UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2024
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DIVISION 22 - PLUMBING

SECTION 22 15 19.19 20

NONLUBRICATED ROTARY SCREW AIR COMPRESSORS (100 HP AND LARGER)

05/11

-- End of Section Table of Contents --

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USACE / NAVFAC / AFCEC | **UFGS-22 15 19.19 20 (May 2011)**

Preparing Activity: NAVFAC | **Superseding UFGS-22 15 19.19 20 (November 2009)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

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SECTION 22 15 19.19 20

NONLUBRICATED ROTARY SCREW AIR COMPRESSORS (100 HP AND LARGER)
05/11

****
NOTE: This guide specification covers the requirements for large nonlubricated rotary screw air compressors 75 kW 100 hp and larger.

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).
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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. Nonlubricated rotary screw compressors should be checked for compliance with the 50 percent or more domestic components requirement Buy American Act when submitted by Contractors for installation on construction contracts since they incorporate major parts not made in the U.S.A. For supply contracts, a memorandum of understanding may fulfill requirement of the Buy American Act. CENTRIFUGAL COMPRESSORS MUST BE PERMITTED AS AN OPTION IF NONLUBRICATED ROTARY SCREW COMPRESSORS ARE SPECIFIED IN THE PROJECT, using Section 22 16 19.26 20 LARGE CENTRIFUGAL AIR COMPRESSORS (OVER 200 HP).

****

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 BEARING MANUFACTURERS ASSOCIATION (ABMA)

ABMA 9	(2015) Load Ratings and Fatigue Life for Ball Bearings
ABMA 11	(2014) Load Ratings and Fatigue Life for Roller Bearings

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 619	(2010) Rotary-Type Positive Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries

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	(2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B40.100	(2022) Pressure Gauges and Gauge Attachments
ASME BPVC SEC VIII D1	(2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1
ASME PTC 9	(1970; R 1997) Displacement Compressors, Vacuum Pumps and Blowers (for historical reference only)

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	(2023) 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 2020) 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	(2021) Motors and Generators

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-3316	(1987; Rev C; Am 2 1990) Adhesives, Fire-Resistant, Thermal Insulation
MIL-T-19646	(1990; Rev A; Notice 1 2021) 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 and Air Force 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 and Air Force 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

SD-03 Product Data

****

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

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Air Compressor

Inlet Air Filters

Line Silencer

Air Flow Rate and Pressure Recorder

[Carbon Monoxide Monitor

] Filter Housing

Submit manufacturer's catalog data for compressor and auxiliary equipment in the format provided in API Std 619, Appendix A. For air compressors, include intercoolers, oil cooler, lubrication system, and control valves. Submit air compressor, intercooler, aftercooler, and bypass cooler performance curves at specified summer and winter design conditions. For electric motors include overall physical features dimensions, ratings, service requirements, efficiency, and weight of equipment.

SD-06 Test Reports

Air compressor performance tests

Sound Level Tests

Obtain approval prior to shipping compressor.

Government must have the option to observe test procedures and vendor will provide two (2) copies of test results and two (2) copies of maintenance manuals.

Air Compressor Performance Tests

Instrumentation Test

Sound Level and Run-in Tests

Air Compressor System Test

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

SD-07 Certificates

Work Plan

Factory Test Procedures

Factory Testing Certification

Qualifications of Field Supervisors

Field Test Procedures

Training Material

Air Compressor System

Air Compressor System Installation

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. Data must contain information required for maintenance and repair and must 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.

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 government personnel, including instructional materials at least three weeks prior to start of tests.

1.4.5 System Installation

Submit certification of performance conforming to ASME PTC 9 and ASME BPVC SEC VIII D1. Submit certification of proper installation in accordance with paragraph entitled "Supervision."

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 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 meter 7 feet from floor level, and use of electrical safety devices. Thermal insulation, furnished by equipment manufacturer, must 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. However, insulation is not required for hot piping inside sound enclosure.

1.6 EQUIPMENT ARRANGEMENT

Arrangement selected must maintain 0.9 meters 3 foot clearance for access passage and 1.20 meters 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 must 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 must be performed by the Contractor at no additional cost to the Government.

1.6.1 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] [_____].

