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USACE / NAVFAC / AFCEC / NASA	**UFGS-22 16 19.26 20 (November 2009)**

Preparing Activity: NAVFAC	**Superseding**
	UFGS-22 16 19.26 20 (April 2006)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

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LARGE CENTRIFUGAL AIR COMPRESSORS (OVER 200 HP)

11/09

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SECTION 22 16 19.26 20

LARGE CENTRIFUGAL AIR COMPRESSORS (OVER 200 HP)
11/09

****

NOTE: This guide specification covers the requirements for large centrifugal air compressors over 150 kW 200 hp and certain accessories.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

****

****

NOTE: Cooling towers, closed-circuit coolers, cooling water piping, and other items are not included and must be included in other sections of the project specification. CENTRIFUGAL COMPRESSORS MUST BE PERMITTED AS AN OPTION IF NONLUBRICATED ROTARY SCREW COMPRESSORS ARE SPECIFIED IN THE PROJECT.

****

****

NOTE: The following information shall be shown on the project drawings:

1. Compressor, accessory equipment, and piping arrangement and details.

2. Equipment foundations.

3. Equipment schedules. If equipment schedules include operating conditions for the compressor, delete the information from this section.
****

PART 1 GENERAL

1.1 REFERENCES

****
NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
****

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

AMERICAN GEAR MANUFACTURERS ASSOCIATION (AGMA)

AGMA 2011	(2014B) Cylindrical Wormgearing Tolerance and Inspection Methods
ANSI/AGMA 2009	(2001B; R 2008) Bevel Gear Classification, Tolerances, and Inspection Methods

AMERICAN PETROLEUM INSTITUTE (API)

API Std 672	(2004; Errata 2007; Errata 2010) Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B1.20.1	(2013; R 2018) Pipe Threads, General Purpose (Inch)
ASME B16.1	(2020) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250
ASME B16.5	(2017) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard

ASME B40.100	(2013) Pressure Gauges and Gauge Attachments
ASME BPVC SEC VIII D1	(2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1
ASME PTC 10	(1997; R 2014) Performance Test Code on Compressors and Exhausters

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel
ASTM B111/B111M	(2018) Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
ASTM B171/B171M	(2012) Standard Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers and Heat Exchangers
ASTM B209	(2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B209M	(2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric)
ASTM C553	(2013; R 2019) Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
ASTM E84	(2020) Standard Test Method for Surface Burning Characteristics of Building Materials

COMPRESSED GAS ASSOCIATION (CGA)

CGA G-7.1	(2011) Commodity Specification for Air; 5th Edition

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 112	(2017) Standard Test Procedure for Polyphase Induction Motors and Generators

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 2151	(2004) Acoustics - Noise Test Code for Compressors and Vacuum Pumps - Engineering Method (Grade 2)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2	(2000; R 2005; Errata 2008) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V

NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures
NEMA MG 1	(2018) Motors and Generators

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-3316	(1987; Rev C; Am 2 1990) Adhesives, Fire-Resistant, Thermal Insulation
MIL-PRF-17331	(2019; Rev L) Lubricating Oil, Steam Turbine and Gear, Moderate Service
MIL-T-19646	(1990; Rev A) Thermometer, Gas Actuated, Remote Reading

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

29 CFR 1910.219	Mechanical Power Transmission Apparatus

1.2 GENERAL REQUIREMENTS

Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS, applies to this section except as specified herein.

1.3 SUBMITTALS

****

NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G". Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force, and NASA projects, or choose the second bracketed item for Army projects.
****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Air compressor system

Include wiring diagrams of the air compressor with all accessories. The minimum acceptable scale is [1:50 1/4 inch to one foot] [_____].

SD-03 Product Data

****
NOTE: Include carbon monoxide monitor in systems which are used for breathing air per DM 3.5, Section 3.
****

Air compressor

Air intake devices

Bypass line silencer

Air flow rate and pressure recorder

[Carbon monoxide monitor]

Submit manufacturer's catalog data for compressor and auxiliary equipment in the format provided in API Std 672, Appendix A. Submit all applicable information. For air compressor, include aftercooler, intercoolers, oil cooler, lubrication system, and control valves. Submit air compressor and intercooler performance curves at specified summer and winter design conditions.

SD-06 Test Reports

Air compressor performance tests

Balance tests

Sound level and run-in tests

Obtain approval prior to shipping compressor.

Air compressor performance tests

Instrumentation test

Sound level tests

Air compressor system tests

The test supervisor shall certify performance by test to be in compliance with specifications.

SD-07 Certificates

Air compressor system

Air compressor system installation

Work plan

Factory test procedures

Factory testing certification

Qualifications of field supervisors

Field test procedures

Training material

SD-10 Operation and Maintenance Data

****

NOTE: Obtain approval of equipment with proprietary maintenance requirements from the appropriate contracts office.

****

Air compressor system, Data Package 3

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

SD-11 Closeout Submittals

Posted operating instructions for air compressor

Submit text.

1.4 QUALITY ASSURANCE

1.4.1 Work Plan

Submit a written schedule of dates of installation, start-up, checkout, and test of equipment.

1.4.2 Factory Testing Certification

Submit a statement that the air compressor factory is equipped to perform all required factory tests. Submit in accordance with paragraph entitled "Manufacturer's Certifications."

1.4.3 Qualifications of Field Supervisors

Submit the name and certified written resume of the engineer or technician, listing education, factory training and installation, start-up, and testing supervision experience for at least two projects involving compressors similar to those in this contract.

1.4.4 Training Material

Submit a detailed training program syllabus for training of government personnel, including instructional materials at least three weeks prior to start of tests.

1.4.5 System Installation

Submit certification of air compressor system performance conforming to ASME PTC 10 and ASME BPVC SEC VIII D1. Submit certification of proper system installation in accordance with paragraph entitled "Supervision."

