Annex "A"

CCGS LOUIS S. ST. LAURENT
BUBBLER SYSTEM COMPRESSOR REPLACEMENT

CANADIAN COAST GUARD
ATLANTIC REGION

Alongside St John's NL – Fall 2017

SPECIFICATION
SINGLE-STAGE INTEGRALLY GEARED INLET GUIDE VANE CENTRIFUGAL AIR COMPRESSORS
(ELECTRIC MOTOR DRIVEN)

PART 1: GENERAL

1.01 Project Summary

The Canadian Coast Guard vessel Louis S St Laurent is Canada's heaviest ice breaker displacing 14,504 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.

The existing bubbler system is made up of two (2) separate units; one port and one starboard. Both units are comprised of; Compair Reavell Type 9006 CH Compressor, Rated Capacity 6m3/sec, Press 1.61 Bar, Blower Speed 11800 rpm coupled through a reduction gearbox to a 6600vac electric motor. Compressors are controlled locally in the bubbler compartment and remotely from port and starboard bridge consoles.

The existing units and control systems are in excess of 25 years old, with reliability and supportability becoming an issue. The Coast Guard is seeking a suitable system that will be used to replace the existing arrangement in its entirety. Systems will be required to meet the minimum requirements listed in the document below, and will be evaluated accordingly.

1.02 SCOPE OF SUPPLY

A. The contractor shall supply, test, and ensure satisfactory operation of two (2) electric motor driven, single-stage, integrally geared, single vane centrifugal compressor, local control panels, a bubbler master panel, and two remote control bridge stations

B. Compressors, instrumentation, controls and all other equipment shall be provided as shown on the contractor supplied drawings, and as specified herein for a complete compressor system. All equipment specified in this section shall be designed and furnished by the Contractor, who shall be responsible for the suitability and compatibility of all included equipment.

C. The replacement system must provide all original functionality, meet or exceed original performance criteria as indicated in section 2.02 and 2.03 of the attached technical specification. The system must be compatible with the existing ship's machinery Alarm and Monitoring system and be adaptable to existing supply and discharge piping.

D. The new system must be resiliently mounted and provided with an acoustic enclosure to reduce noise transmission into adjacent structure and be capable of utilizing existing zone valve control system.

E. Compressor assembly shall fit through a space of 1.5 meters x 1.7 meters (61" x 65"), the smallest entry point into the compressor compartment. If required for entry, contractor shall disassemble compressor into appropriate sized components and provide reassembly assistance once components are inside the compressor compartment.

F. Systems must be Lloyds approved for marine use and meet all requirements as detailed in the attached technical specification.

G. The control systems shall be PLC based using Siemens S7 1500 series PLC units. The control system shall be capable of operating existing valves in the current system.

H. The electrical service, including fuses, overload protection and cables shall match that of the existing compressors or be replaced by new. Existing electrical service is comprised of 3GA2121 fuses, 7.2 KV, 63KA rated current 250Amps; 3C 1/0 15KV cable. If existing is not suitable, contractor shall provide details of material required.

1.03 MANUFACTURER / SUPPLIER

A. All air compressor mechanical components shall be supplied by a single Contractor who is fully experienced, reputable, and qualified in the supply of the equipment specified. The Manufacturer shall have at least six (6) installations of single-stage, integrally geared centrifugal compressors of similar frame size in North America that have been in operation for at least ten years.

B. The Manufacturer's machining and assembly shops must be ISO 9001 certified in order to assure conformance to the highest quality standards of the industry.

C. The Contractor shall have local Service located in Eastern Canada and be able to respond Service issues within 24 hour period.

D. The equipment detailed is specified by proprietary name, trade name and/or name of one Manufacturer, without the addition of such expressions as "or equal". These items are so specified here in for reasons of functionality and compatibility.

1.04 DELIVERABLES

NOTE: All documentation shall 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 shall be provided.

A. **Preliminary Design Proposal (shall form part of the technical submission at bid closing)** - The design proposal shall 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.

