 speed AC (1800/900 rpm), 3 phase motor for main hoist hook rotation controls hydraulic actuated sliding-jaw clutch and power via cable spool.

7. Power and controls to the trolley are fed via cable track on the south side of the bridge top chord attached at one end to trolley and the other to the bridge.

8. The crane is rated CMAA 70 Class "C", Moderate Service.

9. The existing building ambient temperature at the crane ranges from 40 degrees F to 100 degrees F with 10% to 95% relative humidity.

2.2 MECHANICAL EQUIPMENT

Provide steel shafts, gears, keys, and couplings.

Cast iron and aluminum used to support components of the hoist, bridge or trolley power transmission train must be ductile.

All bearings, except those subject only to small rocker motion, must be anti friction type.

Key sizes shall conform to ANSI B17.1 for the respective shaft diameter. Keys may be made of cold-finished low carbon steel key stock or heat-treated alloy steel. Keys and keyways shall be dimensioned, and detailed on drawings.

2.2.1 Drives

2.2.1.1 Main Hoist

The main hoist consists of twin 100 hp DC shunt wound motors, holding brakes with a gear reducer coupled to a pinion and bull gear attached to the end of the wire rope drum. Separate sets of hoist machinery are provided on each side of the drum to provide additional safety to the load should one component in the hoist machinery fail. This also provides the ability to operate while loaded with one motor.

The Contractor shall provide two new variable speed AC squirrel cage closed loop vector control main hoist motors rated such that the two motor combination can raise a rated load at all speeds addressed in section titled "Speed Requirements. ~~As an alternate the main hoist control can include DC motors and motor drives in lieu of AC motors and drives as long as specified performance is met.~~ Each motor will have its own individual drive. The motor horse power rating should be sized not to exceed the pre-existing gear reducer capacity and the rest of the remaining drive components, but large enough to provide highest speed single motor operation. The single motor operation limitation shall be determined by the Contractor, and the restrictions presented in a certificate and approved by a professional engineer (see paragraph titled Special Engineering Assessment, Single Motor Operation).

The contractor is responsible for replacing both hoist motors and hoists brakes, modification to the motor and brake footprints to accommodate installation of the new motors and brakes, coupling and alignment of the new motors and brakes to the hoist gear reducers. This includes replacing all wiring, adding control devices such as encoders, tachometers, and installation and testing of new controls needed for a complete system. ~~The contractor is responsible for replacing both hoist motors, modification of the motor footprint to accommodate installation of the new motors, coupling and alignment of the new motors to the holding brakes. This includes replacing all wiring, adding control devices such as encoders, tachometers, and installation and testing of new controls needed for a complete system.~~

2.2.1.1.1 Main and Auxiliary Hoist Holding Brake Testing

The contractor shall provide a method to statically test the holding torque of each main and auxiliary hoist holding brake. The test will demonstrate

the torque necessary to cause each brake to hold the load (independent of each other) at its full design torque (i.e. the design holding torque produced by the brake). The brakes shall be statically tested by the contractor at 100% of design torque for no movement at the brake wheel and at 110% for slip.

This testing method may require the contractor to provide a shaft extension with a lug on the back of the new motor. Torque is applied by using a torque multiplier and a calibrated torque wrench to manually apply a known torque to each motor shaft extension to measure the capacity of each brake.

The Contractor shall provide the torque multiplier and all fittings necessary to perform these tests with an appropriate testing procedure. The torque multiplier and fittings shall be provided to the government after testing. The calibrated torque wench will be provided by others.

It must be possible to perform this test without major disassembly of components for attachment of torque measurement devices. Other approved methods for brake testing can be provided.

~~2.2.1.1.1 Main Hoist Holding Brake Testing~~

~~The existing main hoist holding brakes will be reused.~~

~~The Contractor shall provide a means to test the two main hoist holding brakes independently at full design torque. The brakes shall be statically tested at 150% motor torque for no movement and at 160% for slip. This method may include providing a shaft extension with a lug on the back of the new motor. Then using a torque multiplier manually apply a torque to the shaft extension using a calibrated torque wrench to measure the capacity of the brake.~~

~~The Contractor shall provide the torque multiplier and all fittings necessary to perform these tests and the appropriate testing procedure. The torque multiplier and fittings will be provided to the government. The calibrated torque wench will be provided by others.~~

~~Other approved methods for brake testing can be provided.~~

2.2.1.1.2 Main Hoist Miscellaneous Items

The Contractor shall provide a hoist holding brake release indication to the PES for control verification. This may include adding a proximity switch or other device to the brake shoe linkage. This must indicate a physical movement of the brake linkage, not energizing the brake coil. This brake release information will be provided to the PES to assure brake release occurs correctly, to enable hoist run commands.

The Contractor is to provide metal safety guards over the hoist brake wheels. These guards shall be shaped to provide close fitting protection so moving parts are guarded from contact with personnel on the trolley and they shall protect against debris from falling onto the brake wheel. These covers shall be easily removable to accommodate maintenance.

2.2.1.1.3 Main and Auxiliary Hoist Electric Holding Brakes

The main and auxiliary hoist brakes shall be DC operated two-shoe type, spring applied, foot mounted, and electrically released. Holding brake capacity shall match the capacity of the existing brakes. Based on the results of the Special Engineering Assessment (ref. paragraph 2.2.1.6.1) the selected brake capacity may be increased through a contract modification.

Brake wheels shall be brake manufacturers standard high strength ductile-iron casting provided the material exhibits wear characteristics in the form of powdered wear particles and is resistant to heat cracking.

All brakes shall be adjustable from 50-100 percent of their rated capacity. Brakes shall have thermal capacity for frequency of operation required by service.

Manual release mechanism, hand lever or other easily actuated release method, shall be provided. This feature shall not self-lock in the open position.

Emergency load lowering shall be provided by using the manually release feature on the hoist holding brakes. This can be done by technicians manually opening one of the two hoist holding brakes and manually opening and closing the other holding brake, slowly lower the load to the floor in a controlled manner. Emergency lowering of the load shall be demonstrated during acceptance testing.

All brake shoe friction material shall be non-asbestos type.

2.2.1.2 Auxiliary Hoist

The auxiliary hoist consists of twin 40 hp DC shunt wound motors, holding brakes with a gear reducer coupled to a pinion and bull gear attached to the end of the wire rope drum. Separate sets of hoist machinery on each side of the drum provide additional safety to the load should one component in the hoist machinery fail. This also provides the ability to operate while loaded with one motor.

The Contractor shall provide two new variable speed AC squirrel cage closed loop vector control auxiliary motors rated such that the two motor arrangement can translate a rated load at all speeds addressed in section titled "Speed Requirements". ~~As an alternate, the axiliary hoist control can include DC motors and motor drives in lieu of AC motors and drives as long as specified performance is met.~~ Each motor will have its own individual drive. The motor horse power rating shall be sized not to exceed the pre-existing gear reducer capacity and the rest of the remaining drive components but large enough to provide single motor operation. The single highest speed motor operation limitation shall be determined by the Contractor, and the restrictions presented in a certificate and approved by a professional engineer (see paragraph titled Special Engineering Assessment, Single Motor Operation).

The Contractor is responsible for replacing both auxiliary hoist motors, modification of the motor footprint to accommodate installation of the new motors, coupling and alignment of the new motors to the holding brakes. This

includes replacement of control devices such as an encoder, tachometer and all wiring and installation and testing needed for a complete system.

~~2.2.1.2.1 Auxiliary Hoist Holding Brake Testing~~

~~The existing auxiliary hoist holding brakes will be reused.~~

~~The Contractor shall provide a means to test the two auxiliary hoist holding brakes independently at full design torque. The brakes shall be statically tested at 150% motor torque for no movement and at 160% for slip. This method may include providing a shaft extension with a lug on the back or the new motor. Then using a torque multiplier manually apply a torque to the shaft extension using a calibrated torque wrench to measure the capacity of the brake.~~

~~The Contractor shall provide the torque multiplier and all fittings necessary to perform these tests. The torque multiplier and fittings will be provided to the government. The calibrated torque wench will be provided by others.~~

~~Other approved methods for brake testing can be provided.~~

2.2.1.2.2 Auxiliary Hoist Miscellaneous Items

The Contractor shall provide a hoist holding brake release indication to the PES for control verification. This may include adding a proximity switch or other device to the brake shoe linkage. This must indicate a physical movement of the brake linkage, not energizing the brake coil. This brake release information will be provided to the PES to assure brake release occurs correctly, to enable hoist run commands.

The Contractor is to provide metal safety guards over the hoist brake wheels. These guards shall be shaped to provide close fitting protection so moving parts are guarded from contact with personnel on the trolley and they shall protect against debris from falling onto the brake wheel. These covers shall be easily removable to accommodate maintenance.

2.2.1.3 Bridge

The bridge drive consists of four independent subsystems at each end truck. This includes a 10 hp DC motor, brake and gear reducer that drive one wheel at each corner of the crane. This provides four driven wheels. Separate sets of bridge drive machinery provide some redundant drive capability for the bridge, where one pair of bridge drive systems (on the same side of the crane) can be used move the bridge along the crane runway. Also, one pair of bridge drive system (one the same end of the crane) can provide a means for skew correction.

The Contractor shall provide four new variable speed AC squirrel cage close loop vector control bridge motors rated such that the four motor combination can translate a rated load at all speeds addressed in paragraph titled "Speed Requirements." Also the Horse Power rating shall be sized not to exceed the pre-existing gear reducer ~~capicity~~capacity and all of the remaining drive components. The bridge drive system shall have a drive for each motor. They shall be configured in a prime/slave relationship or each individual drive prime to its own motor. The contractor shall insure that

whatever relationship is chosen it will meet the following three requirements.

The drives shall be set up to equally load all four motors during normal operations.

The drive shall be able to limit skewing of the bridge automatically. Also the operator shall be able to manually de-energize drives on one end of the crane and run the other end to remove skewing ~~The drives shall be able to limit skewing of the bridge automatically, or allow the operator to manually de-energize the drives on one side and run the other side to remove skewing~~. This arrangement shall not result in erratic movement when moving in small increments. Error correction or "de-skewing" shall occur during normal speed range movement only. De-skewing shall not occur during the micro travel mode of operation. De-skewing shall not cause movement opposite to the direction commanded.

Upon loss of a motor or drive, the operator shall be capable of disabling the motor and drive, and allow the operation to continue at rated load and reduced speed. This will require the ability to back drive the failed motor and reducer with its brake released. The operator shall be able to switch to this configuration with the least amount of effort i.e. no rewiring or auto tuning. Reference "Special Engineering Assessment, Single Motor Operation" section.

The crane Contractor is responsible for replacing all bridge drive motors, modification of the motor footprint to accommodate installation of the new motors. Provide new motors, couplings, and alignment of the new motor to the existing bridge drive machinery, new bridge travel drive holding brakes, all wiring installation and testing needed for a complete system.

The existing bridge drive system is equipped with four (4) 150 ft-lb shoe brakes at each bridge drive location on all four corners of the crane. Each bridge brake shall be replaced with a new brake.

A Stearns solenoid actuated spring set disc brake of the same existing capacity (or approved equal) directly mounted on each bridge drive motor is acceptable. Brakes shall be self adjusting for brake lining wear and lining made of non-asbestos friction material.

Operation, adjustment and setting of brake shall provide smooth deceleration and holding at full speed and full load. Brakes shall have an externally accessible means to manually release the brake.

The Contractor shall provide a hoist holding brake release indication to the PES for control verification. This may include adding a proximity switch or other device to the brake shoe linkage. This must indicate a physical movement of the brake linkage, not energizing the brake coil. This brake release information will be provided to the PES to assure brake release occurs correctly, to enable hoist run commands.

2.2.1.4 Trolley

The trolley drive consists of two independent mechanical systems that each includes a 15 hp DC motor, brake and gear reducer that drive two drive wheels. The two separate systems located on the east and west side of the

trolley drive, a total of four wheels. Separate sets of trolley drive machinery provide some redundant drive capability for the trolley.

The Contractor shall provide two new variable speed AC squirrel cage closed loop vector Control motors rated such that the two motor combination can translate a rated load at all speeds addressed in paragraph titled "Speed Requirements." Also the Horse Power rating shall be sized not to exceed the pre-existing gear reducer capacity and the rest of the remaining drive components. The trolley drive system shall be configured with two drives, one for each motor. The drives may be set up in a master/slave relationship or one drive per motor. Upon the loss of one drive or motor, the other motor shall be able to move the trolley with a rated load at reduced speed. This will require the ability to back drive the failed motor and reducer with the brake released. Reference "Special Engineering Assessment, Single Motor Operation" section.

The Contractor is responsible for replacing both Trolley motors, modification of the motor footprint to accommodate installation of the new motors, coupling and alignment of the new motors to the holding brakes. This includes replacement of control devices such as an encoder, tachometer and all wiring and installation and testing needed for a complete system.

A Stearns solenoid actuated spring set disc brake, of the same existing capacity, (or approved equal) directly mounted on each trolley drive motor is acceptable. Brakes shall be self adjusting for brake lining wear and lining made of non-asbestos friction material.

Operation, adjustment and setting of brake shall provide smooth deceleration and holding at full speed and full load. Brakes shall have an externally accessible means to manually release the brake.

The Contractor shall provide a hoist holding brake release indication to the PES for control verification. This may include adding a proximity switch or other device to the brake shoe linkage. This must indicate a physical movement of the brake linkage, not energizing the brake coil. This brake release information will be provided to the PES to assure brake release occurs correctly, to enable hoist run commands.

