PART 1 – GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

B. Related Sections include the following:
   1. Section 15050 "Basic Mechanical Materials and Methods" for equipment and accessory labels.
   2. Section 15055 "Motors" for electric motors that are an integral part of packaged system components.
   3. Section 15075 "Mechanical Identification" for equipment and accessory labels.
   4. Section 15211 "General Service Compressed Air Piping" for compressed-air piping and specialties.
   5. Section 15900 "HVAC Instrumentation and Controls" for equipment, piping, and accessories for building temperature controls.

1.2 SUMMARY

A. This Section includes equipment and accessories for building compressed-air systems operating at 200 psig and less.

1.3 DEFINITIONS

A. Low-Pressure, Compressed-Air Systems: ASME B31.9, "Building Services Piping," for systems operating at pressure of 125 psig or less and at temperature of 200 deg F or less.

B. Medium-Pressure, Compressed-Air Systems: ASME B31.1, "Power Piping," for systems operating at pressure between 125 and 200 psig, or at temperature of more than 200 deg F.


1.4 SUBMITTALS

A. As a minimum, Contractor shall submit the following shop drawings or catalog cut sheets and ordering information for the following:
   1. Air Compressor General Arrangement, Foundation Requirements, Customer Connections.
   2. Lubrication System: Piping and Instrumentation Diagram, Main Oil Pump, Prelube Oil Pump and Motor, Temperature Regulating Valve, Filters, Coolers, Oil Heaters and Controls.
   3. Intercoolers and Aftercooler.
   5. Condensate Drain Valves
   6. Inlet Expansion Joint.
8. Discharge and Blow-off Expansion Joints.
10. Silencer(s).
11. Discharge Check Valve.
18. Meters, Motor Starters for Auxiliary Equipment and Sequence of Operations.
19. Main Motor Drive: Connection Diagram, Thermal Damage Curve, Time vs. Speed Curve, Terminal Box, Drive Coupling & Guard.
20. Piping and Instrumentation Diagrams
21. All Instrumentation, Including: Pressure Gauges; Thermometers; RTD’s; Pressure, Differential Pressure and Flow Transmitters, Vibration Probes, Level Switches Flow Switches
22. Automatic Control Valves and Accessories.
23. Heat Exchanger Water Requirement

B. Wiring Diagrams: For each item of equipment with electric power supply. Include ladder-type wiring diagrams for interlock and control wiring required for installation. Differentiate between factory-installed and field-installed wiring.

C. Coordination Drawings: For compressed air equipment and piping, including relationship to other services that serve same work areas.

D. Certificates of Shop Inspection and Manufacturers Data Reports: As required by ASME Boiler and Pressure Vessel Code.

E. Maintenance Data: For equipment to include in the maintenance manuals specified in Section 1.

F. Compressor Control System: The following shall be submitted for the compressor control system:
   1. A complete equipment and component list, including a complete functional description of the system.
   2. All drawings and specifications required for design, fabrication and installation of the system.
   3. A detailed list of recommended spare parts including the original manufacturer's catalog number.
   4. Shop drawings for all instrumentation and control components, including control panel wiring diagrams and layout drawings.
   5. Characterization profiles for all control valves illustrating percent open vs. percent flow.
7. Performance and loading data on compressors.

1.5 QUALITY CONTROL

A. Product Options: Drawings indicate size, profiles, and dimensional requirements of compressed-air equipment and accessories and are based on specific types and models indicated. Other products with equal performance characteristics, made by specified manufacturers, may be considered. Refer to Division 1 Section "Substitutions."

B. Electrical Component Standard: NFPA 70.

C. Provide listing/approval stamp, label, or other marking on equipment made to specified standards.

D. Listing and Labeling: Provide equipment and accessories specified in this Section that are listed and labeled.
   1. Terms "Listed" and "Labeled": As defined in National Electrical Code, Article 100.

E. All equipment shall be new and unused. All work is to be performed in a neat and workmanlike fashion. All designs are to be "State of the Art" in concept and execution.

F. All equipment, materials, and practices shall be in compliance with the most current applicable standards and recommendations of the following:
   (IEEE) Institute of Electrical and Electronic Engineers
   (UL) Underwriter's Laboratories
   (NEC) National Electric Code
   (NEMA) National Electrical Manufacturers Association
   (ISA) Instrument Society of America
   (OSHA) Occupational Safety and Health Act
   (ANSI) American National Standards Institute

G. On any point for which specific provisions are not made in this specification, the most stringent provisions of National, State and/or Local Codes shall be observed.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver and store equipment and large accessories on factory-installed shipping skids and small accessories in factory-fabricated fiberboard containers.

1.7 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed, are packaged with protective covering for storage, and are identified with labels describing contents. Deliver materials to Owner.
   1. Air-Compressor, Inlet-Filter Elements: Equal to 100 percent of amount installed.
PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Water-Cooled, Centrifugal Air Compressors:
   a. Ingersoll-Rand Company
   b. Quincey
   c. Atlas Copco Compressors, Inc

2. Lubricated, Reciprocating Air Compressors:
   a. Ingersoll-Rand Company
   b. Quincey
   c. Atlas Copco Compressors, Inc

3. Oil-Flooded, Rotary-Screw Air Compressors:
   a. Ingersoll-Rand Company
   b. Quincey
   c. Atlas Copco Compressors, Inc

4. Aftercoolers, Air Cooled:
   a. Hankison International
   c. Compressed Air Systems

5. Air Dryers:
   a. Hankison International
   c. Compressed Air Systems

2.2 AIR COMPRESSORS, GENERAL

A. General: Factory-assembled and -tested packaged units; simplex, duplex, or multiplex units; and with capacities, features, and electrical characteristics indicated.


C. Control Panels: Automatic control station with load control and protection functions. Comply with NEMA ICS 2, "Industrial Controls and Systems: Controllers, Contactors and Overload Relays, Rated Not More than 200 Volts AC or 750 Volts DC"; and UL 508, "Industrial Control Equipment."
   1. Mounting and Wiring: Factory installed and connected as an integral part of equipment package.
   2. Enclosure: NEMA ICS 6, "Industrial Control and Systems: Enclosures," Type 12 control panel, except where a higher degree of enclosure is specified.
   a. Control Voltage: 120 V, ac or less, using integral control power transformer.
   b. Motor Overload Protection: Overload relay in each phase.
   c. Starting Devices: Hand-off-automatic selector switch in cover of control panel, plus pilot device for automatic control as indicated.
   d. Automatic Alternating Starting: Switch lead compressor for duplex air compressors.
   e. Sequence (Lead-Lead-Lag) Starting: Switch lead compressor for multiplex air compressors.
   f. Reduced-Voltage Starting: Instead of full-voltage starting, where indicated.

4. Instrumentation: Include air-receiver pressure gage, discharge-line pressure gage, air-filter maintenance indicator, hour meter, compressor discharge air and coolant temperature gage, and control transformer.

D. Receiver Tanks: ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels" construction and bear appropriate code symbols, with pressure gage, pressure-reducing valve, and automatic drain.
   1. Exception: Omit receiver tank for freestanding air compressors and include receiver tank as an accessory where indicated.

E. Factory Pre-piping: Entire unit, except where otherwise indicated.

2.3 SAFETY VALVES

A. Safety Valves: Poppet type complying with ASME Boiler and Pressure Vessel Code, Section VIII, bear appropriate labeling, and factory sealed after testing.

2.4 CENTRIFUGAL MULTI-STAGE COMPRESSORS, WATER COOLED

A. General
   1. Air compressor shall be a multistage, centrifugal type which will efficiently provide oil-free compressed air at the specified quantity and pressure.
   2. Unit shall be designed for continuous operating service and shall be of a make, model, and size which has been in commercial service a minimum of 100,000 operating hours.
   3. A common fabricated steel base plate shall be provided for mounting and supporting the compressor, driver and all auxiliaries which can effectively be factory-assembled into a single shippable package. The entire base plate top surface shall be covered with 1/4" thick (minimum) steel checkered plate to enclose all areas for housekeeping and safety. If access is required into the base plate, provide hinged access doors with locking latches. The compressor base plate shall be anchored to an elevated equipment pad.
   4. Motor-compressor alignment shall be adjustable via threaded bolts in "Stillson Blocks" that are welded to the motor and compressor baseplates.
5. The equipment shall be designed so that motor-compressor shaft alignment is not disturbed during replacement of impeller bearings or shaft seals.

6. Vibration and Balance
   a. Compressor manufacturer shall analyze the complete unit (driver, gear box, compressor and all couplings) to insure that no torsional critical speeds are within 15% of operating speeds.
   b. Design of shaft ends (keyways, keys, etc.) and couplings will be such that there will be no failure due to torque during starts and stops (up to two cold starts or one hot start per hour).
   c. The rotating compressor elements shall be dynamically balanced. Rotor balance during shop test shall be such that during operation at maximum continuous speed, the double amplitude of vibration in any plane measured on the shaft adjacent to any rotor bearing housing shall not exceed 1.0 mils.

