CCGS TERRY FOX
AIR BUBBLER COMPRESSOR SYSTEM REPLACEMENT REQUIREMENT

1.0 SCOPE

1.1.1.1 The Canadian Coast Guard vessel Terry Fox is a 1200 class heavy ice breaker displacing 4234 tonnes. The vessel operates in the Gulf of St. Lawrence in the winter months and in Canada's high Arctic in the summer and fall. To assist in ice breaking the vessel utilizes an air bubbler system which blows low pressure air through nozzles in the hull, below the waterline, to help reduce ice friction or blow ice away from the hull. The bubbler system has multiple zones which are capable of being isolated and can also be used as a bow thruster for precise maneuvering.

1.1.1.2 The air bubbler system consists of compressor machinery (described below), air distribution piping and related piping zone control valves. The valves are hydraulically operated via an independent hydraulic power unit and controlled through the system Master Control Panel (MCP).

1.1.1.3 The existing bubbler compressor machinery is made up of two (2) separate units; one port and one starboard. Both units are comprised of:

Cord Type KA 22S Compressor,
Rated Capacity of 11018 SCFM
Discharge Pressure of 26.376 PSIA
Blower Speed of 11596 RPM,

1.1.1.4 Each compressor is coupled through a reduction gearbox to a 600HP (441KW), 460 VAC, 60hz electric motor.

1.1.1.5 Compressors are controlled locally in the bubbler compartment at Local Control Panels (LCP's), one at each compressor, and remotely, in Machinery Control Room (MCR) from a Master Control Panel (MCP) and at either of four Bridge Control Panels (BCP).

1.1.1.6 The existing units are 40 years old, with reliability and supportability becoming an issue. The Coast Guard is seeking suitable equipment that will be used to replace the existing bubbler compressors, auxiliary equipment, and control panels in their entirety. Equipment will be required to meet the minimum requirements listed in the document below and will be evaluated accordingly.

1.1.1.7 The intent of this RFP is to supply new, Class approved, compressors, motors, Local Control Panels, Master Control Panel, Bridge Control panels and auxiliary equipment as defined herein, and interconnecting controls. This will NOT include the motor starters, zone valves or valve control hydraulic power unit.

2.0 REFERENCES

2.1 Existing Equipment to Be Replaced:

2.1.1.1 Cord Type KA22S Turbo Blowers (2 of), serial numbers 1797 and 1798, Capacity of 11018 SCFM at 26.376 psia

2.1.1.2 Brown Boveri compressor drive motor, Type Q0XY 355 M2 B 10, 600 HP, 3570 RPM, 460VAC, 3 Phase, 60Hz (2 of)

2.1.1.3 Compressor Blow Off valves (2 of)

2.1.1.4 Compressor Discharge Check valves 2 (of)

2.1.1.5 Local Control Panels (2 of)

2.1.1.6 Master Control Panel (1 of)

2.1.1.7 Bridge Control Panels (4 of)

2.2 Standards

2.2.1.1 The requirements of the following standards must be complied with in supplying the compressor and control systems. Current editions of documents at the time of solicitation are to be applied.

a) Rules and Regulations for the Classification of Ships (Lloyds Register or equivalent)
b) Canada Shipping Act, 2001 (CSA 2001)
c) Marine Machinery Regulations
d) Transport Canada Publications
e) TP127 – Ships Electrical Standards
f) IEEE 45: Recommended Practice for Electrical Installation on Shipboard

2.3 Drawings and Documents

2.3.1.1 Table 2-1: List of applicable drawings and documents.

Drawing/Document Number	Description
T13-1051-001	General Arrangement Profile and Main deck
60-00-01	Machinery Arrangement
07-82-21	Air Bubblers Control System Block Diagram
07-82-22	Air Bubbler System Connection Diagram
07-82-23	Air Bubbler System Connection Diagram Equipment in Air Bubbler Compartment
15-00-03	Seat 88 air Bubbler Compressors

Drawing/Document Number	Description
71-10-01	Air Bubbler System Diagram
71-10-03	Arrangement of Air Bubbler System in Machinery Space
Reference 1	Existing Compressors – Footprint Dimension Sketches
Reference 2	Compressor Space 3D Scan link; ; http://truview.epco.ca/ (Username: DFOTFScans, Password:DFOTF01)
Reference 3	Hydraulically Operated Air Discharge Valve System
Reference 4	Cord Compressor Specifications
Reference 5	Cord Drawing #CA50-0191, HV Turbo Compressor Mod "KA22S"

3.0 TECHNICAL

3.1 General

3.1.1.1 The intent of this specification is to supply new compressors, motors, control panels, and auxiliary equipment and interconnecting controls, as defined below, to replace the vessel's existing air bubbler system compressors and control systems.

3.1.1.2 The contractor must supply, test, and ensure satisfactory operation of two (2) electric motor driven, single stage, integrally geared, single vane centrifugal compressors, Local Control Panels, a bubbler Master Control Panel and four remote bridge control panels.

3.1.1.3 All new hardware must be Class approved for marine use and meet all requirements as detailed in the technical specification included herein.

3.1.1.4 All references to approval within this specification are defined as Class approval by one of the Recognized Organizations (RO) approved by Transport Canada within the Delegated Statutory Inspection Program (DSIP) and the Marine Machinery Regulations (CSA 2001).

3.1.1.5 The existing compressor dimensions are available in the document package. The contractor must supply full dimensional drawings showing that the new compressors and ancillary equipment will fit within the existing bubbler compressor compartment to satisfaction of the Technical Authority.

3.1.1.6 The replacement system must provide all original functionality, meet, or exceed original performance criteria of the attached original compressor technical specification. The system must be compatible with the existing ship's machinery Alarm and Monitoring system and be connected to existing supply and discharge piping. It will be the contractor's responsibility to supply new hardware to connect the new compressors to the existing supply and discharge piping.

3.1.1.7 The compressors, instrumentation, controls, and all other equipment must be provided as specified herein for a complete compressor system. All equipment

specified must be designed and furnished by the Contractor, who must be responsible for the suitability and compatibility of all included equipment.

3.1.1.8 The new systems must be resiliently mounted and must utilize the existing discharge zone valve hydraulic control system.

3.1.1.9 Primary electrical service must be 460VAC via variable frequency drive for main motor, 460 and 120VAC for auxiliary equipment requirements.

3.1.1.10 The control systems must be PLC based using Siemens S7 1500 series PLC units or equivalent. The control system must be capable of operating existing air discharge valves in the current system.

3.1.1.11 All air compressor mechanical components must be supplied by a single Contractor who is fully experienced, reputable, and qualified in the supply of the equipment specified. The Manufacturer's machining and assembly shops must be ISO 9001 certified to assure conformance to the highest quality standards of the industry.

3.1.1.12 The new compressor hardware must have Original Equipment Manufacturer (OEM) representation in Canada. The manufacturer's appointed service organization must hold a stock of essential spares and be capable of providing qualified field service representatives (FSRs), thorough component documentation support, with the capability to provide technical support for standard overhaul as well as repair. The service organization must be capable of delivering these services and parts to St. John's, NL, within 24 hours of notification by the CCG.

3.1.1.13 The Manufacturer must have equipment installations of single stage, integrally geared centrifugal compressors of similar frame size in North America on at least three (3) marine offshore vessels with proven operational success. The Manufacturer must provide references to validate these requirements.