1.4.6 Air Compressor System

Submit operation and maintenance data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Data shall contain information required for maintenance and repair and shall contain no evidence that proprietary maintenance arrangements with the manufacturer will be necessary. Compressors which will require proprietary maintenance arrangement with the manufacturer require Government review and approval. The compressors may be disapproved if circumstances do not justify approval of compressors with limited availability of maintenance.

1.5 SAFETY

Construct all components of the unit in accordance with the requirements of OSHA 29 CFR 1910.219. Requirements include shaft coupling guards as specified in Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS, thermal insulation and jacketing with manufacturer standard covering or aluminum sheet of all surfaces at 52 degrees C 125 degrees F and higher within a height of 2.10 m 7 feet from floor level, and use of electrical safety devices. Thermal insulation, furnished by equipment manufacturer, shall conform to ASTM C553, Type I (flexible resilient), Class B-5 (up to 204 degrees C 400 degrees F), 32 kg/m3 2 pcf nominal. Cement insulation to surface with MIL-A-3316, Class 2, adhesive and fasten with 16 gage wire bands at maximum 405 mm 16 inches on center spacing. Cover insulation with ASTM B209M ASTM B209 sheet aluminum jacket. The thermal insulation is required for unit with separate intercooler and aftercooler units.

1.6 EQUIPMENT ARRANGEMENT

Arrangement selected shall maintain 0.9 m 3 foot clearance for access passage and 1.20 m 4 foot clearance for personnel to operate equipment. There are substantial physical and connection point differences among the several air compressors which comply with this specification. The Contractor shall be responsible for selecting equipment and submitting arrangement drawings covering required changes for approval by the Contracting Officer. Changes from the equipment arrangement shown on the contract drawings shall be performed by the Contractor at no additional cost to the Government.

1.7 ELECTRICAL REQUIREMENTS

Comply with the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, [and [_____]].

1.8 SUPERVISION

The Contractor shall obtain the services of a qualified engineer or technician from the compressor manufacturer to supervise installation, start-up, and testing of the compressor. After satisfactory installation of the equipment, the engineer or technician shall provide a signed certification that the equipment is installed in accordance with the manufacturer's recommendations.

1.9 DEFINITIONS

Conform to API Std 672 and the following:

Compressor power is shaft power at shaft coupling, including all aerodynamic and mechanical losses.

1.10 INSULATION

Thermal and acoustical insulation shall have flame spread rating not higher than 75, and smoke developed rating not higher than 150 when tested in accordance with ASTM E84.

1.11 POSTED OPERATING INSTRUCTIONS

Provide for air compressor. Include start-up and shutdown sequence instructions.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Materials and equipment complete with accessories shall be selected by the Contractor for performance compatibility.

2.2 AIR COMPRESSOR

The air compressors shall be the packaged, integrally geared, centrifugal type. Include the electric motor driver, integral gears and cases, staged compressors, intercoolers and moisture separators, aftercoolers and moisture separators, instruments, controls, pressure lubrication system with prelubrication pump and shaft-driven lubrication pump, steel base and accessories. The aftercoolers may be mounted separately to meet the performance requirements.

2.2.1 Manufacturer's Certifications

The manufacturer shall certify that the air compressors proposed are of the same design, construction, and frame size, and of equal or not more than 10 percent smaller in capacity as compressors which have been in satisfactory continuous service for at least 2 years at not less than two locations. Furnish the name of the owner, the address of the installation, and the name of a person at the installation who can be contacted for verification. The manufacturer shall also certify that the factory is equipped to perform all required factory tests.

2.2.2 Guaranteed Performance

****
NOTE: Designer should furnish required information to complete the specification.
****

a. Net Compressed Air Output (All seal losses shall be considered internal and not included in the net output) (Minus zero plus 4 percent): [_____] liters per second (L/s) [_____] SCFM

b. Output Pressure Immediately Downstream of Aftercooler (Minus zero plus 4 percent): 862 kPa (gage) 125 psig

c. Output Air Maximum Temperature Downstream of Aftercooler: 38 degrees C 100 degrees F

d. Inlet Air Pressure at First Stage: [_____] kPa (absolute) psig

e. Inlet Air Temperature at First Stage: [_____] degrees C F

f. Inlet Air Filtration Efficiency: 99.9 percent of 0.5 micrometer size

g. Barometric Pressure: [_____] kPa (absolute) psig

h. Relative Humidity: [_____] percent

i. Cooling Water Inlet Temperature: [_____] degrees C F

j. Total Cooling Water Flow Rate: [_____] L/s gpm

k. Maximum Cooling Water Pressure Drop Through the Compressor and Any Intercooler, Aftercooler, or Oil Cooler: [_____] [55 kPa] [8 psi]

l. Maximum Compressor Power Required. (Plus or minus 4 percent): [_____] kW hp

m. Unloaded Compressor Power and Compressor Interconnections: [_____] kW hp

n. Maximum sound levels one meter horizontal from compressor and 1.5 meters 5 feet above floor as measured per ISO 2151 Test Code for the Measurement of Sound from Pneumatic Equipment: 84 dBA, 90 dB for any octave band.

2.2.3 Additional Performance Requirements

2.2.3.1 Air Quality

Air at compressor intake will be considered breathing air quality conforming to CGA G-7.1, Type I, Grade D or better. Air compressors shall introduce no material, gases, or particles, or chemically alter any materials that will adversely affect or reduce the quality of the air passing through the unit.

2.2.3.2 Surge Output Pressure

API Std 672, paragraph 2.1.12.

2.2.3.3 Unloading

The compressor shall be designed to unload prior to surge limit. The surge limit shall not occur at a capacity greater than 70 percent of the guarantee point capacity. Unloaded compressor power shall not exceed 20 percent of full load power.