B. Casing
   1. The compressor case shall be aerodynamically designed to allow lowest turbulence loss, maximum pressure rise and high efficiency, and shall be hydrostatically tested to one and one-half times the design pressure. It shall be made of ductile iron, cast steel or cast iron and designed to conform to certain safety standards such as the ASME Code for unfired pressure vessels.
   2. Inlet air, discharge air, blow-off air and water connections shall be flanged.

C. Impellers
   1. Impellers shall be built of corrosion-and erosion-resisting stainless steel.
   2. Impellers shall have all surfaces machined and shall be dynamically balanced. Welding to achieve balance is prohibited. After machining, the impeller shall be subjected to a liquid-dye penetrant inspection.
   3. Impellers shall be keyed or fastened to the shaft with a shrink fit sufficient to prevent looseness when operating at a speed 115% of the design speed.

D. Gear Unit
   1. The gear unit rotating elements shall be designed and manufactured in accordance with A.G.M.A. standards for high-speed gearing. Gear unit minimum efficiency shall be 98%.
   2. All rotating elements shall be rated for the nameplate horsepower of the compressor driver and selected for a minimum 1.3 service factor.
   3. Heat treatment and finishing of gears shall be in accordance with A.G.M.A. tooth proportions and accuracies. Minimum surface finish of teeth shall be 32 micro-inches r.m.s.
   4. Gearing shall be dynamically balanced for the operating speed.
   5. The gear shall be lubricated by the air compressor lubrication system.

E. Seals
   1. Air seals shall be labyrinth type or segmented carbon ring set at close clearance to the shaft to provide minimum air leakage.
   2. Oil seals shall be labyrinth type or segmented carbon ring set at close clearance to the shaft to provide minimum leakage. Adjoining air and oil seal shall be separated by a pressurized air space.
F. Bearings
   1. Radial bearings shall preferably be of the tilting pad type with renewable liners or shells. The bearing shells or liners shall be removable without disturbing the rotating element. Bearings shall be designed to prevent oil whip at any operating speed. The maximum journal velocity shall be 250 feet per second with a maximum projected area bearing load of 250 pounds per square inch.
   2. Thrust bearings shall be of the multi-segment type, designed for thrust in both directions. The thrust bearing shall be adjustable for axial positioning of the impeller shaft. The thrust bearing preferably shall be located at the outboard end of the compressor.
   3. Bearings shall be designed for pressure lubrication and arranged to minimize foaming. Drain openings shall be designed to insure proper drainage.

G. Flanges
   1. All customer connections shall be ANSI 150 lb. raised face weld neck flanged. Slip-on type flanges are not acceptable.

H. Coupling for The Main Driver
   1. Shaft coupling shall be the non-lubricated, resilient block type. Coupling shall permit a minimum axial shaft displacement and angular misalignment.
   2. Coupling shall be one of the following, or as approved by the Purchaser:
      Manufacturer       Model Number
      Kopper             Max C, Type WB

I. Intercoolers
   1. Air compressor shall be equipped with interstage coolers which preferably shall be an integral part of the compressor assembly, or be close-coupled to minimize losses.
   2. Coolers shall be shell and tube type. Tube bundles shall be removable and interchangeable with provisions for inspection and cleaning.
   3. The cooler shells shall be of welded or cast steel. Tubes shall be of admiralty metal or approved copper alloy and shall be of straight tube design. Fins and tube sheet shall be the same material as tubes to minimize galvanic corrosion on both air and water sides.
   4. Each intercooler shall be furnished with a moisture separator. For external intercoolers, the moisture separator shall be of the cyclone type, all 304 stainless steel construction, complete with moisture reservoir and sight gauge, and shall be furnished with 150 pound ANSI raised face flanged connections. Moisture separator shall be manufactured by one of the following, or as approved by the Purchaser:
      Manufacturer
      Wright-Austin
      R. P. Adams Co.

      The moisture separator shall be equipped with a high level alarm, of a type proven in similar service.
J. Lubrication System

1. Compressor package shall include a complete forced feed lubrication system, sized to furnish proper lubrication for all lubricated items of the compressor, driver, gears and auxiliaries.

2. Pumps, filters, strainers, coolers, etc. shall be constructed of cast iron or cast steel. Strainer from the reservoir to the auxiliary oil pump and main oil pump shall be located above the reservoir and equipped with a full size nipple and drain valve.

3. Main oil pump shall be driven by the compressor drive shaft. Pump shall be complete with pressure regulating and bypass valves, arranged to pump oil to bearings regardless of shaft position.

4. Pre-lube oil pump shall be electric motor-driven, designed for full capacity and pressure and suitable for continuous operation. Pump shall be complete with necessary starters, relays, and auxiliaries, controlled to automatically start upon failure of the main pump or reduction in pressure. Pump motor shall be in accordance with the GM Standard Specification 7EH.

5. Interlocks shall provide the following functions:
   a. Prevent start of compressor motor if oil pressure is below set point.
   b. Stop compressor motor when oil pressure drops below set point.
   c. Start pre-lube pump when oil pressure drops below set point.
   d. Stop pre-lube pump when main pump attains set pressure at compressor bearings.

6. Oil Reservoir:
   a. The oil reservoir shall have a minimum useable capacity of 3-1/2 minutes retention time based on normal oil flow rate. The interior shall be descaled, rust-proofed, and sealed prior to shipment to prevent entrance of dirt, water, or any other contaminants.
   b. The reservoir shall be designed with a full size drain valve to permit complete drainage and shall contain a bolted, gasketed manway to permit access for cleaning and inspection. Provide a lockable fill opening with a perforated metal fill cup, dipstick and a visual level gauge for oil level measurement.
   c. Provide an oil reservoir demister, complete with 460-3-60 Hz motor. Starter and all necessary devices shall be included in the control panel. Demister shall be the following, or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Air Filter Co.</td>
<td>Dynapure Model A-1</td>
</tr>
</tbody>
</table>

7. Oil Filters:
   a. Provide two full-flow oil filters, piped in parallel, capable of removing particles ten microns and over, with a clean pressure drop not to exceed 5 P.S.I. at design temperature and flow. Filters shall be complete with necessary piping, valves, and fittings and shall be located above the reservoir’s normal operating level. Filters shall be equipped with full size nipple and drain valve. Filters shall be located to facilitate element replacement without oil drippage.

8. Oil Coolers:
a. Provide two 100% capacity oil coolers, piped in parallel. Coolers shall be of the shell and tube type with removable heads. Mounting brackets for the coolers shall be provided on the shell so that the cooler heads can be removed for maintenance without removing the complete cooler. Cooling water shall circulate through the tubes. Construction shall meet the requirements of TEMA “C”. Tubes shall be minimum of 3/8” diameter and made of admiralty metal. Coolers shall be designed for 85 degree F entering water temperature.

b. The oil coolers and oil filters shall be piped in parallel and valved to permit the removal of either cooler or filter from service without interrupting compressor operation.

9. The lubrication system will be furnished complete with all components necessary including interconnecting pipe, valves, relief valves, and fittings. Provide flanges or unions as required for maintenance.

10. Oil Heaters:
   a. Provide two electric immersion oil heaters, sized to heat the oil from 40 degrees F to the proper operating temperature within 20 minutes, including all necessary thermostats and contactors. Heaters shall operate on 460/3/60 power. All necessary electrical devices, including safety disconnect switches, shall be included in the control panel.

11. Temperature regulating valve for oil cooling water shall be a pneumatically actuated two-way globe pattern valve, installed on the water outlet from the oil cooler. Valve shall have a flanged cast-iron body, stainless steel trim and flanged end connections. Valve shall be furnished with a 3-15 psig pneumatic diaphragm spring return actuator, positioner, transducer and air set, all factory assembled using stainless steel tubing. Valve shall be manufactured by one of the following, or as approved by the Purchaser:

   Manufacturer
   Fisher
   Masoneilan
   Jordan

12. Oil temperature control system shall include an RTD with thermowell in the oil piping leaving the coolers. Temperature control shall be through the compressor control system.

13. Provide thermometers in thermowells at the oil outlet of bearings and gears.

K. Compressor Driver
   1. Refer to Division 15, Section "5KV Induction Type Drive Motor" for compressor driver specifications. Driver rated horsepower shall not be exceeded at any air inlet condition.

L. Aftercooler
   1. Aftercooler shall be shell and tube type, complete with moisture separator capable of removing 99% of all liquid having particle size larger than ten micron. Aftercooler shall have sufficient surface area to cool the air from the compressor to within ten (10) degrees F of the cooling water inlet temperature. Water inlet temperature shall be a maximum of 85 degrees F and water temperature rise
shall not exceed 20 degrees F. Water shall be on the shell side and shall have a velocity between six (6) and eight (8) feet per second.

2. Aftercooler shall be of the horizontal type with floor mounting saddles, or it shall be incorporated within the compressor housing.

3. The air pressure drop across the aftercooler and moisture separator shall not exceed 2.0 psi at maximum compressor flow rate.

