Equipment Specification

Refuelling Machine Upgrade

KRŠKO NUCLEAR POWER PLANT

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1.0 SCOPE

This specification supplements the original Refuelling Machine Specification 677055, rev. 6, and addendum 677072 rev. 2. This specification shall be used in conjunction with technical specification SP-ES1454 to upgrade the Refuelling Machine. The specification includes original Refuelling Machine (or Reactor Cavity Manipulator Crane) requirements, as well as requirements related to the upgraded design. This specification outlines the overall requirements for the refuelling machine.

This specification covers the design, manufacturing tests, inspection, and delivery of a refuelling machine to be used for refuelling a pressurized water reactor.

2.0 REFERENCES

2.1 Attached

2.1.1 Refuelling Canal Drawings

a) 1209E82, Sh. 1 - REACTOR PLANT ARRANGEMENT CONTAINMENT PLAN

b) 1209E82, Sh. 2 - REACTOR PLANT ARRANGEMENT - ELEVATION

2.1.2 Refuelling Machine Outline Drawings

a) 1459F99, Sh. /, Rev. 3, KRSKO NUCLEAR PLANT - REFUELING MACHINE

b) L-22830, Sh. 1 Rev. 3, GENERAL ARRANGEMENT REFUELING MACHINE

c) L22650, Sh. 101, Rev. 2, UPPER STRUCTURE ASSEMBLY, REFUELING MACHINE

d) 22830-6, Sh. /, Rev. E, R.H. TROLLEY ASS'Y REFUELING MACHINE

2.1.3 Fuel Assembly Outline Drawings

a) 1451E29, Sh. 1, Rev. 10, 16 X 16 FUEL ASSEMBLY INTERFACE PARAMETERS

2.2 Not Attached

2.2.1 National Electric Code ANSI/NFPA 70 - 2020

2.2.2 ASTM material specifications

2.2.3 29CFR1910-OSHA Act

2.2.4 CMAA Spec #70:2015 Specification for Electric Overhead Traveling Cranes

2.2.5 AWS D14.1/D14.1M:2005, Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment

2.2.6 AISC Steel Construction Manual, 13th Edition (ASD)

2.2.7 SP-S702, Rev. 10, SEISMIC ANALYSIS, TESTING, AND DOCUMENTATION

2.2.8 ANSI/ANS-57.1-1992, Design Requirements for Light Water Reactor Fuel Handling Systems

2.2.9 REGULATORY GUIDE 5.71, Revision 1, CYBERSECURITY PROGRAMS FOR NUCLEAR POWER REACTORS

3.0 GENERAL DESCRIPTION AND OPERATING CONDITIONS

The Refuelling Machine described in this specification will be used to refuel a pressurized water reactor. The bridge spans a water-filled refuelling canal over the reactor. Fuel is handled underwater by a gripper mechanism on the bottom end of a vertical telescoping mast extending down into the water from the crane structure. The water containing 3000 ppm boric acid, serves as radiation protection for the operators and a cooling medium for the fuel.

The function of the bridge is to position the vertical mast accurately over any core position and to transport the fuel assemblies between core positions to the fuel transfer system or control rod changing fixture (see Ref. 2.1).

Hoisting of the fuel assemblies is done by the vertical mast, which telescopes to lift the fuel assembly over the reactor vessel flange. At the maximum lift, the inner mast section and fuel assembly are drawn completely up into the stationary outer mast section.

The basic design philosophy of the refuelling machine can be described as follows. The removal and insertion of fuel assemblies in the core is a precision operation requiring that the lift point of the hoist be accurately located above the center line of the fuel assembly and that the lift be made in a true vertical direction. It is intended that this be accomplished by providing a rigid and true crane structure positioned by an electrical repeat back system with sufficient accuracy that the inner mast tube and gripper can be lowered on the end of the hoist rope unguided, except for keying to prevent rotation, depending on the natural plumb bob tendency to maintain true vertical travel. The outer mast tube and rollers are intended only to restrain and damp out the swing of the inner tube and fuel assembly.

4.0 GENERAL DESIGN INSTRUCTIONS

4.1 Materials

4.1.1 The basic structural material for submerged parts shall be 300 series austenitic stainless steel. Parts requiring hardenability shall be stainless steel ASTM A564, Grade 630 H1100. Machining of parts after hardening is acceptable, providing machining does not reduce hardness below specified value. Charpy impact testing is not required. Martensitic 400 series stainless steel, or carbon steel shall not be used.

4.1.2 All structural steel shall conform to ASTM specifications. Other materials used in bridge and trolley above the water line shall be accepted materials of good quality industrial crane design. CMTR’s or equivalent certificates shall be provided for hoisting materials (gripper, inner mast, ropes, etc.).

4.1.3 Aluminium, tin, lead, or their alloys shall not be used without specific approval by NEK. Use of mercury in any component is not permissible. Mercury or mercury alloys are NOT acceptable. Manufacturing and assembly shall be in a controlled area to prevent contamination from tools scrap or dirt containing these materials.

4.1.4 Manganese Bronze ASTM B-138-58, Alloy B, or ASTM B-147, Alloys 862 or 863, may be used for submerged bushings or other wearing parts where necessary to prevent galling of stainless steel.

4.1.5 Organic materials shall not be used below the water line unless otherwise specified. Lubrication for submerged parts shall be Dow Corning Silicon Compound 111 or a proved equivalent.

4.1.6 Type 300 stainless steels shall be welded by the shielded metal-arc (SMA), gas tungsten-arc (GTA), or the gas metal-arc (GMA) welding processes. Filler metals shall be selected from American Welding Society (AWS) Specifications A5.4 or A5.9. A564 parts shall not be joined by welding.

4.1.7 ASTM A36 steel shall be welded in accordance with AWS D14.1 "Specification for Welding Industrial and Mill Cranes".

4.1.8 High strength bolts shall conform to ASTM F3125, Type A325.

4.1.9 Hardened washers, for use with high strength bolts, shall conform to ASTM F436-1 and the specification for Research Council on Structural Connections Specification for "Structural Joints Using High-Strength Bolts".

4.1.10 All bolts other than high strength bolts shall conform to ASTM A 307, Grade A, or better.

4.1.11 Welding electrodes shall be selected in accordance with the provisions of AWS D1.1 and be suitable for the type of steel to be welded. Electrodes for manual shielded metal arc welding processes shall be E7018, low-hydrogen type in accordance with AWS A5.1. Electrodes for all other welding processes shall be low-hydrogen type and shall give a deposit of 500 MPa minimum tensile strength, with impact properties equal to those of the manual shielded metal arc electrodes specified above.

4.2 Electrical

4.2.1 Electrical design and manufacturing shall be in accordance with National Electric Code ANSI/NFPA 70 – 2020 or equivalent.

4.2.2 All exposed wiring shall be run in metal conduit or waterproof plastic flexible conduit with steel reinforcement. All conduit joints shall be dust-tight.

4.2.3 Power circuits wire running through conduit shall be rated for 75 °C service in wet or dry locations and shall be AWG 12 minimum size regardless of load rating. Insulation shall be flame resistant thermo setting plastic (IEEE 383 or VW1).