2.2.3.4 Ambient and Inlet Conditions Operating Ranges

****
NOTE: Designer should furnish required information to complete the specification.
****

Allowing for rational engineering performance adjustments due to variations in ambient and inlet conditions, the compressor shall be designed, equipped, and furnished to be fully operational without abnormal wear throughout the entire range between and including the limits of the winter and summer design conditions specified.

a. Summer Design Conditions:

Inlet Air: [_____] degrees C F dry bulb and [_____] degrees C F wet bulb temperatures, [_____] percent relative humidity

Inlet Cooling Water: [_____] degrees C F

Ambient Compressor Room Temperature: [_____] degrees C F

Barometric Pressure: [_____] kPa (absolute) psig

b. Winter (Low Ambient) Design Conditions:

Inlet Air: [_____] degrees C F dry bulb and [_____] degrees C F wet bulb temperatures, [_____] percent relative humidity

Inlet Cooling Water: [_____] degrees C F

Ambient Compressor Room Temperature: [_____] degrees C F

Barometric Pressure: [_____] kPa (absolute) psig.

2.2.3.5 Critical Speeds

Conform to API Std 672, paragraph entitled "Critical Speed."

2.2.3.6 Vibration and Balance

Conform to API Std 672, paragraphs entitled "Vibration and Balance."

2.2.4 Electrical Service Conditions

2.2.4.1 Air Compressor Drive Motor

[_____] volts, 3 phase, 3 wire, 60 hertz electrical service.

2.2.4.2 Accessory electrical Service

****
NOTE: Change accessory voltages if required for site conditions.
****

See Table I.

TABLE I - COMPRESSOR ACCESSORY ELECTRICAL SERVICE SCHEDULE			
Item	Voltage	Phase	Frequency
Control Power and Motors under 3/8 kW	120	1	60 Hz
Accessory Power	460	3	60 Hz

TABLE I - COMPRESSOR ACCESSORY ELECTRICAL SERVICE SCHEDULE			
Item	Voltage	Phase	Frequency
Control Power and Motors under 1/2 hp	120	1	60 Hz
Accessory Power	460	3	60 Hz

2.2.5 Compressor Controls

Provide complete pneumatic load range control system with each compressor with a manually selectable capability for two modes of load range control as specified. Provide additional electrical, electro-pneumatic, or solid state electronic controls for other specified control and monitor functions. All controls shall conform to NEMA ICS 2 as selected by the compressor manufacturer. Control system enclosure shall conform to NEMA ICS 6. Controls shall be suitable for individual operation of the compressor or parallel operation with one or more other compressors.

2.2.5.1 Two-Step Control Mode

The two-step control mode shall actuate the compressor suction inlet control valve to either a full open position or to a full closed position in accordance with specified, adjustable pressure settings. The pressure settings shall be an adjustable band width plus and minus percentage of an adjustable output gage pressure set point. The compressed air output gage set point shall be adjustable in the range of 724 to 862 kPa 105 to 125 psig, and the gage pressure sensor measurement for this set point shall be made downstream of the aftercooler. The adjustable band width about the set point shall be from plus or minus 2 1/2 percent to plus or minus 5 percent. Controls shall close the compressor inlet valve at the high pressure limit of the band width and simultaneously open a bypass vent valve which shall also be provided. Controls shall open the compressor inlet valve at the low pressure limit of the band width and simultaneously close the bypass vent valve.

2.2.5.2 Dual Control Mode

A pressure regulation control mode shall be furnished to control

compressor output pressure to within plus or minus one percent of an adjustable output pressure set point. Provide an adjustment range of 724 to 862 kPa 105 to 125 psig. When the compressor operates at capacities above surge limit unload setting and below maximum flow stonewall conditions, the control system shall throttle flow at the compressor suction inlet control valve in response to increasing discharge pressure due to decreased demand for compressed air. At lower demand, prior to reaching surge limit at a flow capacity not more than 70 percent of guarantee point capacity, the compressor shall unload by closing the compressor inlet suction control valve and simultaneously opening the bypass vent valve. Use of the bypass vent valve alone to achieve pressure control by a modulation technique of spilling excess air is prohibited. At the low discharge pressure limit, the inlet valve shall open and the bypass vent valve shall close to load the compressor.

2.2.5.3 Unloaded Compressor Start-Up

Each of the two pneumatic control mode systems shall have provision for start-up of the compressor in the unloaded control setting with the compressor inlet valve closed and the bypass valve open.

2.2.5.4 Electrical Start-Up Interlocks

The manual starting circuit of each compressor shall have interlocks to prevent starting until pre-lubrication pump oil pressure and cooling water pump water flow have been established to the required values for safe operation as determined by the compressor manufacturer.

2.2.5.5 Monitor and Safety Controls

Provide supplementary electric, electro-pneumatic, or solid state electronic controls to provide alarm and shut down requirements, plus interlocks with accessories. Requirements are as follows:

a. Shutdown requirements shall cause the controlled compressor to shut down, energize alarms, and light labeled red lights.

b. Alarm only requirements shall not cause the controlled compressor to shut down, but shall sound the same alarms and light labeled amber lights.

c. Light only requirements shall not cause the controlled compressor to shut down, but shall light labeled amber lights.

d. The individual monitor and safety controls shall be as shown on Table 2.