4. The cooler shell shall be welded or cast steel. Tubes shall be of admiralty metal or approved copper alloy and shall not be of "U" tube design. Fins and tube sheets shall be of the same material as tubes to minimize galvanic corrosion on both air and water sides.

5. If the aftercooler is external to the compressor, it shall be furnished with 150-pound ANSI raised face flanged water and air connections.

6. Aftercooler shall be furnished with a moisture separator. For external aftercoolers, the moisture separator shall be of the cyclone type, all 304 stainless steel construction, complete with moisture reservoir and sight gauge, and shall be furnished with 150 pound ANSI raised face flanged connections. Moisture separator shall be manufactured by one of the following or as approved by the Purchaser:

   Manufacturer
   Wright-Austin
   R. P. Adams

7. The moisture separator shall be equipped with a high level alarm, of a type proven in similar service.

8. Aftercooler shall be manufactured by one of the following, or as approved by the Purchaser:

   Manufacturer
   American Standard
   Patterson Kelly
   R. P. Adams

M. Air Intake Filter
   1. A two-stage dry type air filter shall be provided for each compressor. The first stage shall be an inertial type capable of removing 93% of particles 8 microns and larger. It shall be constructed of a non-corrosive high-density polypropylene with stationary air inertial spinners that impart a high radial velocity to the air. Pressure drop through the first stage filter shall not exceed 0.75" W.G. at 1,200 CFM.

   2. The second stage shall have sufficient area so that the velocity of the incoming air based on the active filtering area shall not exceed 13 FPM at rated compressor inlet capacity; 99.97% of particles larger than 2.0 microns shall be removed in this stage. Second stage elements shall be pleated, panel type with PVC encapsulated ends.

   3. The design of the filter shall incorporate safeguards that do not allow foreign objects to enter the intake pipe during changing of any filter element. Gasketed doors and room for maintenance shall be provided for both compartments. Second stage filter element grating opposite the door shall be hinged for...
accessibility to the plenum box. Filter system shall be capable of operation under surge conditions without damage.

4. Filter and inlet plenum box interior shall have two (2) coats of zinc rich primer (except stainless steel portions). All filter and plenum box exterior surfaces shall be primed and finish painted (except stainless steel portions) as specified in this Section.

5. Total clean pressure drop through the two stages shall not exceed 1.5" W.G. and filter shall be able to withstand 15" W.G. without dirt penetration.

6. Provide a clean air plenum with a back outlet transition and nozzle. Filter housing downstream of second stage filter shall be 304 stainless steel. Clean air plenum outlet nozzle shall be drilled for mating with 150-pound ANSI flange of compressor air inlet expansion joint.

7. Filter housing shall be provided with three 1/2" pressure gauge connections: at the inlet of the first stage, between the first and second stages, and at the outlet of the second stage.

8. All gasket material shall be Buna "N," 1/16" thick.

9. First stage bleed air blower shall have capacity equal to 10% of the nominal rating of the air compressor. Blower shall be of the centrifugal type, direct connected to the motor. Motor shall be 460/3/60, with a maximum speed of 1,800 rpm and shall conform to GM Standard Specification 7EH.

10. Motor starter for the bleed air blower shall be located in the compressor control panel. Provide a non-fusible disconnect switch adjacent to the fan, complete with a control circuit interlock contact and all interconnecting wiring. Provide a "Jog" push button at the motor.

11. Bleed air blower shall operate whenever the compressor main drive motor is operating. Provide an interlock circuit to indicate "Filter Bleed Blower Failure" whenever compressor drive motor is operating and filter bleed blower motor is not.

12. Provide suitable, low-temperature fluorescent lighting in the primary and secondary compartments, complete with switches and wired to a terminal strip in a single junction box.

13. Filter shall be shipped completely wired. All devices, such as lights and blower, shall be wired to terminal boxes.

14. Filter shall be one of the following, or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
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<tbody>
<tr>
<td>Dollinger Corporation</td>
<td>SSH-V-2D-18000-240</td>
</tr>
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</table>

15. Provide primary and secondary differential pressure gauges, mounted on and piped to the filter housing gauge connections. Ranges shall be as required. Gauges shall be one of the following, or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwyer “Photohelic”</td>
<td>Series 3000</td>
</tr>
</tbody>
</table>

16. Provide a "smart" electronic filter differential pressure transmitter that will provide a 4 to 20 mA digital signal to the compressor control system. The transmitter shall include an integral LCD meter and integral, coplanar, 316 stainless steel, 3-
valve manifold. The fill fluid shall be inert; silicone oil will not be permitted.
Transmitter shall be the following or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model No.</th>
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<tbody>
<tr>
<td>Rosemont</td>
<td>3051CD</td>
</tr>
</tbody>
</table>

N. Silencers
1. Provide dry type silencers for discharge and blow-off. Silencers shall have 150-
pound ANSI raised face flanged end connections. Blow-off silencer capacity
shall be approximately 75% of the air compressor capacity and designed for
residential 80 dbA silencing.
2. Silencers shall be manufactured by one of the following, or as approved by the
Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>Burgess-Manning</td>
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<td>Kittel</td>
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<tr>
<td>Maxim</td>
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<tr>
<td>Stoddard</td>
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<tr>
<td>Universal Silencer Corp.</td>
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</table>

O. Air Flow Measurement
1. Provide a fabricated insert flow tube type primary device for measurement of
compressed air flow rate downstream of each aftercooler. Device shall have
150-pound ANSI carbon steel flanged end connections and 304 stainless steel
throat and body. Unit shall have a "beta" ratio to produce approximately 50" w.g.
differential pressure at maximum compressor output. Flow tube accuracy shall
be ± 1.0% of the actual rate of flow.
2. Airflow primary device shall be one of the following, or as approved by the
Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
</tr>
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<tbody>
<tr>
<td>Badger Meter</td>
<td>PMT-IF</td>
</tr>
<tr>
<td>BIF</td>
<td>183</td>
</tr>
<tr>
<td>Johnson Yokogawa</td>
<td></td>
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</table>

3. Provide a "smart" electronic flow transmitter that will provide a 4 to 20 mA digital
output signal that is directly proportional to mass flow rate. Transmitter shall
have integral pressure compensation. Temperature compensation shall be by an
RTD input to the transmitter. Transmitter shall be provided with an integral LCD
meter and integral, coplanar, 316 stainless steel, 3-valve manifold. Transmitter
shall be the following or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosemont</td>
<td>3095M</td>
</tr>
</tbody>
</table>

P. Discharge Check Valve
1. Discharge check valve shall be of the "center pivoted" or "duo-check" type.
Valve shall have a flanged 150 lb. carbon steel body, stainless steel plates, 304
stainless steel shaft and stop pin, Buna-N seal, 316 stainless steel hinge pin and springs and with an elastomeric seal suitable for the service.

2. Valve shall be manufactured by one of the following, or as approved by the Purchaser:

Manufacturer
Centerline
Hoerbiger

Q. Inlet Air Expansion Joint
1. Inlet air expansion joint shall be corrugated rubber, with reinforced bolt rings and 150 lb. ANSI flanges. Expansion joint shall be one of the following, or as approved by the Purchaser:

Manufacturer
Mercer

R. Discharge and Blow-Off Expansion Joints
1. Discharge and blow-off expansion joints shall be 150 lb. ANSI raised face flanged, stainless steel, with liner guides and stops, designed for 150 PSIG and 450 degree F discharge air.

2. Expansion joints shall be manufactured by one of the following, or as approved by the Purchaser:

Manufacturer
Flexonics

S. Inlet Guide Vane
1. Inlet guide vanes shall be constructed of air foil shape stainless steel vanes, cantilevered from oil impregnated bearings, within a sealed housing to minimize entrance of unfiltered air.

2. Inlet guide vane shall be of the metal seated type and specifically designed for throttling service. Valve shall be designed to be mounted between 150 lb. ANSI flanges, and shall be complete with pneumatic operator and positioner.

3. Inlet guide vane shall be manufactured by one of the following, or as approved by the Purchaser:

Manufacturer
Air Relief, Inc.