4.2.4 Wires enclosed in control console or other panels shall be based on NFPA-70.

4.2.5 All wires shall be identified at terminals with marked plastic sleeve, with heat shrunk or with continuous insulation marking. Numbering system shall be consistent throughout machine and shall relate to connection diagrams and circuit diagrams. Ring tongue lugs or ferrules shall be used for connection to terminal points.

4.2.6 Control system for bridge, trolley, and hoist motors shall be provided. Control system shall be provided to control all three motors.

4.2.7 All electrical equipment shall operate from 380 V AC, 3 phases, 50 Hz supply. 24 V DC shall be supplied for control and receptacle circuits by transformer sized to run all circuits simultaneously. If supply voltage is other than 380 V AC, supplier shall provide a suitable transformer for control system.

4.2.8 Motors connected across the main power shall have NEMA standard ratings for voltage and frequency variation. The bridge, trolley and hoist motors shall be matched to the requirements of control system. All motors shall have totally enclosed frames and shall be protected with thermal overload devices. Bridge, trolley and hoist motors shall have insulation rated for high humidity service and shall have a heater embedded in the windings, if motors with windings are used.

4.2.9 All electrical enclosures shall be purchased as NEMA Class 12, prior to penetrations. Penetrations will include gaskets, except for control console and control panel which shall have heaters to prevent moisture and condensation. All enclosures without exception shall be grounded.

4.2.10 Power is supplied to machine through flexible cable (cable reel and/or cable track). Cable shall have separate ground conductor for connection to plant system ground.

4.2.11 All electrical equipment shall be technically suitable for installation to environment (Reactor Building) where RCMC is physically positioned.

4.2.12 Supplier shall submit for NEK approval an electrical schematic diagram and point-to-point wire connection diagrams of the entire electric system.

4.2.13 Interlock and/or limit switch circuits already designated as requiring redundant protection shall remain redundant to meet the single failure criteria of USAR section 9.1.4.3.1 and ANSI/ANS-57.1-1992. Such circuits to be acceptable must be completely independent with no shared components. For example, two redundant limit switches may both have contacts wired directly into the control circuit, however, if relays must be used, each limit switch shall actuate a separate relay with contacts in the interlocked circuit. Two switches wired to the coil of the same interlocking relay, or two switches wired to the coil of the same main line contactor are not acceptable. Also single failure, like PLC failure, shall not cause omission of any safety function.

4.3 Structural

4.3.1 The primary design requirement of the machine shall be reliability. A conservative design approach shall be used for all load bearing parts. Where possible, components shall be used that have a proven record of reliable service. Throughout the design, consideration shall be given to the fact that the machine will spend long idle periods stored in an atmosphere of 40 °C and high humidity.

4.3.2 Except as otherwise specified the crane structure shall be designed and constructed in accordance with Ref. 2.2.4, CMAA Spec 70.

4.3.3 Design load for crane structure shall be normal dead and live loads plus hoist load.

4.3.4 The crane structure was originally designed to meet the allowable stresses as specified in Subarticle XVII-2200 of Appendix XVII of the ASME Code Section III, (1974). The allowable stresses for normal operating conditions for modified crane structure, and structures supporting the weight of the fuel shall be as specified in AISC Steel Construction Manual, 13th Edition (Allowable Stress Design method). Hoisting components loaded in simple tension shall have an allowable stress of 0.20 times ultimate stress.

4.3.5 All components critical to the operation of the machine or located so that parts can fall into the reactor shall be assembled with the fasteners positively restrained from loosening under vibration. Spring or tooth type lock washers are not considered as positive restraint. Fasteners on purchased components above the water line that cannot be wired or tack welded shall be backed out, coated with locking compound and retightened.

4.3.6 The machine shall be designed to withstand, without derailing, the combined effects of all normal operating loads acting simultaneously with seismic motion arising from the Safe Shutdown Earthquake (SSE). The seismic analysis shall be performed using a dynamic normal mode analysis along with a response spectrum analysis. Design horizontal response spectra and design vertical response spectra are given in SP-S702 Fig. A13-A14 for OBE and Fig. B10-B12 for SSE. The response spectra for 4% equipment damping shall be used for the

SSE and 2% for OBE. The equipment shall be subjected to three orthogonal components of seismic motion, one vertical and two horizontal. The combined total seismic response for each orthogonal component of motion is obtained by adding the individual modal responses utilizing the square root of the sum of the square's method. The effects of a three-dimensional earthquake shall be determined by combining the three orthogonal earthquake responses by the square root of the sum of the square's method. For seismic design the normal operating load shall be the weight of a fuel assembly at the top stop position.

4.3.7 For normal conditions plus SSE loading, the stress in any load bearing component shall not exceed the allowable values for the faulted condition as given by Appendix F of ASME Section III Code, 2017 edition, and:

a) The machine must not drop a fuel assembly from the gripper;

b) The bridge and trolley must stay on their rails;

c) No part of the machine shall become dislodged and drop into the canal.

4.4 Software

4.4.1 The PLC shall monitor all the switches, position assemblies, load cells, joysticks, push buttons, and inputs from other machines (such as the transfer system). The PLC shall also output signals through isolated discrete and analogue modules to control various electrical components. The machine control program should be stored in battery-backed random access memory (RAM) and in flash memory inside or an SD Card installed in the PLC. Siemens S7-1500® Series PLC rack components should be used for the MC controls. Critical machine functions shall be designed as a fail safe in case of PLC components failure. Robust design needs to be kept, along with possibilities to visually control, approve or override computer/PLC driven actions. Siemens S7-1500® Series PLC Programming shall be done using latest version of SIMATIC STEP7 (TIA portal) programming tools. Preferably, Siemens Basic or/and Advanced Process Libraries shall be used to allow future program migration in case of installed PLC equipment obsolescence.

4.4.2 The hoist motor drive is controlled by the PLC on the industrial network link. Inputs for lights and solenoids are output from the PLC to the associated components by hardwiring. Primary control of the axis drives from the PLC is also over the industrial network link. Speed and direction along with acceleration and deceleration are managed over the network for control.

4.4.3 Requirements from the NRC 10 CFR 73 Cyber security program must be fulfilled for PLC. The criticality per RG 5.71 of the digital equipment shall be assessed.

4.4.4 Programmable limit switch or absolute hoist encoder interlocking shall preserve the interlocking criteria of the original control design.

4.4.5 An industrialized Siemens SIMATIC HMI touchscreen computer shall be provided for use during the initial setup of the MC. The touchscreen computer is in direct communication with the PLC via network, so it can also be used to perform maintenance and system troubleshooting. This computer contains the graphical operator interface drivers for the operator to interface/monitor the database. The database enables the MC to convert alpha-numeric core locations into bridge and trolley position assembly values, data logging files, and fuel move sequence(s) when the system is preprogrammed. In addition, the touchscreen provides helpful information for operational interlocks and troubleshooting aids for maintaining the entire system, including the PLC. The operator interface program is stored on the hard drive of the computer. The touchscreen and computer are mounted in the control console, and the computer is equipped with a universal serial bus (USB) memory stick drive for ease of program transfer and program backup. Two HMIs may be used to perform the above functions.