2.2.1.5 Crane Contingency Modes of Operation

The crane control system shall accommodate several contingency modes of operation to assure failures of an individual motor, its control system or mechanical component cannot prevent the completion of a crane operation needed to safe a load. Safing the load is defined as moving the load with the bridge, trolley and main or auxiliary hoists in any direction at half normal speed in order to return the load to its support structure on the floor. This includes the ability to accurately spot the load using micro travel speeds on the bridge and trolley and micro-inch or float the main and auxiliary hoists.

Crane contingency modes of operation includes single motor operation (see paragraph titled, Special Engineering Assessment, Single Motor Operation) for the main and auxiliary hoists, bridge and trolley. Upon failure of any one hoist or travel drive system, the load can be moved and set into its support structure.

It is for this reason there are two load paths on the hoist that provides single motor operation, two trolley motor and drive systems and two sets of bridge drives one set on the north side of the bridge and one set on the south side. Operation of the intact system must be available to safe the load.

It is necessary to switch to single motor drive operation through switches located in the control panels, without rewiring or electrically disconnecting the motors, or re-auto tuning the drive etc. The contractor shall provide the control system features and necessary switches to accommodate this contingency operation. Also the contractor shall provide a procedure to describe switching for each motor in each control panel. It will also include instructions to the crane operator and the requirements to limit speeds and the duration of single motor operation.

Switching to single motor drive due to a loss of a functioning motor or motor drive, shall not prevent associated brake(s) from electrically releasing and/or functioning properly during contingency modes of operation. Also, fine speed, float, micro-inch /micro-travel speed ranges shall function during contingency modes of operation.

Failure of the supervisory system will be accommodated by supervisory by-pass switch. See paragraph titled Supervisory PES and the description of the Supervisory PES By-Pass switch function.

The crane manufacturer shall provide procedures for each of the above operations. They will be demonstrated in the shop and acceptance testing. Procedures will be placed in the O&M manual.

Contingency mode of operations shall not induce single failure points into the system.

2.2.1.6 Special Engineering Assessment, Single Motor Operation

The main and auxiliary hoist machinery arrangement provides two hoist motors, gear reducers and twin pinion and bull gears on each end of the wire rope drum. The two hoist motors work together to share the load to provide torque to raise and lower the load. The hoist machinery and motors is conservatively sized to allow the drive motors and machinery to operate at a high overload capacity.

Likewise, the trolley is equipped with two motors and twin sets of drive machinery to each axle. The bridge is equipped with four motors and drive machinery at each corner of the crane. These systems are also sized to allow single motor operation for the trolley and a two motor operation for the bridge.

In the event of a motor or motor control system failure it is desirable to have a single motor operation plan available for such a contingency.

The special engineering assessment will include an assessment of the main and auxiliary hoist machinery, trolley and bridge machinery to assure the machinery is sized for full load single motor/drive operation (one pair of motors for bridge operation). This includes an assessment of the mechanical and structural load path, including gearing, gear hardness, gear contact stresses, lubrication and machinery alignment for single motor/drive

operation. This includes back driving the disabled motor(s), brake operation and other considerations not listed here to provide a complete analysis.

These requirements are extended to cover the failure of a motor drive. Independent motor drives are required to serve separate hoist, trolley or separate set of bridge motors (north or south bridge motor pairs). Single motor drive operation to single motors is required (in part) to accommodate these contingency modes of operation.

Full load operation is needed but full speed operation is not important for such a contingency operation. The electrical engineering assessment should provide a recommendation to limit current draw and motor heating at a reduced speed operation.

Based on the results of this study the control system shall accommodate electrical design needed for this operation. This may include automatic alarms initiated by the crane control system to limit speeds and weights during single motor hoisting. Mechanical limitations shall be reported in the results of the study. Mechanical upgrades, if any, shall be initiated through a contract modification.~~Based on the results of the study the control system shall accommodate electrical design needed for this operation.~~

The results of the special engineering assessment will be provided in report form that details inspections, studies and results of calculations to assure safe single motor operation. The report will be signed by a registered professional engineer.

Single motor operation for each motor will be demonstrated during shop and acceptance testing.

2.2.1.6.1 Special Engineering Assessment, Main and Auxiliary Hoist Holding Brake Capacity

It is desirable to have each hoist holding brake sized to produce 150% of the rated load hoist torque (i.e. the rated load hoisting torque at the point of brake application). This additional brake capacity would provide some enhanced safety. However, it is not desirable to upgrade or replace all components in the hoist load path.

This special engineering assessment shall be completed on main and auxiliary hoist machinery that will remain after demolition to determine the maximum hoist holding brake capacity that is possible without completing upgrades to the existing hoist drive machinery.

The results of the special engineering study will be provided in report form that details these investigations including capacities and deficiencies along the hoist load paths.

Recommendations concerning possible increase in brake capacity without machinery upgrades will be provided along with possible machinery upgrades to achieve up to 150% rated load hoisting torque on the brakes.

The report shall be signed by as registered professional engineer. The report shall be reviewed and approved by the Contracting Officer before any modifications can commence.

2.2.1.7 Mechanical Inspection and Refurbishment

Contractor shall provide mechanical inspection and services on main hoist gear boxes (2 each) and auxiliary hoist gear boxes (2 each), trolley gear boxes (2 each) and bridge gear boxes (4 each). It is likely the bridge gear boxes will need to be removed from the end truck to complete this work.

The inspections will entail splitting the gear case and performing gear and bearing inspections. Report all findings to the contracting officer.

Upon approval reassemble gear box cases and replace all gear box seals and return to service. Special care must be taken to assure bridge gear boxes are reinstalled and aligned properly with bridge wheel couplings.

2.2.1.8 Main and Auxiliary Hoist Gear Reducer Oil Pumps

To assure proper gear lubrication during the extremely slow main hoist sustained micro inching operation (this operation could last three hours, ref. paragraphs 2.3.1.1 and 2.3.2) the contractor shall install new gear reducer oil pumps and lubrication piping on the two main hoist gear reducers. This work will be completed during gear box mechanical inspection and refurbishment (ref. paragraph 2.2.1.7 of this section).

Oil pumps and oil filter with automatic bypass feature (in the event of a clogged filter) shall be external to the gear reducers. Piping shall have an external pressure gauge visible from the trolley deck to indicate proper system pressure and operation. Piping and spray nozzles internal to the gear box shall be provided to circulate oil from the gear reducer reservoir and direct oil to gear mating locations.

Oil pumps shall run when the “main and auxiliary hoist selector switch” on the operators control console is selected for main hoist operation. The oil pumps turn off when auxiliary hoist is selected (reference paragraph 2.5.2 of this section).

2.2.2 Wire Rope Spool Monitoring System

Main and auxiliary hoist shall be equipped with a drum mis-spooling limit switch to detect improper spooling of hoist rope in hoist drum grooves. Actuation of this switch shall result in removal of power from the hoist motor and setting of the hoist holding brakes.

Actuation of this limit device shall prevent further hoisting or lowering until a key operated bypass (provided on the crane operators control console) is used to enable lowering out of the mis-spooling condition with further hoisting prevented until the mis-spooling condition is corrected. This system will be tested during the crane acceptance testing.

2.2.3 Main Hoist Powered Hook Rotation Motor

The main hoist is equipped with a powered hook rotation drive consisting of a 2-speed, 2(1/2) hp squirrel-cage motor. The main hook can be rotated 360 degrees in both clockwise and counter clockwise directions from the operators cab. The direction of rotation is as-viewed from the operators cab. It permits angular orientation of the load as desired.

The existing hook rotation motor shall be replaced. New motor and control shall be provided. The hook rotation speeds is described in paragraph titled "Speed Requirements." Existing gear reducer and clutch machinery will be reused.

2.2.3.1 Main Hoist Powered Hook Rotation Clutch Actuator

The hook rotation drive is equipped with a hydraulically operated sliding-jaw clutch to engage and disengage the powered hook rotation system to allow for powered or manual hook rotation.

The actuating system for the slide-jaw clutch consists of an oil-dyne hydraulic power unit, with 1/10 hp 115 VAC motor and pump, with a double acting hydraulic cylinder, with a clutch actuation linkage and corresponding controls. The Contractor will verify the as-built configuration of the clutch actuator system.

The Contractor is required to replace the current hydraulic system with a new electromechanical system. The clutch linkage systems will be reused. It will be inspected and cleaned and lubricated to assure fully functional operation.

2.2.3.2 Main Hoist Powered Hook Rotation Position Display System

A new position display system will be provided on the hook rotation system. This will indicate hook rotation motion back to the operators cab on position display screens. The hook rotation position indication signal shall be provided by a resolver or encoder on the motor shaft or other method as recommended by the crane manufacturer. See paragraph titled "Position Display Screens" of this section for hook rotation drive position display requirements.

Power and controls for the hook rotation system and signals for the position display will be provided though cable reel system to the operators cab.

Hook rotation direction and control switches and two clutch indicator lamps are provided on the operators control console in the cab. The clutch indicator lamp(s) shall be actuated by limit switches operated by the clutch electromechanical actuator. Intermediate position shall be indicated by no illumination. The switches and their corresponding indicator lamps shall indicate full engage and full disengage position of the clutch. The hook rotation clutch switch and hook rotation and direction control switches are both spring return to the off position. For a description of required operation see paragraph titled "Operator's Control Console" of this section.~~Hook rotation direction and control switches and clutch indicator lamp is provided on the operators control console in the cab. The hook rotation clutch switch and hook rotation and direction control switches are both spring return to the off position. For a description of required operation see paragraph titled "Operator's Control Console" of this section.~~

The Contractor shall demonstrate proper operation of the hook rotation drive, position display system and clutch actuating systems during acceptance testing.

2.2.4 Cable Reel

The main hoist is equipped with an electric motor driven cable reel and electric cable that provides power, control and instrumentation conductors from the trolley to the lower block.

The Contractor is responsible to remove the existing cable reel and its electrical cable and replace it with new cable reel and electrical cable.

The cable reel shall meet the minimum requirements as follows:

a. Automatically maintain tension on the electric cable supporting the weight of the electric cable such that there is no sag for all hook elevations and all speed ranges of the main hoist.

b. Provide heavy duty collector rings for low resistance, continuous operation, at the amperage required for each lower block conductor. A minimum of two spare collector rings will be provided. Provide separate isolated collector rings for the encoder cable.

c. The electric cable shall provide a minimum of 10% spare conductors with at least one spare conductor for each wire size and wire type. This shall include at least one spare shielded twisted pair for the encoder. A dedicated ground wire shall be provided. Conductors shall consist of stranded #10 copper for power and 120v control wiring with 600 volt insulation. Separate shielded cable shall be provided as required by the encoder manufacturer. Overall jacket insulation of this cable shall be 600V. All instrument cables and conductors shall be provided in the cable assembly under a single overall outer jacket.

d. The electrical cable shall provide strain relief so conductors are not under tension from cable weight and shall be electrically shielded as needed for separate power, control and instrumentation functions.

e. The cable reel shall meet the duty service class of the hoist for operation without electrical breakdown or overheating of the motors, resistors, controls or brakes.

The cable reel drive system shall be a Cavotec 9000X AF constant torque drive and motor system, or approved equal. The motor shall be equipped with two independent brakes each capable of bring the cable reel to a stop and holding without movement. Each brake shall be equipped with proximity switches (or another means to indicate brake linkage position to indicate the brake is open or closed). Brake position shall be reported back to the crane control system.

The cable reel drive system shall be set to fault on loss of torque. The cable reel drive system shall be able to determine loss of encoder power, loss of connections to the encoder, encoder input signal and improper brake position. Cable reel drive faults must output to the crane control system for normal crane shutdown.

The brakes shall have an externally accessible means to manually release each brake (without tools). The Contractor shall determine the hook height where maximum cable reel torque is reached. This is a combination of the effective radius of the cable reel spool and the weight of the hanging cable. The Contractor shall test each brake independently at the position of

greatest torque on the cable reel to assure stopping and holding capacity and operation.

~~The cable reel drive system shall be a Cavotec or approved equal, constant AC torque drive and motor system. The motor shall be equipped with two independent brakes each capable of bring the cable reel to a stop and holding without movement. The brakes shall have an externally accessible means to manually release each brake. The Contractor shall test each brake independently at the position of the cable reel to its maximum torque. The drive shall be set to fault on loss of torque. The drive shall be able to determine loss of encoder power, loss of connections to encoder, or encoder input signal. These shall result in a fault condition in the drive. Cable reel drive faults must output to the control PES for normal crane shutdown.~~

The drive shall be connected to a Gleason cable reel and slip ring drive system (or approved equal).

2.3 ELECTRICAL CONTROLS

All electrical enclosures shall be labeled with PPE requirements per Section 26 05 71.00 40 LOW VOLTAGE OVERCURRENT PROTECTIVE DEVICES.

The operator input has direct control of the speed. Provisions shall be provided so that the crane control system can tolerate both actuation of an emergency stop and loss of power or the interruption of over-current protection devices without damage to components under 100 or 125% load. In order to mitigate software corruption due to power transients, provisions shall be made to insure that line power supplied to microprocessor based devices is conditioned to remain within the input specifications of the devices and is monitored by the supervisory system which shall initiate a shutdown upon detection of the out-of-tolerance condition. Provide UPS for these functions with 10% spare capacity and full load run time of 30 minutes.

Performance response to controls shall be instantaneous, except where time delay devices and relays are provided. Operation shall be smooth and quiet. Heat rise in motors, brakes, and transistors during maximum capacity operation shall not exceed the design limitation.

The control system shall include over-current protection, under and over-voltage protection, phase loss protection and line transient protection. The system shall be capable of detecting these conditions before they adversely affect the control system and perform a safe and normal shut-down.