T. Blow-Off Valve
1. Blow-off valve shall be of the eccentric butterfly type with equal percentage flow characteristic and selected for tight shutoff and throttling service. Valve shall be sized to pass at least 75% of the compressor capacity and shall be designed to limit noise generation to 80 dbA. Valve shall be provided with 150 pound ANSI flanges, pneumatic operator, positioner and shall be normally open. Construction shall be carbon steel body, hardened stainless steel trim and Teflon packing.

a. Valve shall be one of the following, or as approved by the Purchaser:
U. Back Flush Valves
1. Each intercooler, motor cooler and aftercooler shall be supplied with a four port, two-way plug valve, designed to allow the flow of cooling water to be manually reversed to backflush each heat exchanger. Valves shall be 125 lb. cast iron, flanged, and furnished with handle.
2. Valves shall be one of the following, or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
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<tbody>
<tr>
<td>Fisher</td>
<td>1051-8500-3610J</td>
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<tr>
<td>Masonelilan</td>
<td></td>
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<tr>
<td>Jordan</td>
<td></td>
</tr>
</tbody>
</table>

V. Automatic Moisture Traps
1. Each intercooler and after-cooler moisture separator shall be supplied with an automatic moisture trap, consisting of a reservoir that is drained by a pneumatically operated ball valve. Internals of the trap shall be capable of handling liquid with a pH of 3 without damage. Moisture traps shall be snap-acting such that the ball drain valve is either full open or full closed.
2. Traps shall be manufactured by one of the following, or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain-All, Inc.</td>
<td>1500</td>
</tr>
</tbody>
</table>

W. Valves and Piping
1. Manual valves for condensate drain lines shall be ball type of Type 304 or 316 stainless steel construction with Teflon seals. Valves shall be provided at inlet of the moisture trap and in the bypass pipe. Provide separately piped discharge points, one on the outlet of the trap and one at the bypass valve outlet.
2. Manual oil valves shall be ball type with Teflon seals and either flanged or threaded end connections. Threaded valves shall be seal welded.
3. Valves shall be one of the following, or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jamesbury</td>
<td>4000</td>
</tr>
</tbody>
</table>

4. All condensate drain piping shall be Schedule 40 Type 304 stainless steel. Provide a union on the inlet of each moisture trap to permit testing of trap operation and replacement of the trap while the compressor is running.
5. Oil piping upstream of filters shall be Schedule 40 carbon steel pipe with steel butt welded fittings or 150 lb. weld neck flanged joints. Piping downstream of oil filters shall be Type 304 stainless steel, Schedule 10S, with butt welded joints. Stainless steel tubing may be used downstream of the filters, and it shall be fully annealed Type 304 stainless steel hydraulic tubing with ferrule type fittings.
Minimum tubing outside diameter shall be 1/2" and minimum tubing wall thickness shall be as follows:

<table>
<thead>
<tr>
<th>Tubing O.D.</th>
<th>Minimum Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot; through 1&quot;</td>
<td>0.083&quot;</td>
</tr>
<tr>
<td>1-1/4&quot; through 2&quot;</td>
<td>0.120&quot;</td>
</tr>
</tbody>
</table>

X. Main Motor and Aftercooler Water Flow Device
1. Provide a water flow switch device in the cooling water piping (from the motor bearing coolers and from the aftercooler) to initiate an alarm and prevent motor starting if cooling water is not flowing.
2. Flow switch device shall be one of the following, or as approved by the Purchaser:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetrol</td>
<td>F1000</td>
</tr>
</tbody>
</table>

Y. Compressor Regulation and Control
1. The compressors shall be provided with the following three capacity control methods:
   a. Constant pressure and surge control (modulating).
   b. Total closure control (two-step).
   c. Constant pressure plus total closure control (automatic dual).
2. Constant Pressure and Surge Control:
   a. The compressor shall be supplied with a pneumatically activated constant pressure and surge control system. The purpose of the control is to provide a constant discharge pressure and also provide automatic surge control to protect the equipment during periods of low demand.
   b. The pressure control system shall be of the constant speed, inlet guide vane type. As the system demand falls off, the compressor shall establish a new operating point at the reduced flow but at a higher pressure on its characteristic curve. The guide vane will adjust to a position where the compressor flow has decreased to a point that satisfies the system demand and equilibrium is again established at a new higher pressure.
   c. The compressor surge control shall be of the blow-off type. The blow-off valve shall be modulated to maintain the flow of the compressor above the surge limit. As long as the system requirement is above the surge limit, the blow-off valve shall be closed. The sum of the flow to process and the flow through the blow-off valve shall always be equal to or greater than the minimum stable compressor flow.
3. Total Closure Control:
   a. The total closure (or idle) control shall provide economical operation when the system air requirement is less than the stable limit of the compressor for considerable periods.
   b. The compressed air piping system will provide the storage capacity for the compressed air and the system shall be charged to a preset maximum pressure. This unloading pressure shall be selected so that it will fall just inside the stable operating range of the compressors. When
the system reaches this pressure, the air to the compressor shall be shut off by closing the inlet guide vane to a minimum open position. At the same time, the discharge of the compressor, before the check valve, shall be unloaded to atmosphere by the blow-off valve. The compressed air system then will supply the air to fulfill the system demand until the preset minimum pressure on the compressor operating curve is reached. When the system falls to this pressure, the inlet guide vane shall be opened and the bypass valve closed, automatically loading the compressor.

c. The lower, or cut-in pressure setting on "Total Closure Control" shall be the same pressure setting as that selected for "Constant Pressure Control." The upper, or cut-out pressure setting shall be approximately 5 psi above the cut-in pressure.

4. Constant Pressure plus Total Closure Control

a. On decreasing air flow, when the constant pressure control has throttled back to the surge limit set point, the inlet guide vane shall close no further, the blow-off valve shall be blocked shut, and the discharge air pressure shall be allowed to build up. As the discharge pressure attains a value approximately 5 psi above the constant pressure control set point, the compressor shall unload until the system pressure returns to the constant pressure control set point, at which time the compressor shall return to the constant pressure control mode.

5. A selector switch shall be included on the control panel for selection of any one of the capacity control types described above.

6. An automatic over-ride shall be included for start-up operation. In order to relieve the duty of the motor during the starting period, the instrument air pressure shall be reduced to zero. The loss of instrument air shall cause the guide vane on the compressor inlet to close and the bypass valve to open, which are the desired positions for unloading the motor during start-up. After start-up, control air pressure shall be re-established which shall open the inlet guide vane and close the blow-off valve in order to load the compressor.

Z. Compressor Control System Design Features and Requirements

1. The compressor control system shall include all instrumentation and hardware components, software and control panels required including, but not necessarily limited to, the following:

   a. A master pressure control for the compressor network. The master pressure setpoint shall be adjustable from any individual compressor control panel. The pressure at the point being measured shall be held within +/- 1 PSI of the setpoint under all normal operating conditions. The pressure setpoint and regulating window shall be adjustable via security code-protected front panel access.

   b. Each compressor shall have its own local control panel (LCP) which shall act as the local "start-stop" station for the associated compressor. The LCP shall also be capable of automatic "Start-Stop" and "Pressure Control", either based on system demand or on a pre-programmed schedule.

   c. The compressor control system shall monitor the operation of each compressor, and "network" multiple compressors in order to operate the
overall system in the most energy efficient manner. The LCP’s shall be
linked together in bi-directional communication such that any LCP can
provide control of all compressors, but each shall retain the ability to
provide capacity control and protection for its compressor, without an
external connection on a “stand-alone” basis.

d. Each unit shall be able to act as the “lead” compressor and control the
operation and loading of the other compressors. Should the “lead”
compressor fail, the next pre-designated unit shall automatically take
over the role of the “lead” compressor.

e. The LCP for each centrifugal compressor shall provide automatic
modulating capacity control, predictive and reactive surge protection,
permissive start protection, machine protection, and alarm and shutdown
capabilities. It shall include an override system that shall allow manual
capacity control and operation of the compressor and auxiliaries in the
event of an automatic control system failure.

f. The system shall be designed so that the “base load” and “swing”
compressor combinations can be changed by the operator from any
LCP.

g. All software and hardware necessary to link the compressors together
and create an automatic capacity control network.

h. One IBM PC-compatible workstation and all software for data collection,
monitoring and reporting. The control system shall record alarms and
status-change events to a magnetic (hard disk) storage system in the
workstations and to printers.

i. A modem which will allow for system troubleshooting, monitoring and
supporting services from remote locations.

AA. Local Control Panel (LCP) Construction

1. Each compressor shall have one free standing, totally enclosed Local Control
Panel (LCP) containing all controls and instrumentation as indicated herein and
as required for a complete and operable system. Control panel shall be
delivered with all internal components installed, pre-wired and piped to terminal
blocks and bulkhead fittings.

2. Junction box(es) shall be provided as necessary for remote instrumentation and
control devices. Wiring to/from the devices shall be routed to the junction
box(es).

3. Control cabinet enclosure shall be rated NEMA 12, fabricated of 3/16” thick
stretcher level steel plate and shall be a maximum of six feet high above the
bottom of the compressor base plate. All corners shall be rounded. Panel shall
be designed for front-only access with a hinged front access door. The exterior
shall be primed and finish painted with three coats of machine enamel in
accordance with this Section. The interior shall have a two-coat finish of white
enamel.

4. Control panel shall be provided with a main fused disconnect switch interlocked
with the enclosure door. Power supply shall be a single uninterruptible 480 VAC
source. A 480V to 120V isolation transformer for control power shall be provided
within each LCP. All power wiring for the LCP and associated sensors shall be
supplied from this source.
5. Cabinet shall have two compartments: one compartment shall contain pneumatic instruments and control equipment, and the other compartment shall contain all electrical/electronic equipment including control transformer, pre-lube oil pump starter, air filter bleed air blower starter, oil reservoir demister starter and oil heater contactors. A sheet metal barrier shall be used for separation.