TABLE 2 - MONITOR AND SAFETY CONTROL SCHEDULE

Item	Light and Shutdown	Indicating Alarm	Light Only
1. High Discharge Air Temperature 135 degrees C 275 degrees F	Yes	Yes	-

2. High Intercooler Discharge Water Temperature, Each Intercooler	No	Yes	-
3. High Aftercooler Discharge Water Temperature	No	Yes	-
4. High Cooling Water Supply Temperature	No	Yes	-
5. High Lube Oil Temperature	Yes	Yes	-
6. Low Lube Oil Pressure	Yes	Yes	-
7. Low Cooling Water Flow	No	Yes	-
8. Low Oil Reservoir Level	No	Yes	-
9. High Condensate Level Intercooler (wired to one light)	Yes	Yes	-
10. Vibration Monitors Each Pinion	Yes	Yes	-
11. Surge Limit Approach	Yes	Yes	-
12. High Motor Stator Temperature	Yes	Yes	-
13. High Condensate Level Aftercooler	No	No	Yes
14. High Inlet Pressure Drop Across Inlet Air Filters (combined, 3 stage)	No	Yes	-
15. High CO Level	Yes	Yes	-

2.2.5.6 Monitoring Instruments

Provide the following monitoring instruments in addition to the monitor and safety controls. Pressure gages shall conform to ASME B40.100, 115 mm 4 1/2 inch, red marking pointer, single bourdon tube, brass case, black enamel finish. Provide pressure gages with a pressure snubber and a stainless steel barstock needle isolation valve. Thermometers shall be extended stainless steel sheathed bimetallic stem, 90 mm 3 1/2 inch dial, and separable 100 mm 4 inch stainless steel wells. Temperature measurements at inaccessible locations shall be made with remote reading thermometers conforming to MIL-T-19646, Class C separable well of Type 304 stainless steel. Select pressure and temperature gage ranges to give a normal operating reading near the midpoint of the scale range.

a. Oil cooler outlet temperature gages for oil.

b. Oil cooler inlet and outlet temperature gages for water.

c. Lubrication oil pump discharge pressure gage.

d. Compressor seal air pressure gage, if applicable.

e. Inlet air filter differential pressure gage with 1992, zero, 1992 Pa 8, zero, 8 inch water gage. Provide selector valve, tubing, and tap to measure static gage pressure downstream of each filter stage.

f. Pinion shaft vibration monitor readout with stage selection switch.

g. Total running time readout.

h. Cooling water supply to compressor pressure gage.

i. Cooling water return from compressor pressure gage.

j. Interstage air pressure gages for each interstage.

k. Compressed air pressure downstream of aftercooler pressure gage.

l. Compressed air temperature downstream of aftercooler temperature gage.

m. Interstage air temperature after intercooler of each stage temperature gages.

n. Compressed air temperature at discharge of each stage of compression before cooling temperature gages.

o. Compressor inlet air temperature gage.

p. Cooling water to compressor temperature gage.

q. Cooling water outlet temperature at outlet of each intercooler and aftercooler temperature gages.

2.2.5.7 [Gages on Schematics

****

NOTE: Delete paragraphs if control schematics are not shown on project drawings.

****

Certain pressure and temperature gages are designed on schematic flow diagrams in the drawings. Where a monitor gage satisfies the required location on a schematic, no additional gage needs to be furnished.]

2.2.5.8 [Control Schematics

****

NOTE: Delete paragraphs if control schematics are not shown on project drawings.

****

The drawings show a generalized overall control system for compressor, auxiliaries, remote panel transmitting and receiving, and remote panel. The system is shown using relay symbology. Contractor and equipment suppliers may use standard panel features to accomplish the total requirements using other methods of signal, solid state devices, or revised lamping. All wiring diagrams and required devices shall be approved by the Contracting Officer prior to installation.

]2.2.6 Control Air Supply

****

NOTE: Revise paragraph and make provisions for control air if there is no existing air supply.

Specify quantity of control air and maximum dew point.
****

[Extend existing] [Provide new] control air system of dry and purified air for the compressor controls. Sizing shall be based on not less than [_____] [425 L/s] [15 SCFM]. Filtration shall be to 5 micrometers minimum and the air from the dryer shall have a maximum system pressure dew point [4] [minus 18] degrees C [40] [0] degrees F. [The Contractor shall obtain system air for the controls by piping from the existing system.]

2.2.7 Compressor Design Features

Compressor shall be multistage centrifugal, with a minimum of 2 centrifugal compression stages, designed for optimum flow and speed requirements to produce highest space efficiencies at lowest compression ratio and temperature and lowest external noise level. Special attention shall be given to energy saving features in design and arrangement such as radial damper intake valve, long radius interstage piping, and low air velocities. Equipment shall be designed for economical and rapid maintenance. Casing components bearing housings and other major parts shall be shouldered, dowelled, or designed with other provisions to facilitate accurate alignment or reassembly. Shaft seals and bearings shall be accessible for inspection or replacement with a minimum of disassembly.

2.2.7.1 Casings

Casing shall be cast iron, ductile iron, or cast steel. Casing stresses shall be within the limits allowed by ASME BPVC SEC VIII D1. Casings, supports, and baseplates shall be designed and fabricated to preclude excessive and injurious distortion from temperatures, pressures, and forces encountered in service conditions, including surge. Provide jackscrews, lifting lugs, eyebolts, guide dowels, and casing alignment dowels to facilitate disassembly and reassembly. When using jackscrews for parting contacting faces, relieve one of the faces by counterboring or recessing to prevent marring the face, which result in leaking or improper fit. Provide lifting lugs or eyebolts for removable portions of the casings. Flanged casing connections shall conform to ASME B16.1 or ASME B16.5. Threaded connections shall conform to ASME B1.20.1. Casing shall be split in a manner permitting direct access to impellers, shafts, and bearings. Compressors shall be axial flow inlet. Gear cases shall be enclosed, accessible, force lubricated and designed with seals and slingers to keep oil out of air system.

2.2.7.2 Shafts

Shafts shall be of forged or rolled alloy steel and shall have a machined finish throughout their entire length. All rotating components shall be positively secured to shafts by approved mechanical means or interference shrink fits.