Protective devices shall include a fused circuit disconnect switch for each motor controller. The control system shall provide over-current protections, under-voltage protection, and reverse-phase protection.

On AC motors, overload relays shall be provided for each phase of the motor windings. Operation of any protective device (overload, under voltage, undercurrent, control-circuits fuses, or stopping device) shall safely stop motions, without any adverse affects on the control circuit.

Safety devices and brakes shall be positive in action without slipping, chattering, or jamming and shall have a fail-safe design.

2.3.1 Operating Characteristics

The bridge, trolley and hoist shall be capable of simultaneous and independent operation without degradation of control function.

The crane controls shall not allow inadvertent initiation of a run command. All master switches or motion control devices out of center or neutral position shall prevent any crane movement and give a fault to the PES indicating which component is out of proper configuration upon crane power up.

The operators control console will have two operating stations, the hoist operator and the bridge and trolley operator.

2.3.1.1 Main and Auxiliary Hoist Operation

The hoist operator will control the main and auxiliary hoist using the master switches, or float potentiometers. The main hoist will also have a micro inch control and hook rotation capability. The bridge and trolley will translate the load using the master switches or micro travel control. Plugging shall be allowed in any direction. This means that using the master switch or float switch the operator shall be able to change direction (move through neutral) without the brakes setting. The drive should bring the load to a stop and then switch directions without faulting out.

The hoist master switches will be used for normal operation in fine, coarse, and empty hook. Pulling the master switch toward the operator will raise the load and pushing the master switch away from the operator will lower the load. Neutral position will bring the load to a stop and set the brakes.

Load float speed range for main and auxiliary hoists shall be provided from zero (0) speed to 1.0 fpm. Float speed shall be adjustable by the use of the float potentiometer. Motors will be required to float, the full rated load at zero (0) speed for 1 minute duration. Zero (0) speed float shall hold the load without movement of more than 0.005 inches. Also it is required to switch from a "brake-on" stop condition to a "brake-off" float zero (0) speed without load movement of more than 0.005 inches and likewise from the "brake-off" float zero (0) speed to a "brake-on" stop condition without load movement of more than 0.005 inches. The control system shall accomplish this by means of torque proving, velocity and position feedback loops such that the only action required by the operator is to step on the foot switch and release the brakes by use of the master switch. Subsequent movement of the load within the float speed range (0 to 1.0 fpm) shall be accomplished by the operator moving the float potentiometer from the center or null position, clockwise (hoist) or counterclockwise (lower) as appropriate.

Main hoist micro inch controls shall be programmable through the Operator Interface Terminal. The following sequence of steps is used to perform micro inching operation. The speed selector switch shall be placed in the micro inch position. The hoist operator will input a speed command between 0.04 and 0.20 inches per minute in the OIT. The operator can then move the micro inch directional switch to the raised or lower position to initiate movement. Once the switch is released back to neutral the load shall come to a stop and the brakes shall set. Cruise control will be used to assist in long moves.

Control Movements involving the main and auxiliary hoists shall be accomplished by two means. First it will be possible to move the loads in the direction and desired speed using the normal crane controls i.e. the master switch, float potentiometer, foot pedal, etc. In addition, the crane operator will have an automated feature which will allow the crane to run in a desired sustained micro-inch, fine, coarse, or empty hook speed range assuming a hands off/ feet off posture. The crane operator will accomplish this by initiating the desired speed and then switch to cruise control by depressing the cruise control start button. This will allow the operator to release the master switch or any other speed control devices and continue movement. The crane shall continue at the desired speed until the operator depresses the cruise control stop button. At which time the crane shall come to a controlled stop. However, if the operator wishes to continue in the same direction and speed while stopping the cruise control, then he will move the master switch to the position that best simulates the speed and direction that the cruise control is currently moving and then depress the cruise control stop button. At that point the crane shall continue without the brakes setting and with cruise control no longer initiated. The cruise control function shall be automatically stopped during any normal shutdowns such as load imbalance, control faults, limit switches etc. Operation of the cruise control shall not automatically restart upon clearing the control shutdown, without the operator manually initiating the command.

The hoist rotation switches shall consist of two separately operated switches on the control console. Locations shall be as indicated on the Contract drawings. Each switch shall control the operation of the hoist swivel. The first switch, three position spring loaded to center, shall engage or disengage the swivel control.

To engage the hook the operator rotates the main hook rotate selector switch to "engage" and holds until the main hoist "rotate engaged" indicator lamp illuminates (then release the switch). The hook rotate drive is now coupled to the hook which will allow the hook to be rotated by the motor drive or held fixed.

To disengage the hook: Rotate the hook rotate selector switch to "disengage" and hold until the "rotate engaged" indicator lamp goes out (then release the switch). The hook rotate drive is now disengaged from the hook which allows the hook to be rotated freely by the load.

The second switch is a, hook rotation five-position spring loaded to center, switch used to operate the hook rotation drive in either slow or fast speed and in the selected direction. The first détente to the counterclockwise direction shall be slow speed and the second détente will be fast speed. Likewise in the clockwise direction the first détente will be slow speed and the second détente will be fast speed. The actual direction of rotation shall be as seen for the cab looking down on the load. Clockwise will rotate it in the clockwise direction and counterclockwise will rotate it in the counterclockwise direction.

2.3.1.2 Bridge and Trolley Operation

The bridge and trolley operator will control the bridge and trolley motion by using the master switches, or micro travel potentiometers. The master switches will be the normal means of motion and will be oriented in such a way that movement of the master switch will be in the desired direction of

motion i.e. North to move North and East to move East. The micro travel switches are a spring loaded to neutral potentiometer that gives the operator micro travel control.

The bridge and trolley operator will also have a, hook rotation five-position spring loaded to center, switch identical to the hoist operators rotation switch. This switch shall be wired in parallel with the hoist operators switch so that the hook rotation operation can be performed from either operators station. The hook engage and disengage function only needs to be performed by the hoist operator and its function will not be duplicated by the bridge and trolley operator.

2.3.1.3 Absolute Position Indication System

The Contractor shall provide an absolute position indication (API) system that provides the operator the three dimensional location of the hook load block in the transfer aisle. This shall be a laser range finder system accurate to within +/- one inch. The API shall be able to retain its location in a nonvolatile memory during power outages and losses. The systems zero locations shall be both hoist lower limit switches, the north final limit switch, and the east final limit switch. The contractor shall provide the ability for the system to be manually calibrated by the operator. This will be accomplished by placing the crane in the associated limit switch and resetting the position display to zero.

The total length of travel that the API will have to account for is as follows:

Main Hoist 160'-3"
Auxiliary Hoist 169'-0"
Bridge Travel 626'-0"
Trolley Travel 58"-0"

The API position readout will be displayed in the Operator Interface Terminal. The hook height value will be used by the weighing system to accurately correct for rope weight at different elevations. This will give the weighing system the ability of providing the operator a zero load weight for the empty hook at any elevation.

The targets shall be located in such a way as not to interfere with normal crane operation, or obstruct the view of the operator.

All laser systems if used shall be the type and classification which is safe for use in areas occupied by personnel.

2.3.1.4 Speed Requirements

Main hoist shall be variable speed control with the following ranges:

- No load or empty hook speed of 0-25 feet per minute.
- Coarse speed of 0-10 feet per minute.
- Fine speed of 0-2 feet per minute.
- Float control capable of holding a 0 to rated load without movement (for up to 1 minute duration)and making small adjustments in the raise or lower direction not to exceed one foot per minute.
- Micro inch shall be adjustable from .04 to 0.20 of an inch per

minute.

Auxiliary hoist shall be variable speed control with the following ranges:

- No load or empty hook speed of 0-62 feet per minute.
- Coarse speed of 0-25 feet per minute.
- Fine speed of 0-5 feet per minute.
- Float control capable of holding a 0 to rated load without movement(for up to 1 minute duration)and making small adjustments in the raise or lower direction not to exceed one foot per minute.

Trolley shall be variable speed control with the following ranges:

- Coarse speed of 0-50 feet per minute.
- Fine speed of 0-5 feet per minute.
- Micro-Travel speed of 0-1.0 feet per minute.

Bridge shall be variable speed control with the following ranges:

- Coarse speed of 0-75 feet per minute.
- Fine speed of 0-7.5 feet per minute.
- Micro-Travel speed of 0-1.0 feet per minute.

Full load speeds and control shall be maintained to within plus or minus 2 percent.

Hook Rotation Drive shall provide two fixed speeds of 0.25 rpm and 0.125 rpm.

2.3.1.5 Positioning or "Spotting"

The control system shall be capable of repeated movements in increments of 1/64 of an inch for hoist travel and 1/32 of an inch for bridge and trolley travel. The operator shall be capable of positioning the bridge and trolley to within 1/32 inches of a desired location and the hoists to within 1/64 inches of a desired location.

2.3.1.6 Crane Safety

Comply with the mandatory and advisory safety requirements of ASME B30.2, CMAA 70,29 CFR 1910.147, 29 CFR 1910.179, 29 CFR 1910.306B, and all applicable provisions of 29 CFR 1910 and NFPA 70.

2.3.2 Performance Requirements

A standard closed-loop system consisting of an AC induction motor controlled by a flux vector drive shall be used for the main hoist, auxiliary hoist, bridge and trolley motors. Each motion shall have an independent drive for each motor. Selected speeds shall be constant, without any fluctuation within a (+/-) 2% percent error tolerance loaded or unloaded. On a closed loop system the control system shall provide programmable acceleration and deceleration functions. All acceleration shall be continuous with no stepping, and shall follow a linear slope. Controls shall be able to maintain ± 0.005 movement of the load upon brake release and brake engagement. Power system harmonic performance shall be per IEEE 519.

The control system for the main hoist shall be capable of sustained micro-inching from no load to rated load for a 3 hour duration.
~~The control system main and auxiliary hoist shall be capable of sustained micro-inching from no load to rated load for a 3 hour duration.~~

2.3.3 Controls

2.3.3.1 General

The crane control cab shall be suspended below the north bridge beam on the crane. The control console shall have two primary operator stations, one for lateral movements and the other for vertical movements. Each station shall have selector switches, indication lights, master switches, control potentiometers, and computer generated position displays. The hoist control station shall have an Operator Interface Terminal (OIT) as indicated on the drawings for inputting micro-inch speed, and displaying fault codes.

The crane controls shall provide independent operation of each motion (main hoist, aux hoist, bridge, trolley) and main hoist hook rotation drive via operator controls.

2.3.3.2 Main and Auxiliary Hoist Load Cells

The contractor shall provide new strain gage sensor load cells on the main and auxiliary hoists. The ultimate design factor of the load cell shall be no less than 5:1. The strain gauge type load cell shall have a system accuracy of +/- 3 percent.~~The strain gauge type load cell shall have a system accuracy of +/- 0.5 percent.~~

In order to meet reliability requirements, two load cells are needed for both hoists (failure of proper load cell feedback to the control system could result in load motion beyond acceptable range). The load cells will be placed on the dead end of wire rope reeving, at the wire rope equalizer. Other approved locations for the load cell as recommended by the contractor may be acceptable.

These load cells will be used to provide control feedback to the hoist controls, this is necessary to assure proper motor torque is present before hoist holding brakes are released. It is also needed to provide load indication to the operators in the operators cab.

The first load cell will serve as the primary; the second load cell will serve as a secondary measurement. The crane control system will compare the two load cell measurements to assure they both read within an acceptable tolerance. Should one of the two load cells read an out of tolerance value, the crane control system will initiate a fault. Load cell faults can be corrected and crane operations continue through a by-pass load cell fault feature on the OIT. This OIT feature provides manually entered (password protected) estimated load weight entered into the crane control system. This load cell value will be substituted into control system operating parameters so the load can be moved. This load cell value will remain in effect within the crane control system and the fault remains displayed on the OIT until the crane is powered off. This load cell by-pass mode is used to safe a load during a load cell system failure.~~The first load cell will serve as a primary, the second load cell will serve as a secondary measurement. The PES will compare the two load cell measurements to assure they both read within~~

~~an acceptable tolerance. Should one of the two load cells read an out-of-tolerance value, the control system will initiate a fault.~~

The load indication will be adjusted to provide a more accurate weight on the hook by subtracting the effective lower block weight and number of parts of reeving. Additionally, load weight will be further refined to account for wire rope weight estimates based on hook height. The hook height measurement will be taken from main and auxiliary hoist absolute position display from the Operators Interface Terminal (OIT).

The load display will be provided on the OIT and displayed in pounds.

2.3.4 Drive Controllers

Provide static reversing, adjustable frequency flux vector controllers for the main and auxiliary hoists, bridge and trolley electric drives. Provide dynamic braking for all electric drives. All electric drives should be sized with dynamic braking resistors capable of bringing the rated load to stop without overheating the drive.

The main and auxiliary hoist, trolley and bridge brakes must set only after the associated controller decelerates the motor to a controlled stop.

All motors must run smoothly, without torque pulsations at the lowest speed and be energized at a frequency not exceeding 60 HZ at the highest speed except at empty hook speed.

The hoist controller must enable the drive motor to develop full torque continuously at zero speed. The motor drives shall be Magnetek Electromotive flux vector Impulse VG+ series 4 motor drives or approved equal. The drive shall be listed to UL 508C and comply with NEMA ICS 7.

The motor drive shall provide insulated-gate, bipolar transistors for power section of the inverter with pulse-width modulation. The flux vector control shall be tuned to the motor. Closed loop speed control shall be provided. Microprocessor controls shall be used in the drive and Ethernet communication provided between the drive and control PES.

The unit shall have the following features:

1. Reverse Plug Simulation function that allows the operator to smoothly and quickly stop and change directions without setting the brake.