1. The design submittal shall include as a minimum 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
2. 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
3. Preliminary Process and instrumentation diagrams (P&ID)
4. General description of the compressor with cross-sectional drawings explaining the design and operation
5. Costing breakdown for spare parts listed in section 1.05 Tools and Spare Parts, Section B
6. 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

7. Compressor performance data
8. Preliminary performance curves
9. Provide compressor and drive motor speed-torque curves. Compressor speed-torque curve shall be at the condition with guide vanes in starting position and at the specified minimum inlet temperature.
10. Provide a detailed description of the guide vane operation.
11. Compressor lubricant specifications and quantity
12. List of all major components and drawings/datasheets for each. The list shall include:
    i. Motors
    ii. Actuators and valves
    iii. Mechanical components
    iv. Instruments
    v. Programmable Logic Controller (PLC)
    vi. Operator Interface/machine monitors
13. Preliminary operation description of Local Control Panels (LCP), Bubbler Master Panel and Remote Control Bridge Station (RCBS). As a minimum, provide a more detailed description than given in this specification, covering all logic and sequences of operation. Typical operator interface screens shall be provided with detailed descriptions.
14. Electrical diagrams of all control panels, which shall include:
    i. Interconnects to all shipped loose components
    ii. Door layout
    iii. Interior layout
15. Surface preparation and coating procedures
16. 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, shall be identified per ASME PTC-10 requirements. As a minimum, the detailed test plan shall include:
    i. Quality control procedures
    ii. Compressor ASME PTC-10 test procedure and method of calculating results
17. Procedures for functional testing of the entire package, including oil lube system, instrumentation, ancillary components and control panels
18. Instrument alarm and trip set points
19. Preliminary drive train torsional analysis procedure. The results of this analysis shall be included in the IOM Manual to confirm there are no torsional critical speeds within the operating range of the unit.

B. **Preliminary Installation, Operating and Maintenance (IOM) Manual** - shall be submitted with the bid submittal package. The preliminary IOM Manual shall include the complete index to be used for the final IOM Manual. The manual shall be complete with the exception of the final test reports and as-built drawings. The IOM Manual must include the following specific information:

1. Receiving and handling information, with a diagram of the recommended lifting method.
2. Preliminary alignment calculations at coupling between the motor and compressor.
3. Storage requirements
4. Mechanical installation instructions for shipped loose components:
   a. Compressor skid
   b. Compressor inlet components and instrumentation
   c. Compressor discharge components and instrumentation
5. Electrical installation instructions
6. Lube oil filling instructions
7. Commissioning procedure
   a. Compressor pre-startup installation checklist
   b. On-site testing description
   c. Recommended spare parts for commissioning
8. Operating and maintenance instructions
   a. Compressor troubleshooting guide
   b. Recommended spare parts
   c. Suggested preventative maintenance schedule
   d. Operating manuals for all major components of the compressor and control system
9. Complete spare part drawings and listings for
   a. Compressor units and gearboxes including pumps, sensors, couplings, and associated instrumentation
   b. Electric propulsion (main compressor) motors
   c. All auxiliary components (pump sets, motors, filter sets, cooler units)
   d. All electrical control equipment in LCP and interface panels

C. **Torsional Critical Speed Analysis** - conducted to ensure the compressor, motor, and coupling are properly designed. All torsional critical speeds shall be outside of the compressor operating shaft speeds by +10/-15%.

D. **Factory Test Reports** – Compressor, main drive motor, and control panel testing shall be witnessed by a Coast Guard representative. Test reports shall be submitted and approved prior to shipment of the equipment to the jobsite.

E. **Final Detailed Design Submittal** – a final revised and detailed version on the initial design proposal indicating any changes or modifications made.

F. **Final IOM Manual** - shall be submitted upon completion of compressor testing and construction. The preliminary manual, as approved, shall 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.

G. **Removal and Install Scope of Work.** – shall include engineering drawings and technical specifications for the removal of the existing equipment and installation on new bubbler units, and control systems. This document shall be written in accordance the Coast Guard refit specification layout. A template will be provided by the Coast Guard for guidance.

The contractor shall 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
Removal and install scope of work	12 weeks ARO
Final IOM Manual	2 weeks ASP

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

1.05 TOOLS AND SPARE PARTS (Show separately in bid)

A. The contractor shall furnish all special tools and appliances necessary to disassemble, service, repair, and adjust the equipment and appurtenances.