4.4.6 The software security shall be based on the multi-level operator logon. “User Names” and “Passwords” must be required on the HMI. Security Levels shall include:

a) Operator Level – limited access, machine operation only

b) Maintenance Level – operator level access plus corrective measures

c) Supervisor Level – maintenance level access plus performance management

d) Manager Level – full access (supervisor level access plus full modification capability to existing programs)

4.4.7 Supplier shall assure the measures to control complete software development lifecycle. The Supplier's software development lifecycle shall include the following (but not limited to) activities: Planning, Requirements, Design, Implementation, Integration, Verification & Validation and Installation (adopted to that project-specific that the most of codes will be migrated).

4.5 Occupational Safety and Health Act

4.5.1 The requirements of paragraph 1910.179 of 29CFR1910 shall apply.

4.5.2 A permanent load rating plate shall be attached in plain view of the operator with the following information on the main hoist:

a) Maximum load-motor operation: 3250 lbs (1475 kg))

b) Maximum load-manual operation: 4800 lbs (2180 kg)

c) Test load: 6000 lbs (2720 kg).

Letters on plate shall be at least 3/4 inches high and units written in lbs and kilograms.

5.0 SPECIAL DESIGN INSTRUCTIONS

5.1 Bridge and Trolley Structure

5.1.1 The drawings included in this specification shall be considered illustrative only and not definitive with respect to details of the structural design. Orientation and limits of travel with respect to mast center line shall be as shown in Ref. 2.1.1.

5.1.2 The bridge and trolley shall run on machined wheels and rails. One rail for bridge and trolley shall be used as a guide rail and shall be machined on sides and top. Base of rails shall be machined if required to provide a flat surface parallel to the top. Guide rollers on the wheel trucks shall run on the sides of the rail to maintain straight line travel. The other rail shall be machined on top only for a flangeless wheel. The guide rail for the trolley shall be straight within ±0.030 inch (0.8 mm) when in place on the bridge girder. The companion rail on the other girder shall be level with respect to the guide rail within ±0.030 inch. If the bridge girders are cambered, the camber curves in the trolley rails shall match within ±0.030 inch. Bridge rails will be mounted with top surface elevation and length as shown on Ref. 2.4. Supplier shall provide a field installation drawing that specifies rail joints and other information necessary to install rails.

5.1.3 Bridge and trolley wheels shall be true within ±0.010 inch (0.25 mm) on the diameter. Bearings shall be ball or roller-bearings.

5.1.4 The bridge span shall be as shown on Ref. 2.1.2 with clearance dimension beyond rail centers less than 12 inches (300 mm). Clearance under bridge shall be 5 inches (127 mm) over floor elevation. Trolley span shall be as shown on Ref. 2.1.2. Other clearance dimensions for bridge and trolley shall be as shown on Ref. 2.1.2.

5.1.5 Maximum deflection of bridge girders shall be 0.001 inch (0.025 mm) per inch (25 mm) of span under combined weight of trolley, bridge dead weight and fuel assembly. Deflection below horizontal shall be limited to 0.060 inches (1.5 mm) by cambering girders if necessary.

5.1.6 Bridge girders are set on machined seats on trucks and fastened with fitted bolts. Adequate gussets shall be provided to maintain a firm rigid bridge structure.

5.1.7 The trolley deck shall be steel deck plate with 42 inches (1100 mm) handrail and 4 inches (100 mm) toe plate around edge, ¼ inches (7 mm) thick. As shown in Ref. 2.1.2, deck plate shall be omitted from areas adjacent to the control console for visibility of mast and gripper operation.

5.1.8 Mast support tube shall be mounted off center on trolley as shown in Ref. 2.1.2. Structural clearances and trolley travel shall be designed to allow mast center line to be positioned relative to bridge rail center line and end stops shown in Ref: 2.1.2.

5.1.9 The trolley and bridge shall be equipped with spring bumpers to engage solid stops at extreme limits of travel. The bumpers shall be designed to stop machine from full speed.

5.1.10 The bridge shall have a walkway mounted on one girder running the entire length of the bridge, see Ref. 2.1.2. Walkway underside shall be even with lowest clearance elevation of bridge structure. Standard 42 inches (1100 mm) handrail shall be provided for full length of walkway on outboard side. Inboard side of walkway shall be enclosed by short handrail on top of bridge girder. Access to walkway shall be from either end of bridge and from trolley deck.

5.1.11 Handrail, with the exception of that handrail designated on the Construction Drawings as "Removable," shall be welded to structural steel. Removable handrail shall be fastened to structural steel by 16-mm diameter ASTM A 307, Grade A bolts. Bolted connection details shall be as shown on the Construction Drawings.

5.1.12 Walkway floor shall be checkered deck plate with 4 inches (100 mm) by ¼ inches (7 mm) toe plate. Design load shall be 100 lb./sq.ft. (500 kg/m^2) uniformly distributed.

5.1.13 An electric monorail hoist is mounted above the bridge walkway for use with long handled manual tools. The hoist is suspended from a beam running the length of the bridge and supported by columns on the bridge trucks. Capacity of hoist is 3000 lbs. (1360 kg) and total lift is as shown in Ref. 2.1.2. Hook passes 12 inches (305 mm) outboard of the walkway handrail. Hoist is mounted to provide coverage across refuelling canal, as shown in Reference 2.1.2.

5.1.14 The auxiliary monorail hoist is a frequency controlled, motor driven unit with integral motor brake and load brake, up and down travel limit switches, and pendant control box. Hoist is heavy-duty rated for continuous duty at required horsepower. Hoisting speeds are variable and set for 2 fpm (0.6 m/min), 7 fpm (2.1 m/min) and 20 fpm (6.1 m/min). Hoist is suspended from a manual chain driven trolley for traversing the I beam.

5.1.15 Hook is free turning and have safety latch. Hook is large enough to accept one inch (25 mm) diameter bail with the safety latch closed. Wire rope is 7 x 19 stainless steel flexible aircraft cable reeved two-part single.

5.1.16 Electrical receptacle boxes for single phase service are provided at both ends of bridge walkway and two locations on trolley. Receptacles are three prong plug (2 wire with ground) and have screw type cover. Electrical receptacle circuits have ground fault circuit interrupters that meet Underwriters Laboratories Standard 943 for Class A group 1 devices.

5.2 Bridge and Trolley Drives

5.2.1 The bridge and trolley drives shall consist of motor with gear reducers, drive shafts, magnetic brakes, motor controllers, miscellaneous limit and control switches, wiring conduit and support structures. Drives shall be designed for minimum service of 5000 hours without failure. Dual laser/encoder position system shall safely allow simultaneous movement of the bridge and trolley.

5.2.2 Bridge and trolley drive motors shall be NEMA Class D, induction motors with Class H insulation. End of motor shafts shall be adapted for emergency drive with a handwheel. Supplier shall provide suitable lathe type handwheel with loosely keyed or splined hub. Handwheel shall be removed and safely stored when not in use. Access platform for bridge emergency drive shall be provided if necessary.

5.2.3 Brakes shall be spring set, solenoid release, mounted on motor shaft. Torque setting of brake shall be adjustable up to maximum torque of motor. Provision shall be made for emergency manual release of brake. Brakes shall have drip proof cover.

5.2.4 Gear reducers shall be totally enclosed with shaft seals to prevent leakage of lubricant. Drip pans shall be provided under all reducers to catch lubricant in the event of seal failure.