3.1.1.14 The Contractor must provide one site visit for two (2) personnel to the vessel after award of contract to correctly determine all measurements and arrangement of inlet and outlet bellows and piping. The vessel will be located at the Coast Guard base in St John's. Newfoundland, Canada.

3.2 Technical Requirements

3.2.1 General

3.2.1.1 The compressors will be used for supplying a variable volume of air to designated portions of the ship's hull according to the operation required. All items specified in this section must be supplied by the contractor to provide a properly functioning compressor system. All components must be new and suitable for Marine Environments and per the general environmental conditions specified in section 3.2.3. It must be understood that components specified establish minimum requirements only, and do not relieve the contractor of responsibility for providing a properly functioning system.

3.2.1.2 The compressors must be electric motor-driven, centrifugal single-stage centrifugal, vertical split type complete with integral gearbox, self-contained lubricating oil supply, dedicated local control panels, and accessories as described herein.

3.2.2 Design Conditions:

3.2.2.1 The new compressors must meet, or exceed, the following performance requirements:

a) Minimum Rated Capacity:	11018 SCFM
b) Design inlet pressure at blower inlet (P0):	14.6 PSIA
c) Design discharge pressure at blower outlet (P1)	26.4 PSIA
d) Compressor turndown, % of capacity:	100% to 45%
e) The maximum db of the compressors	100db

3.2.2.2 The compressors must be capable of delivering a flow of at least 11018 SCFM at ambient conditions ranging from -40°C to 35°C

3.2.2.3 The compressors must not surge or exceed the nameplate motor rating over the entire range of operation. The compressors must not exceed 485 KW of total power per unit.

3.2.2.4 The new compressors must have a output rating of 16,168 Nm^3/hr at discharge pressure of 0.811 barg and inlet conditions of 1.013 bara, 0% R.H., 0ºC.

3.2.3 General Environmental Conditions

3.2.3.1 The equipment must be designated for the following service conditions:

a) Air temperature range of - 40°C to 35°C and must operate without deterioration in air temperature peaks up to 55°C.
b) Water temperature, minus -2°C to plus 30°C.
c) Inclination in all directions from the mounting position 22.5°, rolling 22.5°, 10 seconds full period; and linear vertical acceleration of ± 1.0g.
d) A permanent list of 15° port or starboard, not cumulative with the roll.
e) Pitch of vessel, +/-12°, cycle frequency 6 seconds.
f) A permanent trim of 5° above or below the horizontal, not cumulative with the pitch.
g) Under the following conditions of relative humidity: – 95% r. h. at temperatures up to 35°C; and – 70% r. h. at all other relevant temperatures.
h) Shock loading: 2.5 g horizontal, 1.5 g vertical.
i) Under the following vibration conditions: – 2.0 - 13.2 Hz, displacement amplitude ± 1.0 mm; – 13.2 - 80.0 Hz, acceleration amplitude ± 0.7 g, maximum acceleration .7 g natural frequencies at supports for equipment and parts of equipment must not lie within the 0 - 80 Hz range, except that where they cannot be kept outside this range by constructional design methods, the vibration must be damped so

that undue amplification is avoided.

3.2.3.2 Any conditions not mentioned must follow the most current version TP127E or IEEE45-2002.

3.2.3.3 Any power cables, protection devices; breakers/fuses, alarm & Monitoring cables and control cables must be TCMS approved, marine rated cables, PVC jacketed, armored, suitable for intended use.

3.2.4 Compressor and Integral Gearbox Casing

3.2.4.1 The compressor casing must be made of closed grain cast iron. A flexible connection supplied by the contractor must allow for direct connection to the existing inlet air piping. The discharge flange must be faced and drilled to ANSI 16.1 standard, Class 125. A port must be provided at the lowest point of the casing for drainage. The compressor casing must be provided with lifting lugs capable of supporting the compressor/gearbox. The impeller must be capable of being removed from the inlet side without removal of the casing.

3.2.4.2 The gear drive housing must be of close-grained cast iron, horizontally or vertically split and sufficiently rigid to maintain the shaft positions under maximum loads. Two inspection ports, with bolt-on covers, must be provided in the upper portion of the gearbox housing. The ports must allow access to the gearbox internals for the purpose of inspection. A bolt-on plate located on the high-speed shaft centerline, opposite the impeller end, must be removable. This removable plate must facilitate inspection and replacement of the high-speed shaft opposite impeller end journal and thrust bearing without disassembly of the gearbox.

3.2.4.3 The compressor and gear housing assemblies must be machined to close tolerances for bearing fit, gear alignment, air, and oil tightness.

3.2.4.4 The gearbox must be of ample size and rated to transmit the maximum torque and horsepower input requirements to the compressor under continuous duty for all operating conditions.

3.2.4.5 Lifting lugs must be included for easy access and removal of components when required for replacement or maintenance. Identification of lifting lugs and lifting points must be included in Installation, Operation and Maintenance (IOM) Manual with weights of components included.

3.2.5 Impellers

3.2.5.1 The impeller must be of the open radial-flow type, constructed of lightweight, high strength, corrosion resistant material, capable of resisting service applicable dynamic forces. The impeller must be statically and dynamically balanced in accordance with ISO 1940.

3.2.5.2 The axial gap between the impeller and compressor casing must be adjustable by means of shims to assure the prescribed gap. Gap adjustments by means of

machining the casings or shafts are not acceptable.

3.2.6 Shafts, Gears, and Seals

3.2.6.1 The compressor gear shafts must be machined from heat-treated, forged steel and suitably ground. Any responsive lateral critical speed of the rotating assembly must be at least fifteen (15) percent from the normal operating speed. Any torsional resonances of the package must be at least ten (10) percent from the normal operating speed. All shafting must conform to “Design and Selection of Components for Enclosed Gear Drives” (AGMA 6001-D97).

3.2.6.2 The speed-increasing gears must be made of case-hardened alloy steel forgings with the gear teeth precision ground. All gears must be rated in accordance with “Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth” (AGMA 2101-C95). The gears must be manufactured to a minimum AGMA quality number of twelve (12) per “Gear Classification and Inspection Handbook” AGMA 2000-A88.

3.2.6.3 The shaft seals must be of a non-contact, multi-point, labyrinth type and operated dry. A vented space between air and oil seals must be provided. Any leakage must be minimized by having small clearances between female and male parts. The female part must be made of aluminum or bronze to avoid damage to the shaft in the event of a seal rub. Numerous slinger rings (diameter changes) on the shaft must be provided in the sealing area to ensure oil is centrifugally slung off the shaft. Uniform shaft diameter without multiple slinger rings in each sealing area will not be acceptable.

3.2.7 Bearings

3.2.7.1 Hydrodynamic oil pressure lubricated bearings must be utilized with sufficient oil film thickness under all operating conditions.

3.2.7.2 Slow speed shaft radial bearings must be cylindrical journal type. Slow speed shaft thrust bearings must be of multiple segment design for thrust in both directions.

3.2.7.3 High speed shaft radial bearings must be multiple segment, babbitted, and designed to suppress hydrodynamic instabilities and provide sufficient dampening to limit rotor vibrations. High speed shaft thrust bearings must be multiple segment, tapered land type, and designed for thrust in both directions.

3.2.7.4 Bearings must be fitted with Resistance Temperature Detector (RTD’s) for temperature monitoring. The RTD sensors must be connected directly to an RTD input card in the LCP PLC system.