B. The following spare parts shall be furnished:

1. Two sets of oil filter elements for each unit
2. One set of compressor seals and bearings for each unit
3. One set of motor bearings for each unit
4. One inlet guide vanes actuator
5. One mechanical oil pump
6. One complete auxiliary oil pump assembly
7. One spare PLC
8. One (1) laptop loaded with PLC program and software licenses
9. PLC I/O cards
    i. Two analog input cards
    ii. Two digital input cards
    iii. Two digital output cards
    iv. Two RTD cards
10. Two spare PLC power supplies
11. One spare operator interface
12. One spare local control panel 24v power supply
13. One motor/compressor coupling
14. One fan motor for the oil cooler
15. Two spare pressure transmitters for each pressure range.
16. Two spare process temperature RTD's for each temperature range.

C. All spare parts shall be suitably packaged for marine environments and long term storage. Packing shall be clearly identified with indelible marking on the containers. Tools and spare parts (except for the air and oil filters) shall 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.

PART 2: TECHNICAL SPECIFICATIONS

2.01 GENERAL

A. 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 shall be supplied by the contractor to provide a sole source responsible for a properly functioning compressor system. All components shall be new and suitable for Marine Environments and per the General Environmental Conditions specified in paragraph 2.03 of this Section. Both workmanship and materials shall be of the very best quality and conform to all applicable sections of these specifications. It shall be understood that components specified establish minimum requirements only, and do not relieve the contractor of responsibility for providing a properly functioning system.

B. The compressors shall 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. Each compressor shall be provided with axial inlet and radial discharge. The discharge orientation shall be selectable in fifteen (15) degree increments.

2.02 DESIGN CONDITIONS

A. Design Conditions:

1.	Rated Capacity:	6 m^3/s
2.	Design ambient pressure:	1.014 Bar
3.	Design inlet pressure at blower inlet (P0):	1.002 Bar abs
4.	Design maximum inlet temperature:	35°C
5.	Design maximum relative humidity:	60 %RH
6.	Design minimum inlet temperature:	-40°C
7.	Design maximum discharge pressure (P2):	1.9 Bar abs
8.	Compressor turndown, % of capacity:	100% to 45%

B. Compressors shall be capable of delivering a flow of at least 6 m^3/s at ambient conditions ranging from -40°C to 35°C

C. Compressors shall not surge or exceed the nameplate motor rating over the entire range of operation.

2.03 GENERAL ENVIRONMENTAL CONDITIONS

The equipment shall be designated for the following service conditions:

A. Air temperature range of - 40°C to 35°C and shall operate without deterioration in air temperature peaks up to 55°C.

B. Water temperature, minus 2°C – 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 shall not lie within the 0 - 80 Hz range, except that where they cannot be kept outside this range by constructional design methods, the vibration shall be damped so that undue amplification is avoided.

J. Any conditions not mentioned to follow most current version TP127E or IEEE45-2002.

K. Any power cables, protection devices; breakers/fuses, alarm & Monitoring cables and control cables shall be Lloyd's approved, marine rated cables, PVC jacketed bronze armoured, suitable for intended use. Separated and secured as per Lloyd's and TP127.

2.04 FACTORY TESTING

A. Each main drive motor shall 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 shall be included in the final IOM manual.

B. Each compressor shall 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 shall be determined by the heat balance method, as per Paragraph 4.43 of the Code with a ±4% tolerance. Shaft power consumption shall include one operating oil pump. The test shall include determination of the surge point and verification of the guarantee points.

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

2. The capacity of the compressor shall 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 shall be measured in a suitable manner to exclude effectively all external leakage losses from sources such as shaft seals." That is, air flow shall be measured on the discharge side of the compressor at zero percent tolerance.

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

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

5. The Test Engineer shall 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.

6. The compressor test report shall 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, shall be cause for rejection of the performance tests.

C. Upon completion of assembly, each compressor, motor, and oil lubrication system shall be functionally tested with the local control panel (LCP). Operational test should be done using the master bubbler control station and remote control bridge stations (RCBS) connected to all skid mounted instruments, electric valve actuators and ancillary equipment. All start/stop sequences and all safety/alarm systems shall be tested, simulating start of the compressor drive motor.