5.2.5 Trolley drive shall have stepless variable speed up to 40 fpm (0.2 m/s). Bridge drive shall have stepless variable speed up to 60 fpm (0.3 m/s).

5.2.6 The speed of the MC bridge and trolley shall be limited, so that the inertial loads imparted to fuel assemblies and control components during handling operations do not exceed the allowable limits for which the fuel assemblies and components are designed. The control system shall operate within the existing Westinghouse F-5 specifications, which limits all axis acceleration times to be between one and three seconds. Deceleration times shall be designed to stop from full speed with a decelerating force, not exceeding more than 40 m/s^2.

5.2.7 Bridge and trolley positioning system shall provide data to control system logic which performs boundary zone checking per Ref. 2.1.1 and to interlock the bridge and trolley drives per Section 5.7.11.

5.2.8 The bridge and trolley shall be positioned in relation to a grid pattern reference to the core. Grid lines shall be spaced and identified as shown in Ref. 2.1.1. Coordinates for pickup of fuel assemblies shall be determined by trial and error at the site. Both trolley and bridge positioning systems shall be repeatable within 1/8 inch (3 mm).

5.2.9 Bridge and trolley position shall be indicated by dual laser/encoder position system for redundancy (2 systems per each bridge and trolley). Bridge and trolley main drive controls shall be lever or joystick type with spring loaded neutral position at center, where drive signal shall be de-energized and brake circuit shall be open to set brakes via the PLC. Joysticks provide an analog signal directly to the PLC.

5.2.10 In the event of a laser/encoder positioning assembly failure, the control system shall allow operation with only one position assembly in operation for an axis. In the event of a position system failure, the PLC shall automatically fail over to use the second system without operator intervention. A laser/encoder alarm shall appear on the HMI. The operator may also temporarily disable the faulty position assembly and continue to operate manually.

5.2.11 An adjustable steel target scale, marked for each bridge and trolley position shall be located on the inside of the bridge girder. Pointer shall be located in the cutout area of trolley and bridge deck and shall be readable by operator standing at console. Lighting shall be provided and may be integrated with the cameras.. The Index camera system is mounted on the bridge and trolley and will interface with the video monitor on the MC control console. The index cameras provide the operators with a visual verification of the existing MC bridge and trolley position marker locations.

5.2.12 Modes of operation. Bridge and trolley drives shall be driven and controlled by PLC enabling following modes of operation:

a) Automatic Mode enables fully automatic operation of refuelling machine reading preloaded fuel handling sequence and requiring operator only to confirm steps as they are following.

b) Semi-automatic Mode requires operator to manually select upcoming fuel sequence step or pre-defined location. Bridge and trolley positioning to the target step is automated based on the most optimal path, observing restricted zones.

c) Manual Mode involves using of the joystick to drive bridge and trolley to target location.

d) Interlock Override Mode bypasses the PLC to control motor drive directly via push-buttons at a reduced speed. In this case all interlocks and restricted zone limitations are bypassed.

e) Manual Emergency Mode enables recovery to safe handling status in case of power loss with a use of handwheels and manual brakes releases and visual/mechanical bridge, trolley and hoist position indicators.

5.3 Main Hoist Equipment

5.3.1 The main hoist system including the hoist, ropes, sheaves and mounting hardware shall be designed with redundant components such that the failure of any one item cannot cause a free fall of the fuel assembly. Two ropes will be used, each reeved one part single. The ropes will be attached to opposite ends of the hoist drum, carried over a double sheave block and attached to the top of the gripper tube.

5.3.2 The Fuel Hoist Drive assembly consists of a hoist drum and wire rope assembly with an AC motor, dual brake system, handwheel, stowage proximity switch or equivalent, handwheel shaft cover, and required mounting brackets mounted to a fabricated pan for the hoist drive assembly.

5.3.3 The hoist motor shall be a NEMA Class D, induction motor, with Class H insulation. Internal thermostat shall be provided to signal temperature approaching rating of insulation. Alternatively, servo motors with minimum Class H insulation can be used. End of motor shaft shall be adapted for emergency manual operation by hand wheel similar to Section 5.2.2.

5.3.4 The hoist shall have two independent holding brakes to prevent the load from overhauling the hoist. Either brake will be capable of holding 125% the rated load. An integral encoder connected to the hoist drum shaft shall be provided as required for interlocking purposes.

5.3.5 Hoist rope shall be stainless steel. Rope load rating shall be sufficient to support five times the design load when reeved as specified in Section 5.3.1. Ropes shall be considered to share the load such that each supports half the design load. Rope shall be thoroughly cleaned of oil or lubricants. The ropes shall be attached to the gripper tube through an equalizing mechanism that will equalize the load in the two ropes during normal operation and yet support the gripper tube by one rope in the event of failure of the other. Attachment device shall also contain a swivel to prevent wind up of ropes when mast is rotated.

5.3.6 The hoist drum shall be constructed of stainless steel with cut grooves for winding the ropes attached at either end of the drum toward the center. The drum shall be long enough to take the hoisting ropes, anchor turns and one extra turn in a single layer. The drum shall have guarded flanges to keep ropes from slipping between drum and frame.

5.3.7 Sheaves shall be hardened A564 stainless steel and shall have a pitch diameter appropriate for the specified wire rope. Wire rope guards shall be provided around the sheaves to prevent the rope from coming off. The main sheave support structure shall be designed with a sufficiently high factor of safety to ensure that the probability of a catastrophic support failure is extremely low, thereby eliminating the need for a secondary sheave support. Alternatively, a secondary support shall be provided to catch the sheaves in the event of failure of the sheave support. Sheaves shall have sealed ball bearings or bushings capable of running dry.

5.3.8 The sheaves shall be hung from the support structure through an electric load cell, which shall be connected to a readout meter or HMI screen on the console calibrated to read total suspended load. The readout meter shall have a digital display from 0 to 6000 lbs (2720 kg) with tare adjustment of at least 3000 lbs (1360 kg).

5.3.9 The fuel hoist load is measured by a single primary or a dual-bridge, compression-type strain gauge load cell provided with built-in temperature compensation. The signal from the strain gauge is processed and displayed by the load meter. The load signal is sent to the PLC as an analog input. The PLC compares the input with pre-set weights (maximum overload, overload, underload, loaded, and slack cable) to generate the required interlock signals. The load cell can remain in containment, but the load meter will be installed in the control console, which will be removed from containment between outages.

5.3.10 A backup, secondary, load cell device or load limit switch shall be provided to open the hoist up drive circuit at a weight of 125% to 135% (and above) of the fuel assembly and gripper tube weight. The primary and back up overload monitoring devices and circuits shall be redundant as defined in Section 4.2.13. Readout from the backup system is not required, and no bypass circuit shall be provided.

5.3.11 Static design load for hoist, and all components supporting the load, shall be 4800 lbs (2180 kg applied with handwheel) plus gripper tube weight. Dynamic load for hoist motor rating shall be 1600 lbs (725 kg) plus gripper tube. Hoisting speed shall be variable up to 40 fpm (0.2 m/s) with total lift as shown in Reference 2.1.2.