6. Every control or indicating device of the panel front and within the panel shall be labeled with an engraved laminated plastic nameplate, in accordance with the shop drawings and this specification. The engraved lettering shall be black on white background.

7. All control equipment (instruments, gauges, operators, etc.) shall be flush mounted in the panel, completely piped, and wired to terminal blocks on a raised bracket near the bottom. Terminal blocks shall be numbered to correspond to the control diagrams. Each wire within the panel shall be identified at both ends with single-piece markers.

8. Construction of the control panel shall be in accordance with SAE HS-1738 and this Specification. All control circuits shall be grounded. Provide a panel-mounted air conditioning system if required, based on maximum ambient temperature and the temperature ratings of electronic components.

9. All control tubing shall be Type 316 stainless steel, 1/4" diameter and 0.030" wall thickness minimum. Fittings shall be nut-and-ferrule compression type (Swagelok or equal). Field tubing connections to the panel shall be via bulkhead fittings with female pipe thread (1/4" NPT).

10. Provide interior fluorescent lighting (with switch) and one duplex receptacle for each control panel compartment. Lighting and receptacle shall be powered from a totally enclosed, combination transformer/disconnect, minimum rating of 1,000 VA. Unit shall have fused main primary disconnect with separate secondary fusing for the receptacles and lighting. Fuse blocks shall be of the fuse puller type.

   a. Transformer/disconnect shall be one of the following, or as approved by the Purchaser.

   Manufacturer    Model Number
   Square D    SK 5271

11. Control Power Relay

   a. An enclosed, front accessible sheet metal box shall be installed on the back panel of the electrical section of the control panel. There shall be a hinged door providing access to items within this box. The door shall be mounted on concealed hinges and shall be held closed by two 1/4 turn, spring-loaded fasteners. A red nameplate with white letters reading "Danger-Multiple Voltage Source" shall be affixed to this door.

   b. The box shall contain control relays and terminal strips of the type hereinafter specified. The coil(s) of the CPR relay(s) shall be energized directly from the control transformer secondary. The purpose of the CPR relay(s) is to ensure that all exposed wiring within the electrical compartment is de-energized when the main disconnect switch is in the "Open" position.

   c. CPR relay(s) is required for disconnecting and shorting the following circuits:
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1) Disconnecting:
   a) Potential transformer leads to the power factor meter.
   b) 125-Volt DC leads from the circuit breaker closing and trip circuits.

2) Shorting:
   a) Current transformer leads to the ammeter.
   b) Shorting type terminal blocks shall be used for all current transformer (CT) terminations.

d. CPR relay shall be Allen Bradley Bulletin 700 Type "P" or approved equal.

e. A minimum of two (2) spare normally open contacts shall be provided.

f. CPR box shall include terminal strips for all connections. External wiring from the circuit breaker and motor terminal box shall be made directly to this terminal strip. CT, PT, and DC terminals shall be separated from each other.

12. All alarm and indicating functions shall have "dry" contacts for alarm relays wired to a separate terminal block for connection to a monitoring and recording system. All digital signals shall be on independent contacts and shall be optically isolated. All analog signals shall be 4-20 mA (DC) signals. A minimum of 20% spare analog and 20% spare digital I/O (input/output) shall be provided.

13. The LCP shall include a screen display for display of all monitored and controlled points and shall include a full function, touch-sensitive membrane keypad to select items to control and to initiate control actions. Membrane switches shall be rated for at least 1,000,000 operations.

BB. Local Control Panel (LCP) Functional Requirements

1. The compressor controllers shall be in constant high speed, bi-directional communication with each other so that all compressors will operate as part of a single, real time, distributed control system. The distributed capacity control system shall utilize a multi-master topology, such that each controller is capable of directing the actions of all other controllers.

2. Each LCP shall have integral machine protection capability. Each monitored point shall be able to be set as both a warning alarm and trip alarm. In addition, the same monitoring points shall be able to be separately enabled, disabled and a unique alarm setpoint established during the compressor start-up and shutdown control sequences. In the event of an alarm, the LCP display shall identify the alarm point and the time of occurrence. Alarm setpoints shall be accessible through the operator panel via a security code system.

3. The LCP shall be equipped with a comprehensive capacity control and surge control system. The objectives of centrifugal compressor control are:
   a. Maintain the pressure setpoint as closely as practical.
   b. Prevent the compressor from entering a surge condition.
   c. Use as little energy as possible.
   d. Protect the compressor from damage.

4. The capacity control and surge control functions shall be integrated and features shall include:
   a. Surge point prediction shall use the relationships of polytropic head and real work of compression. Vibration readings and water temperature rise through intercoolers shall also be used to predict surge. Non-linear
functions adapted to surge prediction shall be employed to provide maximum turndown without the risk of surge.

b. Compressed air flow measurement range shall be between 10% below the surge point to 10% above the maximum compressor flow. Flow shall be measured, and not calculated using other variables.

c. High performance, digital, time-velocity based, multi-variable, Proportional-Integral (PI) control algorithm with seamless transition between all operating modes. The PI algorithms shall incorporate Anti-Reset Windup and Directional Velocity Limits.

d. Control of the inlet and blowoff valves shall compensate for the non-linearity of valve position versus flow rate. Both the inlet and blowoff valves shall be utilized for surge prevention.

e. Surge detection utilizing process variable signature analysis of instantaneous power and/or interstage pressure shall be employed as a backup to the primary surge control method.

f. Automatic adoption of the actual surge setpoint if a surge should occur.

g. Compressors not operating efficiently shall be automatically unloaded to their least power usage point and/or turned off, based on system air requirements, in order to obtain maximum efficiency at low demand.

h. The blowoff valve shall be opened immediately to a configurable percent opening if the discharge pressure exceeds the high pressure safety limit.

i. The manual mode of surge control by use of inlet vanes shall be available, but protected by a security code system to allow only authorized access.

5. Each LCP shall have data logging capabilities. The data to be logged shall include: all monitored and calculated data points at a configurable time interval; all control and alarm events; all security code-controlled access to the system for adjustments; compressor run time over each assigned capacity range; and compressor off time. SCFM output and kWh usage shall be totalized, and compressed air system efficiency (SCFM/kWh) shall be calculated and displayed.

6. Provide audible and visual warning signals at each LCP. Signals shall be activated one minute (adjustable) prior to compressor startup. A sign adjacent to the visual alarm shall read: "WARNING - COMPRESSOR WILL START BY REMOTE CONTROL IN UNDER 60 SECONDS".

CC. Monitor and Control Station (MCS) Requirements

1. One Monitor and Control Station (MCS) shall be provided, and the network shall accommodate multiple MCS’s located up to a mile from any compressor. MCS workstation shall be an IBM-compatible personal computer as manufactured by IBM, Digital, Dell or approved by Purchaser and equipped as follows:

Intel Pentium II Microprocessor with MMX technology, 300 Megahertz
Full tower case with filtered ventilation
64 MB RAM, expandable up to 512 MB
512 KB cache memory
1.44 MB, 3.5" floppy drive
6.4 GB hard drive
8 MB SVGA-compatible video card
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20" color monitor; 0.26mm maximum dot pitch, 1600 x 1280 (minimum) dot resolution
1 parallel; 2 serial ports
24 speed CD-ROM
32 bit Wavetable sound card
101 key keyboard manufactured by Microsoft
3 button mouse manufactured by Microsoft
33,600 BPS internal fax/modem incorporating "X2" technology
300 MB internal tape backup
One "Laser-Jet" and one "Ink-Jet" color printer. Both printers shall be capable of printing on letter-size or legal-size paper.
MS DOS 6.x
MS Windows NT
MS Office 97 "Professional" Edition

2. All cable and conduit necessary to interconnect the workstation and the LCP's shall be provided. Modem communication is not acceptable.

3. All workstation software shall be Microsoft Windows-compatible and provided with password security access. Software shall include automatic data logging, file management and monitoring capabilities that can operate as a background process allowing the personal computer to be used for other purposes while executing its primary functions.

4. The data logger software shall be able to interrupt any other software that may be running to notify the operator of a system alarm condition. Automatic telephone paging over a dedicated phone line shall also be available to notify personnel of conditions requiring attention.

5. Custom-designed computer graphic displays shall be provided as follows:
   a. One for each compressor.
   b. One for each air dryer.
   c. One for each cooling tower and related circulating water pumps.
   d. One for overall cooling water system.
   e. One for overall compressed air system.

6. Displays shall show real-time values and status of all points to be monitored or controlled, in accordance with the Drawings. Display layouts shall be subject to review by the Purchaser prior to beginning any programming.

DD. Wiring Products

1. Network wiring shall be coaxial cable or twisted and shielded multi-conductor wiring, as selected by the Contractor for the application.

2. Sensor (AI) wiring shall be 18 AWG (minimum) copper, twisted and shielded, with 2, 3, or 4 wires to match the analog function hardware.