2.05 COMPRESSOR AND INTEGRAL GEARBOX CASING

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

B. The gear drive housing shall 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, shall be provided in the upper portion of the gearbox housing. The ports shall 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, shall be removable. This removable plate shall facilitate inspection and replacement of the high speed shaft opposite impeller end journal and thrust bearing without disassembly of the gearbox.

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

D. The gearbox shall 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.

E. Lifting lugs shall be included for easy access and removal of components when required for replacement or maintenance. Lifting lugs and lifting points shall be included in IOM with weights of components included.

2.06 IMPELLERS

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

B. The axial gap between the impeller and compressor casing shall be adjustable by means of shims in order to assure the prescribed gap. Gap adjustments by means of machining the casings or shafts are not acceptable.

2.07 SHAFTS, GEARS, AND SEALS

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

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

C. The shaft seals shall be of a non-contact, multi-point, labyrinth type and operated dry. A vented space between air and oil seals shall be provided. Any leakage shall be minimized by having small clearances between female and male parts. The female part shall 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 shall 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.

2.08 BEARINGS

A. Hydrodynamic oil pressure lubricated bearings shall be required with sufficient oil film thickness under all operating conditions. All bearings shall be of bronze construction.

B. Slow speed shaft radial bearings shall be cylindrical journal type. Slow speed shaft thrust bearings shall be multiple segment designed for thrust in both directions.

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

D. Bearings shall be fitted with RTD's for temperature monitoring. The RTD sensors shall be connected directly to an RTD input card in the LCP PLC system. The readings shall be made available to the A&M via Ethernet.

2.09 VARIABLE VANES

A. The purpose of the inlet guide vane system shall be to facilitate turndown of each compressor from 100% to 50% of capacity, while maximizing efficiency over the entire turndown range.

B. An adjustable inlet guide vane assembly shall be provided to pre-rotate incoming air, thus, maximize efficiency. Inlet guide vanes shall 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 shall not be used for capacity control.

Inlet guide vane position shall be controlled from the LCP.

C. Flat steel plates shall not be used for inlet guide vanes.

D. The inlet guide vane assembly shall be mounted integrally with each compressor, multi-leaf and pivoted. All vanes shall be mounted in permanently lubricated sleeve bearings. Operating linkages for inlet guide vanes shall 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 shall not be acceptable.

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

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

2.10 OIL LUBRICATION SYSTEM

A. A complete lube oil system shall 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 shall be factory assembled, consisting of main and auxiliary oil pumps, oil filter, oil cooler, pressure relief valve, and piping required for a complete system.

B. One gearbox shaft-driven main oil pump and one electric motor-driven auxiliary oil pump (for pre-lube and post-lube) shall 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 shall operate at start/stop of the compressor and, at low oil pressure, be activated by the control system located in the LCP. The motor shall be 3 phase, 60 Hz, TEFC, NEMA premium efficiency and have adequate power to pump oil equal to the mechanical oil pump flow rate. The motor shall be provided with an anti-condensation heater.

C. 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 shall operate to ensure the load bearing components are adequately lubricated to prevent wear from the vessel vibration and movement.

D. The oil reservoir shall 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 shall be certified for use in lubricating oil service. Reservoirs shall 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 shall be provide with multiple access points that allow for clean out.

E. The oil filter shall 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 shall indicate when a filter is dirty and requires changing. Filters shall be designed such that changeover of the lube oil filters during operation is available.

F. Provide an air/oil cooler to maintain constant oil temperature and mount on each compressor skid.

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

2.11 COUPLING

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

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

2.12 EQUIPMENT BASE AND MOUNTINGS

A. A base sized to support the compressor, gearbox, motor, lubricating system, and accessories shall be supplied. The base shall be constructed of fabricated Lloyds grade A steel in an integral welded box configuration with a drip lip, lifting eyelets, and have sufficient rigidity to permit lifting (using a four-point lift) with all equipment mounted. The base shall contain the oil reservoir.

B. The base shall be fully self-supporting and mounted on Contractor supplied vibration isolators suitable to absorb the weight and vibration of the compressor assembly without undue stress or distortion. The vibration isolators shall be designed for a transmissibility of less than two (2) percent.