5.3.12 HMI controls shall be provided in the weight indication system as follows.

a) LIGHT overload shall open the hoist up circuit at 150 lbs (70 kg) above the combined wet weight of the fuel assembly + wet weight of mast (and above). The PLC shall control the OVERLOAD indicating light on the console.

b) HEAVY overload shall open the hoist up circuit at 150 lbs (70 kg) above the combined wet weight of the fuel assembly + wet weight of mast + wet weight of RCC (and above). The PLC shall control an OVERLOAD indicating light on the console.

c) LIGHT underload shall open the hoist down circuit at 150 lbs (70 kg) below the combined wet weight of the fuel assembly + wet weight of mast (and below). The PLC shall control an UNDERLOAD indicating light on the console.

d) HEAVY underload shall open the hoist down circuit at 150 lbs (70 kg) below the combined wet weight of the fuel assembly + wet weight of mast + wet weight of RCC (and below). The PLC shall control an UNDERLOAD indicating light on the console.

5.3.13 In addition to the programmable setpoints above, the system shall be provided with design load conditions as follows.

a) Underload (light and heavy) shall be automatically bypassed at the bottom of the core and transfer basket (the last 25-50 mm (1-2 inch)) to allow the mast to continue down motion to the slack cable setting.

b) Manual bypass for overload or underload interlock shall be provided using the override key switch at control console.

c) A programmable setpoint shall be set to discriminate between the loaded and unloaded conditions of the gripper, with the set point at 120% (and below) of the weight of the gripper tube (1200 lbs or 545 kg). The PLC shall open the gripper interlock solenoid valve, Section 5.6.5, and complete the circuit for the lower stop position of Section 5.3.14.

d) The PLC shall open the hoist lower circuit at a weight just sufficient to release the mechanical lock of 5.6.6. This shall also turn on a low load indicating light (SLACK CABLE) on the console and turn on a SLACK CABLE indication on the HMI.

Load settings shall be adjustable over the full range. The load meter shall be accurate to 0.5% with a sensitivity of 10 lbs (5 kg).

5.3.14 The hoist shall be provided with interlocks at two elevations that shall function to stop this hoist and close the bridge-trolley interlock circuit (5.7.11b)). The upper stop position shall be set where a fuel assembly has been withdrawn completely into the outer mast (Full Up). The lower stop position shall be set where the empty gripper has been withdrawn completely into the outer mast (Gripper Up Disengage).

The upper stop position shall be controlled by a trip type switch that sends a signal to the PLC. One set of contacts shall open when tripped to stop the hoist. A second set of contacts shall close to complete the interlock circuit of Section 5.7.11b).

A back up trip type switch shall be mounted above the primary switch to open the power circuit to the hoist motor, if the primary switch fails (Full Up Overtravel).

An encoder shall be provided below the primary to close the interlock circuit. This encoder shall be redundant to the primary switch per Section 4.2.13 so that both circuits must be satisfied to complete the interlock circuit of Section 5.7.11b).

Trip type switches shall be effective at any rotational position of the mast.

The lower stop position shall be determined by the encoder and the PLC will stop the hoist and complete the bridge-trolley interlock circuit. To prevent this stop from functioning when there is a fuel assembly in the gripper, redundant circuits (see 4.2.13) shall be provided such that the stop is effective and the bridge-trolley interlock released only when both:

a) gripper disengaged position switch is actuated,

b) the weight indicator shows there is no fuel assembly suspended from the gripper (Section 5.3.8).

A Jog Permissive switch shall be provided to cancel the lower stop.

5.3.15 The hoist encoder shall also be used to provide two automatic slow zones at the elevations shown in Reference 2.1.2. Slow zone switch shall change main drive speed to minimum (2 fpm, 0.01 m/s). HMI shall also indicate when gripper is in slow zone elevation.

Upper gripper slow zone shall be configured so that it is effective only when the bridge is over core area and the gripper is engaged to a fuel assembly.

5.3.16 The fuel hoist position is monitored using dual encoders mounted to the main hoist assembly. Additionally, the manual ZZ-tape (or equivalent) redundant positioning system is maintained for redundant hoist position verification information. The HMI readout will be in inches and accurate within +1/16 inch (~1.6 mm).

5.3.17 The fuel hoisting system shall detect an overspeed for emergency shutdown. In case of excessive motor speed, a dual encoder system provides position elevation information of the gripper and full down lower limit protection, and limit switches for setting normal up (FULL UP), up over travel back-up (FULL UP OVERTRAVEL).

5.3.18 Hoist control shall be lever or joystick type with spring loaded neutral position at center of travel where drive signal shall be de-energized and brake circuit shall be open to set brakes via the PLC. Joystick provides an analog signal directly to the PLC.

5.3.19 Hoist slow zones are provided in conjunction with the boundary zone protection system. Additional provisions to control the hoist speed are included as a function of the Control System. The boundary zone protection system includes programmed slow zones that automatically reduce the hoist speed (in both directions) regardless of the commanded speed to eliminate excess load peaks during these transitions. Slow zones are also programmed for fuel insertion zones (as the bottom of the assembly is inserted into the core or upender) and at the set-down elevations.

5.3.20 The PLC tracks the core contents (the presence or absence of fuel in each core location) in order to make the determination of where off-indexing may occur. During Auto or Semi-Auto modes, the proposed Off-Index position will be presented to the operator on the touchscreen, who may then acknowledge or reject it. If more than one Off-Index move is possible, the software will select one based on a “preferred direction” algorithm that is built into the program (i.e., the operator will not be given a choice of direction).

5.3.21 The MC will have the capability to determine Off-Index positions when in automatic or semiautomatic operation only. The Off-Index position is an area of 2” by 2” that starts at a point diagonally 2.82 inches from the center of the requested position (when the bridge and trolley are both 2 inches from the center of the requested position). When a fuel assembly is Off-Index, it is moving to an open water location 2.82 inches diagonally away from adjacent fuel assemblies in the core or the core baffle. This then allows the hoist to operate at high speed down to a point about ~6 inches above core full down. If in manual and in open water, the hoist is also allowed to operate at high speed above low zone. The HMI provides the off-index target location graphically whenever the operator has accepted the proposed off-index move. This screen displays a close-up view of Off-Index Transit parameters and presents a target location for the operator to traverse to.

5.4 Mast

5.4.1 The mast is constructed in two telescoping sections, the outer tube and the inner or gripper tube. The outer tube is mounted on the trolley in a bearing support and provides guidance of the gripper tube. The gripper tube is raised and lowered by the hoist and carries the gripper mechanism. During transport of fuel assemblies, the fuel assembly is withdrawn up into the outer tube.

5.4.2 The bearing support for the outer tube shall support the weight of the outer tube on a thrust bearing and maintain it in vertical alignment with radial bearings. The outer tube shall be able to rotate from a normal operating position to positions at 90°, 180°, and 270°. A removable pin or latch shall be provided to lock the tube in each of the four positions and a stop shall prevent continuous rotation of the tube. Rotation shall be manual either directly or through a gear reduction unit.

5.4.3 The outer tube shall be heavy wall pipe approximately 16 inches (406 mm) diameter. Length shall be as shown in Ref. 2.1.2.

5.4.4 The gripper tube shall be pipe or tubing approximately 10 inches (254 mm) diameter. Total weight of gripper tube, operating tube (Section 5.6.5) and gripper shall be less than 1000 lbs (450 kg). The tube shall be long enough to reach the full down position with the upper end of the tube engaged in two sets of guide rollers in the outer mast tube.