2.2.7.3 Impellers

Impellers shall be of 400 series or 17-4 PH stainless steel, open or closed design, with backward leaning vanes, and of welded, milled, or cast construction.

2.2.7.4 Gears

Gears shall be of alloy steel, ANSI/AGMA 2009 and AGMA 2011 Quality Number 12 or better for both bull and pinion gears. Gears shall be hardened to 275 Brinell for bull gear and 320 Brinell for pinion, unless otherwise approved. Gears shall be ground to the required contours, checked for proper contact during assembly at the factory, and shall not require a break-in period in the field for proper operation. All gears shall be pressure lubricated.

2.2.7.5 Seals

Separate air and oil shaft seals shall be provided to confine air in the casing and prevent contamination of the air stream by lubricating oil. Shafts seals shall be labyrinth type, carbon ring type, or a combination of the two types. Provide an air space vented to the atmosphere between the air and oil seals. Seals shall be suitable for all operating conditions including suction throttling, start-up, shutdown, and momentary surge.

2.2.7.6 Thrust Bearings

Axial impeller thrusts shall be absorbed by thrust bearings on the pinion or transferred to the bull gear shaft by conical rider-ring thrust collars. Pinion thrust bearings shall be hydrodynamic (fluid film), multiple-segment type, entitled pad type, or other approved type, and shall be adequate to accommodate all operating conditions, including surging or stonewall operation. Bull gear thrust bearings shall be sized for equal thrust in both directions and shall be adequate for any axial loads transmitted through the driver coupling.

2.2.7.7 Radial Bearings

Radial bearings shall be hydrodynamic (fluid film), precision bored sleeve or pad type, designed for easy replacement by a split design or axially removable arrangement. High speed pinion bearings shall be anti-oil whip, tilting pad, tilted pad, or other approved type. Bearing design shall provide low vibration and sufficient damping at rated speed and all operating modes, including rated capacity and unloading down to 15 to 20 percent of unloaded power.

2.2.7.8 Intercooler, Aftercoolers, and Oil Coolers

Intercoolers, aftercooler, and oil cooler shall include admiralty brass [or copper] tubes conforming to ASTM B111/B111M in admiralty tube sheets conforming toASTM B171/B171M with plate fins and baffles for optimum cooling and fouling resistance using [fresh] [_____] water. Provide an intercooler between stages of compression factory assembled on unit base with piping. The aftercooler may be mounted separately. Intercoolers, aftercooler, and oil cooler shall be factory tested at 1.5 times operating pressure. External intercoolers and aftercooler shall be constructed in accordance with ASME BPVC SEC VIII D1, requirements and be ASME code stamped for 1207 kPa (gage) 175 psig working pressure. Intercoolers and aftercooler shall be capable of one piece bundle removal. Each intercooler shall be equipped with an integral or direct connected moisture separator with condensate trap or automatic drainer valve assembly. Piping to drainer and drainer assemble shall be Class 300 stainless steel. Design intercoolers and aftercooler for 11 and 8 degrees C 20 and 15 degrees F approach, respectively, and a fouling factor of

0.001 for both sides of exchanger; however, the approach temperature used to size the coolers shall be reduced if required to meet aftercooler maximum air outlet temperature specified. Nonstandard coolers shall be provided if required to meet the aftercooler maximum air outlet temperature requirement. All coolers shall be of counter-flow design.

2.2.7.9 Lubrication System

Include reservoir, shaft driven positive displacement pump, twin oil coolers, twin filter/strainer (readily replaceable cartridges while operating) and parallel piping and valving provisions to accommodate a separately driven prelube lubrication oil pump for start-up and standby. System shall be factory assembled and tested. The oil reservoir shall retain a minimum 3-minute oil supply. Lubricating oil shall conform to MIL-PRF-17331, Lubricant No. 2190-TEP or as recommended by compressor manufacturer. Oil cooler shall be designed for a fouling factor of 0.001 for both sides of exchanger. Pressure lubricate hydrodynamic bearings. Provide the oil sump with level indicator and drain and fill connections.

a. Prelubrication pump shall be sized by air compressor manufacturer for the requirements of the system, but shall meet the following requirements. Pump shall be positive displacement gear pump separately mounted with motor on a common base plate with drip lip and drain.

   (1) Performance: Pump shall have separate safety valve bypass set at [_____] [172 kPa] [25 psi] above peak expected pressure.

   (2) Materials shall be hardened steel gears and shaft, cast iron case, bronze bearings, mechanical seal.

   (3) Flexible coupling with shaft guard shall be provided, except that these items are not required for a close-coupled pump.

   (4) Motor shall be NEMA MG 1, Design A, Class B insulation, of open drip-proof type. Furnish combination type starter for motor.

b. Lube Oil Heater: Provide thermostatically controlled electric heater in lubrication oil sump of sufficient capacity to heat up and maintain manufacturer's recommended oil temperature when unit is cold at [_____] [0 degrees C] [32 degrees F] ambient. Provide low oil level indicator with light for protection of heater.

2.2.8 Electric Motors

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NOTE: Polyphase motors shall be selected based on requirements of the driven equipment, service conditions, motor power factor, life cycle cost, and high efficiency in accordance with NEMA MG 10.

Use Motor Master software program to identify the most efficient and cost effective polyphase motor for a specific application. Motor Master is located in the "TOOLS" section of Construction Criteria Base (CCB). For additional guidance contact Charlie Mandeville of the NAVFAC Criteria Office at (757) 322-4208. Another source of information on energy efficiency is E-source, accessible to Navy users on

the Naval Facilities Engineering Center (NFESC) home page http://energy.navy.mil/**.**

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Efficiency and losses shall be determined in accordance with IEEE 112. Unless otherwise specified horizontal polyphase squirrel cage motors rated one to 125 horsepower shall be tested by dynamometer Method B as described in Section 6.4 of IEEE 112. Motor efficiency shall be calculated using Form B of IEEE 112 calculation procedure.