1.7 ELECTRICAL REQUIREMENTS

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

1.8 SUPERVISION

The Contractor must 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 must provide a signed certification that the equipment is installed in accordance with the manufacturer's recommendations.

1.9 DEFINITIONS

Conform to API Std 619 and the following:

Compressor power is shaft power at shaft coupling, including all losses and connected appurtenances.

1.10 INSULATION

Thermal and acoustical insulation must 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 must be selected by the Contractor for performance compatibility.

2.2 AIR COMPRESSOR

****

NOTE: The use of restrictive requirements for the nonlubricated rotary screw air compressor specified in this guide specification has been approved by NAVFACENGCOM HQ (Code 021) in accordance with the requirements of the Naval Facilities Acquisition Supplement (NFAS). NFAS can be found at the following link:
https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_forbusinesses_pp/smallbusiness/contracting/navfac
The paragraphs in this guide specification may be

used without any further NAVFACENGCOM HQ approval or request for waiver.

****

The air compressors must be packaged, positive displacement rotary screw compressors capable of delivering oil-free air. No lubricant must be used within the compression chamber. Include air compressor, electric motor driver, coolers, lubrication system, and regulation and control systems mounted on a common base frame, and completely enclosed for noise control.

2.2.1 Manufacturer's Certifications

The manufacturer must certify that the air compressors proposed are of the same design, construction, 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 must 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 must be considered internal and not included in the net output) (plus or minus 2 percent): [_____] standard liter 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 micron 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 (gage)] [8 psig]

l. Maximum compressor power required. (Plus or minus 4 percent): [_____] kW hp

m. Unloaded compressor power (maximum): [_____] kW hp

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

2.2.3.3 Critical Speeds

Actual critical speeds must not encroach upon operating speed ranges at specified loads ranges. Rotors must be of a stiff shaft construction with the first actual rotor bending critical speed at least 120 percent of the maximum operating speed.

2.2.3.4 Vibration and Balance

Major parts of rotating elements, such as rotors, gears, and similar items must be individually dynamically balanced. During the factory and site tests of the assembled machine at operating speed, the double amplitude of vibration in any plane measured on the shaft adjacent and relative to a radial bearing must not exceed the limits of API Std 619, paragraph 2.7.2.5. For shafts which are not accessible, the manufacturer must

submit a testing procedure to the Contracting Officer for approval.

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

2.2.5.1 Compressor Start-Up

The compressor must start unloaded. The manual starting circuit for the compressor must have interlocks to prevent the compressor drive motor from starting until pre-lubrication pump (if provided), oil pressure, and cooling water pump water flow have been established to the required values for safe operation as determined by the compressor manufacturer.

2.2.5.2 Load Regulation

The compressor must operate continuously at constant speed after being started. Provide means to load and unload the compressor automatically at

preset minimum and maximum pressure settings. Minimum pressure must be 689 kPa (gage) 100 psig, and maximum pressure must be 862 kPa (gage) 125 psig. Unloading must be accomplished by a combination of closing the inlet valve and bypassing or venting the outlet of the compressor; however, input power at fully unloaded operation must not exceed 20 percent of full load input. Bypassed air must be cooled by the bypass cooler and if returned to the inlet of the first stage through an internal loop and must be limited to the minimum flow required to maintain compressor cooling. Air vented to the atmosphere when unloading need not be cooled.

2.2.5.3 Monitor and Safety Controls

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

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

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

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

d. The individual monitor and safety controls must 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)	No	No	Yes
10. High Bleed-Off Air Pressure	Yes	Yes	-
11. High Motor Stator Temperature	Yes	Yes	-
12. High Condensate Level Aftercooler	No	No	Yes
13. High Inlet Pressure Drop Across Inlet Air Filters (combined, 3 stage)	No	Yes	-
14. High CO Level	Yes	Yes	-

2.2.5.4 Monitoring Instruments

Provide the following monitoring instruments in addition to the monitor and safety controls. Pressure gages must conform to ASME B40.100, 114 mm 4 1/2 inch diameter, 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 must be extended stainless steel sheathed bimetallic stem, 90 mm 3 1/2 inch dial, and separable 100 mm 4 inchstainless steel wells. Temperature measurements at inaccessible locations must 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 temperature gages for water.

c. Lubrication oil bearing supply 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. Total running time readout.

g. Cooling water supply to compressor pressure gage.

h. Cooling water return from compressor pressure gage.

i. Interstage air pressure gages for each interstage.

j. Compressed air pressure downstream of aftercooler pressure gage.

k. Compressed air temperature downstream of aftercooler temperature gage.