2. Encoder loss detection.

3. Phase loss detection.

4. Brake test allowing testing of available brake torque.

5. Snapped Shaft Detection.

6. Load sharing, to allow two or more mechanically coupled motors to be controlled in a master/slave torque control fashion.

7. Load Float, allowing load to be held aloft at zero speed without setting the brake.

8. Provide a redundant hardware safety circuit that guarantees motor and brake power are removed when an E-STOP switch or safety controller opens that drive.

9. Ground Fault protection.

10. Key pad display including diagnostics.

11. Stall Prevention.

12. Static Auto Tune.

13. Load checking that prevents lifting an overload.

14. Output accuracy 0.01% or greater.

15. Braking torque 150%.

16. Thermal Overload UL recognized.

17. Drives shall conform to CENELEC EN 61800-3.

18. Input THD less than 5%.

19. Prior to the release of any hoisting brakes the drive shall provide torque proving to verify motor can hold load without movement.

2.3.5 AC Motors

Motors must meet all applicable requirements of NEMA MG 1 and UL 1004-1. Provide insulated inverter duty motors for Variable Frequency Drives (VFD). Motor insulation must be Class H, but with a Class B temperature rise. Provide AC squirrel cage induction type motors for the main hoist, auxiliary hoist, bridge and trolley drive systems. Provide Class F motor insulation for motors with conventional starters. Provide motor overload protection utilizing multiple thermal sensitive device embedded in its windings.

2.3.6 Protection

Protection must not be less than that required by NEMA ICS 2, NEMA ICS 8, CMAA 70, NFPA 70,UL 1004-1, UL 1449, UL 489, UL 50, UL 943, 29 CFR 1910.147, 29 CFR 1910.179, 29 CFR 1910.306B and all applicable provisions of 29 CFR 1910. Provide enclosed type circuit breaker readily accessible to the crane operator for crane disconnect. Provide for lockout/tagout of all hazardous energy sources.

2.3.6.1 Motor Starters

Motor starters and contactors shall be per Section 26 05 71.00 40 LOW VOLTAGE OVERCURRENT PROTECTIVE DEVICES.

2.3.6.2 Circuit Breakers

Circuit breakers shall be per Section 26 05 71.00 40 LOW VOLTAGE OVERCURRENT PROTECTIVE DEVICES.

2.3.6.3 Control Devices

Control devices shall be per Section 26 05 71.00 40 LOW VOLTAGE OVERCURRENT PROTECTIVE DEVICES unless otherwise indicated in this specification section.

2.3.6.4 Indicating Lights

Indicating lights shall be per Section 26 05 71.00 40 LOW VOLTAGE OVERCURRENT PROTECTIVE DEVICES.

2.3.6.5 Switchboards

Switchboards shall be per Section 26 23 00.00 40 SWITCHBOARDS AND SWITCHGEAR.

The switchboard main breaker shall be shunt-trip type. Coordinate with upstream power-feed breaker per Section 26 05 71.00 40 LOW VOLTAGE OVERCURRENT PROTECTIVE DEVICES. The main breaker shall be able to be actuated by the operator without accessing the interior of the enclosure.

A harmonic filter shall be provided just downstream of the main-line breaker for the crane.

2.3.7 Limit Switches

The main and auxiliary hoists shall be furnished with upper and lower control limit switches to prevent hook overtravel in either vertical direction. These limit switches shall allow the motor to come to a normal stop and allowing the brakes to set, and shall be set to attain maximum vertical hook height at any speed and to provide safe margins for drift. The lower limit switches shall be a geared type control circuit lower limit switch. The upper control limit switch shall be a weight operated type limit switch. The control circuitry design shall provide these limit switches to stop motion in the protected direction permitting normal operation in the opposite back-out direction. These switches shall be located in accessible areas and shall reset automatically.

The main and auxiliary hoists shall be furnished with a second, higher power type, weight-operated upper limit switch. This switch is wired independent of the directional controllers and the control type upper limit switch. Actuation of this switch shall shunt-trip the crane's main disconnect breaker. This weight-operated limit switch must require hoist resetting prior to operation of the hoist in any direction. Backing out of the weighted limit will require a manual over-ride of the control arm.

Both weight operated upper limit switches shall be mounted above the trolley deck or other accessible area and counterweight-operated upon the lifting of a suspended weight by the load block.

The weighted upper limit shall be adjusted sufficiently low to ensure that the hoist will not two-block (or otherwise damage wire rope) if the hoist actuates the weighted upper limit at full speed with no load. Both limits

shall be tested from slow speed to full speed to verify correct operation and clearance.

Bridge and trolley end of travel limit switches shall be provided and installed and shall be heavy-duty quick-break type in metal housings and shall conform to CMAA 70 and NEMA Requirements. Actuation lever shall be straight-forked type. Limit switch interruption of a motion in one direction shall not prevent the opposite motion in fine or coarse speed range.

Bridge and trolley speed limiting switches of the same type as above, shall be provided to decelerate the motion to fine range speed prior to actuation of final end travel limit switches. These slow down limit switches shall not prevent motion in the opposite direction in coarse speed range. Limit switches shall reset automatically.

Limit switch actuators shall be provided and adjustable and set to provide the specified hook coverage when tripped and shall provide safe margins for drift prior to contacting end-of-travel crane stops.

2.3.8 Crane Electrification

All wiring shall have 10% spare wires pulled in every run. The conduits shall not exceed 90% of NFPA 70 required fill capacity allowing 10% left for additions. A non-conductive messenger cable shall be added to each conduit run to provide future wire pulling capability.

All wiring shall be terminated on a terminal strip and labeled with the wire number as indicated in the drawings. All spare wires shall be terminated on a terminal strip and marked with a wire number in addition to being labeled "spare".

All crimped lugs shall be ring lugs; forked lugs will not be allowed.

No wire splices will be allowed. All termination to be made at terminal blocks or on electrical devices.

All wiring will be verified upon completion for proper location and labeling. All devices shall be properly marked in accordance with the drawings. No components shall be marked as hoist/lower and high/low.

Convenience outlets shall be located every 25 feet along the bridge catwalks and trolley catwalks. Two outlets shall be installed on the trolley, one on the North side and one on the South side. All receptacles shall be 120 VAC, 20 amp, and GFCI protected.~~Convenience outlets shall be located every 20 feet along the bridge catwalks and trolley catwalks. Two outlets shall be installed on the trolley, one on the North side and one on the South side. All receptacles shall be 120 VAC.~~

Routing of conduit along the floor of the bridge catwalks and trolley decks and other walking surfaces is generally not permitted. If this is necessary it shall be minimized. It shall not exceed location and size of existing conduits across walking surfaces. If conduit is installed across walking surfaces it must be covered by decking to eliminate tripping hazards.

Wire and cable shall be located, arranged and or shielded to eliminate any possible objectionable inductive and capacitive effects between circuits.

A separate panelboard shall serve crane lighting, 120V receptacles and air conditioning of the operators control cab and electrical enclosures. Power to the panelboard shall be provided independent of crane power so lighting, receptacles and air conditioning will operate with crane power is off. A minimum of two spare breaker slots shall be provided in the lighting panelboard.

2.3.8.1 Bridge and Runway Electrification

Power is transmitted to the crane through an existing fixed runway electrical feed rail and bridge mounted dual collector shoes. The items will be retained and reused. Electrical conductors from the dual collector shoes shall be replaced with new conductors of a suitable size and type. Conductors shall be compatible with collector shoe lugs.

2.3.8.2 Trolley Electrification

Power and control conductors from the bridge to the trolley shall be carried in an articulated steel cable tray suitable for outdoor service. Instrumentation/control power and power conductors shall be physically separated within the cable tray to eliminate objectionable inductive and capacitive effects between circuits.~~Power and control conductors from the bridge to the trolley shall be carried in an articulated steel cable tray.~~ Provide #3/0 copper grounding jumper from bridge to trolley run in this cable tray. Grounded Jumper shall be bonded to the trolley and bridge structures. Cable tray shall be Gleason Power Trak, Gortrac, or approved equal.

The articulated steel cable tray shall contain 20% spares for each wire size and type of conductor.

Provide TC rated copper cables 600 volt insulation for articulated steel cable tray. Provide NEMA 12 terminal boxes at both ends of cable tray with separate compartment for instrumentation and power. Provide four RG9 cables terminated in the instrumentation section on F type connectors at both end and four 3 conductor #18 shielded for future use in addition to the instrumentation cables. Terminate all cables on terminal blocks in the terminal boxes.

2.3.8.3 Crane Grounding Shoe

There are two existing grounding shoes located on the east and west crane runway rails. They are used to provide the crane electrical ground. The grounding shoes will be retained and re-used. The conductor for the grounding shoes will be replaced with copper #3/0 conductor. Exothermically weld wire to crane frame.

2.3.9 Wiring, Wiring Devices, and Raceways

See Section 26 05 00.00 40 COMMON WORK RESULTS FOR ELECTRICAL REQUIREMENTS.

2.3.10 Enclosures

Provide enclosures for control panels, controls, and brakes in accordance with NEMA 250 and NEMA ICS 6, Classification Type 12. Paint electrical enclosures in accordance with Section 09 97 13.00 40 METAL COATINGS.

Provide cooling unit on each control panel except the control console in the cab. Provide ductwork, etc. inside each enclosure for uniform airflow distribution. The cooling unit shall be designed not to require condensate drain and cool the panel interior to 80 degrees F with all equipment running at full load. Cooling units shall be accessible for regular service and maintenance.

Cooling units shall be equipped with thermostatic control to prevent overcooling of enclosure.

All enclosures shall have handle-actuated, three-point latches that are lockable and cored to a single key.

Circulation fan shall be designed to uniformally cool the entire enclosure.

Provide over temperature alarm contact to control PES. Set alarm at 85 degrees F and adjustable between 75 degrees F and 95 degrees F.

Enclosures shall meet or exceed 47 CFR 15 Class A requirements.

Each enclosure shall contain one 120 volt, 20amp duplex receptacle that is GFCI protected.

Each enclosure shall be equipped with fluorescent lighting with a lens cover per section 26 51 00.00 40 interior lighting.

2.3.10.1 Panel Markings

Panel components such as connectors, controls, indicators, jacks, keys, switches and fuse holders shall be marked with a suitable work, phrase, or abbreviation indicating the use or purpose of the part to identify these parts on the electrical schematics. These markings shall be legible so that the function of the component can be readily identified. Variable control components shall be provided with markings that permit the operator to set the control easily and correctly to a predetermined point. Laminated type plates shall be used where practicable. Components shall have permanent marking labels or plates located on or adjacent to the designated component.

~~The visible surface adjacent to panel facilities such as connectors, controls, indicators, jacks, keys, switches and fuse holders shall be marked with a suitable work, phrase, or abbreviation indicating the use or purpose of the part or symbol which identifies these parts on the electrical schematics. These markings shall be legible so that the function of the panel facility can be readily identified by the operator. Continuously variable operating controls shall be provided with markings that permit the operator to set the control easily and correctly to a predetermined point. Laminated type plates shall be used where practicable.~~

2.3.10.2 Terminal Markings

All terminal strips shall have permanent marking labels or plates which will identify each termination point. The terminal blocks and all other electrical control components shall be identified by permanent marking

labels or plates permanently located adjacent to the designated component. All marking identifications shall match those on schematics and wiring diagrams.

2.4 SOFTWARE AND HARDWARE

2.4.1 Software

It is expected that there will be several different software systems that will need to communicate and pass information between units. All communication between electronic systems will be of the speed and data quality such that operations between units appear seamless. Random communication faults will not be acceptable. All software systems shall be tied together with a common clock such that when comparing reported data events within or between systems it shall be discernable to the relative timing sequence of when these events occurred relative to each other.

All crane communication and software related wiring shall be protected against outside interference and static noise. Any loss of communication between software systems, on either primary or redundant channels, shall be detectable and reported as a system fault. It will be determined whether this loss of communication is sufficient reason to automatically shut down crane operations or whether the crane can continue operations. These determinations will be approved by the Contracting Officer.

Crane software shall have the ability to display up to 250 discrete fault codes on the Operators Interface Terminal (OIT) in the crane cab. These fault displays communicate to the operator(s) general conditions on the crane such as tripped limit switches or the conditions associated with a crane fault indication such as a drive shutdown. These faults codes shall display on the OIT the reason for a crane or motion shutdown associated with any fault light displayed in the cab on the position display screens. Each fault displayed on the OIT shall have a discrete fault number and short description of the fault. Once all motion on the crane is stopped, the operator shall have the ability to reset the crane faults through a key switch on the operators console. If fault condition still exists, it shall remain on the screen and the operator or engineers can refer to the troubleshooting instructions for the fault code in the O&M manual.

In addition to the fault display on the OIT in the cab, those faults are also displayed on a Human Machine Interface (HMI) touch screen located in a cabinet on the bridge girder near the PES. This display is meant for engineering personnel usage to evaluate crane conditions. This fault display will be able to retain fault code memory across a power loss and shall have a separate means to reset fault codes. Each fault displayed will be time stamped for occurrence and the first fault that initiated a crane or motion shutdown sequence shall be highlighted. In addition, faults or information from the Supervisory PES, communication faults, watchdog faults, and additional information useful to the engineers will be displayed on this screen.

All PES logic must be commented with sufficient description, as determined by the contracting officer.

Any user code which determines faulting conditions must have appropriate documentation (referencing any registers by both number and name) that

describes the process behind identifying the fault. This can include rising/falling edge clock cycle type graphs where timers are used to show flow of conditions.

All PES registers for I/O devices which are shown on electrical schematic drawings must match the drawing in both number and name.

All PES logic shall account for delay in communication/clock cycle delays.