Polyphase motors larger that 125 horsepower shall be tested in accordance with IEEE 112 with stray load loss determined by direct measurement or indirect measurement (test loss minus conventional loss).

The efficiency shall be identified on the motor nameplate by the caption NEMA Nominal efficiency or NEMA Nom eff.

2.2.8.1 Main Electric Drive Motor

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NOTE: Centrifugal compressors are normally provided with 3600 rpm induction motors. The specification will be considered restrictive by manufacturers if an 1800 rpm synchronous motor is specified because a special speed increasing gearbox will make them noncompetitive with nonlubricated rotary compressors.

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The main drive motor for each compressor shall be an induction motor, [_____] kW horsepower, with a continuous service factor of 1.0. Size the motor so that the nameplate kW horsepower rating is not exceeded under the entire range of operating conditions specified. Motor shall be high efficiency type, rated not less than 95 percent based on IEEE 112 testing and labeling. Electrical service will be as specified. Motor shall be designed for reduced voltage starting [at [50] [65] [80] percent of full voltage], allowing for characteristics of the connected load, and shall start without undervoltage tripping. Provide resistance temperature detectors (RTD) attached to or imbedded in motor winding for control system. The motor shall meet the requirements of NEMA MG 1 with Class F insulation. Motor design shall include acoustical covering and reduced noise air intake housing and be rated for 84 dBA or less at 0.9 m 3 feet under full load. Provide space heaters for protection of windings during motor shutdowns.

2.2.8.2 Accessory and Related Equipment Motors

Motors less than 3/8 kW 1/2 horsepower shall be single-phase induction motors and shall conform to NEMA MG 1. Motors 3/8 through 3.75 kW 1/2 through 5 horsepower shall be three-phase induction motors and shall conform to NEMA MG 1. Single-phase and three-phase motors shall have bimetallic disk thermostats attached to or imbedded in the motor winding. Motors shall have NEMA MG 1 Class B insulation.

2.2.9 Control Panel

Control unit panel conforming to NEMA ICS 6, package or frame mounted, factory designed, assembled, and mounted shall be provided complete with connections made to sensing points. The panel shall be fabricated of

formed stretcher leveled sheet steel, reinforced, and assembled into a rigid unit. Gasketed access doors shall be provided as required. Panel shall be factory finish painted. The panel shall meet NEMA 12 requirements.

a. Panel shall contain electric and safety control work required, including either alarm annunciator or individual labeled pilot lights arranged in a group. Panel shall contain alarm device with light and silencing. Generalized arrangement in accordance with drawings.

b. Panel shall contain start and stop buttons (the latter with lockout feature), vibration monitor subpanel, discharge air pressure gage, control test switch and lights, reset button, green unit running light, and control selector switch.

c. Oil pressure gages shall be mounted separately from panel.

2.2.10 Accessories

Required accessories include:

2.2.10.1 Control Valves

Pneumatically controlled valves on suction inlet of compressor and on blowoff bypass line. Mount suction inlet control valve on unit.

2.2.10.2 Air Intake Devices

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NOTE: Change compressor air inlet description to suit project if required.
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Compressor air inlet shall be piped to the outside of the building and consist of the following:

a. Intake weather hood with rain hood and bird screen. Material shall be galvanized steel or aluminum alloy, minimum 20 gage.

b. Intake pipe, ASTM A36/A36M steel galvanized, 12 gage or Schedule 5 minimum, from intake weather hood to filter housing flange, welded construction.

c. Filter housing by filter manufacturer to include filter frames, access door(s). Material for housing shall be 1.65 mm 0.065 inch thickness, Class 5000 aluminum alloy. Unit shall be rigid and free from distress with all seams sealed.

d. Intake Pipe from Filter Enclosure to Compressor: Aluminum alloy ASTM B209M ASTM B209, Alclad alloy 5052-H32 or equivalent, minimum 10 gage, flanged, welded with 5XXX welding rod using TIG method and including expansion bellows.

2.2.10.3 Compressor Air Outlet Connections

Compressor air outlet flexible connection of stainless steel bellows with braided steel cover jacket, with stainless steel liner sleeve, 460 mm 18 inch nominal length bellows, flanged ends, Class 150. If air bypass connects separately to the compressor from the outlet line, provide a

second flexible connection of stainless steel bellows with braided jacket for the bypass.

2.2.11 Inlet Air Filters

Provide a three-stage filter system, complete with mounting racks (horizontal flow), interstage seals, and replaceable filters. Filter unit shall be provided complete including enclosure or housing, and frames. Enclosure shall be Class 5000 aluminum alloy with inlet and outlet flanges. Construction shall be welded or, where welding is not practical, close riveted and caulked, weathertight, with access doors for filter replacement and cleaning. Access doors shall be reinforced, fully gasketed with continuous flexible neoprene gaskets, corrosion-resistant continuous hinges and quarter-turn latches to ensure tightness. All internal ferrous surfaces, including galvanized, shall receive a factory-applied epoxy prime and finish coat for corrosion resistance. Filters shall consist of three separate stages and sized to fit the available space.

2.2.11.1 First-Stage

First-stage filter shall be flat, 50 mm 2 inch thickness, replaceable media, and rated for the required air quantity at 2.54 m/s 500 FPM nominal face velocity, friction clean 62 Pa 0.25 inch water gage, efficiency 98 percent of 15 micrometers 0.60 microinches and 90 percent of 5 micrometers 0.20 microinches.