3.2.8 Inlet Guide Vanes

3.2.8.1 The compressors must include an inlet guide vane arrangement and control system. The purpose of the inlet guide vane system must be to facilitate turndown of each compressor from 100% to 50% of capacity, while maximizing efficiency over the

entire turndown range.

3.2.8.2 An adjustable inlet guide vane assembly must be provided to pre-rotate incoming air, thus, maximize efficiency. Inlet guide vanes must be made in an aerodynamic, streamlined design in cross-section and located in a radial fashion around the annular inlet to minimize downstream wakes. The inlet vanes must not be used for capacity control.

3.2.8.3 Inlet guide vane position must be controlled from the LCP.

3.2.8.4 Flat steel plates must not be used for inlet guide vanes.

3.2.8.5 The inlet guide vane assembly must be mounted integrally with each compressor, multi-leaf and pivoted. All vanes must be mounted in permanently lubricated sleeve bearings. Operating linkages for inlet guide vanes must be housed within the compressor. Compressors with variable vane assemblies located external to the compressor housing, and/or have ball-in-socket linkages or other moving parts requiring periodic lubrication must not be acceptable.

3.2.8.6 Each variable vane assembly must include a compressor casing mounted electric actuator, limit switches, and open/closed indication on the LCP. Independent deck mounting of the actuator, or its operating mechanisms, must not be allowed.

3.2.8.7 The position of the vanes, from fully open to fully closed, must be transmitted to the LCP. Position of the vanes must be indicated by an adjustable manual lever arm and calibrated dial on the compressor casing. The inlet guide vane position must be indicated on the LCP.

3.2.9 Oil Lubrication System

3.2.9.1 A complete lube oil system must be provided with each compressor, installed integrally with the compressor base, and arranged to permit ease of accessibility for operation, maintenance, inspection, and cleaning. The system must be factory assembled, consisting of main and auxiliary oil pumps, oil filter, oil cooler, pressure relief valve, and piping required for a complete system.

3.2.9.2 One gearbox shaft-driven main oil pump and one electric motor-driven auxiliary oil pump (for pre-lube and post-lube) must be provided, each capable of full capacity and pressure to supply lubrication for the air compressor/gearbox when operating and during start/stop. The electric motor-driven oil pump must operate at start/stop of the compressor and, at low oil pressure, be activated by the control system located in the LCP. The motor must be 3 phase, 60 Hz, Totally Enclosed, Fan-Cooled (TEFC), National Electrical Manufacturer Association (NEMA) premium efficiency and have adequate power to pump oil equal to the mechanically driven oil pump flow rate. The motor must be provided with an anti-condensation heater.

3.2.9.3 During equipment idle periods, while the vessel is operating without the bubbler system, the (i.e. the compressor is not in operation), the electric oil pump must operate to ensure the load bearing components are adequately lubricated to prevent

wear from the vessel vibration and movement.

3.2.9.4 The oil reservoir must be integral to the compressor base with the reservoir interior de-scaled and rust-proofed by the application of a permanent oil resistant epoxy coating. The tank coating must be certified for use in lubricating oil service. Reservoirs must be baffled to minimize air entrainment, to isolate foam, be equipped with a suitably sized vent and breather filter, an oil level dipstick, and have a minimum working capacity of three (3) minute retention time based on normal flow. The reservoir must be provided with multiple access points that allow for clean out.

3.2.9.5 The oil filter must be of the full flow, replaceable cartridge, duplex type with integral transfer valve, and capable of removing particles over ten (10) microns with a clean oil filter element pressure drop kept to a minimum. A visual gauge and electric switch connected to the LCP must indicate when a filter is dirty and requires changing. Filters must be designed such that changeover of the lube oil filters during operation is available.

3.2.9.6 An air/oil cooler to maintain constant oil temperature must be included and mounted on each compressor skid.

3.2.9.7 An oil heater to heat the oil if the ambient temperature around the compressor falls below 10° C (50°F) must be provided. The oil heater must be designed to heat lightweight oil with no more than fifteen (15) watts per square inch. The heater operation must be controlled by the LCP based on the oil reservoir temperature transmitter reading. The compressor must not start unless the oil is above a minimum permissive limit. Low oil temperature warning indication must be provided on each LCP.

3.2.10 Noise Abatement

3.2.10.1 The compressor air ends and air discharge cones must be fitted with noise abatement blankets.

3.2.10.2 The compressor assembly noise levels must be limited and abated to the greatest extent possible without the use of a specific noise abatement enclosure.

3.2.11 Coupling

3.2.11.1 A flexible, dry type spacer coupling must be furnished with each compressor to connect the compressor and motor. Couplings requiring grease lubrication must not be allowed. Coupling and spacer must be balanced and sized with a minimum service factor of 1.5. Coupling construction must be such that either shaft of the equipment assembly may be removed without disturbing adjustment of the other. A steel guard must be installed over the coupling.

3.2.11.2 The coupling selection must be confirmed with a torsional critical speed analysis. All torsional critical speeds must be outside of the compressor operating shaft speeds by +10/-15%.

3.2.12 Electric Motors

3.2.12.1 Each compressor must be provided with a horizontal, constant speed, Totally Enclosed Air-To-Cooled (TEAACI) squirrel cage induction motor designed in accordance with applicable NEMA, ANSI and IEEE standards. The motor horsepower must be of continuous rating equal to, or more than, the maximum load that will be imposed at any point in the operating range of the design conditions specified. Each motor must have a 1.15 service factor with Class "B" temperature rise at rated load and minimum Class "F" insulation. Motors must be supplied with lifting lugs.

3.2.12.2 Drive motors must be suitable for operation on 460volts/60 Hertz/3 phase power for ambient air temperature up to 40°C and suitable for application with variable frequency drive.

3.2.12.3 Motors must be inverter duty design as defined by NEMA MG 1.

3.2.12.4 Motors must be precision balanced to meet NEMA MG 1 Grade B unfiltered vibration limits for rigid mounting.

3.2.12.5 Motors must be supplied with suitable variable frequency drives matched to application. VFD's must be water cooled. Water cooling connection will be by others.

3.2.12.6 Means must be included in the motor/ VFD package to prevent circulating and capacitive currents from passing between the motor shaft and the bearings of both the electric motor and the driven compressor. The installation must include correct cabling detail, correct grounding detail, insulated motor bearings and/or grounding slip rings at the drive end motor bearings.

3.2.12.7 The motors must have a space heater. The space heater must be wired to and controlled by the motor starter.

3.2.12.8 The motor main terminal boxes must be oversized to provide adequate space for connections and any specified terminal box mounted accessories. The terminal box must be constructed of cast iron or fabricated steel, diagonally or vertically split, neoprene gasketed and bolted. The motor leads must be permanently marked in agreement with the connection diagram.

3.2.12.9 The motor main and auxiliary terminal boxes must be mounted on the left-hand side of the motors when looking at the non-drive end.

3.2.12.10 The motors must have factory installed fail-safe winding protection in each phase consisting of two embedded 3-wire, 100 ohm platinum (PT100) RTD temperature sensors per phase (one operational, one spare). Winding temperature RTD's must connect to the LCP for monitoring and alarm.

3.2.12.11 The motors must be supplied with anti-friction type ball bearings.

3.2.12.12 The motors must have provisions for installation of velometers at each motor bearing.

3.2.12.13 The no load, free-field, A-weighted sound pressure level measured in four (4) quadrants at one (1) meter distance from the motor must average 90 ±3 dB(A) or less.