3. Control (AO) wiring for analog functions shall be 18 AWG (minimum) copper with 600 Volt insulation, twisted and shielded, with 2, 3, or 4 wires to match the analog function hardware.

4. Sensor (DI) and low voltage control (DO) wiring for binary functions shall be 18 AWG (minimum) copper with 600 Volt insulation.

5. All 120 Volt wiring for START STOP functions to motor starters shall be 14 AWG (minimum) copper with 600 Volt insulation. Multi-conductor wire shall have an approved outer jacket.
6. The minimum conductor sizes specified for digital and analog functions shall take precedence over any requirements for Class 2 low energy remote-controlled and signal circuit conductors specified elsewhere.

7. All wiring shall be UL listed and labeled for specific use. Outer jackets shall meet the approval of the State of Ohio and meet GM Standards.

EE. Compressor Control System Instrumentation

1. Instrumentation and control hardware for the compressor control system shall conform to the following requirements, unless noted otherwise:
   a. Temperature detectors shall be platinum resistance temperature detector (RTD), dual element, 3 wire, 100 Ohms at 0 deg. C.
   b. Thermowells shall be machined from 316 stainless steel barstock, with threaded process and instrument connections. Thermowells shall include lagging extensions as required and shall extend to the center of the pipe.
   c. Temperature transmitters shall be two wire, 24 Volt DC loop-powered with an output current of 4-20 milliamps, accuracy of 0.1%, and shall provide an output signal directly proportional to temperature.
   d. Pressure, differential pressure and flow transmitters shall be two wire, 24 Volt DC loop-powered with an output current of 4-20 milliamps, accuracy of 0.1%, and shall provide an output signal which is accurate to 0.25% of the calibrated span.
   e. Pressure switches shall consist of a diaphragm assembly, switch mechanism, terminal block and NEMA 4 enclosure, with an operating range suitable for the process, equipped with at least one Form C contact rated 10 Amps at 115 Volts AC.
   f. Water flow switches shall be of industrial grade with a dust-tight, corrosion resistant NEMA 4X housing, differential pressure type, equipped with at least one Form C contact rated 10 Amps at 115 Volts AC.
   g. Air solenoid valves shall be bronze body, high flow, three-way, 120 Volt AC, Class F (minimum) coil, NEMA 4/7/9 enclosure, industrial grade, 3/8 inch minimum port size.
   h. Air flow measuring devices shall be flanged short-form Venturi or proprietary flow tube as specified herein. Provide specified transmitters and accessories. All airflow rate calculations shall be pressure- and temperature-compensated.
   i. Vibration probes and transmitters shall provide a 4-20 milliamp output signal proportional to displacement, as manufactured by Bently-Nevada.
   j. I/P (current to pressure) signal transducers shall have 4-20 milliamp DC input which is field adjustable, and a pressure output as required by the field device.
   k. Power transmitters shall be of the AC watt transducer type, 1-1/2 elements, loop-powered, 1% accuracy.
   l. A barometric pressure transmitter shall be provided to measure inlet air conditions and shall have specifications equivalent to that for pressure transmitters.
   m. Automatic cooling water and compressed air isolation valves shall be provided where indicated, completely factory-assembled and prepiped.
using stainless steel tubing and compression fittings. Each valve assembly shall include the following:
1) A line-size valve in accordance with this Specification;
2) A pneumatic vane or piston type, spring return actuator, 60 PSIG maximum air operating pressure;
3) Three-way pilot solenoid valve with NEMA 4/7/9 enclosure and adjustable speed controls for opening and closing;
4) Speed controls to adjust the opening and closing speed of the valve;
5) Limit switch in NEMA 4 enclosure to indicate full open and closed positions of the valve;
6) Air filter/regulator.

2. pH sensor shall include integral cable and integral and separate temperature compensation. Sensor shall be inserted through a full port ball valve and shall be removable from the process line without interrupting process flow, TBI-Bailey Model TB557 or approved equal. pH indicator shall be analog type with one analog output and two adjustable dry SPDT relay outputs, temperature compensation, digital display, TBI-Bailey Model TB540 or approved equal.

3. Conductivity sensors shall be 316 stainless steel with replaceable electrode tips, inserted through a full port ball valve and shall be removable from the process line without interrupting process flow, TBI-Bailey Model TB461 or approved equal. Conductivity indicator shall be microprocessor type with two adjustable isolated analog outputs and two adjustable dry SPDT relay outputs, temperature compensation and indication, graphic display, dedicated relay for dirty sensor, TBI-Bailey Model TB700 or approved equal.

4. Quantity and location of instruments and points to be monitored shall, as a minimum, be in accordance with the Drawings.

FF. Painting
1. All structural steel members and equipment surfaces shall be provided with one prime coat of paint and two finish coats of machinery enamel. Surfaces shall be thoroughly cleaned of scale, oil, grease, rust, and other foreign matter before painting. All equipment shall have a finish color of medium blue urethane enamel, Glidden No. 77-01, or as approved by the Purchaser. Provide touchup painting after construction as required.

2.5 RECIPROCATING AIR COMPRESSORS

A. Description: Freestanding, lubricated, reciprocating air compressors, with inlet silencer filter, safety valve, discharge pressure gage, pressure regulator, and shutoff valve.

B. Description: Tank-mounted, lubricated, reciprocating air compressors, with inlet silencer filter, safety valve, discharge pressure gage, pressure regulator, and shutoff valve.

C. Receiver Tank Orientation: Horizontal, except where vertical tank is indicated.

D. Enclosure: Steel sheet, lined with acoustic material protected by perforated steel sheet, inlet and outlet air silencers, and finned-cylinder head cover.
2.6 ROTARY-SCREW AIR COMPRESSORS

A. Description: Single-stage, heavy-duty, asymmetrical, oil-flooded, rotary-screw air compressors with oil-cooled and oil-flooded lubricated screws.

B. Bearings: Separate axial and thrust antifriction bearings.

C. Drive: Non-lubricated, flexible coupling; or multiple oil-resistant V-belts with minimum 1.5 service factor, and provisions for belt tension adjustment.

D. Lubrication System: Unit-mounted, with differential pressure oil circulation system, oil stop valve, full-flow 10 micron cartridge type filter, and thermostatic oil bypass valve for temperature control. Oil cooler shall be a shell and tube water-cooled heat exchanger, sized for 85 deg. F entering condenser water temperature and 30 deg. F (maximum) rise. All fittings shall be SAE O-ring type.

E. Air Inlet Filter: Two-stage dry type, with cleanable, replaceable filter element.

F. Air/Coolant Receiver and Separator: 150-psig rated tank, ASME Boiler and Pressure Vessel Code, Section VIII construction with required nameplate and National Board registration. Furnish with ASME safety valve, oil level gage, multistage separator element, minimum pressure check valve, air blowdown valve, oil drain valve with drain hose, and connections for measuring separator pressure drop.

G. Capacity Control: When air demand is below throttling limit, unload compressor by using pressure switch and blow-down valve. Provide noise attenuation for blowdown.

H. Lubricant: Compressor shall be shipped with a full charge of synthetic lubricant, suitable for 8,000 hours operation.

I. Aftercooler: Fixed bundle, shell-and-tube water-cooled heat exchanger, sized for 85 deg. F entering condenser water temperature. Air shall be cooled to within 10 deg. F of entering water temperature. Aftercooler shall be rated at 250-psig and tested at 350-psig. Provide moisture separator and automatic drain valve in accordance with this Section.

J. Enclosure: Steel frame assembly with full sheet metal enclosure (including bottom) and oil-resistant, sound-proofing liner. Access through hinged doors (with safety interlock switches) and removable access panels. Vibration isolation for package frame and for air-end, motor and separator separately.

2.7 AFTERCOOLERS

A. Aftercoolers, Air-Cooled: Tubular, rated at 250 psig and leak tested at 350-psig minimum air pressure, in capacities indicated. Size units to cool compressed air in compressor-rated capacities to 10 deg F above summertime maximum ambient temperature.

B. Aftercoolers, Water-Cooled: Fixed-bundle, tubular aftercoolers, rated at 250 psig and leak tested at 350-psig minimum air pressure, in capacities indicated. Size units to cool
2.8 AIR DRYERS - REFRIGERATED TYPE

A. Description: Direct expansion, refrigeration type air dryer with air-to-air heat exchanger for pre-cooling inlet air/reheating leaving air and a water-cooled refrigerant condenser. Sealed refrigeration system fully charged and tested at the factory. Supplied with all interconnecting piping, wiring, controls and components mounted on an open frame skid.

B. Performance: Dry 5,000 CFM of saturated inlet air at 100-PSIG and 100 deg. F to a NFPA Class H pressure dew point of 33 deg. F to 38 deg. F, and capable of operation from 0% to 100% of rated capacity without freezeup. Total airside pressure drop shall not exceed 5 PSI. Dried air shall be reheated to within 10 deg. F of the temperature of air entering the dryer. Entering temperature of condenser water will not exceed 85 deg. F Suitable for operating air pressure of 150 PSIG minimum.