C. Base and compressor assembly must be designed to withstand the forces exerted by the ship movements as specified in paragraph 2.03 of this Section. Proposal must include statement confirming equipment is designed for the vibration conditions specified in paragraph 2.03 of this Section.

D. The units shall be factory precision aligned on the base prior to shipment.

2.13 ACOUSTIC ENCLOSURE

A. An acoustic enclosure covering the complete compressor; including electric motor, for average sound level less than 85 dB(A) at 1 meter distance from the compressor skid according to ASME PTC 36-1985 with a tolerance of ± 3 dB(A).

B. Acoustic enclosure shall be fabricated with alu-zinc coated steel cover, with layers of mineral wool, mineral wool with felt, a perforated, galvanized sheet, strengthening sheets and sealing strips of rubber. Enclosure shall be corrosion resistant and suitable for marine environments.

C. Enclosure must be a modular design that allows disassembly for extended maintenance of the compressor and motor and subsequent reassembly of enclosure.

D. Enclosure must have access panels to allow routine maintenance checks to be performed without the use of tools. The hood shall be equipped with a door for easy access to the inside of the enclosure, on sight window and a thermostatic controlled ventilation fan. Each panel of the enclosure shall be provided with handles making assembly of reassembly easy.

E. Enclosure must be incorporated with the compressor to allow inlet and outlet piping, cabling and applicable penetrations without affecting the acoustic properties of the enclosure.

F. Enclosure must not interfere with the operation of the Local Control Panel.

G. Contractor to provide a detailed assembly drawing with instructions on assembly and disassembly of the enclosure.

2.14 ELECTRIC MOTORS

A. Each compressor shall be provided with a horizontal, constant speed, TEAACI squirrel cage induction motor designed in accordance with applicable NEMA, ANSI and IEEE standards. The motor horsepower shall be equal to, or in excess of, the maximum load that will be imposed at any point in the operating range of the design conditions specified. Each motor shall have a 1.15 service factor with Class "B" temperature rise at rated load and Class "F" insulation. Motors shall be supplied with lifting lugs.

B. Motors shall have a space heater. The space heater shall be wired to and controlled by the motor starter.

C. Motors shall be premium efficiency design as defined by NEMA MG 1.

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

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

F. The main and auxiliary terminal boxes shall be mounted on the F1 side.

G. All motors shall be suitable for operation on 6600volts/60 Hertz/3 phase power for ambient air temperature up to 40°C. Motors shall be suitable for reduced voltage start. The motor shall be designed to start on 90% of rated voltage.

H. Motors shall 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 shall connect to the LCP for monitoring and alarm.

I. The motor shall be supplied with anti-friction type ball bearings.

J. The motor shall have provisions for installation of velometers at each motor bearing.

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

2.15 AIR INLET SEPERATOR AND INTAKE SPLITTERS

A. The compressor shall draw air from outside by use of a flexible connection to existing air inlet separator and intake splitters. This shall be supplied as per 2.05.A

2.16 DISCHARGE EXPANSION JOINT

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

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

2.17 DISCHARGE CONE/SILENCER

A. Provide a discharge cone/silencer to increase both compressor outlet sizes to the larger diameter air discharge piping. Maximum sidewall angle increase shall be 7° per side (14° total). The discharge flange and bypass flange size shall be as shown on the drawings. Instrument connections shall be provided for a components mounted on the cone/silencer. Minimum ¼ plate, painted carbon steel shall be used.

B. The inside of the discharge cone/silencer shall 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), so as to form sandwiched layers of the external cone/silencer surface, acoustical material, and internal perforated steel plate.

2.18 BLOW-OFF (BYPASS) VALVE

A. Provide each compressor with cast iron body wafer type resilient seated butterfly valves. This shall be capable or wiring to the LCP to allow unloaded start-up and stop. The valve materials shall be suitable for low pressure air service <50 psi and maximum temperature of 121°C. The valve operator shall 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 shall be mounted in each LCP.

2.19 CHECK VALVE

A. Provide each compressor 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 shall be mounted in a horizontal run of piping.

2.20 BLOW-OFF VALVE SILENCER

A. A carbon steel blow-off silencer shall be provided for each blow-off valve. The blow-off silencer shall be fitted with one (1) flange for direct bolting to the blow-off valve.