3.2.13 Air Intake Connection Conditions

3.2.13.1 Each compressor must be supplied with a suitable air intake flexible connection suitable for connecting the new compressors to the existing air intake silencers which are to be retained and re-used.

3.2.14 Discharge Expansion Joint Conditions

3.2.14.1 Each compressor must be provided with a discharge expansion joint capable of withstanding the vacuum, pressure, and high discharge air temperature under all operating conditions. The expansion joint must be rated for a discharge temperature of 150°C. The expansion joint must be suitable for mounting between flanges drilled for a standard ANSI Class 150 bolt pattern.

3.2.14.2 When metal bellows type expansion joints are supplied, they must include sound attenuating wraps for installation.

3.2.15 Discharge Cone/Silencer

3.2.15.1 A discharge cone/silencer must be provided with each compressor to increase both compressor outlet sizes to the larger diameter air discharge piping (20”). Maximum sidewall angle increase must be 7° per side (14° total). Instrument connections must be provided for components mounted on the cone/silencer. Minimum ¼ plate, painted carbon steel must be used.

3.2.15.2 The inside of the discharge cone/silencer must be lined with deep layers of sound absorbing material, resistant to high temperatures, covered by fiberglass cloth and a perforated stainless-steel plate (minimum 10-gauge thickness), to form sandwiched layers of the external cone/silencer surface, acoustical material, and internal perforated steel plate.

3.2.16 Blow-Off (Bypass) Valve

3.2.16.1 Each compressor must be provided with an electrically operated 10” cast iron body wafer type resilient seated butterfly valve to accommodate air discharge blow off to atmosphere. This must be capable of wiring to the LCP to allow unloaded start-up and stop. The valve materials must be suitable for low pressure air service <50 psi and maximum temperature of 121°C. The valve operator must be motorized, 460/60/3, NEMA 4X, open/closed in 15 seconds or less and equipped with integral reversing starter and open/closed limit switches. Controls for the blow-off valve must be mounted in each LCP.

3.2.16.2 The blow off valves and actuators must be configured to fail to the closed position.

3.2.17 Check Valve

3.2.17.1 Each compressor must be provided with a discharge check valve of the dual plate type with center hinge, spring closure, cast iron wafer style body, BUNA-N seat, corrosion resistant plates and springs, rated for temperatures up to 205°C. The check valve must be mounted in a horizontal run of piping.

3.2.18 Nuts, Bolts, And Gaskets

3.2.18.1 The Supplier must provide all nuts, bolts, and gaskets required for assembly of the supplied valves and silencers. All nuts and bolts must be grade 8 or better and all gaskets must be suitable for the intended service.

3.2.19 Local Control Panel (LCP)

3.2.19.1 Each compressor must be furnished with a PLC-based control, monitoring and sequencing Local Control Panel (LCP).

3.2.19.2 The control panel must be mounted on anti-vibration mounts for withstanding motion in both the vertical and horizontal planes. All instruments and controls on the compressor skid must be factory wired to the LCP. All controls and instruments must fail into a safe condition. The controls must be designed such that the compressor cannot operate unless the controls are energized, nor can they operate with any defective controls. Vibration mounts must be designed to withstand the vibration and forces specified in paragraph 3.2.3 of this Specification.

3.2.19.3 LCP enclosures must be IP55 rated and must be fitted with a hinged door for front access. All wiring within the panel must be grouped together in harnesses and secured to the structure. The LCP must be factory assembled and wired such that System Installer field wiring must consist only of connection to terminals. The panel must have an internal light and duplex 120/60/1, receptacle. Each assembled control panel must carry a UL-C for Canadian service certifying the assembled industrial control panel complies with UL 508A.

3.2.19.4 Each compressor LCP must monitor status of all compressor operating parameters, all compressor peripheral hardware such as blow off valves, compressor air inlet door position, blow off air discharge door position and any other item as required to facilitate a complete functional and fully functional system.

3.2.19.5 Each compressor LCP must monitor and contain controls for compressor motor starting, surge and overload detection, shutdown control and sequencing, alarm and emergency shutdown systems, inlet guide vanes, blow-off valve, air inlet door position, blow off air discharge door position and the oil lubrication system operation.

3.2.19.6 The Compressor LCP must be capable of seamless interface with the new Bubbler Master Control Panel & Bridge Control Panel Systems.

3.2.19.7 Full scope of control functionality must meet overall compressor and air bubbler system needs as required by the compressor manufacturer. Minimum requirements are as follows.

3.2.19.8 Each LCP must:

a) Include a main power disconnect, which interlocks with the enclosure door.

b) Provide starters for variable vane operators, air/oil cooler, oil pump and oil heater, all must be mounted inside the panel.

c) Provide for power distribution to feed motorized valve motor controllers located at the valves.

d) Provide a transformer with 120V secondary and a separate 24V DC regulated power supply.

e) Isolate all low voltage variable power signals entering the LCP.

3.2.19.9 All branch circuit protection must be in accordance with NEC codes, as well as protection for the instrumentation power, the (120/60/1) duplex receptacle, Operator Interface, and the PLC.

3.2.19.10 A PLC must start and shut down the compressor in a permissive sequence, receive input, monitor**,** and control operating variables. The PLC must also contain a program for continuous optimization of compressor efficiency with respect to changes in capacity, inlet temperature, and differential pressure across the compressor. The PLC must be Siemens S7 1500 series or equivalent.

3.2.19.11 Transient voltage surge suppression must be provided for 460V power.

3.2.19.12 LCP wiring must have PVC insulation and jacket.

3.2.19.13 Surge suppressors must be provided for electrical “noise” protection and to remove transient peaks across all inductive loads.

3.2.19.14 Isolation amplifiers, R/I transmitters, RTD/vibration transmitters, and other controls must be supplied, as required, for complete system control.

3.2.19.15 Each end of each wire must be identified by a unique wire number printed on an indelible heat shrunk sleeve marker.

3.2.19.16 An Operator Interface Touch sensitive (OIT), color monitor, minimum 9-inch size that incorporates all controls, alarms, and meters in easy-to-interpret screens must be provided.

3.2.19.17 The LCP must include a basic set of buttons and lights for system back up control in the event of any failure of the Ethernet communication hardware (Ethernet switch)

between HMIs and PLCs.

3.2.19.18 The display screens on the OIT must provide easy access to all functions that plant operating personnel will need for operation and maintenance of the compressor. The controls/displays must generally be functionally grouped as operations, service, alarms/trips or configuration. Access to these separate control functions must always be displayed in the form of a touch-sensitive screen point selection button/tab on each operator interface screen and be accessible by one-touch selection. The following general design protocol must be followed:

3.2.19.19 A main operations page must be provided that consolidates the basic control functions on one screen, including: start and stop control, local and remote operating mode selection, important operating status message display, capacity increase and decrease control, capacity indication in % and motor amperage indication. All operating parameters and transmitter values must be accessible from the main operations page. If multiple pages are required to display operating data, navigation between pages must be simple and obvious to the operator, in the form of one-touch selection buttons or tabs. Operating data must be organized and clearly identified to facilitate fast and easy viewing by the operator.