All software reviews will occur at the 75% design review. Any field changes to the code after the design review, including any adjustment of control parameter settings, tuning, ect. shall be formally reviewed and properly commented and documented.

All final software developed shall have a 100% code review performed as part of acceptance.

All data communication between modules, subsystems, panels, cards, etc. shall be diagrammatically shown and include register numbers, names, and path flow.

2.4.2 Laptops

Two new laptop computers with individual protective carrying cases, shall be provided with this contract. Both laptops shall be loaded with identical software containing all the software development platforms used to develop custom software for this crane as well as any software written specifically for this crane. Two back-up copies shall also be provided on non-volatile memory such as a memory stick or card. All software licenses and software code custom written for this crane shall become the property of the Government. Any passwords, keys, locks, etc shall be given to and become property of the Government. There shall be a procedure available to allow for password changes. All interface cables needed for communications between the laptop and crane devices shall be provided for each laptop. The laptop shall be able to connect to the PES directly or through ethernet from the cab.

Laptops shall be able to communicate with data systems on the crane when directly connected to crane interface components. When the laptop(s) is connected to devices on the crane through direct connection, there shall be no restrictions except for password protection.

The laptop(s) shall be able to view operating software and operating logic "real-time" to the greatest extent possible. Where individual devices are monitored, such as relays, encoders, brakes, master switches, potentiometers, switches, etc the laptop displays shall show the changes of states of these devices as they occur as well as the internal ladder logic (or equal) state changes within the PES or other software devices. The software shall have the ability to add notes into the program to explain ladder logic.

2.4.3 Data Recorder

The Contractor shall supply a crane operations recording unit (Data Recorder). This unit shall have the capability of recording crane parameters such that it would be possible to re-create the crane operational conditions

at a selected time to within 1/10 sec intervals. This device shall record at a minimum incoming power and voltage at the main circuit breaker, all operator cab control positions and display readouts, limit switch positions, actual crane operational speeds and directions, and operating system faults. Final list of recorded data points shall be approved by the Contracting Officer. Data shall be time stamped when recorded and able to be retained in non-volatile memory for a minimum of fourteen days. Software shall be provided to access and view this database through the crane laptops and allow data gathering, sorting and display of this information.

The Data Recorder System shall be an industrial, rack-mounted type system with a solid state hard drive that is designed specifically for continuous operation for multiple years without downtime in the vibration conditions expected on the crane.

The Data Recorder System shall include USB access ports and LCD screen.

The Data Recorder System shall include licenses, and install CDs for all necessary software for development and use, including Operating System and any preinstalled programs.

2.4.4 Control PES

The primary crane control is accomplished through the programmable Electronic System (PES) and motor drive. Its software monitors the operator inputs, limit switches, motor and motor drive feedback, checks for system errors and provides output signals to control the crane subsystems and motor velocity.~~Its software monitors the operator inputs, limit switches, and motor feedback, checks for system errors, and provides output signals to control the crane subsystems and motor velocity.~~ The PES consists of a standard chassis and plug in cards. The cards include power supplies, central processing unit (CPU) with memory, digital input, digital output, analog input, bus transmitter, bus receiver and I/O cards mounted in the cab. In addition to controlling crane functions, the PES monitors crane motions for discrepancies and will stop motion when they occur.

The control PES shall monitor communication health. Specifically but not exclusively, it shall monitor the position indication system to preclude such conditions as a "frozen display" that would otherwise be undetected.

The control PES shall monitor the function health of the data recorder and all uninterruptible power supplies.

2.4.5 Supervisory PES

The supervisory PES shall be a secondary PES that monitors the health of the control PES, including the motion controller to verify proper operation. In the event that the control PES fails to react properly, the supervisory PES will shunt trip the main breaker, stopping all movement.

The supervisory system shall come with a switch that will allow the bypass of the supervisory system and its shut downs. This switch shall be a keyed switch with two positions. One position is for normal operation and the other is supervisory PES bypass. This provides the ability to by-pass the supervisory PES when it is malfunctioning and allows load movement to the safest location. The switch location shall be next to the HMI.

In order to achieve fail-safe requirements, a Programmable Electronic System (PES) must perform supervisory monitoring of the motor drives and all dynamic control circuits. It is the intent of this system architecture to conform to a Safety Integrity Level of 2 (SIL 2) according to the requirements set forth in ANSI/ISA S84.00.01~~Parts 9, 10, 11 and Annex B of ANSI/ISA S84.01~~. A basic block diagram of this configuration is provided in the contract drawing 79K39174 and is a high level concept of a possible control system configuration.

The Supervisory processor shall not command any portion of the Crane Motor Electrical Control System. The supervisory PES is used to monitor the performance of the drive comparing control or system output to commanded input from the control console. In the event of improper output(s) or system feedback, the supervisory PES will record the fault and initiate shutdown through the emergency stop system. The addition of a supervisory PES safety circuit shall not result in any intervention that would disable, or produce undesirable action in the hard-wired Emergency Stop circuitry.

Divergent hardware should be utilized to reduce common mode failures among these programmable electronic systems.

In no situation is it permissible to have a failure of the Supervisory PES affect an output or feedback device from the basic process control system. Proper isolation must be provided if a condition could occur where inter-connectivity would allow feedback loops to exist.

2.4.6 Watchdog

A watchdog circuit (i.e. electromechanical, solid-state, or microprocessor based) shall monitor the operation of the supervisory PES. If the supervisory PES fails, the Watchdog processor must detect this failure and initiate a shutdown through the emergency stop system. The addition of a watchdog safety circuit shall not result in any intervention that would disable, or produce undesirable action in the hard-wired Emergency Stop circuitry.

The watchdog needs to guarantee the integrity of the Supervisory PES. The watchdog system shall be an independent circuit. An independent method to check the integrity of the Supervisory PES and the watchdog shall be configured. Likewise, the supervisory PES must also supervise the watchdog. If the watchdog fails, the supervisory PES shall initiate crane shutdown thorough the emergency stop system. When these shutdown occur, there shall be provisions for the supervisory PES and the watchdog processors to retain error codes and system configuration or conditions leading to the shutdown in a non-volatile memory device to be available for diagnostics. This memory device shall be a removable media but shall also be accessible through the programming port of the PES and watchdog.

2.4.7 Operator Interface Terminal (OIT)

The Contractor shall supply an Operators Interface Terminal (OIT) located in the operators cab. This touch screen display is meant to give the operator(s) critical information about crane motion and position. Screen shall be of size and location such that both crane operators in the cab can

view and read display from their normal operators positions. Refer to drawing 79K39174, Sheet E-502.

OIT shall provide the operators crane fault reporting. The OIT shall have a status reporting area capable of reporting up to 250 discrete fault or informational codes. Informational data such as limit switch engagement shall automatically appear and clear as movement in and out of the limit occurs. All problem indicating faults shall remain on the screen until the fault reset key is initialized by the crane operator and faults may then be erased. Any faults still in existence after fault clearing action occurs shall reappear.

OIT shall provide absolute position displays. The OIT shall display the absolute position of the main hoist and aux hoist above the floor of the VAB. The OIT shall display the absolute position of the main and auxiliary hook to the crane north bridge travel hard stop and the trolley east travel hard stop. All positions shall be accurate to within +/-1 inch.~~OIT shall provide absolute position displays. The OIT shall display the absolute position of the main hoist and aux hoist above the floor of the VAB. The OIT shall display the absolute position of the main hook to crane north bridge travel hard stop and the trolley east travel hard stop. All positions shall be accurate to within +/-1 inch.~~

OIT shall provide microinch speed input capability. The OIT shall allow the crane operator(s) to manually enter the microinch speed. Once initiated, a keypad will appear to allow speed entry (without decimal point). Once operator enters desired microspeed and it is accepted, the keypad will disappear and the main hoist microspeed set point will appear on the screen. When moving in cruise control mode on the main hoist during microinching , the actual micro-inch speed will also be displayed since set point and actual speed may vary when switching microinch speeds "on the fly".

The OIT shall receive an input from the control PES and display the weight for both the main and auxiliary hoists.

The OIT shall have the ability to receive the weight from the control PES and manually input this value into the associated drive in the event that the drive should lose its load value.

The OIT communications shall be monitored to ensure screen is updated showing latest information. If communications to the OIT are lost, the screen must prominently indicate this status.

The Operator Interface shall accept, process, and display all updated data at a rate of no less than 15 cycles per second.

2.4.8 Crane Control System Faults and Diagnostics

The crane control system design will include a series of systems faults to detect loss of communication, component failures, corrupted signals, anomalous current/voltages or frequencies that indicate system or control problems. This is for the purpose of early detection of control system failure that could result in unwanted or un-commanded load movement. This shall provide additional layers of protection within the control system design for enhanced safety. This is also provided as a diagnostic tool to aid in troubleshooting the control system failures. The contractor's control

system design shall provide these features considering the capability of system architecture, commercial motor drives, supervisory PES, and other control features designed to provide enhanced safety for the crane.

The contractor shall provide a list of faults for approval by the contracting officer. The intent of the fault list to demonstrate comprehensive crane safety and provide diagnostics to give the crane engineer enough direction too properly troubleshoot the crane. The list shall be separated into three levels of response. The first being diagnostic i.e. slow down limit switch activation, and the second will be faults that cause a controlled stop of the motion causing the fault. The third will be an emergency stop that causes the shunt trip of the main breaker removing all control power to the crane.

The faults shall be specific to the component level. That is, it must identify the exact component, voltage, current etc. that caused the fault. For example, should a brake fail to release, the fault shall indicate the specific brake that did not release.

The section below covers only a few of the desired faults. This list is intended to give the contractor an idea of what type of faults are expected that will insure the crane is always maintained in the safest condition possible.

Special system faults:

a) A fault shall indicate anytime a drive motor brake fails to release to insure the operator does not drive through a brake causing damage to that brake.

b) All power supplies shall be monitored for proper output and a fault sent to the PES specifying which power supply is out of configuration.

c) A fault shall indicate if the inline power is out of specification i.e. loss of phase, low voltage, high voltage etc.

d) A fault shall indicate any movement in the bridge, trolley, or hoist that is opposite to the direction commanded greater than .005 inches.

e) Cable reel drive faults must output to the control PES for normal crane shutdown.

f) All master switches or motion control devices (potentiometers) out of center or neutral position shall prevent any crane movement and give a fault to the PES indicating which component is out of proper configuration.

g) A fault shall be initiated if a load cell reads an out-of-tolerance value.

h) Any loss of communication between software systems, on either primary or backup channels, shall be detectable and reported as a system fault.

i) A fault shall be initiated anytime a speed is greater than commanded in any direction and in any selected speed (micro, float, fine, coarse,

and empty hook). The words greater than commanded mean anything above the allowable tolerance of +2%.

Upon power restoration all crane systems shall automatically reboot/power-up without special re-initiation.

2.5 CRANE OPERATOR'S CONTROL CAB

Cabs shall be bridge-mounted, located and as a minimum sized as indicated on the contract drawings. Crane operator's cab shall be enclosed for air conditioning. Cab location or shape shall not interfere with hook travel. The cab shall be of neat appearance and framed with steel as shown on contract drawings.

A stairway with handrails shall be provided for access to the cab from the footwalk. An entrance platform complete with handrails, and toeguards shall be provided for access to the cab. The entrance platform shall be as indicated on the drawings.

Handrails and toeguards for cab and entrance platform shall be provided. The cab shall have three sides fitted with weather-proof hinged steel frame windows of such size, number, and location that all clear window surfaces (interior and exterior) can be cleaned from the inside the cab. Windows shall be yellowing resistant, minimum 1/4 inch thick polycarbonate and shall extend to not more than 6 inches from the floors and shall cover not less than 70 percent of the area of each side.

Windows shall be restrained from falling to the ground by a stainless steel braided wire tether attached to each window pane and window frame at all four sides such that in the event the window pane should pop out or break in four parts they will not fall to the floor.

Window framing shall be so located as not to interfere with operator's normal lines of vision when seated or standing. Window frames shall be resiliently mounted to relieve window panes from stresses due to sway or deflection forces.

Safety bars shall be provided across lower angled windows. A door shall be provided with weather stripping, having bronze cylinder locks and hinges, and with the upper panel glazed as specified for windows.

2.5.1 Crane Operator's Controls Cab Console

The crane operator's control cab console shall be designed in accordance with control console layout provided on the contract drawings. Considerations pertaining to correct human factors practices shall be provided. This shall include access of controls and console interior parts for operation and maintenance with emphasis on operator reach, visibility and operation of controls. Legibility of all displays and access to components shall be provided.

The crane operator's controls cab console shall be built with superior workmanship and attention to detail. This includes proper layout of controls and uniform console appearance. Console shall include ferrous metal construction, painted in accordance with Section 09 97 13.00 40 with brushed stainless steel, hinged and locking access doors that house control

components for access to all console interior components, wiring and terminal boxes.

2.5.1.1 Warning Devices

Provide an amber rotating beacon that is illuminated when the crane is powered and a warning bell that rings during any crane motion.

The rotating beacon shall be field located at the north east corner on the crane lower foot walk. The location shall be accessible for easy maintenance and it will not shine directly into the operators cab (provide appropriate opaque shields if needed). The rotating beacon shall be securely retained and design and located in such a way the any broken pieces will not fall to the VAB floor.