2.21 NUTS, BOLTS, AND GASKETS

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

2.22 INSTRUMENTATION

A. Instrumentation components shall 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. The following design parameters apply:

1. Butt type connectors for any connections shall not be used, only terminal strips are acceptable. All wires shall be marked at both ends.

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

3. Instrumentation shall be designed for marine environments and shall be highly resistant to vibration.

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

1. Inlet air temperature gauge

2. Inlet air temperature PT100 RTD sensor/transmitter, 4-20 mA HART – Inlet high temperature and recirculation surge indicator

3. Surge switch

4. Discharge air pressure gauge

5. Differential pressure (inlet/discharge) transmitter, 4-20 mA HART, with LCD display

6. Oil temperature PT100 RTD sensor/transmitter, 4-20 mA HART, installed in the oil reservoir

7. Oil temperature gauge (located in oil supply line to gearbox)

8. Oil low pressure switch (located on main oil pump discharge)

9. Oil low-low pressure switch (located in oil supply line to gearbox)

10. Oil pressure gauge (located in oil supply line to gearbox)

11. Oil filter differential pressure indicator/switch – filter change warning

12. Low oil level switch (located in oil reservoir)

13. Inlet guide vane position transmitter and open/closed limit switches

14. Blow-off valve limit switches, integral with blow-off valve and capable of being wired to the LCP

C. The temperature monitoring system shall 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 shall be connected directly to an RTD input card in the LCP PLC system. The system shall monitor and display actual winding and bearing temperature at the LCP. Monitoring signals shall be communicated to the A&M in the control room via Ethernet. The LCP Operator Interface shall 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 shall be displayed until the condition is corrected and the trip is acknowledged at the Operator Interface.

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

E. Process temperature sensors (inlet/discharge air, lube oil) shall 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 shall include a 316 stainless steel thermo well. The sensor and transmitter shall be pre-wired and pre-configured. Temperature transmitters shall be 4-20 mA, HART, configured for 100 ohm platinum RTD, 3- or 4-wire.

F. A shaft vibration monitoring system shall be furnished for each compressor and motor. The system shall include:

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

2. 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 shall be a combination vibration sensor/transmitter and be mounted over the bearing on each end of the motor.

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

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

2.23 LOCAL CONTROL PANEL (LCP)

A. Each compressor shall be furnished with a skid-mounted PLC-based sequencing panel. The control panel shall be mounted on anti-vibration mounts for withstanding in both the vertical and horizontal planes. All instruments and controls on the skid shall be factory wired to the skid-mounted LCP. All controls and instruments shall fail into a safe condition. The controls shall be designed such that the compressor cannot operate unless the controls are energized, nor can they operate with any defective controls. Vibration mounts shall be designed to withstand the vibration and forces specified in paragraph 2.03 of this Specification

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

C. Each compressor LCP shall 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, and the oil lubrication system operation. The Compressor LCP shall be capable of seamless interface with the new Bubbler Master Control Panel & Bridge System.

D. Each LCP shall contain a main power disconnect, which interlocks with the enclosure door. Starters for variable vane operators, air/oil cooler, and oil pump shall be mounted inside the panel. Provide for power distribution to feed motorized valve motor controllers located at the valves. Provide a transformer with 120V secondary and a separate 24V DC regulated power supply. Isolate all low voltage variable power signals entering the LCP. LCP I/O cards shall be compatible with the ships standard.

E. All branch circuit protection shall 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.

F. A PLC shall start and shut down the compressor in a permissive sequence, receive input, monitor and control operating variables. The PLC shall 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 shall be Siemens S7 1500 series.

G. TVSS surge suppression shall be provided for 460V power.

H. LCP wiring shall have PVC insulation and jacket.

I. Surge suppressors shall be provided for "noise" protection and to remove transient peaks across all inductive loads.

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

K. Identify each end of each wire by a unique wire number printed on a heat shrunk sleeve marker.

L. Provide an Operator Interface touch sensitive, color monitor, minimum 9-inch size that incorporates all controls, alarms, and meters in easy-to-interpret screens.