3.2.19.20 A service page must be provided to allow maintenance and troubleshooting of the compressor controls and ancillary devices. From the service page, one-touch selection buttons must be provided to select the normal mode of operation or the service mode of operation. In the normal mode, the service page(s) must display the individual operating status of all devices while the compressor is operating. In the service mode, the main motor must be disabled. Service mode must allow independent operation of all devices. When service mode is activated, a banner must be displayed to alert the operator that the compressor is in service mode. In addition, compressor start must be prohibited when the compressor is in service mode.

3.2.19.21 If an alarm or trip is detected, there must be a message displayed and/or a visual indication of the presence of an alarm on the main operations page. An alarm/trip status page must be accessible from any other page or mode of operation with a one-touch push button selection. The Alarm/Trip status page must give a listing of all active alarms or trips with a detailed description of each and the time of occurrence. All alarms, once corrected, may automatically be cleared without acknowledgement. However, any trip condition must require an operator to acknowledge the trip condition after it has been corrected by a one-touch selection button on the alarm/trip page. Compressor start must be inhibited if there are any active alarms. The control system must also prevent a re-start of the compressor until all trips are corrected and acknowledged. A horn must sound (and a beacon must illuminate) when any alarm or trip condition occurs to alert plant operating personnel. A one-touch selection button on the alarm/trip page must be provided to silence the alarm horn.

3.2.19.22 A configuration page must be provided which includes power-up default settings. The power-up default settings will determine the control mode the compressor will be in upon power up of the LCP. The configuration page must also include a Test Mode that diverts main motor starter start signal to test logic that simulates motor start to facilitate testing of the control system without starting the drive motor.

3.2.19.23 Additional selector switches, pushbuttons, and indicators must include:

a) Emergency stop mushroom button on panel door
b) Separate, non-resettable hour meter on panel door

3.2.19.24 In addition to the OIT indicating lights, pushbuttons must be provided to allow for operation and monitoring of the compressor if the OIT is inoperable or Operator prefers not using the OIT.

3.2.19.25 The Operator Interface must display and monitor all analog signals, including, but not limited to:

a) Motor amps
b) Inlet guide vane position
c) Temperature signals
d) Pressure signals
e) Vibration signals

3.2.19.26 The compressors must start under an automatic sequence initiated by the local start signal or the remote start signal (i.e., Bubbler Master Control Panel) when in remote/auto control. Upon signal to start, the PLC must confirm the inlet guide vanes are at minimum, the blow-off (bypass) valve is open, and the bubbler air inlet doors are opened. All vanes and valves must be equipped with limit switches on both the open and closed position to indicate position. Bubbler air intake doors must be provided with proximity switches to indicate open or close position of doors.

3.2.19.27 The oil pre-lubrication system must energize and run for a minimum of two (2) minutes pre-lubrication time. Once all pre-start permissives are confirmed, the compressor motor must be started. A feedback signal from the main motor starter must confirm the main drive motor starter has been energized. When the compressor reaches operating speed, as determined by the motor start sequence, the PLC must, stop the electric oil pump, release control of the inlet guide vanes to local/remote control and initiate “Ready” status indication. If the components are not correctly positioned, interlocks must prevent compressor operation after a pre-set delay time. A sequence fail alarm and trip, if any portions of the start, run, or stop sequence are not properly executed must be provided. The Operator Interface must annunciate the function that caused the trip.

3.2.19.28 Once “Ready” has been indicated, compressor control may be transferred to remote control where it must be accepted by the operator at the remote location.

3.2.19.29 The surge detection system must sense unbalanced/surge conditions by use of pressure sensing devices. Detection of surge conditions must trip the compressor off-line.

3.2.19.30 Motor overload protection software must be provided to control the maximum vane setting on the compressor, so that motor current does not exceed a pre-set level.

3.2.19.31 The output of the compressor must be graphically and numerically displayed on the operator interface as a percentage of maximum capacity, from 45% to 100%.

3.2.19.32 There must be three means of shutting down the compressor:

a) Normal Stop – Initiated by pushing the stop button on the Operator Interface or remote stop. The unit normally stops such that no surging occurs. On completion of the stop sequence, the blow off valve must be in the closed position and remain in the closed position until the next start request.

b) Soft Stop – Soft stop must de-energize the main drive motor eight (8) seconds after alarm initiation to allow the blow-off valve to partially open. Normal post-lube and other normal stop functions follow. Initiated by:

i. High oil temperature
ii. High inlet air temperature (recirculation/surge)
iii. High motor winding temperature
iv. High bearing temperature (compressor or motor)
v. Discharge valve has not fully opened within two (2) minutes after PLC receives feedback signal from main motor starter.
vi. Blow-off valve has not closed within five (5) minutes after PLC receives feedback signal from main motor starter.
vii. High discharge temperature or pressure
viii. High motor amps
ix. Surge

c) Emergency Stop – Emergency stop must de-energize the main drive motor immediately. Normal post-lube and other normal stop functions follow. Initiated by:

i. Pushing emergency stop button.
ii. Low-low oil pressure
iii. High vibration
iv. No feedback signal from main motor starter during Start Sequence.
v. Loss of feedback signal from main motor starter during Normal Operation
vi. Sequence failure during start-up
vii. PLC failure
viii. Stop sequence failure during shutdown (vanes not at minimum, discharge valve not closed, blow-off valve not open within 120 seconds of issuing a stop command).
ix. The high inlet air temperature (recirculation) alarm and the zero-speed switch must be active when there is no main motor feedback present at the LCP from the main motor starter. The purpose of these sensors is to detect reverse air flow through the compressor and reverse rotation of the impeller.

3.2.19.33 The LCP must include provision for data communication with the New Air Bubbler

Master Control Panel and Bridge Controllers. This compatible interface must be an ethernet based industrial standard data communications protocol compatible with the selected PLC type.

3.2.19.34 Data communication to/from the LCP must be as follows via PLC interface:

a) To Bubbler Master Control Panel and Bridge Controllers

i. Compressor ready for start
ii. Compressor on
iii. Maximum air flow
iv. Minimum air flow
v. Common alarm
vi. Currently active compressor control location – LCP, MCP or one of the four Bridge Control Panels

b) To and From Main Motor Starter – (Hardwired digital signals by the System Installer)
c) Motor run signal to main motor starter (digital signal from LCP to main motor starter)
d) Motor feedback (run confirmation) signal (digital signal from main motor starter to LCP)
e) To plant process control (for compressor monitoring purposes)

i. All monitored and displayed data managed by the LCP PLC must be available to the vessels Centralized Control, Alarm and Monitoring System (CCAMS) for CCAMS HMI display, monitoring and alarm annunciation directly. The LCP PLC must be configured to facilitate communication with the CCAMS via standard, industrial data communications protocol such as Modbus, Profinet or equivalent. All LCP PLC data string identification must be made available to facilitate integration with the CCAMS.

3.2.19.35 The LCP must include “Normal Mode”, “Service Mode” and “Test Mode” selection options as follows.

a) When in “Normal Mode” the compressor must operate with all sequences and alarms enabled.

b) When in “service Mode” the following components must be able to be manually turned on and off from the operator interface:
i. Manual start/stop of auxiliary oil pump
ii. Manual open/close of the blow of valve (BOV)
iii. Manual open/close of the inlet guide vanes (IGV)
iv. Manual start/stop of oil cooler fan motor

c) When in “Test Mode” the main motor start function must be simulated. The signal

to start the main motor must be bypassed and a simulated feedback signal from the main motor starter must be created so a start-up procedure can be simulated without running the motor. The remainder of the compressor functionality must remain the same as in “Normal Mode’

3.2.19.36 The “Service Mode” and “Test Mode” selection options must be disabled when the compressor is in start sequence or on-line.