5.4.5 The gripper tube outer diameter shall be held to ±0.030 inches (0.76 mm) at any point on the tube. Straightness of the tube shall be held within 0.060 inches (1.5 mm) camber over the length of the tube. A key bar shall be attached the full length of the gripper tube and shall be straight within ±0.030 inches (0.76 mm). The bottom end of the gripper tube shall be a mounting plate for attachment of the gripper mechanism.

5.4.6 The gripper tube shall be restrained within the outer tube by rollers mounted on the outer tube at approximately 4 feet (1200 mm) intervals. One set of rollers shall be contoured to engage the key bar on the gripper tube to prevent rotation. Radial clearance between the rollers and gripper tube shall be nominal 1/16 inch (1.6 mm), but roller mountings shall be adjustable for field setting of clearance. Rollers and mountings shall be kept within a clearance envelope of 28 inches (700 mm) diameter about the mast center line. Roller mounting brackets and matching seats on outer mast shall be machined to hold roller axis perpendicular to radius of mast.

5.4.7 Guide bars shall be provided in the lower end of the outer tube to limit the lateral swing of the fuel assembly and prevent it from touching the guide rollers. The guide bars shall be located at the four corners of the fuel assembly and shall be at least 60 inches (1500 mm) long. Material shall be hardened A564 stainless steel. Surface contacting fuel shall have finish of 64 micro inches (1.6 µm) or better. Clearance between bars and corners of fuel assembly nozzle shall be 0.050 inches (1.3 mm) to 0.080 inches (2 mm) inches at each corner.

5.4.8 The structure above the mast, supporting the sheave, weight indicator and take-up reels, shall be designed for easy removal to allow the gripper tube to be pulled out the top of the outer tube with the overhead plant crane. Design load shall be as specified in Section 5.3.11.

5.4.9 The gripper tube travel shall be repeatable within the following limits, with the gripper tube extended and positioned over a target point:

a) The gripper tube end shall be displaced 1/4 inch (6 mm) by a lateral force, released, and shall then return to the original position within ±1/32 inch (0.8 mm).

b) The gripper shall return to the original position within ±1/16 inch (1.6 mm) after being raised and lowered.

5.5 Pneumatic Air Supply System

5.5.1 Pneumatic Air Supply System consists of stainless-steel piping, air supply hoses, reels, actuators and controls, for interfacing to the plant air routed onto the MC. No quick connectors shall be used.

5.5.2 Compressed air at 70 to 100 psig (5 to 7 bars) shall be supplied to the refuelling machine from the instrument air system through a trailing rubber hose. Hose shall be suspended similar to power cable and attached to plant system as shown in Ref. 2.1.1.

5.5.3 The compressed air shall be delivered through a filter element and a shut off valve mounted in a convenient manner on the trolley.

5.5.4 Air shall be delivered to the gripper cylinder (Section 5.6.5) by a neoprene or rubber hose wound on a constant tension hose reel mounted on the support structure. Hose shall be double, welding type for air delivery to both sides of the cylinder from one hose reel.

5.6 Gripper

5.6.1 The gripper shall be a pneumatically operated mechanism to grip and hold fuel assemblies. The gripper fingers shall attach to the fuel by engaging under the inside edge of the fuel assembly top plate (Ref. 2.1.3). The gripper mechanism shall be mounted on a base plate for attachment to matching plate on the end of the gripper tube. Design load for the gripper shall be as specified in Section 5.3.11 with allowable stress as specified in Section 4.3.4.

5.6.2 Fuel assemblies will be handled with the control rod cluster at the top of the fuel (Ref. 2.1.3). The gripper mechanism shall be designed to clear these items.

5.6.3 The entire gripper mechanism shall be contained within a space envelope equal to the size of the fuel assembly cross section for 5 inches (127 mm) above mating surface between the gripper and fuel assembly. This applies to both engaged and disengaged condition.

5.6.4 The three holes in the top of the fuel assembly shall be engaged by guide pins on the gripper to maintain alignment between the gripper and fuel assembly. The two larger holes on opposite corners of the fuel top plate shall be engaged by guide pins with tapered ends to lead the gripper into the fuel assembly. The smaller hole shall be used to ensure correct orientation of the gripper and fuel. A corresponding pin on the gripper will allow the gripper to enter and engage the fuel only when the pin is aligned with and can enter the hole. If the gripper is 180° out of orientation the pin shall seat on the solid corner of the fuel top plate and prevent the gripper from entering and latching to the fuel. The orientation pin shall have a blunt end and shall be shorter than the guide pins. All three pins shall be hardened A564 stainless steel.

The gripper shall be designed to feed into and engage a fuel assembly with a 1/4 inch (6 mm) misalignment between gripper and fuel assembly and with fuel nozzle sloped at an angle of 0.5 degree with horizontal.

5.6.5 The gripper shall be operated by an air cylinder located at the top of the gripper tube and connected to the gripper mechanism by an operating tube running down the inside of the gripper tube. The cylinder shall be double acting type with double end piston rod utilizing air to disengage gripper and air plus a spring for engaging. Gripper control shall be through a manual valve on the console. A solenoid valve shall be provided in air supply line to the control valve for electric interlocking of gripper operation. A bypass valve shall be provided around the solenoid valve (see Section 5.7.11).

5.6.6 The gripper mechanism shall be designed with an internal, mechanical locking device that will lock the mechanism and prevent operation of the gripper unless the gripper is resting on a fuel assembly with the gripper tube pressing down on it. In addition, the fingers shall be locked in the engaged position so that the fingers cannot open under shock or eccentric loading. The lock shall release at 330 lbs (150 kg) or less compression.

5.6.7 Gripper fingers shall be made of hardened A564 stainless steel. Finger design shall be proven by making a test finger from heat/lot material, and tensile testing. Finger shall pull 6000 lbs.

(2720 kg) to meet requirements of Section 5.3.11 and 4.3.4. Report of test shall be submitted on a generic basis for each finger design.

5.6.8 Waterproof hermetically sealed micro-switches or proximity switches shall be provided to close a control circuit when the gripper mechanism is fully engaged and fully disengaged. The switches shall be mounted to register against a trip cam on the rear piston rod of the gripper operating cylinder.

5.6.9 The control circuits shall be connected to the gripper switches by neoprene covered type S0 electric cable or similar. Connection to switch wires shall be through a waterproof connector or otherwise sealed to insure a waterproof junction. The wire shall be wound on a constant tension spring takeup reel mounted on the lifting structure.

5.7 Control Station

5.7.1 The control station shall consist of a control console containing all the necessary switches, pushbuttons, indicating lights, gages, controlling electronics such as the PLC, user interface monitor. Transformers, contactors, surge suppressors, phase monitor, indicators, air conditioner and motor controllers should be contained within the Motor Control Center (MCC). The pneumatic panel will contain all necessary pneumatic controls, including valves. The control console, MCC, and pneumatic panel shall be located on the trolley as shown in Reference 2.1.2. The control console is a modular enclosure with lifting hardware on top to facilitate removal from containment between outages. The enclosure or an enclosure cart will have casters for mobility. The MC console will mount to the MC trolley deck using the existing Trolley mount.