C. Refrigeration System: R-22 refrigerant, semi-hermetic compressor with crankcase heater, filters/strainers, suction dryer, liquid refrigerant receiver, refrigerant suction accumulator, liquid line sight glass and over-pressurization relief valve. Capacity control via a minimum of 1 solenoid-operated compressor suction valve unloader, minimum of 1 hot gas bypass valve and a modulating thermal expansion valve.


E. Moisture Separator and Automatic Drain Valves: In accordance with this Section. Provide automatic drain valve at the evaporator outlet and the separator drain.

F. Insulation: Provide minimum ½” thick closed-cell neoprene insulation on all heat exchangers, separator and interconnecting air and refrigerant piping to eliminate condensation on exterior surfaces.

G. Control Panel: Comply with UL 508, Industrial Control Equipment. Enclosure shall be Type 12 accordance with NEMA ICS 6, “Industrial Control and Systems: Enclosures” and factory-installed and connected as an integral part of the dryer package.

1. Motor Controller: Full-voltage, combination magnetic type with undervoltage release feature, motor circuit protector type disconnect, and short circuit protective device, mounted and wired in control panel.
   a. Control Voltage: 120 VAC via integral control power transformer.
   b. Motor Overload Protection: Overload relay in each phase.
   c. Starting Devices: On-Off switch on panel.

2. Indicator Lights: Power on, compressor on; high air temperature alarm.
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3. Indicators: In addition to instrumentation specified in Section “Meters and Gages”, provide panel-mounted gauges for compressor suction pressure (or temperature) and compressor discharge pressure (or temperature).

4. Safety Shutdowns: High refrigerant discharge pressure, low refrigerant suction pressure, low oil pressure and high motor temperature.

2.9 AIR DRYERS - REFRIGERATED THERMAL MASS TYPE

A. Description: Thermal mass, flooded type, cycling chiller air dryer with air-to-air heat exchanger for pre-cooling inlet air/reheating leaving air, a water-cooled refrigerant condenser, a thermal mass heat exchanger (air-to-thermal mass) and a refrigerant evaporator (refrigerant-to-thermal mass). Sealed refrigeration system shall be fully charged and tested at the factory. Supplied with all interconnecting piping, wiring, controls and components mounted on an open frame skid. Quantity and capacity as scheduled on the Drawings.

B. Performance: Dry saturated inlet air at 100 PSIG and 100 deg. F to a NFPA Class H pressure dew point (33 deg. F to 38 deg. F) and capable of operation from 0% to 100% of rated capacity without freezeup. Total air side pressure drop shall not exceed 3 PSI at rated capacity. Dried air shall be reheated to within 12 deg. F of the temperature of air entering the dryer. Entering temperature of condenser water will not exceed 85 deg. F Suitable for operating air pressure of 150 PSIG minimum.

C. Refrigeration System: Cycling type using R-22 refrigerant. Semi-hermetic compressor with crankcase heater, filters/strainers, suction (or liquid) dryer, liquid refrigerant receiver, refrigerant suction accumulator, liquid line sight glass and over-pressurization relief valve. Capacity control via a minimum of 2 solenoid-operated compressor suction valve unloaders and a modulating thermal expansion valve.


E. Thermal Mass System: Water and propylene glycol solution circulated by a centrifugal pump with mechanical seal. Thermal mass piping and heat exchanger capacity shall be sized to allow no more than 6 refrigeration compressor starts per hour. System to include makeup tank with level gauge and fill/vent connection, service shutoff valves at the inlet and outlet of the circulating pump, pump suction strainer and all interconnecting piping.

F. Moisture Separator and Automatic Drain Valves: In accordance with this Section. Provide automatic drain valve at the evaporator outlet, separator drain, and any other location where moisture may collect.

G. Insulation: Provide minimum ½ inch thick closed-cell neoprene insulation, with 2 coats of an approved protective coating, on all heat exchangers, separators and interconnecting
air and refrigerant piping to eliminate condensation on exterior surfaces. See Specification Section “Mechanical Insulation” for requirements.

H. Control Panel: Comply with UL 508, “Industrial Control Equipment”. Enclosure shall be Type 12 accordance with NEMA ICS 6, “Industrial Control and Systems: Enclosures” and factory-installed and connected as an integral part of the dryer package.
   a. Control Voltage: 120 VAC via integral control power transformer.
   b. Motor Overload Protection: Overload relay in each phase.
2. Indicator Lights: Power on, compressor on, high air temperature alarm.
3. Indicators: In addition to instrumentation specified in Section “Meters and Gages”, provide panel-mounted gauges or other indicators for compressor suction pressure (or temperature), compressor discharge pressure (or temperature), inlet air temperature, inlet air pressure, outlet air pressure, thermal mass temperature and cooling water supply temperature.
4. Safety Shutdowns: Provide necessary primary devices for first-out annunciation and shutdown on high inlet air temperature/pressure, high thermal mass temperature, high refrigerant suction/discharge temperature, high refrigerant discharge pressure, low oil pressure, high motor temperature, and compressor overload.

I. Dewpoint Analyzer: Provide one dewpoint measuring system to measure dried air dewpoint at the outlet of each dryer. System shall include probe, control panel and interconnecting wiring. Control panel shall include digital display of dewpoint. System shall provide a 4-20 mAADC output to compressor control system for monitoring, alarming and control purposes.

2.10 AIR DRYERS, DELIQUESCENT TYPE

A. Description: Single tower, charged with an absorbent desiccant, in capacities and with characteristics indicated. Equip with drain connection.

2.11 ACCESSORIES

A. General: Include accessories with working-pressure rating not less than system pressure at location where used, and compatible with equipment and piping system used.

B. Intercoolers: Air-cooled, fixed-bundle, tubular intercoolers, rated at 250 psig and leak tested at 350 psig minimum air pressure, in capacities indicated. Size units to cool compressed air in compressor-rated capacities to 10 deg F above summertime maximum ambient temperature.

C. Intercoolers: Water-cooled, fixed-bundle, tubular intercoolers, rated at 250 psig and leak tested at 350 psig minimum air pressure, in capacities indicated. Size units to cool
compressed air in compressor-rated capacities to 10 deg F above summertime maximum water temperature.

D. Separators: Conical-shaped, centrifugal air-line separators in sizes and capacities indicated. Equip with water-removal trap and drain. Size units for maximum pressure drop through units of 3 psig from air inlet to outlet.

E. Receivers: ASME stamped; cylindrical, vertical or horizontal installation as indicated; galvanized steel; with safety valves in sizes, working pressures, and temperatures indicated, and with drain connection.
   1. Pressure Rating: Not less than maximum discharge pressure.

2.12 SPECIALTIES

A. Safety Valves: ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels" construction, National Board certified, labeled, and factory sealed; constructed of bronze body with poppet safety valve for compressed-air service.
   1. Pressure Settings: Higher than discharge pressure and same or lower than receiver pressure rating.

B. Automatic Drain Valves: Corrosion-resistant metal body and internal parts, rated for 200-psig minimum working pressure, capable of automatic discharge of collected condensate.

C. Pressure Regulators: Bronze body, direct acting, spring loaded, manual pressure-setting adjustment, and rated for 250-psig inlet pressure, except where otherwise indicated.
   1. Type: Diaphragm operated.
   2. Type: Pilot operated.

D. Pressure Regulators: Aluminum alloy or plastic body, diaphragm operated, direct acting, spring loaded, manual pressure-setting adjustment, and rated for 250-psig inlet pressure, except where otherwise indicated.

E. Filters: 2-stage, mechanical-separation type, air-line filters in sizes and ratings indicated. Equip with deflector plates; resin-impregnated-ribbon-type filters with edge filtration, 40 micron thick; and drain cock.

F. Coalescing Filters: Capacities and types indicated. Equip with activated carbon capable of removing water and oil aerosols, with color-change dye to indicate when carbon is saturated and warning light to indicate when selected maximum pressure drop has been exceeded.

PART 3 - EXECUTION

3.1 CONCRETE BASES

A. Install concrete bases of dimensions indicated for air compressors and accessories. Refer to Division 3 Section "Cast-in-Place Concrete" and Section 15050 "Basic Mechanical Materials and Methods."
SECTION 15251

GENERAL SERVICE PACKAGED AIR COMPRESSORS AND RECEIVERS

3.2 SHOP TESTS

A. Each complete compressor unit with job driver shall be tested by the Seller at his factory to determine its compliance with these specifications. Performance of the machine shall be tested by checking bearing temperatures, lubrication, vibration, flow rates and other pertinent mechanical and electrical measurements. Power consumption and flow rates shall be measured in accordance with the latest applicable A.S.M.E. Power Test Code. Test conditions shall be mutually agreed upon. At the specified volume flow and inlet conditions, the specified discharge pressure shall be met or exceeded; and the power consumption, when corrected to the specified pressure and flow conditions, shall not exceed the quantities shown in the bidder's proposal by more than 4%. In the event that the compressor fails to perform in accordance with this guarantee, the Seller shall make such modifications as are necessary to comply.