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

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

n. Compressor inlet air temperature gage.

o. Cooling water to compressor temperature gage.

p. Cooling water outlet temperature at each outlet of each intercooler, aftercooler, and bypass air cooler temperature gages.

[2.2.5.5 Gages on Schematics

****
NOTE: Delete paragraph 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.

][2.2.5.6 Control Schematics

****
NOTE: Delete paragraph 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 must be approved by the Contracting Officer prior to installation.

]2.2.6 Compressor Design Features

The compressor must be a multistage, oil-free rotary screw compressor, with a minimum of two compressor stages, flanged to an integral speed increaser. Each stage must be driven from a common bull gear to ensure optimum speed and efficiency. An intercooler must be provided between stages and aftercooler must be provided after the final stage of compression. Silencers, lubricating system, cooling system, control system, and driver must be mounted as part of the package. Provide a common base frame for the compressor system and driver. Provide a sound enclosure over the compressor and driver. Equipment must be designed for economical and rapid maintenance. Casing components, bearing housings, and other major parts must be shouldered, dowelled, or designed with other provisions to facilitate accurate alignment or reassembly. Shaft seals and bearings must be accessible for inspection or replacement with a minimum of disassembly; however, compressors with compression elements (air end) provided as a factory-assembled not repairable in the field may be approved by the Contracting Officer if determined to be in the interest of the Government.

2.2.6.1 Casings

Casings must be cast iron, ductile iron, cast steel, or fabricated steel. Casing stresses must be within the limits allowed by ASME BPVC SEC VIII D1. Casings, supports, and baseplates must be designed and fabricated to

preclude excessive and injurious distortion from temperatures, pressures, and forces encountered in service conditions. 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 for external piping must conform to ASME B16.1 or ASME B16.5. Threaded connections for external piping must conform to ASME B1.20.1. Air compression portion of the casing must be one-piece and must be provided with integral coolant passages and a large inlet port. Gear cases must be enclosed, accessible, force lubricated, and designed with seals and slingers to keep oil out of air system.

2.2.6.2 Shafts

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

2.2.6.3 Rotors

Rotors must be steel, and of one-piece construction, with an asymmetric profile to minimize leakage losses, and ensure high efficiency. Rotors must be treated for corrosion resistance. It rotors are welded to the shaft, the assembly must be stress relieved and heat treated for proper strength. Rotors must be dynamically balanced to ensure vibration-free operation.

2.2.6.4 Gears

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

Timing gears must be provided on the rotor shafts to maintain the rotors in correct relative position. The compressor design must allow the timing gears to absorb no more than 10 percent of the total input power at full load.

2.2.6.5 Seals

Separate air and oil shaft seals must be provided to confine air in the casing and prevent contamination of the air stream by lubricating oil. Shaft seals must be the restrictive ring type. The seal rings must be stainless steel, brass, or carbon, and retainers must be made of stainless steel. Provide an air space vented to the atmosphere between the air and oil seals. Seals must be suitable for all operating conditions including suction throttling, start-up, and shutdown.

2.2.6.6 Thrust Bearings

Thrust bearings must be anti-friction ball or roller type or hydrodynamic (fluid film) type. Anti-friction bearings must have an L-10 life of

80,000 hours in accordance with ABMA 9 or ABMA 11. Axial rotor thrusts due to air compression must be absorbed by main thrust bearings or transferred to auxiliary thrust bearings by a load balancing arrangement. Hydrodynamic thrust bearings must be Kingsbury type or other approved type and must be adequate to accommodate all operating conditions. Speed increaser bull gear thrust bearings must be sized for equal thrust in both directions and must be adequate for any axial loads transmitted through the driver coupling.