5.7.2 The specific configuration of the control console utilizes a two-processor design. The first processor, a programmable logic controller (PLC), performs all interlocks, load weighing, and boundary zone monitoring and control. The second processor is an industrialized computer and touchscreen that provides the operator with a graphical machine interface and fuel movement sequence monitoring. This base scope system will perform Manual, Semi-Automatic, and Automatic control in this proposed configuration.

5.7.3 The control console does not require a continuous power supply between outages. The control console will be capable of being powered once it is removed from containment.

5.7.4 Bridge, trolley, and hoist position as well as hoist load and gripper position provide input to the PLC and will identify zones where motor driver speeds will be automatically decreased when boundary limits are approached. Motions will cease once a boundary limit is exceeded.

5.7.5 The control console shall have controls and related indicating lights or instruments logically grouped according to function. All controls and lights shall be identified by engraved plastic tags attached directly below the subject item or with manufacturers standard identifying plate. Indicating lights shall have "push to test" capability.

5.7.6 An EMERGENCY STOP push-button shall be provided within reach of the operator at the console to disconnect main power supply via a master safety relay. The EMERGENCY STOP will not remove power from the monorail hoist.

5.7.7 A disconnect shall also be provided for the main control drive system of the MC and another disconnect for the monorail hoist. The disconnects shall be mounted at one end of bridge walkway. Both disconnects shall have provisions for positive locking in the open position.

5.7.8 All external electrical circuits entering console shall connect to internal console circuits through terminal blocks. Exceptions may be made for circuits requiring shielding. Within the pneumatic panel, external pneumatic lines shall connect to internal lines through unions.

5.7.9 The console shall be a sheet metal enclosure with sloped operating surface designed for an operator in standing position. The console enclosure shall have a hinged door with key lock on the front, and maintenance access panels as required.

5.7.10 The following controls and instruments will be located on the console. Indicating lights shall be on the console or adjacent to the console in clear view of the operator. Alternatively, to physical hardware, controls and indicators may be accomplished through HMI screen, with exception of Interlock Bypass/Override Switch and Gripper Engage/Disengage Switch, which shall be mechanical. This list shall not be considered exclusive; other items may be added as design proceeds.

5.7.10.1 Controls

a) Bridge drive control,
b) Trolley drive control,
c) Hoist drive control,
d) Gripper control valve switch (ENGAGE / DISENGAGE),
e) Fuel weight selector switch (HEAVY / LIGHT),
f) Interlock override key switch (INTERLOCK BYPASS).

5.7.10.2 Indicating Lights and Instruments

a) GRIPPER TUBE UP position light (upper stop, Sec. 5.3.14),
b) Hoist low load indicating light (UNDERLOAD),
c) GRIPPER ENGAGED indicating light,
d) GRIPPER DISENGAGED indicating light,
e) Excessive weight indicating light (OVERLOAD),
f) Bridge and trolley position indicator, hoist elevation readout and weight indicator,
g) Gripper SLOW ZONE indicating lights,
h) Air pressure gage located on the pneumatic panel for gripper controls on trolley,
i) INTERLOCK BYPASSED indicating lights (bridge, trolley, hoist and gripper),
j) GRIPPER INTERLOCK FAILURE alarm and indicating light,
k) GRIPPER UP-DISENGAGED indicating light (lower stop, Sec. 5.3.14),
l) SLACK CABLE indicating light (low load indicating light)

5.7.11 The following INTERLOCKS shall be provided in addition to travel limit switches, to prevent hazardous design criteria of ANSI 57.1:

a) Hoist drive shall be inter-locked to bridge and trolley drive to prevent simultaneous vertical movement with any horizontal movement.
b) Bridge and trolley drive operation shall be prevented except when both gripper tube up position circuits are satisfied (Section 5.3.14), or when the lower stop elevation is reached (gripper up disengaged). Also, the existing TELESCOPIC VIDEO MAST RETRACTED limit switch shall be actuated to allow bridge and trolley movement.

c) Solenoid valve in air line to gripper shall be de-energized (closed) except when load cell switch indicates gripper is empty.

d) Hoist drive circuit in up direction shall be opened when either excessive suspended weight condition of Section 5.3.12 or 5.3.10 is present.

e) Hoist drive circuit in up direction shall be operable only when either the engaged or disengaged indicating switch on gripper is actuated. A monitoring circuit shall be provided to actuate a visible and audible alarm (GRIPPER FAILURE) if both engaged and disengaged circuits are in the permissive (closed) condition at the same time.

f) Bridge and trolley drives shall be interlocked such that travel beyond the edge of the core is restricted to path or zones shown on Reference 2.1.1. Over the core, bridge and trolley drive shall be interlocked to prevent collision between mast and guide studs in vessel flange.

g) The manipulator crane shall be interlocked with the fuel transfer system. Wiring shall be provided to close a circuit when either of two conditions is satisfied; (1) the gripper tube up or gripper up disengaged position condition is present, or (2) the crane is over the core. Interlock circuit shall be carried to transfer system by a trailing wire attached similarly to the power cable.

h) Hoist drive in the up direction shall not be operable when the gripper is disengaged, and the load cell indicates a load greater than 1200 lbs (545 kg).

5.7.12 Interlocks (a), (b), (d) and (g) shall have redundant electrical circuits per Section 4.2.13. However, interlocks could be accomplished through PLC logic. Interlock (c) shall have mechanical redundancy per section 5.6.6. Interlocks of Section 5.7.11 except (a) and (g) shall be bypassed individually or in groups. Interlock (g) should be bypassed on the transfer system. Bypass/Override key switch shall be mechanical and located on control console. Individual bypass toggles will be controlled via the HMI. Gripper air solenoid valve shall be bypassed by manual valve that feeds air directly to gripper. Bypass toggle switches shall also turn on red indications on the HMI.

5.7.13 The MC control console shall be designed to use existing plant power (380 VAC +/-10%, 3Ø, 50 Hz), operating at approximately 30 KVA maximum normal load.

5.7.14 The PLC should be programmed to create a secure zone that the manipulator crane can safely be operated within. The PLC inputs data to the control system logic and performs boundary zone checking to prevent manipulator crane interference with reactor cavity walls, reactor core shroud, obstructions protruding from transfer canal walls, control rod brackets, or any other equipment programmed into the exclusion zone(s). To move refuelling machine into non-secure areas, the operator must use the travel override feature to bypass the zone.

5.7.15 The secure zone can be bypassed by activating the travel override push button. When the button is activated, an override activated message will be shown on the touchscreen, and the travel override light will illuminate. This condition will clear when the machine re-enters the secure zone or if power is turned off or if travel override push button is released. Movement outside of the secure area is logged in the database, which may be viewed at any time.

5.8 Communication Interfaces

5.8.1 Internal MC control signals are passed over two (2) communication interfaces. Network communication is used for the PLC programming interface and Fieldbus (or equivalent) is used for the industrial network link to control equipment.

5.8.2 The overall topology of the control system is a network, which is used for monitoring and the programming interface functions. The network is designed to latest network cable standards, and communications are managed with a central switch. The switch connects the PLC and the external laptop interface port. The communication link controls the loading and updating of the PLC application program and configuration software. Both the application program and configuration software monitor the status of the network for communication failures. The HMI software displays an error message for the operator notifying that the network communications have failed, and PLC communication is unavailable.