The warning bell shall be field located on the north east corner of the crane upper foot walk. The location shall be accessible for easy maintenance and it shall be securely retained.~~Provide a warning rotating beacon that is illuminated as long as the crane is powered and warning bell that rings at all times during crane motion.~~

2.5.1.2 Crane Operator's Cab Air Conditioning

The operator's control cab shall be provided with an air cooled ductless split system heat pump and shall include the following features:

a. Condensing unit shall be equipped with vibration isolation supports.

b. Thermostat control for cab design conditions 72 degrees F.D.B., plus or minus 3 degrees F., 60% R.H. when the ambient conditions surrounding the cab vary from 92.6 degrees F.D.B./78.6 degrees F.W.B. in the summer to 39 degrees F.D.B. in the winter. There is no direct solar heat gain. Heat loads shall be based on two operators in the cab, heat load of electrical control equipment, lights, infiltration, ventilation and radiation heat from surrounding ambient conditions.

c. Minimum cooling capacity of 10,400 BTU. Provide cooling load and sizing calculations for final equipment selection.

d. Minimum heating capacity of 11,600 BTU. Provide heating load and sizing calculations for final equipment selection.

e. Minimum efficiency 17 SEER

f. 120 volts/single phase/60 Hertz, Max. Fuse Size 20A, Max. Circuit Ampacity 20A

g. Ductless split system with fan unit and controls mounted in the cab.

h. Adjustab1e multi-directional air flow diffusers on the fan unit.

i. Variable air flow speed adjustment.

j. Fan unit shall have sound attenuation material applied to control the ambient cab noise level to not more than defined by noise criteria curve (NC) 40.

k. Built in replaceable air filters.

l. Adjustable fresh air damper.

m. Condensate drain pan shall be insulated, mastic lined galvanized steel connected to an electronic condensate evaporator tank such that no water is allowed to drip to the footwalk or floor. Fan unit shall be equipped with a condensate pump to pump condensate to the electronic condensate evaporator tank.

n. Condensate evaporator system shall have water level controls providing for automatic evaporation of condensate. Evaporation shall be of the infra-red type consisting of high intensity quartz lamps mounted above and out of the water. Evaporation pan shall be stainless steel arranged for easy cleaning. The entire assembly shall be housed in an enclosure with hinged access doors. Provide emergency overflow and alarm. The entire unit shall be mounted in a galvanized steel drip pan. Electronic condensate evaporator tank shall have minimum 15 quart capacity at 1.4 kW and 120 volts/single phase/60 Hertz.

o. The entire heat pump/condensate evaporator package shall be located in a manner to provide ease of maintenance and minimum noise transmission to the operator's cab. Location shall not obstruct the cab entrance or egress pathway.

2.5.2 Operator's Control Console

Operators control console shall be equipped with the following control and display components:

- Crane Power on/off Keyed Selector Switch (with momentary contact to Start position, then release to On position)

- Crane Power Green indicating lamp to turn on after crane power-up.

- Indicator Lamp Test Button used to simultaneously turn on all indicator lamps throughout the control console to check that lamps have not burned out.

- Emergency Stop Red Mushroom Button used to shunt trip the main disconnect breaker and safe the crane in the event of crane control erratic operation. Because of the size of this control console two red mushroom buttons will be provided.

- Motor Over Temperature Lamps shall be provided for each drive motor. This includes two main hoist motors, two auxiliary hoist motors, two trolley drive motors and four bridge drive motors. This will include a high motor temperature amber warning lamp and a red temperature shutdown lamp. Amber temperature lamps warn that a drive motor is overheating. Red temperature lamps indicate that a drive motor has overheated and motion will be automatically stopped.

- Motion Control Master Switches shall be provided for each direction including the main and auxiliary hoists, bridge and trolley motions. Each master switch shall have a brake release pushbutton on the ~~handle~~ button and shall be spring return to neutral position. The master

switches shall have dual output potentiometers and switches for input verification.
~~- Motion Control Master Switches will be provided for each motion both main and auxiliary hoist, and bridge and trolley motions. Each master switch will have a brake release handle. The master switches shall have dual output potentiometers and switches for input verification.~~

- Hoist Micro-Inch 3 position selector switch spring loaded to center with positions of Hoist, Neutral (STOP), Lower.

- The bridge and trolley shall each have a spring loaded to center potentiometer to initiate micro-travel.

- Speed range selector switches shall be provided for the bridge, trolley and the main and auxiliary hoists. Bridge and trolley shall have a three-position selector switch and shall select between micro, fine and coarse speed ranges. The auxiliary hoist shall have a three-position selector switch and switch between fine, coarse and empty hook speed ranges. The main hoist shall have a four position selector switch and shall switch between micro, fine, coarse and empty hook speed ranges. Fine and course speed ranges are the only speeds ranges the operator shall be allowed to switch between without first coming to a complete stop. Switching between fine or course speed ranges to empty hook speed, float, and micro-inch/ micro-travel speed ranges without stopping first (while the crane or hoist is in motion) is not permitted. If the operator attempts this a system fault shall occur and the crane shall come to a controlled stop as initiated by the crane control system, and a fault shall appear describing nature of shutdown.

- Wire Rope Spooling Error Red Indicating Lamp will be provided for both the main and auxiliary hoists. This will indicate wire rope mis-spooling on the hoist drum and will result in an automatic shutdown of the hoist and setting of the hoist brakes.

- A key-operated bypass switch shall be provided to clear mis-spooling errors on the main and auxiliary hoists. These switches will enable hoist lowering out of the mis-spooled condition. Further hoisting shall be prevented until the mis-spooled condition is corrected.

- Load Imbalance Red Indicator Lamps will be provided for both the main and auxiliary hoists. This is used to indicate a load imbalance between the two hoist motors and one hoist drive is not operating properly. This will result in an automatic shutdown of the hoist.

- Empty Hook Speed Allowed Blue Indicator Lamp will be provided for both the main and auxiliary hoists. This lamp indicates an empty hook is detected and higher than full load hoist speeds is allowed.

- Main Hoist Hook Rotation control items include a Main Hoist Hook Rotation Clutch Engage and Disengage Selector Switch, a Hook Rotate Engaged Amber Indicator Lamp and Two Hook Rotate Speed and Direction switches.

- Main and Auxiliary Hoist Selector Switch is used to directly select between operation of the two hoists. The selected hoist is operational while the other hoist is not allowed to function.

- A hoist selector by-pass keyed switch shall be provided to allow both hoists to operate at the same time for maintenance purposes. This is a uniquely keyed switch.

- Hoist Float Control is provided on both the main and auxiliary hoists. The control console shall be equipped with a Float Foot Switch, the Hoist Master Switch with brake release handle and a Float Potentiometer.

- Position Display Screens shall be provided for the bridge, trolley, main and auxiliary hoists and the main hoist hook rotation drives. These position display screens provide incremental position display for the respective motion.

- Position Display Screen Reset Button is used to reset the indicator dial and the distance digital counter.

- Position Display Source Selector Switches will be provided for the bridge, trolley, main and auxiliary hoist position display screens. Each position display screen will have two encoders available to provide position information to its respective screen. The position display source selector switches are used to select the appropriate encoder. This is needed if one encoder is not functioning.

- Operator Interface Terminal (OIT) - Reference paragraph titled "Operator Interface Terminal (OIT)".

- Computer Fault Red Indicating Lamp used to indicate a fault within the control PES or safety PES. This is not used for operational faults. The Operator Interface Terminal (OIT) and signal the crane operator the crane operation is automatically shut down by the crane safety systems and will display the fault code.

- PES Fault Reset Keyed Momentary Contact Switch is provided to reset all crane faults and turn off Computer Fault red indicating Lamp.

2.5.2.1 Hoist and Travel Speed Indicator

Each travel and hoist position display screen shall provide an indication of speed in ft/min. Display shall be formatted XX.X and be accurate to within +/- .1 ft/min.

Main hoist hook rotation screen shall display speed range selected (slow, fast).

2.5.3 Position Indication Systems

This crane is required to perform precise motion control of the load. For this reason the operator is in need of suitable position displays to provide visibility of actual load motion.

Each motion, the main hoist, auxiliary hoist, bridge, trolley motions and main hoist hook rotation drive shall have a position indicating system. This system shall provide high fidelity local position indication of fine crane and hoist movement.

The crane operators console in the cab shall have three thick film transistor (TFT)color liquid crystal display video screen (GE quick panel or approved equal) with a virtual display dial and a rotating pointer showing display of spotting movements of the bridge, trolley, main, main hoist hook rotation and auxiliary hoists respectively. Each display screen will also be equipped with a five digit counter that can be reset to zero at any time by the crane operator. Also, the display screen shall show direction indicating arrows next to the dial showing actual crane motion.

Dial motion shall be smooth, positive and shall not dither during movement or in the stop position. The system will be required to accurately track fine movements of all directions. The display screen refresh rate shall be a minimum of 15 cycles per second.

The virtual display dial and pointer will be a minimum of 4 inches in diameter. The dial will relate to linear movements as follows:

Crane Motion: Dial (1 rotation): Dial Graduations:

Main Hoist 1/4 inch 1/128 inches
Main Hoist Hook
Rotation 10 degrees of
hook rotation 0.1 degrees
Auxiliary Hoist 1/4 inch 1/128 inches
Trolley 1/2 inch 1/64 inches
Bridge 1/2 inch 1/64 inches

Each display will have a five digit XXX.XX feet (with zero "000.00" reset button) for each linear movement. The hook rotational display shall be four digit XXX.X degrees.

The position display system will include encoder or other approved device incorporated within the drive machinery, microprocessor to read and interpret the direction and magnitude of movement with input to the operators cab position display screen. A second encoder (or other approved device) shall be provided and shall serve as a backup to the primary encoder for each direction of motion.

Safety features within this control system will assure system failure will not freeze the screen or otherwise indicate false or erroneous movement without automatic warning, error, or fault code to the operator.

2.5.3.1 Position Display Screen Function

The position display screens shall provide the following features.

- Direction indication, "hoisting", "lowering", "north", "south", "east", "west", "clockwise" or "counterclockwise" for the respective screen. When no motion is occurring the screen will indicate "idle".

- Direction indication by direction arrows around the display dial that point in the direction of movement. When no movement is occurring for the respective motion the arrowhead disappear and a solid line remains.

- Digital Distance is shown by "Distance", shows a cumulative distance moved since the last reset with the reset pushbutton. This will be indicated in feet or degrees as applicable.

- Fractional/Decimal touch screen button changes reading between decimal feet or feet-inches for the digital distance scale.

- Speed Range Indicator displaying "Micro," "Fine," "Coarse," "Empty Hook Speed" for the respective travel and hoist directions or "Fast" or "Slow" speed ranges for hook rotation drive. The speed mode indicator should match the respective speed selector switch selections.

- Speed indicators (speedometers) in all directions. The display shall show xx.x feet per minute.

- Last Movement indicator shows distance and direction of last movement. Brakes shall have to be set for 5 seconds or more to define a new movement.

- Visual indication of when cruise control is engaged.

- Safety Warning Display shall be automatically displayed on the position display screen in the event of a detected error in the encoder input signal (that could result in a frozen screen or other incorrect displays).

- Safety Red Banner Display will appear across the digital display portion of the screen to indicate a fault has occurred with an encoder or a loss of communications and information displayed may not be correct.

- Safety Fault Display will be provided in the center of the display screen in block letters "Fault" in the event of a fault (the OIT will show specific fault codes).

- The Contractor shall provide the operator the ability to move position displays among the three screens.

- Screens shall default to their normal positions upon start-up unless a fault in one of the three screens shows it inactive.

2.5.4 Micro Travel Pots

Micro-travel potentiometers for bridge and trolley motion shall be provided. Located below the masterswitch on the main operators console for both the bridge and trolley motions shall be a "micro-travel" potentiometer. Potentiometer may be used to take the place of the masterswitch during small movements to allow for precise movements of the bridge or trolley. Pot shall be spring loaded to center neutral (off) position. For the bridge clockwise rotation from center position shall move bridge north and counterclockwise from center shall move bridge south. For trolley clockwise rotation from center position shall move trolley west and counterclockwise rotation shall move the trolley east. Full travel of pot shall result in a speed command of 1 ft/min. Speeds command will have a linear slope from center off position to full speed position. Provide a three-position selector switch on the control console to select between the micro, fine and coarse speed ranges.

2.6 LIGHTS

Provide evenly spaced lights along the bridge and trolley as indicated. Lights shall be per Section 26 51 00.00 40 INTERIOR LIGHTING.

Emergency lighting with battery backup shall be provided from the cab and along the egress route.

Below trolley lighting shall be added to allow for proper illumination for maintenance.

Lighting in enclosures~~cabinets~~ shall be on interlock switches so that the light comes on when the door to the panel is opened and goes off when the door is shut.

2.7 STRUCTURAL MODIFICATIONS

2.7.1 Cab Fabrications

Cabs shall be bridge-mounted, located and as a minimum sized as indicated on the contract drawings. Crane operator's cab shall be enclosed for air conditioning. Cab location or shape shall not interfere with headroom hook travel. The cab shall be of neat appearance and framed with steel. A stairway with top and bottom landings and handrails shall be provided for access to the cab from the footwalk. See Contract Drawings for configuration. The bottom landing shall access the cab at the same elevation as the floor of the cab.

2.7.2 West Catwalks

West catwalks shall be modified to the configuration indicated on the Contract Drawings.

2.7.3 Footwalks, Handrails, Toeguards and Ladders

Modification to existing footwalks, handrails and toeguards are shown in the contract drawings.

Handrails shall be not less than 42 inches high with verticals not more than 4 feet apart. A 4 inch high toeguard will be provided along all new handrail to match existing toeguards. Hand rails and verticals shall be constructed of 3 by 2 by 1/4 inch angles or of 1-1/2 inch round extra strong weight pipe or 2 by 2 by 3/16 structural tubing. An intermediate rail shall be placed approximately midway between the top of the toeguard and the handrail.