2.2.6.7 Radial Bearings

Radial bearings must be anti-friction roller or ball type or hydrodynamic type. Anti-friction bearings must have an L-10 life of 40,000 hours in accordance with ABMA 9 or ABMA 11. Hydrodynamic bearings must be precision bored sleeve or pad type, designed for easy replacement by a split design or axially removable arrangement. High speed hydrodynamic pinion bearings must be anti-oil whip, tilting pad type. Hydrodynamic bearing design must provide low vibration and sufficient damping at rated speed and all operating modes, including rated capacity and unloading down to 20 percent of unloaded power.

2.2.6.8 Speed Increaser

The speed increaser must be an integral part of the compressor unit and must include the main drive shaft and bull gear. The main drive shaft must be supported through anti-friction bearings.

2.2.6.9 Intercoolers, Aftercooler, Bypass Cooler, and Oil Coolers

Intercoolers, aftercooler, bypass cooler, and oil cooler must include ASTM B111/B111M admiralty brass or other corrosion resistant tubes in ASTM B171/B171M admiralty or steel tube sheets 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 must be mounted on the unit base. Intercoolers, aftercooler, bypass cooler, and oil cooler must be factory tested at 1.5 times operating pressure. External intercoolers and aftercooler must be constructed in accordance with ASME BPVC SEC VIII D1 requirements and be ASME code stamped for 1034 kPa (gage) 150 psig working pressure. Intercoolers and aftercooler must be capable of one piece bundle removal. Intercoolers and aftercooler must be equipped with an integral or direct connected moisture separator with condensate trap assembly. Design intercoolers and aftercooler for 11 and 8 degrees C 20 and 15 degrees F approach, respectively; however, the approach temperature used to size the coolers must be reduced if required to meet aftercooler maximum air outlet temperature specified. Nonstandard coolers must be provided if required to meet the aftercooler maximum air outlet temperature requirement. All coolers must be of counter-flow design, with a fouling factor of 0.002 for both sides of the coolers.

2.2.6.10 Lubrication System

Include an integral sump, positive displacement pump, oil cooler, and twin filter\strainer (readily replaceable cartridges while operating). Provide a prelube lubrication oil pump for start-up and standby for hydrodynamic bearings or if required by the compressor design. System must be factory assembled and tested. Lubricating oil must conform to recommendations of the compressor manufacturer. Spray lubricate drive gear, anti-friction bearings, and timing gear in each stage. Pressure lubricate hydrodynamic

bearings. Provide the oil sump with a level indicator and drain and fill connections.

a. Prelubrication pump, if required, or motor-driven main lubrication pump must be sized by air compressor manufacturer for the requirements of the system, but must meet the following requirements. Pump must be positive displacement gear pump separately mounted with motor on a common base plate with drip lip and drain.

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

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

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

(4) Motor must be NEMA MG 1, Design A or B, 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.

2.2.7 Electric Motors

2.2.7.1 Main Electric Drive Motor

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NOTE: Polyphase motors must be selected 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 Charles 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 Service Center (NFESC) energy home page http://energy.navy.mil/.

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The main drive motor for each compressor must be [an induction,] [or] [a synchronous] motor, [_____] kilowatt (kW) horsepower (hp), with a continuous service factor of 1.0. Size the motor so that the name plate kW hp rating is not exceeded under the entire range of operating conditions specified. Efficiency and losses must be determined in accordance with IEEE 112. Unless otherwise specified horizontal polyphase squirrel cage motors rated one to 125 horsepower must be tested by dynamometer Method B as described in Section 6.4 of IEEE 112. Motor efficiency must be calculated using Form B of IEEE 112 calculation procedures. Polyphase motors larger than 125 horsepower must 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 must be identified on the motor nameplate by the caption NEMA Nominal efficiency or NEMA Nom eff. Electrical service will be as specified. Motor must be designed for reduced voltage starting [at [50] [65] [80] percent of full voltage], allowing for characteristics of the connected load, and must start without undervoltage tripping. Provide resistance temperature detectors (RTD) attached to or imbedded in motor winding for control system. The motor must meet the requirements of NEMA MG 1 with Class F insulation. Provide space heaters for protection of windings during motor shutdowns.

2.2.7.2 Accessory and Related Equipment Motors

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

2.2.8 Control Panel

Control unit panel must conform to NEMA ICS 6, floor or frame mounted, factory designed, and assembled, and must be provided complete. The panel must be fabricated of formed stretcher leveled sheet steel, reinforced, and assembled into a rigid unit. Gasketed access doors must be provided as required. Panel must be factory finish painted. The panel must meet NEMA 12, requirements.