2.2.11.2 Second-Stage

Second-stage filter shall be deep pleated type, 229 mm 9 inchesnominal depth and rated for the required air quantity at 1.78 m/s 350 FPM nominal face velocity, friction clean 50 Pa 0.20 inch watergage, efficiency 98 percent to 5 micrometers 0.20 microinches and 90 percent to 3 micrometers 0.12 microinches.

2.2.11.3 Third-Stage

Third-stage filter shall be deep pleated type 305 mm 12 inchesminimum depth and rated for the required air quantity at 1.78 m/s 350 FPM nominal face velocity, friction clean 75 Pa 0.30 inch watergage, efficiency 99.9 percent to 0.5 micrometer 0.02 microinches.

2.2.11.4 Filter Media

Filter media shall be rated and listed UL Class 2. Filter efficiencies shall be based on National Bureau of Stands (NBS) type discoloration gravimetric test method using atmospheric dust.

2.2.12 Bypass Line Silencer

Provide a bypass line silencer with each compressor as selected by compressor manufacturer for sufficient noise attenuation to meet sound level criteria not greater than 84 dBA measured at an elevation of 1.50 meters 5 feet, and 3 meters 10 feet horizontally from silencer.

2.2.13 Isolating Pad

If specifically recommended by the compressor manufacturer, each compressor steel frame shall be mounted on a neoprene waffle or rib type

isolator pad which extends uniformly and continuously along the base mounting surface. The neoprene material shall be of bridge bearing pad quality neoprene and shall be formulated for 40 durometer hardness. The maximum bearing pressure on the isolating pad shall be 345 kPa 50 psi. The pads shall be composed of two layers or 8 mm 5/16 inch neoprene bonded to and sandwiching 16 gage galvanized steel. Compressor bolt down through the pad shall be accomplished using 6 mm 1/4 inch thick neoprene impregnated duck washers. Neoprene bushings are not acceptable.

2.3 AIR FLOW RATE AND PRESSURE RECORDER AND MEASUREMENT

Provide a complete flow and pressure measurement and recording package. Provide orifice flanges with pressure taps, square edged stainless steel paddle orifice plate. The orifice plate shall be concentric type, of 3 mm 0.125 inch thickness and shall meet ASME Standards. Orifice shall be sized for 10 kPa 40 inch water column differential at a full scale flow rate of [_____] L/s SCFM at compressor based on 827 kPa (gage) 120 psig upstream pressure. Static gage pressure measurement device of the recorder shall have a range of zero to 1379 kPa (gage) 200 psig. Provide copper interconnecting tubing between the pressure taps and the recorder as part of this measurement and recording package. Provide a two-pen recorder for the measurement station. Pens shall record pressure (0 to 1379 kPa (gage) 200 psig range) and air flow (0 to [_____] L/s SCFM). Recorder shall be electric drive and housed in dust-tight steel cabinet. Charts shall be 305 mm 12 inch diameter with evenly divided graduations. Drive shall be 7 day circle. Provide continuous flow integration of a 7 digit counter type. Pens shall be supplied with long-life cartridges and capillary supply. Chart case shall be internally illuminated. Access to charts shall be through front access window door. Calibrated overall accuracy of the recorded measurements shall be within plus or minus 1.0 percent of full scale. Furnish a supply of 400 charts with the recorder.

2.4 CARBON MONOXIDE MONITOR

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NOTE: Include carbon monoxide monitor in systems which are used for breathing air per DM 3.5, Section 3.

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The carbon monoxide (CO) monitor unit shall be of the pressure type with attached sampling system. The unit shall be solid state type operation, 2 to 50 ppm range, CO indicating, with provisions for milliamp signal to remote recorder, adjustable set point, and normally open/normally closed contacts for remote signal. Power shall be 120 volt, single phase, 60 hertz with power cord and plug. Response time normally 2 minutes per sample/purge. Unit shall be mounted in a gasketed enclosure with face gage indication CO readings.

2.4.1 Sampling System

Sampling system shall include shutoff valve filter/regulator, pressure gage, manual drainer, and line humidifier set at 50 percent. Draw sample from compressor discharge.

2.4.2 Test System

Test system shall include calibration gas (20 ppm CO) cylinder test gas (200 ppm CO) cylinder, and calibration connectors with quick disconnect.

2.5 SOURCE QUALITY CONTROL

2.5.1 Factory Test Procedures

The completely assembled air compressor package, including the actual contract drive motor, intercoolers, lubrication system, and control panel shall be subjected to performance tests, balance tests, and sound level and run-in tests. Unit shall comply with guarantee requirements applying engineering adjustments to guarantee conditions. Test shall be certified by the manufacturer. Test shall be run on the manufacturer's test stand using driver for this contract. Tests shall be in accordance with ASME PTC 10 format. Full-range performance tests shall indicate performance at maximum rated flow, rating point, and blowoff conditions. All accessory performance conditions shall be reported, including intercoolers, aftercoolers, and lubrication and control systems. The complete unit shall be factory tested with sound meters in accordance with ISO 2151. Location shall be one horizontal meter from unit at 1.5 meters above the floor. Test shall include readings at each octave band midpoint and the "A" scale, and shall be 84 dBA or less and 90 decibels at any octave band. Results of test shall be included in the factory test report on the ISO 2151 format. Factory test data may be corrected to the levels of an equivalent background noise level of 60 dBA showing calculations for reference use.

2.5.2 Supervision of Testing

System and components testing shall be conducted or supervised by either a designated authorized and factory trained representative of the compressor manufacturer supplying the unit or a registered Mechanical Engineer experienced in such work.

2.5.3 System Test

Testing of system shall conform to requirements outlined and shall be witnessed by the Contracting Officer.

2.5.4 Approval of Testing Procedure

Proposed testing procedure shall be approved by the Contracting Officer and the individual in charge of testing prior to conducting tests.

2.5.5 Certification of Performance Tests

The test supervisor shall certify performance by test to be in compliance with specifications.