Spring closing gates shall he provided along all walkways where ladders enter footwalks. Spring closing gates shall provide 42 inch high horizontal rail to match handrail height and a mid-rail 23 inches from walking surface. Safety gate shall be Cotterman safety gate, or equal.

As a minimum footwalks, handrails, and toeguards shall conform to the requirements of OSHA 29 CFR 1910.

2.7.4 Miscellaneous

All belt driven devices shall have notch belts not smooth.

Drip pans will be provided under new component installed under contract that contains oils or grease.

All couplings with setscrews shall have loctite applied to them and marking putty applied to indicate any loosening.

All belts, chains, and rotating equipment shall have proper covers to prevent inadvertent contact from personnel.

All new Zirk fittings shall be pressure relief fittings.

No plastic tie wraps are permissible on the crane exterior.

The Contractor shall not install anything that hangs over the side or bottom of the crane that is not preapproved by NASA.

A cabinet for spare parts, tooling and drawings shall be located on the crane located on the south footwalk. This cabinet shall be at the minimum six feet high four feet wide and eighteen inches deep. It shall be fastened to the crane and lockable.

NASA will define any passwords.

Four keys will be provided for every lock.

2.8 SAFTEY AND RELIABILITY

2.8.1 Reliability Engineering Analysis

A crane control system reliability analysis will be completed by an independent third party under NASA contract. This reliability analysis will begin upon first receipt of the electrical control system drawings, control schematics and block diagrams. This will continue throughout the submittal process to final acceptance testing of the crane.

In order to assure accuracy of this analysis, the Contractor will provide the services of the cranes electrical controls engineer(s) to assist with the reliability analysis. The Contractor shall provide those services and at the completion of the final acceptance testing and submit a certification that the reliability engineering analysis is correct and accurate and reflects proper control system design and safety function of the crane.

Should the reliability analysis reveal any single item failure given the stated criteria, the Contractor will be responsible for correcting this problem at no additional cost to the contract.

The reliability engineering analysis will involve a step by step component failure analysis of the crane electrical control system. This is a formal engineering analysis to determine if the a failure of any individual component causes the crane to react in a unsafe manner. This is a comprehensive system and component analysis on the crane electrical control system that assumes failure of any individual component and determines if the crane fails in a safe state.

This will include failure modes and effects analysis (FMEA) and a software analysis. This will determine all possible failure states of the components and the effect of each failure state on the rest of the crane system (and ultimately the safety of the load).

The contractor electrical control engineer(s) will be responsible for providing detail information to the reliability engineer to assure a full understanding of the control, safety systems and software. As the reliability analysis is completed the contractor will review and comment on the adequacy and correctness of the analysis until the reliability analysis is completed and agreed upon.

2.8.1.1 Automatic Functional Safety Requirements

The control system shall be designed fail safe to ensure that a failure of any component will not cause the crane to operate in an unsafe manor as defined below.

Failure modes that cause a slowdown of load motion or results in load motion coming to a safe stop are acceptable.

Failure modes that cause an increase in speed, an un-commanded direction shift, and/or loss of load control are unacceptable.

Failure modes that actuate an emergency stop, or a stop made by an emergency shutdown system is acceptable.

2.8.1.2 Failure Modes of Electronic and Microprocessor Based Systems

When programmable electronic microprocessors are used in the crane control, system must be fully understood and their inherent failure modes must be considered.

The effects of these failure modes can be grouped in the following three categories:

Incorrect control (cause: the input/output signals are distorted, or the program instructions are incomplete, wrong or insufficient).

Failure of a safety shutdown function, i.e., the system is not shut down at all, or it is not turned off in a fail-safe condition (cause: same as above).

Occurrence of false (nuisance) trips (cause: misinterpretation of inputs signals, or too sensitive max, min acceptable values).

System testing during shop testing and preoperational testing should demonstrate where possible the control system's electrically fail-safe capabilities on a function-by-function basis.

2.8.1.3 Crane Functional Safety

The items above must be applied to all motion control including the bridge, trolley, main and auxiliary hoists, main hoist hook rotation system, position display screens and input functions and displays of the Operator

Interface Terminal. This includes the contingency modes of operation for the main and auxiliary hoist, bridge and trolley.

The slow speed control of each motion is required to provide precise load spotting in close proximity to stationary components. The load and stationary components can be considered fragile and any un-commanded load motion that results in contact between load and stationary components is unacceptable.

Additionally, the operator is remotely located in the operators cab. The operator must rely on radio commands to direct load movements from persons located at the load. The position display screens are used to precisely move the load within this very tight spotting accuracy. The safety features of this control system shall assure position display screen failure will not freeze the display screens or others indicate false or erroneous movements.

The Reliability Engineering Analysis is used as part of the overall crane design process to determine if the electrical control system design configuration and its system components are fail-safe, i.e. does the system design provide fail-safe protection against single component failures and the load remains safe based on the criteria above.

2.8.1.4 Fail Safe Protection Through Manual or Automatic Means

Fail safe protection can be accomplished through manual or automatic means.

Operator intervention can (only rarely) be used to provide fail safe protection. For this to be acceptable, the operator, while operating the crane, must first perceive the incorrect load motion and react to it by releasing the control button, master switch, or depress the emergency stop switch on the control station. This must occur before unacceptable load motion occurs. Manual operator intervention is only acceptable when the crane operator has time to recognize the control failure has occurred and react within an acceptable time frame.

In almost all cases automatic safety systems within the control system must be used to protect the load. The crane control system must be designed to recognize anomalous load motion based on operator inputs. This can be accomplished by utilizing many electrical, electronic, and microprocessor based programmable electronic components to provide automatic failsafe protection to the load (this protects the crane from a variety of anomalous crane operation including erratic or uncontrolled load movement caused by a failure within the crane control system).

Safing the load through manual or automatic means is accomplished by removing power from the crane either manually through the emergency stop switch or automatically through the automatic control systems of the crane control system e-stop or shutdown system. Removing power on the crane using circuitry that is independent of the crane control system remains the fundamental electrical fail-safe feature provided to protect the load.

If a fault is only associated with a particular motion, i.e main hoist, auxiliary hoist, bridge, or trolley then the fault shall only effect or shutdown that motion. The crane will be able to operate the other motions. If a fault is associated with the basic crane process control system or safety system then automatic shutdown will affect all motions by removing

all power from the crane.~~Safing the load through manual or automatic means is accomplished by removing power from the crane either through the emergency stop switch or through automatic control means. Removing power on the crane using circuitry that is independent of the crane operating controls remains the fundamental electrical fail-safe feature designed to protect the load.~~

2.8.1.5 Fail Safe System Architecture

Refer to paragraph titled Supervisory PES and the control system safety configuration block diagram on the contract drawings 79K39174 for a description of a system architecture that provides a functional fail safe operation.

The arrangement shown is not intended to be complete. It shows a basic diagrammatic block view of the crane control architecture only. It does not show feedback systems and control paths needed for a complete system. However, the functional relationship shown allows the use of commercial equipment and software. It also allows for a simple reliability analysis by reducing the number of systems that must be analyzed. With this system architecture internal failure modes of commercial drives (including its proprietary hardware and software) do not need to be analyzed. Rather a properly designed supervisory system independently protects against commercial hardware and software failures to provide the fail safe protection required.

This is one of many control system architectures that can be used to meet this these fail safe requirements. It is not mandatory for the crane control system architecture conform to this diagram. The contractor can provide a different architecture. However, the control system must meet the fail safe requirements. The reliability analysis must be possible to complete without needing to understand internal failures of commercial equipment.

PART 3 EXECUTION

3.1 GENERAL

The crane manufacturer shall complete the fabrication, installation, installation and testing of control systems in accordance with approved shop drawings. All work shall be completed by workmen skilled in this type of work and in accordance with contract documents. All work will be under the supervision of the Contractor.

3.1.1 Steel Fabrication

Shearing and chipping shall be done neatly and accurately. Corners shall be square and true. Flame cutting, using a tip suitable for the thickness of metal, may be employed instead of shearing or sawing. All bends of a major character shall be made with metal dies or fixtures in order to ensure uniformity of size and shape. Precautions shall be taken to avoid overheating.

3.1.2 Bolted Connections and Fasteners

Bolt holes shall be accurately punched or drilled and shall have burrs removed. All bolts, nuts and screws shall be torqued to develop the full

strength of the fastener. All fastenings or parts which might become loosened by vibration, shock, or operation of the crane shall be secured by suitable locking devices. Any fasteners that are in a position to fall to the ground shall use nuts that are a nylon insert type.~~Bolt holes shall be accurately punched or drilled and shall have burrs removed. All bolts, nuts and screws shall be torqued to develop the full strength of the fastener. All fastenings or parts which might become loosened by vibration, shock, or operation of the crane shall be secured by suitable locking devices or self locking nuts.~~

3.1.3 Installation and Testing

All testing will be completed in accordance with approved written procedures. At conclusion of testing, procedures shall be prepared by the crane manufacturer and test reports shall be dated and signed, witnessed, and approved by the NASA technical representative.

No equipment shall be shipped to KSC until all equipment has completed its required shop testing. Shipment to KSC and installation shall be completed in accordance with the requirements of the contract documents. All materials, equipment and methods used for installation of the new control system shall be in accordance with appropriate ASME and ANSI safety standards.

Installation and testing shall include requirements in Division 26.

3.1.4 Painting

Painting shall be completed in accordance with Section 09 97 13.00 40.

3.1.4.1 Unpainted Surfaces

Items such as rubber parts, flex hoses, electrical cables, mechanical linkages such as shoe brake adjustment linkages (paint brake body), chain and sprocket assemblies, timing wheels and the like shall be left uncoated.

Items such as carbon steel motor shafts, flex couplings, and the like shall be protected from corrosion during shipment with a suitable corrosion protection coating such as Cosmoline, (or approved equal). This shall be applied to these areas before shipment. Cosmoline shall be reapplied at the end of acceptance testing for lasting corrosion protection in the crane environment.

Items such as treaded fasteners and threaded studs shall be left unpainted. These items shall be coated with a long term corrosion protection film barrier such as Zep Linebacker (or approved equal). This film shall protect against corrosion on outdoor surfaces that resists rain, salt water and many corrosive industrial environments. This can be easily removed with a solvent or degreaser when desired.

3.1.5 Maintainability

Electrical equipment shall be constructed, located/oriented so that all parts (except in the case of sealed units) terminals, and wiring are accessible for circuit checking, adjustment, maintenance, and repair without special access equipment or removal of other equipment with a minimum of

disturbance to other parts. The ability to gain access to equipment is defined as removing covers, etc., and also includes physical and visual access to perform maintenance. Testability of the equipment must be included where appropriate. The design layout of equipment must be completed taking into account man-machine interface relationships to ensure human factors are included.

Wherever possible, parts shall be mounted so that they can be removed and replaced without interference from injury to, or removal of, other parts or wiring. Parts most likely to fail shall be easily replaced. Realignment of the equipment shall not be necessary as a result of the replacement of a component. The equipment shall be designed when practicable, so that it can be operated, maintained, or replaced by personnel with very little or no specialized training or effort.

3.2 TESTING

3.2.1 General Testing Parameters

The crane controls shall be tested in the shop prior to shipment and after installation. The Contractor shall submit test procedures for shop testing, and acceptance testing, to the Contracting Officer for approval at least 30 days prior to testing and make additions and deletions as noted. The Contracting Officer shall be given a minimum of two weeks' notice before the start of testing. The Contractor shall not start any Government required testing until he is prepared to conduct all such tests. Testing will be completed in the presence of the Contracting Officer Representative. Testing will be completed with all control components active. The use of jumper wires, etc., to by-pass control functions will be strictly prohibited unless required to simulate control function or unless agreed to in writing on the test procedure. The Contractor shall rerun any test of portion of a test at the direction of the Contracting Officer where the Contracting Officer determines that a subsequent adjustment has affected a previously demonstrated capability.

The Government reserves the right to require additional testing on any component or system that shows signs of deficiencies, potential failure or other anomalous performance, until determined acceptable by the Contracting Officer. The Contractor shall take immediate action to correct any deficiencies disclosed by test and shall rerun the test as directed by the Contracting Officer. The Contracting Officer will be given a reasonable period of time to evaluate results before notification of acceptance. The Contractor shall be the test conductor and record time and conditions, for each test.

All test data shall be recorded on the written test procedures. This record of test data will serve as permanent record suitable for retention for the life of the crane.

3.2.2 Shop Assembly

The crane control system shall be fully assembled for shop testing purposes. Assembled panels and the crane control console and drive motors shall be temporarily wired and powered with the complete software installed and drive programmed and tuned to the appropriate configuration at the Contractor's

plant. Equipment shall be wired and examined visually and dimensionally for fit, quality of material, adjustment, workmanship, finish, etc.

For the purposes of the shop testing "fully assembled" shall mean that all crane control elements shall be assembled in the shop to permit the demonstration of the full function of the control system performance requirements specified. This will include all control panels (fully assembled), bench test of all motors and brakes, and crane operators console (fully assembled) with all systems temporarily wired for full functional testing. Permanent structural bolted connections made in the field for final assembly need not be made but temporary bolts necessary to develop the required structural strength and rigidity for the shop tests shall be provided. Other bolted connections that do not require removal for shipment shall be completed. Safety covers and guards etc. that will be removed for shipment need not be in place. All safety covers shall be present and fit checked prior to shipment. Electrical pull box and junction box covers need not be installed when electrical connections wire numbers etc. are exposed for inspection, troubleshooting. The crane controls shall be fully wired and a temporary power supply shall be installed.