B. Acceptance or successfully passing shop tests shall not constitute a waiver of requirements to meet the field tests under specified operating conditions, nor does it relieve the Seller of any of its obligations under the Contract.

C. The Purchaser reserves the right to observe and witness the above shop tests, and 14 days advance notification of all testing shall be given to the Purchaser should he desire to be present. Certified copies of test results shall be submitted to the Purchaser in triplicate.

3.3 DISASSEMBLY AND SHIPMENT

A. Upon completion of testing at the Seller's plant, the equipment shall be disassembled as necessary for shipment and all disassembled parts shall be match-marked to facilitate erection in the field. All components shall be suitably braced, protected and packed for shipping to prevent breakage, contamination or distortion while in transit.

B. Unless exception is taken in the bid, each air compressor unit consisting of compressor, gear, motor driver, intercoolers, and all control items, piping and wiring directly attached thereto and mounted on the unit baseplate, shall be shipped as a single unit. The inlet air filter (with clean air plenum), control panel and off-skid items shall be shipped separately.

C. All crates, boxes and cartons shall be clearly marked in order to identify their contents. Shipping invoices shall show the crate, box or carton identification number.

D. Shipping sections shall allow convenient handling.

E. Notify Owner of exact shipment and arrival dates, method of shipment, and provide copies of unloading instructions one week prior to arrival.

3.4 INSTALLATION OF DEVICES

A. All devices shall be installed as required for an operational system and calibrated. In addition, the following precautions shall be followed and equipment shall be provided:
1. Except as noted below, all RTD’s shall be installed in thermowells. RTD’s used for space or ambient temperature sensing shall include a housing suitable for wall mounting which shall shield the sensor from sources of radiation. RTD assemblies shall be readily accessible and installed to allow easy replacement.

2. Pipe temperature sensors shall extend to the center of the pipe and shall be located at least ten pipe diameters downstream of any converging (mixing) pipe flows.

3. Temperature switches shall be installed in a manner similar to RTD’s.

4. All pressure taps in piping shall be provided with root valves.

5. Pressure transmitters installed on liquid lines shall have drains. All pressure transmitters shall have 2-valve manifolds and all differential pressure and flow transmitters shall have 3-valve manifolds. Manifolds shall be 316 stainless steel, flange-mounted to transmitters and designed for pipe stand mounting.

6. Pressure switches and differential pressure switches shall be installed as specified for pressure transmitters and differential pressure transmitters.

7. Impulse piping to pressure and flow instruments shall be 1/2 inch diameter, 0.035” wall, 316 stainless steel with stainless steel compression fittings. Provide self-venting, self-draining installations with low point drains having stainless steel ball type blowdown valves (dirt legs) in all lines and high point vents in liquid lines where required.

8. Relays and contactors shall be installed in the LCPs. Solenoid-operated valves and current to pneumatic transducers shall be installed in the field.

9. Compressed air flow measuring devices shall be installed in locations such that measurement accuracy is maximized and in accordance with ASME Fluid Meters Handbook. Temperature sensors for flow rate compensation shall be installed downstream of the flow element so as to not disturb the reading.

3.5 ELECTRICAL INSTALLATION

A. All wiring, conduits, panelboards, etc. required to provide power for the individual equipment items shall comply with the National Electric Code (NEC), and other applicable codes. All other electrical wiring shall comply with the NEC, and other applicable requirements and shall be installed by licensed journeyman electricians.

B. 120 Volt and 480 Volt wiring shall not be installed in the same conduit.

C. Control wiring shall be installed according to the following provisions:

1. All control wiring, 120 Volt wiring and network wiring shall be installed in conduit in accordance with Division 16.

2. AI, DI, AO and low voltage DO wires may be routed through a single conduit.

3. Singular or multiple 120 Volt DO wires may be routed uniformly through a single or multiple conduits. High voltage (120 Volt) DO wiring shall not be installed in the same conduit as AI, DI, or AO wiring.

4. Network wiring shall be installed in dedicated conduit with no other wiring.

3.6 EQUIPMENT INSTALLATION

A. Installation of Equipment: Comply with ASME B19.1 or ASME B19.3 as appropriate.
B. Install air compressors, intercoolers, aftercoolers, air-receiver tanks, and dryers on concrete bases. Set and connect units according to manufacturers' written instructions. Install units plumb, level, and firmly anchored in locations indicated. Maintain manufacturers' recommended clearances. Orient so equipment, controls, and devices needing service are accessible.

C. Anchor air compressors, receivers, and other equipment to substrate.

D. Install seismic restraints as indicated.

E. Support air compressors using the following vibration-control devices, unless otherwise indicated. Refer to Section 15074 "Vibration and Seismic Control for HVAC Piping and Equipment".
   1. Install tank-mounted compressors, 5 hp or less, with spring isolators.
   2. Install tank-mounted compressors, more than 5 hp, with concrete inertia base and spring isolators.
   3. Install base-mounted compressors with concrete inertia base and spring isolators.
   4. Install other rotating equipment with spring isolators.

F. Install accessories and specialties as indicated. Set and connect units according to manufacturers' written instructions. Install units plumb, level, and firmly anchored in locations indicated. Maintain manufacturers' recommended clearances. Orient so controls needing service are accessible.

3.7 CONNECTIONS

A. Install piping next to equipment and accessories to allow service and maintenance.

B. Connect air piping to equipment and accessories with unions and shutoff valves. Install with strainers where indicated.
   1. Install thermometers on compressor discharge piping, on receiver tanks, and where indicated.
   2. Install pressure gages on compressor discharge piping, on receiver tanks, and where indicated.

C. Connect water piping to air-compressor water jacket, intercooler, and aftercooler units with union and reduced-pressure-zone-type backflow-preventer assembly having strainer, gate valves, and air gap fitting for indirect waste. Connect each unit with separate drain with union and shutoff valve, and discharge over closest floor drain.

D. Install safety valves in receiver tanks, in quantity and size to relieve capacity not less than that of connected compressor.

E. Install automatic drain valves on intercoolers, aftercoolers, separators, receivers, dryers, and other locations indicated. Discharge condensate over nearest floor drain.

F. Install accessories as indicated.
G. Ground equipment.
   1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. Where manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

H. Arrange for electric-power connections to equipment that requires power. Electric power, wiring, and disconnect switches are specified in Division 16 Sections.

3.8 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Provide services of a factory-authorized service representative to supervise the field assembly of components and installation of equipment, including piping and electrical connections, and to report results in writing.

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.9 COMMISSIONING

A. Refer to Section 15995 “Commissioning of Mechanical Systems”. As a minimum, perform the following final checks before startup:
   1. Verify that specified tests of piping systems are completed.
   2. Check that direct potable-water supply connections to equipment have correct type backflow preventer in water supply.
   3. Check for piping connection leaks.
   4. Check for lubricating oil in lubricated-type equipment.
   5. Check V belts for proper tension.
   6. Check that compressor inlet filters and piping are clear.
   7. Check for equipment vibration-control supports and flexible pipe connectors and that equipment is properly attached to substrate.
   8. Check safety valves for correct settings. Ensure settings are greater than air-compressor discharge pressure, but not greater than rating of system components.
   9. Check for proper seismic restraints.
   10. Test operation of equipment safety controls and devices.
   11. Drain receiver tanks.
   12. Check for adequate room ventilation.

B. Starting Procedures: Follow manufacturer's written instructions. If no instructions are prescribed by manufacturer, proceed as follows:
   1. Energize circuits.
   2. Start and run equipment through complete sequence of operations.
   4. Check air pressures.
   5. Manually operate safety valves.
   6. Adjust operating controls, including pressure settings.

C. Operate and adjust operating and safety controls. Replace damaged and malfunctioning controls and equipment discovered by service representative.
D. Upon completion of the installation, each centrifugal compressor shall be surge tested to establish an actual, accurate surge limit line and the performance characteristics of each unit.

E. Upon completion of the installation, the Contractor shall start up the system and perform all testing and debugging operations. An Acceptance Test shall be performed in the presence of the Purchaser’s representative. This test as a minimum shall verify one continuous month of completely automatic and stable system operation, without an unexplained point failure or alarm.

F. Modified field tests, pertaining to power requirements, speed, and capacity, etc., shall be run under supervision of the Seller. Results of such tests shall be recorded and shall be submitted to the Purchaser in triplicate.

3.10 DEMONSTRATION

A. Startup Services: Engage a factory-authorized service representative to perform startup services and to demonstrate and train Owner's maintenance personnel as specified below.

1. Train Owner's maintenance personnel on procedures and schedules related to startup and shutdown, troubleshooting, servicing, and preventive maintenance.

2. Review data in the operation and maintenance manuals. Refer to Division 1 Section "Contract Closeout."

3. Review data in the operation and maintenance manuals. Refer to Division 1 Section "Operation and Maintenance Data."

4. Schedule training with Owner with at least 7 days' advance notice.

END OF SECTION