3.2.20 Local Valve Test Function

3.2.20.1 Air discharge valve test functionality must be incorporated into the LCP or provided by a separate valve test panel.

3.2.20.2 With LCP in Service Mode, all hydraulically operated air discharge zone valves must be able to be manually opened and closed, locally, from within the compressor compartment. Open/Closed position indication must be provided for each valve.

3.2.21 Control and Instrumentation - General

3.2.21.1 Instrumentation components must be provided and mounted on the compressor skid, except as noted, with all electrical connections external to the skid, wired to the LCP by the System Installer.

3.2.21.2 Butt type connectors for any connections must not be used, only terminal strips are acceptable. All wires must be marked at both ends with indelibly printed, heat shrunk sleeves or equivalent.

3.2.21.3 The LCP must be designed to withstand heavy vibration for icebreaking conditions and provided with compression style spring loaded terminal block isolators. Screw type isolators must not be used.

3.2.21.4 Instrumentation must be designed for marine environments and must be highly resistant to vibration.

3.2.21.5 Instrumentation and warning/status/alarm functions for each compressor must include, as a minimum, the following items. Digital and analog signals must be indicated on the Operator Interface. Operator interface must include the ability to change set points for testing and confirming functionality and accuracy.

a) Inlet air temperature gauge
b) Inlet air temperature PT100 RTD sensor/transmitter, 4-20 mA HART – Inlet high temperature and recirculation surge indicator
c) Surge switch
d) Discharge air pressure gauge
e) Differential pressure (inlet/discharge) transmitter, 4-20 mA HART, with LCD display

f) Oil temperature PT100 RTD sensor/transmitter, 4-20 mA HART, installed in the oil reservoir
g) Oil temperature gauge (located in oil supply line to gearbox)
h) Oil low pressure switch (located on main oil pump discharge)
i) Oil low-low pressure switch (located in oil supply line to gearbox)
j) Oil pressure gauge (located in oil supply line to gearbox)
k) Oil filter differential pressure indicator/switch – filter change warning
l) Low oil level switch (located in oil reservoir)
m) Inlet guide vane position transmitter and open/closed limit switches
n) Blow-off valve limit switches, integral with blow-off valve and capable of being wired to the LCP

3.2.21.6 Temperature Monitoring

a) The temperature monitoring system must include 3-wire, 100 ohm platinum (PT100) RTD temperature sensors embedded in the motor windings (two per phase; one active, one spare) and in each bearing of both the motor and compressor/gearbox. The RTD sensors must be connected directly to an RTD input card in the LCP PLC system. The system must monitor and display actual winding and bearing temperature at the LCP. Monitoring signals must be communicated to the CCAMS as per section #3.2.18.29. The LCP Operator Interface must display an alarm when rising temperature levels reach the alarm set point, and then follow with a compressor shutdown when temperature levels continue rising to the trip set point. The trip must be displayed until the condition is corrected and the trip is acknowledged at the Operator Interface.

b) Process temperature sensors (inlet/discharge air, lube oil) must be 100 ohm platinum (PT100) RTD, 3- or 4-wire, assembled to a termination head that houses the temperature transmitter. Temperature sensors installed into the compressed air stream or lube oil system must include a 316 stainless steel thermo well. The sensor and transmitter must be pre-wired and pre-configured. Temperature transmitters must be 4-20 mA, HART, configured for 100 ohm platinum RTD, 3- or 4-wire.

3.2.21.7 Pressure Monitoring

a) Pressure transmitters must be 4-20 mA, HART, with NEMA 4X enclosure and LCD display. Gauge pressure transmitters must be supplied with a 316 stainless steel block and bleed valve for process isolation and calibration. Differential pressure transmitters must be supplied with a standard manifold having NPT threaded process connections.

3.2.21.8 Vibration Monitoring

a) A shaft vibration monitoring system must be furnished for each compressor and motor. The system must include:

i. A vibration transmitter must be installed on the compressor gearbox casing to alarm and shutdown on excessive vibration. A piezoelectric accelerometer type sensor with a velocity vibration detection range of 0 to 2.0 ips must be provided. The instrument must be a combination vibration sensor/transmitter. The vibration transmitter must be IMI Sensors Model 640B09, or equal.

ii. Motor velocity type vibration transmitters (2 each): Piezoelectric accelerometer type sensor with a velocity vibration detection range of 0 to 2.0 ips. The instrument must be a combination vibration sensor/transmitter and be mounted over the bearing on each end of the motor.

b) The PLC in the LCP must receive, and the Operator Interface must numerically display, the vibration signals. The Operator Interface must include an adjustable alarm feature on the rising vibration levels that first alarms and is followed by unit shutdown. The alarm/shutdown must be displayed until reset. Provide necessary hardware for direct communication between vibration probes, PLC, and Operator Interface. All components must be designed to be highly resistant to vibration.

c) Two modes of operation must be selectable, ice breaking mode and thruster mode. For ice breaking mode, contractor must coordinate with CCG on agreeable alarm and trip vibration set points to avoid nuisance alarms, while still protecting the machine.

3.2.22 Bubbler Master Control Panel (MCP)

3.2.22.1 Scope of supply must include an air bubbler system Master Control Panel (MCP).

3.2.22.2 The MCP must provide a PLC based sequencing and control program for managing overall system control from various locations, starting, and stopping the compressors, control of the existing bubbler system zone valves and to facilitate set point control based on the modes of Operation described in section 3.2.24.8.

3.2.22.3 The MCP PLC must be Siemens S7 1500 series or equivalent. The new panel must replace the existing Bubbler System MCP.

3.2.22.4 The MCP enclosure must be free standing IP55 rated and must be fitted with a hinged door for front access. All wiring within the panel must be grouped together in harnesses and secured to the structure. The MCP must be factory assembled and wired such that System Installer field wiring must consist only of connection to terminals. The panel must have an internal light and duplex 120/60/1, receptacle. The control panel must carry a UL-C for Canadian service certifying the assembled industrial control panel complies with UL 508A.

3.2.22.5 The control panel must be mounted on anti-vibration mounts for withstanding motion in both the vertical and horizontal planes. Vibration mounts must be designed to withstand the vibration and forces specified in paragraph 3.2.3 of this Specification.

3.2.22.6 The MCP must be provided with a programmable electronic Operator Interface Terminal (OIT) that must have multiple color screens to display operating variables,

valve positions, and other relevant data. Operating screens must have a touch sensitive screen point to select the mode of operation of the bubbler system, and for local or remote-control mode. The operation must be programmed to be user friendly by providing sufficient prompting that an operator can intuitively follow through the commands to operate the blower system.

3.2.22.7 Displays and controls must be provided to monitor all process variable input for master control and to monitor and modify set points, as required.

3.2.22.8 The MCP must include a basic set of buttons and lights for system back up control in the event of any failure of the Ethernet communication hardware (Ethernet switch) between HMIs and PLCs.