M. In addition to the OIT, the LCP be provided with indicating lights, selector switches and pushbuttons to allow for operation and monitoring in the event that the OIT is inoperable or Operator prefers to not use the OIT. Full monitoring and operation of the compressor should be available through the use of the selector switches, indicating lights and push buttons

N. The display screens on the Operator Interface shall provide easy access to all functions that plant operating personnel will need for operation and maintenance of the compressor. The controls/displays shall generally be functionally grouped as operations, service, alarms/trips or configuration. Access to these separate control functions shall 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 shall be followed:

1. A main operations page shall 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 shall be accessible from the main operations page. If multiple pages are required to display operating data, navigation between pages shall be simple and obvious to the operator, in the form of one-touch selection buttons or tabs. Operating data shall be organized and clearly identified to facilitate fast and easy viewing by the operator.

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

3. In the event that an alarm or trip is detected, there shall 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 shall be accessible from any other page or mode of operation with a one-touch push button selection. The Alarm/Trip status page shall 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 shall 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 shall be inhibited if there are any active alarms. The control system shall also prevent a re-start of the compressor until all trips are corrected and acknowledged. A horn shall sound (and a beacon shall illuminate) when any alarm or trip condition occurs to alert plant operating personnel. A one-touch selection button on the alarm/trip page shall be provided to silence the alarm horn.

4. A configuration page shall 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 shall 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.

O. Additional selector switches, pushbuttons, and indicators shall include:

1. Emergency stop mushroom button on panel door
2. Separate, non-resettable hour meter on panel door
3. In addition to the OIT indicating lights, pushbuttons shall be provided to allow for operation and monitoring of the compressor in the event that the OIT is inoperable or Operator prefers not using the OIT.

P. The Operator Interface shall display and monitor all analog signals, including, but not limited to:
1. Motor amps
2. Inlet guide vane position
3. Temperature signals
4. Pressure signals
5. Vibration signals

Q. The compressors shall start under an automatic sequence initiated by the local start signal or the remote start signal (i.e. bridge or Bubbler Master Panel) when in remote/auto control. Upon signal to start, the PLC shall confirm the inlet guide vanes are at minimum, the blow-off (bypass) valve is open, and the discharge valve (if used) is properly positioned, and bubbler vent doors are opened. All vanes and valves shall be equipped with limit switches on both the open and closed position to indicate position. Bubbler vent doors shall be provided with proximity switches to indicate open or close position of doors. If components are not properly positioned, they shall be moved to their respective start positions automatically by the PLC logic.

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

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

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

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

V. There shall be three means of shutting down the compressor:

1. Normal Stop – Initiated by pushing the stop button on the Operator Interface or remote stop. The unit normally stops such that no surging occurs.

2. Soft Stop – 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

   Soft stop shall 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.

3. Emergency Stop – 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).

Emergency stop shall de-energize the main drive motor immediately. Normal post-lube and other normal stop functions follow.

W. The high inlet air temperature (recirculation) alarm and the zero speed switch shall 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.

X. The LCP shall include provision for data communication with the New Air Bubbler Master Control Panel and Bridge Controllers. This compatible interface shall be Profinet.

Y. Data communication to/from the LCP shall be as follows via PLC interface:

To plant process control (for compressor monitoring purposes)

1. Compressor on
2. Compressor off
3. Common alarm
4. Control status – Local or remote/auto
5. Compressor capacity (%)

To Bubbler Master Control Panel and Bridge Controllers

1. Compressor ready for start
2. Compressor on
3. Maximum air flow
4. Minimum air flow
5. Common alarm
6. Compressor in remote/auto

To and From Main Motor Starter – (Hardwired digital signals by the System Installer)

1. Motor run signal to main motor starter (digital signal from LCP to main motor starter)
2. Motor feedback (run confirmation) signal (digital signal from main motor starter to LCP)

2.24 BUBBLER MASTER CONTROL PANEL (MCP)

A. A freestanding, IP55 or NEMA12 rated enclosure with a PLC-based sequencing program and Operator Interface color monitor and pushbutton/selector switches and indicating lights shall be provided and tested for starting and stopping blowers automatically, control of the existing bubbler system valves and to facilitate set point control based on the following modes of Operation descried in paragraph 2.23.B. The PLC and OITs shall be compatible with the Shipboards existing system. The PLC shall be Siemens S7 1500 series. Panel shall replace the existing Bubbler MCP.