5.8.3 Fieldbus (or equivalent) is the industrial network link communication protocol, which connects the PLC to the hardware control system and is deterministic. The position indicators and motor drives are monitored and controlled by the PLC with this protocol. The protocol relies on a health monitoring system to ensure all devices connected are active and functioning as designed. A Fieldbus (or equivalent) fault will stop motion on applicable axes, and all boundary zone protections will remain in place. Critical faults will stop all motion. The protocol is secure and requires programming changes when adding or removing devices from the network. Auto-connection to the communication network is not possible, unless the specific device is expected on that port.

5.9 PLC Security Management System

5.9.1 The software security is based on “Passwords” that must be entered into the laptop or touchscreen. The password is then granted to open the PLC application program. Changes to the PLC source code require laptop login access. Software and hardware will be designed according to the latest Cyber Security guidelines and rules.

5.9.2 With the first level of security, changes to items such as boundaries, load trip values, position assembly information, and speed settings changes are possible. Changes to the base code and interlocks require additional password input.

5.9.3 Set points provided in the Load Meter are adjustable over the full range of the load cell. The response time for this operation is typically less than 150 milliseconds. The system is designed to continuously monitor the load during all static, raising, and lowering operations to ensure safe fuel movement.

5.9.4 A load simulator test unit with cable and connector will be provided. The load simulator unit can be connected to the load weighing system and used for testing interlocks and some calibration activities during manipulator crane check-out.

5.10 Telescope Sipping System

5.10.1 Telescope sipping is an on-line fuel leak detection method. When a fuel assembly is lifted with the mast of the MC, the ambient pressure-drop results in an outflow of fission products from damaged fuel rods. To detect these fission products, water samples are drawn on-line ("sipped") from the immediate vicinity of the fuel assembly. The water is pumped to the gas separator tank by means of a pump connected to a suction hose with mouthpieces on the gripper. A gas pump conveys the separated gas to a gas detector chamber, where it is measured for radioactivity and is returned to the gas separator tank. The signal from the gas detector is displayed on a monitor and stored in a computer. It is recognizable from this signal whether there is a leak in the fuel bundle tested or not by comparing the background level with the level from the processed fuel bundle.

5.10.2 The Sipping system shall consist of a pump skid, a gas skid, a shielded detector, and a measurement computer. The system shall connect to the sipping nozzles on the manipulator crane mast via a hose and reel on the top of the mast. The Sipping System shall be portable and suitable for immediate connection to the plant service system for detecting leaks in fuel bundles.

5.10.3 The stainless steel tubing shall be permanently mounted inside mast.

5.10.4 Main features of Sipping shall be:

a) Leak tests are done online and does not introduce any additional handling time in normal fuel operations;

b) Proven-in-use mobile equipment that has no safety functions;

c) Detection of fission products Kr-85 and Xe-133 with high sensitivity;

d) Possibility to get water and gas samples of selected fuel bundles;

e) Fully digitized fission product detection system;

f) Modular equipment for easy commissioning/decommissioning and maintenance;

g) Radiation protection for the operator;

h) Remote control from operating deck.

5.10.5 Sipping system shall be enclosed in rigid and weather protective enclosures with lifting lugs and fixtures for quick attachment to trolley platform and safe transportation to and from reactor building.

5.10.6 Telescope sipping shall be provided with radiation shielding to protect operator against high dose stream.

5.10.7 Telescope sipping shall enable remote display and basic commands for operation and signals monitoring from refueling deck.

5.11 Underwater Core Mapping Camera System

5.11.1 The system shall contain an underwater radiation tolerant camera, cable reel, telescopic video mast and mounting components. The underwater camera shall be shielded camera that will be mounted to the telescopic camera mast assembly and shall be controlled with portable control unit with an integrated monitor. All cabling, connectors, and related mounting equipment are be included.

5.11.2 Telescopic video mast shall contain upper position limit switch, which shall be wired to control station to allow bridge and trolley movement.

5.11.3 Underwater camera and control unit will be removed from the trolley between outages.

5.12 Video Camera System

5.12.1 Underdeck camera shall be mounted beneath the trolley to assist with all aspects of manipulator crane fuel movement. The underdeck camera shall be provided with pan/tilt/zoom and rotate capabilities to allow an operator to see under the trolley, especially to verify the position of the fuel transfer system upender. All cabling, connectors and related equipment shall be included.

5.12.2 For the camera system a multiplexer shall be provided in the MC control console to allow the operator to monitor all cameras or switch to a specific camera view. Additionally, required control unit and related cabling shall be provided, along with a 21” (minimum) camera monitor mounted on the control console or somewhere near the control console.

5.12.3 Cameras, monitor and camera control equipment shall be provided with connectors for easy removal between outages.

6.0 ACCEPTANCE

6.1 Performance

6.1.1 The equipment shall be free from defects in design. Workmanship and material shall give satisfactory service under the conditions specified herein without shock, vibration or other objectionable characteristics for continuous service and after periods of idleness.

6.1.2 The performance requirements shall cover the complete unit, including items not manufactured by the supplier, but sub-contracted to other suppliers and items which are reused with limitation of compatibility effects.

6.2 Test and Inspection

6.2.1 Quality assurance program shall be as specified in technical specifications, with following notes:

6.2.1.1 Material traceability shall be required for A564 and steel used for load bearing parts supporting the fuel such as gripper parts, inner mast tube, sheaves, sheave supports and axles.

6.2.1.2 Chemical and physical test reports for bronze parts shall be required to show that material meets ASTM specifications. Traceability to individual parts is not required.

6.2.1.3 Mill reports shall be obtained for all structural steel purchased to establish minimum yield strength used for calculations. Traceability to individual parts shall not be required.

6.2.1.4 A test sample shall be taken from each lot of stainless wire rope. The sample shall be fitted with swaged fittings identical to those used for finished rope assemblies and tensile tested to establish breaking strength. Each rope assembly shall be traceable to the corresponding tensile test.

6.2.1.5 Load bearing stainless steel castings shall be radiographed per ASTM Specification E94-Level 2-2T. Inspection standard shall be ASTM E446.

6.2.1.6 Material traceability shall not be required for standard fasteners.

Prior to final acceptance by NEK, the refuelling machine shall be demonstrated to perform all requirements of the specification. Initial test shall be carried out at the supplier's site to the maximum extent possible with available facilities.

7.0 CLEANING, PAINTING AND PACKING

7.1 During all stages of the fabrication process, transportation, storage and installation, cleaning of items shall be performed in accordance with a written procedure which comply, as a minimum, with the requirements of ASME NQA-1-2008, Ad.2009/2011, Part II, Subpart 2.1 (cleanness Class B) where applicable, as well as other requirements established herein.

7.2 All components except for bare structural steel shall be crated in rain tight crates. Uncrated steel shall be bundled on skids. Packing shall be planned for minimum number of packages. Items requiring inside storage shall be clearly identified on outside of package.

7.3 Any equipment containing shipping bolts, braces, locking pins, desiccant, etc., shall have a temporary sign attached in a prominent manner calling for removal of such items. Gear reducers or similar equipment shipped dry shall have signs calling for addition of proper type lubricant.

7.4 Carbon steel surfaces shall be painted in accordance with NEK specification SP-A501A, PAINTING OF EQUIPMENT IN CONTAINMENT.