3.2.22.9 All monitored and displayed data managed by the MCP PLC must be available to the vessels Centralized Control, Alarm and Monitoring System (CCAMS) for CCAMS HMI display, monitoring and alarm annunciation directly. The MCP PLC must be configured to facilitate communication with the CCAMS via a standard, industrial data communications protocol such as Modbus, Profinet or equivalent. All MCP PLC data string identification must be made available to facilitate integration with the CCAMS.

3.2.22.10 The MCP must include and accommodate the following modes of operation:

a) Bubbler - When selected, the Port and Starboard compressor functions become active.

   i. Bubbler – Compressor output brought to max capacity, air discharge valves for respective compressor opened, blow off valve closed.

   ii. Idle – Compressor output reduced to minimum, blow off valve opened, all air discharge valves closed.

b) Thruster – When selected, Thruster functions become active:

   i. Bow Thruster – “Turn to Port” - In this mode air is discharged through the forward and thruster manifolds on the starboard side, allowing the full thrust from two compressors to be applied to one quarter. Blower capacity is brought to maximum and blow off valve is closed.

   ii. Bow Thruster – “Turn to Starboard” - In this mode air is supplied through both the forward and thruster manifolds on the port side allowing the full thrust from two compressors to be applied to one quarter. Blower capacity is brought to maximum and blow off valve is closed.

   iii. Bow Thruster – “No Thrust” – In this mode blower capacity is reduced to minimum, blow off valve is open, and all air discharge zone valves are closed.

3.2.22.11 The MCP must include at minimum:

a) Local /Off/Bridge Selector Switch
   i. Local – Control of compressors and air discharge valves available at MCP.
   ii. Off – Control not available at MCP or Bridge
   iii. Bridge – Control available at any one of the four Bridge Control Panels

b) Start and stop buttons for both compressors

c) Bridge Control Panel in service indication
   i. Forward
   ii. Aft
   iii. Port Wing
   iv. Stbd Wing

d) Air Discharge Valve Position Indication
   i. Open
   ii. Closed

e) Manual cross over valve position indication
   i. Open
   ii. Closed

f) Blow Off Valve status
   i. Open
   ii. Closed

g) Compressor Status Indication
   i. Ready to Start
   ii. Compressor Running
   iii. IGV Position, Min or Max
   iv. Compressor Fault Alarm Indication
   v. Air Intake Door Position, Open/Closed
   vi. Blow Off Air Discharge Door Position Open/Closed

*Note: Under normal operation it must not be possible to operate Bubbler and Thruster mode at the same time.

3.2.22.12 The MCP must facilitate single compressor operation with the manually operated cross over valve opened.

3.2.22.13 The MCP must facilitate manual operation of air discharge valves when in Local Control.

3.2.22.14 The MCP must integrate with the existing air discharge valve hydraulic operating system.

3.2.23 Bridge Control Panels

3.2.23.1 Four new bridge control panels (forward console, aft console, port, and starboard wing consoles) must be provided to replace the existing panels. The new panels must allow for bridge operations of the bubbler system. Indicating lights, selector switches, and pushbuttons must be provided to allow for this operation as well as control transfer between the four panels. Control must only be active at one panel at any given time.

3.2.23.2 Each Bridge Control Panel must include:

a) Control location selection and indication of which station is active
b) Indication of each compressor availability for bridge control
c) Stop capability for each compressor
d) Mode selection – “Bubbler” or “Thruster”
e) Thruster Control requests – “Turn to Port”, “No Thrust”, “Turn to Stbd”
f) Bubbler/Idle requests for each compressor
    i. Bubbler – Compressor output brought to max capacity, air discharge valves for respective compressor opened, blow off valve closed.
    ii. Idle – Compressor output reduced to minimum, respective discharge valves closed, blow off valve opened.

3.2.24 Hand Held HMI

3.2.24.1 A hand-held HMI controller must be provided as an additional HMI to be utilized for bridge control and as a back-up HMI for the LCP and MCP panels. This unit must be a 9” (min) mobile HMI with 5m cable, seven (7) connection ports for each panel location (LCPs, MCP, four bridge consoles). The mobile HMI must be able to be plugged-in to any LCP, MCP or bridge console for control of both the blowers and the bubbler system. This system must be interconnected via Ethernet cabling and use the same communications protocol for HMI to PLC control as used elsewhere through the control system.

4.0 PRODUCT DELIVERY, STORAGE, HANDLING AND PRESERVATION

4.1.1.1 All equipment must be skid mounted or crated to protect against damage during shipment. All parts must be properly protected so that no damage or deterioration will occur during a prolonged delay from the time of shipment until installation is completed, and the units and equipment are ready for operation.

4.1.1.2 Finished surfaces of all exposed flanges must be protected by fiberboard blank flanges strongly built and securely bolted thereto.

4.1.1.3 Shipping crates must allow for the connection of heaters and any other protective devices, as required for extended storage, without the necessity of opening the crates. Detailed instructions for extended storage maintenance procedures must be provided by the Contractor at time of shipping.

4.1.1.4 All surfaces shall be prepared, shop primed, and finish painted with one finish coat of the marine grade epoxy and urethane paint system.

4.1.1.5 Machined surfaces that are not painted must be suitably protected from deterioration over a prolonged period.

5.0 PROOF OF PERFORMANCE

5.1 Factory Testing

5.1.1.1 Each main drive motor must be given a non-witnessed factory routine test in accordance with ANSI C50.41-2000, NEMA Standard MG1-1998-Rev.1, Section 20.16 and IEEE112-1996 to assure it is free from electrical and mechanical defects. A certified test report for each motor must be included in the final IOM manual.

5.1.1.2 Each compressor must be tested in accordance with the ASME Power Test Code for Centrifugal Compressors and Exhausters, PTC-10-1974 (reaffirmed 1992) edition. Tests may be conducted using the job motor or a factory test motor. In either case, the gearbox/compressor shaft input horsepower must be determined by the heat balance method, as per Paragraph 4.43 of the Code with a ±4% tolerance. Shaft power consumption must include one operating oil pump. The test must include determination of the surge point and verification of the guarantee points.

5.1.1.3 The compressor net delivered flow rate and discharge pressure must be measured, recorded, and guaranteed with no negative tolerance.

5.1.1.4 The capacity of the compressor must be defined as per Paragraph 4.26 of the ASME PTC-10 Power Test Code. Specifically, capacity is defined as, “the net rate of flow compressed and delivered, expressed in terms of cubic feet per minute at the prevailing inlet pressure and inlet temperature. It must be measured in a suitable manner to effectively exclude all external leakage losses from sources such as shaft seals. That is, air flow must be measured on the discharge side of the compressor at zero percent tolerance.

5.1.1.5 All test equipment must be calibrated and certified by an independent test agency no more than twelve (12) months prior to the test date. Certificates must show the stability of calibration over a period of at least one year per ISO 9001, Paragraph 4.11.

5.1.1.6 Velocity vibration versus frequency levels must be recorded within 10-1,000 and 10-10,000 Hz frequency range.

5.1.1.7 The Test Engineer must sign each copy of the test data log sheet certifying the required tests were performed in strict accordance with these specifications and the ASME PTC-10 Code, Paragraph 4.43, Heat Balance Tests.

5.1.1.8 The compressor test report must present computations in exact accordance with Section 5, 6, and 7 of the ASME PTC-10 Code with performance curves showing capacity, pressure, and horsepower inputs. Test results not in verbatim agreement with test results presentation format, per the Code, must be cause for rejection of the performance tests.