B. The MCP shall include the following modes of operation:

1. Port Bubbler
   i. In this mode air is discharged through forward, center and aft manifolds on the port side.

2. Starboard Bubbler
    i. In this mode air is discharged through forward, center and aft manifolds on the starboard side.

*Note: For most ice management operations, it is normal to operate both Port and Starboard bubblers at the same time. Both is a selection on the MCP with manual crossover closed

3. Bow Thruster – "Turn to Port"
    i. In this mode air is discharged through the forward and thruster manifolds on the star board side, allowing the full thrust from two compressors to be applied to one quarter.

4. Bow Thruster –"Turn to Starboard"
    i. 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.

5. Local and remote switch

6. Start and stop buttons for both compressors

7. Three position selector switch for selection of compressor operation modes. Port/Both/Starboard

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

C. The MCP shall be provided with programmable electronic Operator Interface that shall have multiple color screens to display operating variables, valve positions, and other relevant data. Operating screens shall have a touch sensitive screen point to select the mode of operation of the bubbler system, and for local or remote mode. The operation shall be programmed to be user friendly by providing sufficient prompting that an operator can intuitively follow through the commands to operate the blower system.

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

D. Indicating lights and pushbuttons shall be provided in addition to the OIT, to allow for operation and monitoring of the system in the event that the OIT is inoperable or Operator prefers not using the OIT. Full monitoring and operation should be available through the use of the selector switches, indicating lights and push buttons

2.25 Bridge Wing Panels

A. Two new bridge wing panels (Starboard Wing Panel and Port Wing Panel) shall be provided to replace the existing wing panels. Panels shall allow for bridge operations of the bubbler system. Indicating lights, selector switches, and pushbuttons shall be provided to allow for this operation.

PART 3: PRESERVATION

3.01 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. All equipment shall be skid mounted or crated to protect against damage during shipment. All parts shall 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.

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

C. 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 to be provided by the Contractor at time of shipping.

3.02 SURFACE PREPARATION AND SHOP PAINTING

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

B. Machined surfaces that are not painted shall be suitably protected.

PART 4: INSTALLATION **(Part 4 to be included with bid but shown separately)**

4.01 START-UP AND TRAINING

A. The Contractor shall provide a fully trained technician with a minimum of 5 years' experience to inspect the final installation and supervise the field start-up tests of the equipment. The services shall be provided for a minimum of four (4), eight-hour (8-hr.) days for each unit.

B. Compressors and Appurtenances – Initial Start-Up

1. Provide, as a minimum, the following field commissioning:
   a. Visually inspect for proper connection of piping and installation of accessories
   b. Field precision align drive motor to the compressor
   c. Check leveling of compressor base
   d. Confirm proper local control panel (LCP), master control panel (MCP), Bridge Control Panel terminations for all field installed instruments and devices.
   e. Run motor uncoupled for one hour to verify motor rotation and operation.

2. A minimum four (4) hour field run test shall demonstrate that, under all conditions of operation, each unit:
   a. Has not been damaged by transportation or installation
   b. Has been properly installed
   c. Has no mechanical defects
   d. Has fully functional controls and instrumentation
   e. Will start, run, and stop in the prescribed manner
   f. Will run through the entire range of specified pressure and flow
   g. Has the proper shutdown sequence of standard stop, soft stop, and emergency stop
   h. Is free of overheating of any parts
   i. Is free of objectionable vibration and unusual noise
   j. Is free of overloading of any parts
   k. Inlet guide vanes are automatically positioned by the control system according to the efficiency optimization algorithm.

C. Contractor shall provide a qualified Certified Field Service Representative (FSR), to be present during two (2) five (5) day sea trials. FSR shall be available to make compressor adjustments and training as required during the sea trial.

1. Sea trial and training shall be provided for both shifts.
2. At least one Sea Trial shall be arranged to occur during ice conditions with FSR. During this Sea Trial, vibration system shall demonstrate that unnecessary vibration trips (nuisance alarms) are not present during ice breaking mode.

D. An FSR, who has complete knowledge of proper operation and maintenance shall be provided for two (2) days, if necessary, to instruct representatives of the Owner and Engineer, from each crew, on proper operation and preventative maintenance, including start-up and shut-down procedures, proper lubrication practices, and troubleshooting.