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

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

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

2.2.9 Accessories

Required accessories include:

2.2.9.1 Control Valves

Pneumatically or hydraulically controlled valves on suction inlet of compressor and on bypass or vent line.

2.2.9.2 Intake Devices

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

a. Intake weather hood with rain hood and bird screen. Material must 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 must be 1.65 mm 0.065 inch thick, Class 5000 aluminum alloy. Unit must 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.

2.2.9.3 Outlet Connectors

Compressor air outlet flexible connection of stainless steel bellows with braided steel cover jacket, with stainless steel liner sleeve, 18-inch (457-mm) 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.

2.2.10 Inlet Air Filters

Provide a three-stage filter system, complete with mounting racks (horizontal flow), interstage seals, and replaceable filters. Filter unit must be provided complete including enclosure or housing, and frames. Enclosure must be Class 5000 aluminum alloy with inlet and outlet flanges. Construction must be welded or, where welding is not practical, close riveted and caulked, weathertight, with access doors for filter replacement and cleaning. Access doors must 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, must receive a factory-applied epoxy prime and finish coat for corrosion resistance. Filters must consist of three separate stages and sized to fit the available space.

2.2.10.1 First-Stage

First-stage filter must be flat, 51 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 microns and 90 percent of 5 microns.

2.2.10.2 Second-Stage

Second-stage filter must 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 of 5 microns and 90 percent of 3 microns.

2.2.10.3 Third-Stage

Third-stage filter must 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 of 0.5 micron.

2.2.10.4 Filter Ratings

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

2.2.11 Bypass or Vent Line Silencer

A bypass or vent line silencer must be furnished with each compressor as selected by compressor manufacturer for sufficient noise attenuation to meet OSHA sound level criteria, but not greater than 84 dBA measured at an elevation of 1.50 meter 5 feet, and 3 meter 10 feethorizontally from silencer.

2.2.12 Sound Attenuating Enclosure

The compressor package, including the driver motor, must be contained within a noise reducing enclosure. Design of the enclosure must be such as to limit noise transmission to 84 dBA or less at a distance of one meter from the compressor in any direction.

2.2.12.1 Enclosure Frame

The enclosure frame must be designed to support the weight of the sound suppression panels and easily demountable. Connections to the base frame must be designed to allow the enclosure frame to be detached and lifted away without damage to the connections, enclosure frame or base frame, and to allow accessibility and replacement of any component.

2.2.12.2 Panels

The panels must be of rigid construction to allow repeated access without damage or distortion. Sound absorbing material must be mineral fiber, treated to preclude shedding of fibers. Other approved insulation may be used except that polyurethane foam must not be permitted. Top panels must be secured to the enclosure frame with quick disconnect fittings and fabricated to allow easy hand removal for maintenance. End and side panels must be hinged or lift out with positive closure latches. Panels must be designed to allow the maximum access area when opened. Provide acoustic seals as required. Controls and instrumentation mounted on the panels must have flexible connections for panel opening and disconnects for enclosure removal. Disconnects must be of the male-female plug type. Panels must split around all piping connections to allow enclosure removal without detaching piping. Controls must be visible and operable from outside the enclosure.

2.2.12.3 Ventilation

Fan(s) and sound baffled ventilation grilles must be provided as part of the enclosure. Ventilation must be sufficient to limit interior temperature to that required for cooling the motor.