PART 3 EXECUTION

3.1 INSTALLATION

The Contractor shall install the air compressors and accessories in accordance with manufacturer's recommendations and as indicated on the drawings. All equipment shall be installed plumb and level and anchored to structure, matching holes provided.

3.1.1 Manufacturer's Supervision

Install the compressors under the direct supervision of an authorized

representative of the manufacturer.

3.2 GENERAL REQUIREMENTS FOR INSTALLING AIR COMPRESSORS

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NOTE: Delete or modify requirements on existing building and weight handling equipment to suit the project.

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Air compressors with contract motor and accessories shall be factory assembled, run in, and tested complete before shipment to job site. [The Contractor is advised that there are limitations to door opening sizes and available crane lifting capacity. Crane unit is specified to permit single lifts of complete compressor under special approval only.] Should the unit require disassembly for installation, reassembly shall be under the direct supervision of the compressor manufacturer's authorized representative. Complete unit shall be mounted on a rigid single or equivalent mechanically joined steel or iron base. Submit installation sequence plans to the Contracting Officer for approval prior to installation. [Any building materials removed to accomplish installation shall be reinstalled if undamaged by removal procedures; or if damaged, shall be replaced with new materials to match original configuration.]

3.2.1 Prompt Installation

The Contractor is advised that any compressor received shall be installed and placed in operation promptly to prevent time deterioration when not installed. Should the Contractor sustain a delay exceeding 90 days prior to actual installation, the Contracting Officer shall have the option of requiring breakdown and reassembly to inspect and clean prior to placing in operation. This work shall be at no additional cost to the Government.

3.2.2 Start-Up Services

The Contractor shall furnish the services of a compressor manufacturer's authorized representative to supervise prestart checkout, initial start-up, performance testing, and operator instruction. Time available shall be as required to properly start up but not less than 3 consecutive days for the compressor.

3.3 FIELD QUALITY CONTROL

3.3.1 Field Test Procedures

Complete field performance testing of the total system shall be performed by the Contractor and witnessed by the Contracting Officer. Air compressor system tests shall be conducted by either a compressor manufacturer's factory trained and authorized representative approved by the Contracting Officer or a qualified registered Mechanical Engineer. Tests may be run on individual components or on the system as a whole at Contractor option. Field tests require use of the actual compressor drive motor. Test shall include operation at rated capacity for not less than 4 hours.

3.3.1.1 Air Compressor Performance Tests

Complete performance test shall be run at maximum load, rated load, at point of unload but prior to unload, and unloaded condition. Data shall

be recorded listing:

a. Air flow, inlet pressure and temperature, humidity; discharge pressure and temperature.

b. Intercooler water flows, temperatures, and pressures.

c. Aftercooler water flow, temperatures, and pressures.

d. Lube oil cooling water flow, temperatures, and pressures.

e. Lube oil flow, pressures, and temperature.

f. Cooling water pump flow, pressures, and motor amperage.

g. [Cooling tower] [Closed circuit cooler] air flow, water and air temperatures, water pressure, and motor amperage.

h. Electrical load in volts and amperes for compressor motor, prelube oil pump motor, and compressor auxiliaries.

i. Intake filter pressure differential (clean).

j. Start-up sequence, alarm signals and automatic system shutdown.

k. Control sequence, either modulating or two step [in phase with the other air compressors and existing plant air].

l. Test compressor intake and discharge for conformance to CGA G-7.1. Compressor discharge shall show no increase in contaminants.

3.3.1.2 Instrumentation Test

The Contractor may use instrumentation provided in the contract and instrumentation provided by the Contractor to conduct the test. The testing procedure and instrumentation shall be submitted to the Contracting Officer for approval prior to conducting tests. The format of ASME PTC 10 is required. It is intended that a full field test be performed.However, in lieu of precise instrumentation, the Contractor may use certified cooling water pump curves [and [cooling tower] [closed circuit cooler] fan curves]. Shutdown signals shall be caused by throttling selected fluids. Test data, such as air intake temperature and humidity, shall be mathematically corrected to performance test requirement levels.

3.3.1.3 Sound Level Tests

Sound level tests shall be conducted concurrently. Broad Band "A" scale readings and Octave Band readings shall be taken and recorded at the same positions as on the factory testing. Maximum permissible level shall be 84 decibels one horizontal meter from the compressor and 1.5 meters above the floor, with unit in operation and all other significant equipment not required for test within the same building bay shutdown at the same location previously described. A background noise correction to 60 decibels is permissible.

3.3.1.4 Deficiencies Discovered in Testing

Any operational deficiencies noted in the tests shall be promptly

corrected and affected portions of the test rerun.

3.3.1.5 Testing Tolerances

A tolerance of plus 2 percent minus zero on flow, plus or minus 4 percent on power, or plus or minus 5 percent on any other variable for each item of equipment or fluid with all others conforming is permissible on field test results when compared to factory test data and to guarantee performance data except that compressor air flow, discharge pressure, and motor power shall be met.

3.3.2 Approval of Testing Procedure

Proposed testing procedure shall be approved by the Contracting Officer and the individual in charge of testing prior to conducting tests.

3.4 TRAINING OF GOVERNMENT PERSONNEL

During start-up and field testing, train Government station personnel in the operation and maintenance of compressor, [cooling tower,] [closed circuit cooler,] associated equipment, and all control and safety devices. Training shall not commence until equipment is operational and station personnel are in attendance. At least one day of classroom training and one day of field training shall be furnished for each designated Government personnel. When factory training is required by the compressor manufacturer for proper maintenance and overhaul of the compressors, such training shall be furnished by the compressor manufacturer at no additional cost to the Government. The Government will bear the cost of travel and living expenses for Government personnel as necessary for the factory training.

-- End of Section --