~~The drives shall be tested for correct operation. They shall be interfaced to test their motion coordination and communication. All outputs and inputs shall be verified operational.~~

~~The communication between the drives other devices and supervisory system shall be tested. All drive faults (applicable to no load testing) shall be simulated and demonstrated.~~

3.2.3 Shop Testing

The shop test shall demonstrate all control functions the crane controls are designed to perform. Travel speeds in both directions shall be checked and recorded. All brakes shall be checked for proper operation and clearance.

The drives shall be tested for correct operation. They shall be interfaced to test their motion coordination and communication. All outputs and inputs shall be verified operational.

The communication between the drives other devices and supervisory systems shall be tested. All systems/PES/drive faults (applicable to no load testing) shall be simulated and demonstrated.

Motor voltage and amperage shall be checked and recorded. The redundancy feature of the main and auxiliary hoist bridge and trolley drive system shall be verified for proper functioning.

Demonstrate electrical control hoisting and lowering and micro-inch features.

Demonstrate single motor and drive operation for the main and auxiliary hoists, bridge and trolley. The test will be done once for each motor. This includes two hoist motors, two auxiliary hoist motors, two trolley motors and each of four bridge motors. The test will demonstrate disconnecting the failed motor, completing switching inside each respective control panel and instructions to the crane operator to run the remaining motor(s) at reduced

speed. Each single motor operation will be demonstrated. After the testing of each motor, the wiring to the motor and control panel will be placed back into the normal configuration and the crane will be tested to demonstrate proper function.

Demonstrate proper hook rotation motor operation. This is a motor bench test of all hook rotation control features.

The Contractor shall bench test the main and auxiliary hoist motors to operate in course, fine, micro inch, float speed and empty hook speeds.

A functional test of all position indicator systems shall be performed and accuracy and performance verified.

Testing shall record startup and operating voltages and current measurements for electrical equipment. Compare recorded values with design specifications or manufacturer's recommended values; abnormal differences (greater than 10% from manufacturers or design values) must be justified. In addition, note and investigate and correct any high temperatures or abnormal operation of equipment or machinery. Record main and auxiliary hoists, bridge, trolley and main hoist hook rotation speeds for each test.

The proper function of all secondary motor controllers shall be completed with demonstration of switching between primary and backup drives.

Demonstrate the bridge drive system ability to remove skewing.

System testing will demonstrate the control system's electrically fail-safe capabilities for a function by function control sequences and shutdown.

> These tests will include functional testing of all sequences, functions, inputs and outputs. Testing shall be completed for all operating conditions and timing requirements shall be completed. Testing will include testing all fault codes.

These tests shall be completed to verify control stability during selected component failures such as but not limited to out of tolerance voltage or current control signals. Artificial input of voltages, currents, control tolerances and other parameters into the control logic is acceptable to demonstrate where other control functions shut down the appropriate system. The Contractor shall develop these written procedures to complete these tests. Procedures must include correcting artificial parameters after testing.

Any deficiencies noted shall be corrected and retested prior to shipment.

3.2.4 Field Installation and Inspection

The Contractor shall provide all necessary tools, test equipment, and personnel to perform the control system installation. This includes all necessary safety devices required for work at KSC.

Detailed and complete tests per the acceptance test plan shall be made in the presence of the contracting officer representative after the new motors, controls and supervisory systems are installed.

Preliminary inspections shall be made and recorded before acceptance testing. All items shall be installed and all testing will be serially. Inspection will include checking for proper motor alignment and shimming. Electrical connections shall be checked for tightness, proper color coding of wires and labeling.

The Contractor shall provide two reference copies of the O&M manuals, two reference copies of updated drawings for use during the acceptance testing. Note, final as-built drawings and final updated O&M manuals will be submitted at the end of the contract in accordance with contract schedule of deliverables.

Field inspections shall be completed to verify all lighting, electrical footwalks, ladders, stairs and control cab comply with Contract Drawings.

3.2.5 Acceptance Tests

3.2.5.1 Personnel

The Contractor shall provide a competent on site engineer/technician and a competent on site control systems engineer/technician to oversee and/or assist in the installation and acceptance testing of the main and auxiliary hoists, bridge, trolley, main hoist hook rotation drives, the position display systems and other systems related to this contract.

3.2.5.2 Equipment

The Government will provide test weights, devices for attaching to the hooks and power for testing.

3.2.5.3 Preparation

Prior to testing, the crane controls shall be inspected for damage during shipment and installation. The crane shall be tested to prove that it meets all operating requirements for which it was designed.

3.2.5.4 Test Procedure

The following tests are required: no-load testing, 50% load testing, 100% rated load tests, 125% proof-load tests, fault testing and system operational testing. All testing shall be performed by qualified personnel in accordance with written approved technical operating procedures. Written, dated and signed test reports shall be prepared by the crane manufacturer, witnessed, and approved by the NASA technical representative.

Test shall include, but not be limited to, the following:

a. Test all limiting controls and safety devices such as limits switches, brakes, at no-load. Set Hoist first upper limit switches to assure maximum hook height is achieved, and there is sufficient distance between first and second limit switches so the actuation of the first switch does not trip the second switch assuming maximum drift is assumed after actuation of the first switch. Likewise, test the second upper limit switch to assure two-blocking cannot occur assuming maximum drift occurs when the lower block encounters the second limit switch.

b. Test all operating controls which the crane is required to perform and which are not otherwise called out in these tests.

c. Test the position indicator systems for all motions and verify the performance and accuracy.

d. Main and auxiliary hoist holding brakes shall be statically tested under no load to verify each brake produces its full design torque. This test will be completed as described in paragraph 2.2.1.1.1 of this section. Acceptance criteria no slippage at the brake wheel shall occur at 100% of brake design torque, slippage shall occur at 110% of brake design torque.

~~d. Main and auxiliary hoist holding brakes shall be statically tested under no load to verify that each brake produces its design torque. This should be done whether holding brakes were provided by this contract or not. This test will be completed by applying a known torque to the brake drum with a torque wrench to verify the brakes slip just over the design torque. Acceptance criteria no slippages at 150% torque slippage must occur at 160% of design torque. Report this test using the motor drive to demonstrate its capability.~~

e. No load test of main hoist and auxiliary hoist, bridge, trolley and main hoist hook rotation drives motions to verify operation in all speed ranges, for all motions, in both directions, from no speed to full speed, and empty hook speed.

f. Load test main hoist, bridge, and trolley at 88 tons, 175 tons. Load test the auxiliary hoist at 12.5 tons, 25 tons. Verify operation in all speed ranges for all motions from no speed to full speed. Operate in all hoist speed ranges for 30 minutes in each speed and load for two complete up down cycles. Operate the bridge and trolley around the perimeter of the VAB Transfer Aisle, with noted loads at maximum coarse speed. ~~Operate for 30 minutes at 0.1.~~ Operate at 10 minutes 1.0 fpm with noted loads. Demonstrate fine speed range and spotting accuracy of the crane at all motions.

g. Test main hoist load float at no load, 88 tons and 175 tons and the auxiliary hoist at 0, 12.5 tons and 25 tons at zero speed and through the speed range to full speed. Zero motion test shall be performed for 1 minute at each load with no movement greater than plus or minus 0.005 inch (with no operator adjustments durinq the 1 minute period). After one minute at each load, set the hoist brake for 10 second and release it again. The float control should continue to hold the load with maximum motion of plus or minus 0.005 inches.

h. Tests for the sustained micro-inching performance for the main hoist shall be completed. The test will be continuous for three hours in duration at 100% rated load and will include sustained micro-inching at speeds of 0.040 - 0.200 inches per minute for one hour in the up direction and one hour in the down direction and one hour which includes several speed changes start/stop cycles (brakes set) back to sustained micro-inching at 0.040 - 0.200 inches per minute. Include different combinations and sequences of each control direction. Insure maximum load movement from start to stop is no greater than 0.005

inches. Demonstrate the ability to change micro-inch speeds without stopping motion by coming in and out of cruise control.

i. Demonstrate that all main hoists, bridge, and trolley motions at 88 tons, 175 tons, and the auxiliary hoist at 12.5 tons and 25 tons are smooth from no speed to full speed in all speed ranges. On bridge and trolley, move the master switch through the detente position, with brakes released, into the opposite direction.

j. Demonstrate single motor operation for the main and auxiliary hoists, bridge and trolley. The test will be done once for each motor. This includes two hoist motors, two auxiliary hoist motors, two trolley motors and each of four bridge motors. The test will demonstrate disconnecting the failed motor, completing switching inside each respective control panel and instructions to the crane operator to run the remaining motor(s) at reduced speed. Each single motor operation will be demonstrated at 100% load. Bridge travel will be approximately 100 feet in both directions, the trolley will travel full length and in both directions across the bridge. The main and auxiliary hoist will lift the test load 100 feet and lower the load to the ground. The lubrication of the pinion and bull gears will be observed during testing. After the testing of each motor the wiring to the motor and control panel will be placed back into the normal configuration and the crane will be tested to demonstrate proper function.

k. Test the systems ability to change speed range while in motion. Place master switch at half speed position on bridge and trolley and switch speed selector between coarse and fine speed ranges. Speed changes should be smooth and positive.

l. Test the hoist drives on the main and auxiliary hoists at no load and full load to verify proper operation with one drive system inoperable.

m. Demonstrate operation of the emergency stop control and reset features while hoisting with main and auxiliary hoist at 100% rated load. Repeat this test while operating the bridge at 100% rated speed. Repeat this test while operating the trolley at 100% rated speed. Verify the respective motion stops and brakes set and stops the crane and load properly.

n. Disconnect or adjust the overload limit device to allow the hoist to lift this test load.

Proof test the main and auxiliary hoists at 125 percent rated load by moving the trolley to mid-span of bridge girders. Raise load 6 inches at slow fine speed range (main), slow fine speed range (auxiliary), stop hold load for two minutes. Raise the hoist until you have one full revolution of the drum. Lower the load in the same manner as it was raised.

Reconnect the overload limit device and raise the test load to verify the overload limit device correctly stop the crane motion. Remove the test weight and verify full function of the crane in all motions and speeds.

o. Demonstrate accessibility and maintainability features of the crane inside the control cabinets. Check for proper wire labels and general maintenance by field performance. Check all wiring against as built drawings, update drawings before final submittal.

p. Test to demonstrate the ability to simultaneously operate the bridge trolley and main hoist, bridge, trolley and auxiliary hoist, at 100 percent load at each speed range for a minimum of 5 minutes.

q. Record actual speeds and motor amperage during each test. Check for motor overheating. For each load test, each speed shall be run consecutively, without break. If adjustments are required during performance of the tests, test will be voided and rerun.

r. A remarks column of the testing validation procedure shall include all necessary references to operating limits.

s. Tests described above will be repeated as applicable to demonstrate proper function of all secondary motor controller. A demonstration of switching between primary and secondary controller will be completed.

t. Test proper main hoist-powered hook rotation both directions and at both speed ranges for 0, 88 tons, 175 tons. Check proper function of hook rotation clutch and demonstrate manual rotation of load at the above loads. Rotate loads 360 degrees. Test function of both hook rotate switches.

u. Testing of the supervisory and watchdog systems shall be conducted using the testing procedures.

v. Emergency load lowering feature of the main and auxiliary hoist holding brakes shall be completed in accordance with the method described in paragraph *2.2.1.1.1* of this section. Testing shall demonstrate lowering the 100% rated load one foot in a slow and controlled manner.

w. All UPS shall be tested to verify they maintain fully loaded output for the required 30 minute duration after line power interruption.

x. The load cell system operation and load indication display shall be demonstrated during all load testing. System accuracy of each load cell shall be individually tested. Out of tolerance fault reading between load cells shall be simulated and verified for proper operation of the crane control system. Load cell system by-pass operation from the OIT shall be demonstrated and system performance evaluated (i.e. control feedback to the hoist controls to assure minimum load drift during brake-on and brake-off sequences is provided).

y. Verify accuracy of the (1) cab ammeters, (2) weighing system accuracy for load lifted and it accuracy at various hook heights, (3) absolute position display system for hoists and travel directions, (4) cab, speed indicators in all directions.

z. Cable reel systems shall be tested throughout all hoist operations and speeds to verify it maintains cable tension with no visible sags. Brakes shall be tested independently at the hook elevation of maximum

cable reel torque. Brakes will be released one at a time to demonstrate the closed brake supports the weight of the hanging cable without slipping. Test will demonstrate proper electrical function of the holding brake proximity switches and there operation with brake mechanical linkages. Also proper coordination of cable reel system faults with the crane control PLC shall be demonstrated.

At the completion of testing the Contractor shall submit a validation test report. Written descriptions of the tests and the results shall be prepared by the Contractor and signed by the authorized representatives of the Contractor and the contracting officer when satisfactorily completed. Any problems, discrepancies and their disposition shall be entered into the written reports. Tests shall be rerun on any test or procedure if the Contracting Officer determines that a subsequent adjustment affected a previously demonstrated capability or adjustment.

All special test equipment including laptop computers, cables, dedicated tooling, fittings, and torque multipliers for the hoist holding brake torque testing shall be turned over to the Government at the end of testing.

3.2.6 Training

The Contractor shall provide a person(s) knowledgeable in the mechanical and electrical features, control characteristics, design function, and limitations of the various crane systems, and a representative of the manufacturer of the electrical drive controllers.

a. Operator Familiarization Class - The above representatives will be required to conduct 3 to 4 hours of operator familiarization and operation training after the crane has been turned over the Government.

b. Controls System Training - The controls representative will be required to present a classroom theory trouble shooting and operation. This part of the training would typically require 5 days. Repair Requirement Documents as described in Paragraph of this section titled "Submittals" will be provided to all persons attending this class. The classes will be held on site with approximately 40 people attending.

-- End of Section --