6.0 DELIVERABLES

6.1 Manuals/Drawings/Reports

6.1.1 General

6.1.1.1 All documentation must be provided in electronic PDF format, bookmarked and searchable. In addition to electronic format, three hard copies of the Final IOM with "As Built" drawings must be provided.

6.1.1.2 The contractor must submit documents to the CCG according to the following typical document submittal schedule:

Document Description	Due Date
Preliminary Design Proposal	submit with bid
Preliminary Installation, Operating and Maintenance (IOM Manual)	submit with bid
Torsional critical speed analysis report	4 weeks ASA
Installation, Operating and Maintenance (IOM) Manual	4 weeks ASA
Factory test reports	2 weeks AT
Final IOM Manual	2 weeks ASP

ARO=After Receipt of Order; ASA=After Submittal Approval; AT=After Test; ASP=After Shipment

6.1.2 Preliminary Design Package (must form part of the technical submission at bid closing)

6.1.2.1 The design package must be issued as a compilation of all information and design details required to determine suitability for the application and compliance with specification requirements. The following specific information must also be included in the design proposal:

a) The design package must include as a minimum, a comments and exceptions paragraph regarding each technical specification paragraph. Provide detailed information on structural, mechanical, electrical, or other changes or modifications necessary to adapt non-specified materials to the arrangement or details shown
b) General arrangement drawings showing compressor base dimensions, mounting deck, skid piping, required maintenance clearances, overall weights with and without oil, and weights of the largest components requiring removal for maintenance.
c) Preliminary Process and instrumentation diagrams (P&ID)
d) General description of the compressor with cross-sectional drawings explaining the design and operation.
e) Costing breakdown for spare parts listed in section 5.2.2, Tools and Spare Parts.
f) Cost of ownership analysis for a 10-year period, based on 2000 hours/year.
    i. Parts and consumables used for routine and regularly scheduled maintenance.
    ii. Field Service Rep cost to oversee any mandatory inspections or overhauls in

that period.

g) Compressor performance data
h) Preliminary performance curves
i) Provide compressor and drive motor speed-torque curves. Compressor speed-torque curve must be at the condition with guide vanes in starting position and at the specified minimum inlet temperature.
j) Provide a detailed description of the guide vane operation.
k) Compressor lubricant specifications and quantity
l) List of all major components and drawings/datasheets for each. The list must include:
    i. Motors
    ii. VFD'S
    iii. Actuators and valves
    iv. Mechanical components
    v. Instruments
    vi. Programmable Logic Controller (PLC)
    vii. Operator Interface/machine monitors
m) Preliminary operation description of Local Control Panels (LCP), Bubbler Master Control Panel (MCP) and Bridge Control Panels (BCP). As a minimum, provide a more detailed description than given in this specification, covering all logic and sequences of operation. Typical operator interface screens must be provided with detailed descriptions.
n) Electrical diagrams of all control panels, which must include:
    i. Interconnects to all shipped loose components
    ii. Door layout
    iii. Interior layout
o) Surface preparation and coating procedures
p) Preliminary compressor performance test procedure: Submit a test plan with complete piping and instrumentation configuration diagram per ASME PTC-10 showing inlet and discharge air test pipe size. The location, type, and quantity of all major instruments necessary for performance data, including those on air, and lube oil with corresponding distances from reference points, must be identified per ASME PTC-10 requirements. As a minimum, the detailed test plan must include:
    i. Quality control procedures
    ii. Compressor ASME PTC-10 test procedure and method of calculating results
q) Procedures for functional testing of the entire package, including oil lube system, instrumentation, ancillary components and control panels
r) Instrument alarm and trip set points
s) Preliminary drive train torsional analysis procedure. The results of this analysis must be included in the IOM Manual to confirm there are no torsional critical speeds within the operating range of the unit.

6.1.3 Preliminary Installation, Operating and Maintenance (IOM) Manual

6.1.3.1 A preliminary IOM manual must be submitted with the bid submittal package. The preliminary IOM Manual must include the complete index to be used for the final IOM Manual. The manual must be complete except for the final test reports and as-built drawings. The IOM Manual must include the following specific information:

a) Receiving and handling information, with a diagram of the recommended lifting method.
b) Preliminary alignment calculations at coupling between the motor and compressor.
c) Storage requirements
d) Mechanical installation instructions for shipped loose components:
e) Compressor skid
f) Compressor inlet components and instrumentation
g) Compressor discharge components and instrumentation
h) Electrical installation instructions
i) Lube oil filling instructions
j) Commissioning procedure
k) Compressor pre-startup installation checklist
l) On-site testing description
m) Recommended spare parts for commissioning
n) Operating and maintenance instructions
o) Compressor troubleshooting guide
p) Recommended spare parts
q) Suggested preventative maintenance schedule
r) Operating manuals for all major components of the compressor and control system
s) Complete spare part drawings and listings for
t) Compressor units and gearboxes including pumps, sensors, couplings, and associated instrumentation
u) Electric propulsion (main compressor) motors
v) All auxiliary components (pump sets, motors, filter sets, cooler units)
w) All electrical control equipment in LCP and interface panels

6.1.4 Torsional Critical Speed Analysis

6.1.4.1 A torsional critical speed analysis must be conducted to ensure the compressor, motor, and coupling are properly designed. All torsional critical speeds must be outside of the compressor operating shaft speeds by +10/-15%.

6.1.5 Factory Test Reports

6.1.5.1 Compressor, main drive motor, and control panel testing must be witnessed by a Coast Guard representative. Test reports must be submitted and approved prior to shipment of the equipment to the jobsite.

6.1.6 Final Detailed Design Package

6.1.6.1 A final revised and detailed version of the initial design package indicating any changes or modifications made.

6.1.7 Final IOM Manual

6.1.7.1 The final IOM manual must be submitted upon completion of compressor testing and construction. The preliminary manual, as approved, must be updated with all final test reports and as-built drawings, and final alignment figures at coupling between motor and gearbox as measured following installation.

6.2 Tools & Spares

6.2.1 Tools

6.2.1.1 The contractor must furnish all special tools and appliances necessary to disassemble, service, repair, and adjust the compressor equipment and accessories.

6.2.2 Spares

a) The following spare parts must be furnished:
b) Two sets of oil filter elements for each unit
c) One set of compressor seals and bearings for each unit
d) One set of motor bearings for each unit
e) One inlet guide vanes actuator
f) One mechanical oil pump
g) One complete auxiliary oil pump assembly
h) One spare PLC
i) One (1) laptop loaded with PLC program and software licenses
j) PLC I/O cards
    i. Two analog input cards
    ii. Two digital input cards
    iii. Two digital output cards
    iv. Two RTD cards
k) Two spare PLC power supplies
l) One spare operator interface
m) One spare local control panel 24v power supply
n) One motor/compressor coupling
o) One fan motor for the oil cooler
p) Two spare pressure transmitters for each pressure range.
q) Two spare process temperature RTD's for each temperature range.

6.2.2.1 All spare parts must be suitably packaged for marine environments and long-term

storage. Packing must be clearly identified with indelible marking on the containers. Tools and spare parts (except for the air and oil filters) must be supplied in a wooden tool chest for long-term storage and marked with Equipment name, along with a description of contents and any applicable part or identifying number.

6.3 Certification

6.3.1.1 The Contractor must provide Class approval documentation for the new compressors and all associated auxiliary and control equipment.