2.2.13 Isolating Pad

If specifically recommended by the compressor manufacturer, each

compressor steel or iron base frame must be mounted on a neoprene waffle or rib type isolator pad which extends uniformly and continuously along the base mounting surface. The neoprene material must be of bridge bearing pad quality neoprene and must be formulated for 40 durometer hardness. The maximum bearing pressure on the isolating pad must be 345 kPa 50 psi. The pads must 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 must be accomplished using 6 mm 1/4 inchthick 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 must be concentric type, of 3 mm 0.125 inch thickness and must meet ASME Standards. Orifice must be sized for 1016 mm 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 must 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 must record pressure (0 to 1379 kPa (gage) 200 psig range) and air flow (0 to [_____] L/s SCFM). Recorder must be electric drive and housed in dust-tight steel cabinet. Charts must be 305 mm 12 inchdiameter with evenly divided graduations. Drive must be 7 day circle. Provide continuous flow integration of a 7 digit counter type. Pens must be supplied with long-life cartridges and capillary supply. Chart case must be internally illuminated. Access to charts must be through front access window door. Calibrated overall accuracy of the recorded measurements must 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 must be of the pressure type with attached sampling system. The unit must 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 must be 120 volt, single phase, 60 hertz with power cord and plug. Response time normally 2 minutes per sample/purge. Unit must be mounted in a gasketed enclosure with face gage indicating CO readings.

2.4.1 Sampling System

Sampling system must 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 must 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, intercooler, lubrication system, and control panel must be subjected to performance tests and sound level and run-in tests. Unit must comply with guarantee requirements applying engineering adjustments to guarantee conditions. Test must be certified by the manufacturer. Test may be run on the manufacturer's test stand using driver for this contract. Tests must be in accordance with ASME PTC 9 format. Full-range performance tests must indicate performance at maximum rated flow, rating point, and unloaded conditions. Motor performance conditions must be reported, including motor efficiency and losses, motor power factor, motor service factor, motor temperature rise, motor noise and balance, and motor torque at full load, locked rotor, pull up, and break down. Include intercoolers, aftercoolers, and lubrication and control systems performance. Completed unit must be factory tested with sound meters in accordance with ISO 2151. Location must be one horizontal meter from unit at 1.5 meters above the floor. Test must include readings at each octave band midpoint and the "A" scale, and must not exceed 84 dBA and 90 decibels at any octave band. Results of test must 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 must 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 must conform to requirements outlined and must be witnessed by the Contracting Officer.

2.5.4 Approval of Testing Procedure

Proposed testing procedure must 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 must certify performance by test to be in compliance with specifications.

PART 3 EXECUTION

3.1 INSTALLATION

The Contractor must install the air compressors and accessories in accordance with manufacturer's recommendations and as indicated on the drawings. All equipment must be installed plumb and level and anchored to structure, matching holes provided. Install the compressor 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 must 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 must be under the direct supervision of the compressor manufacturer's authorized representative. Complete unit must 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 must be reinstalled if undamaged, by removal procedures; or if damaged, must be replaced with new materials to match original configuration.]

3.2.1 Prompt Installation

The Contractor is advised that any compressor received must 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 must have the option of requiring breakdown and reassembly to inspect and clean prior to placing in operation. This work must be at no additional cost to the Government.

3.2.2 Start-Up Services

The Contractor must furnish the services of a compressor manufacturer's authorized representative to supervise prestart checkout, initial start-up, performance testing, and operator instruction. Time available must 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 must be performed by the Contractor and witnessed by the Contracting Officer. Air compressor system test must 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 must include operation at rated capacity for not less than 4 hours.

3.3.1.1 Air Compressor Performance Tests

Complete performance test must be run at maximum load, rated load, at point of unload but prior to unload, and unloaded condition. Data must 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. Bypass cooler water flow, temperatures, and pressures.

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

f. Lube oil flow, pressures, and temperature.

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

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

i. Electrical load in volts and amperes for compressor motor (loaded and unloaded), prelube oil pump motor, and compressor auxiliaries.

j. Intake filter pressure differential (clean).

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

l. Test compressor intake and discharge for conformance to CGA G-7.1. Compressor discharge must 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 must be submitted to the Contracting Officer for approval prior to conducting tests. The format of ASME PTC 9 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 must be caused by throttling selected fluids. Test data, such as air intake temperature and humidity, must be mathematically corrected to performance test requirement levels.

3.3.1.3 Sound Level Tests

Sound level tests must be conducted concurrently. Broad Band "A" scale readings and Octave Band readings must be taken and recorded at the same positions as on the factory testing. Maximum permissible level must 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 Operational Deficiencies

Any operational deficiencies noted in the tests must be promptly corrected and affected portions of the test rerun.

3.3.1.5 Testing Tolerances

A tolerance of plus or minus 2 percent 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 must be met.

3.3.2 Approval of Testing Procedure

Proposed testing procedure must 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 must 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 must 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 must 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 --