PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. This Section applies to the design, manufacturing and testing of the CNG compressors for the compressed natural gas station.

2. The Work includes mechanical and electrical fabrication work and programming required in the shop fabrication of the CNG compression equipment.

B. Related Sections:

1. Section 18000 - All

1.02 QUALITY ASSURANCE

A. Manufacturer Qualifications:

1. Equipment manufacturers shall have at least 10 years experience in manufacturing products and accessories similar to those specified for this Project, with a record of successful in-service performance.

B. Vibration and Pulsation Analysis:

1. A professional regularly engaged in vibration analysis shall supervise the vibration measurements and interpret the results.

1.03 SUBMITTALS

A. Submit in accordance with Section 18000, General:

1. Product data for products and materials in this section.

a. Include for oil carry-over control, the percentage of oil added that will be recovered in the filtration system before the gas leaves the compressor skid.

b. Submit operations and maintenance data in accordance with applicable provisions of Section 18000:

1) Include sections of the compressor not bled down by the service valve.

2. Manufacturer’s qualifications: Provide documented

a. Evidence of oil carry-over performance from other projects.

b. Proposed methodology to achieve performance levels for the station.

3. Testing: Vibration and pulsation levels of equipment used in previous installations.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Comply with the following:

1. Compressors shall be shipped to site only once after the pad has been completed and is ready for permanent installation. Equipment not ready for installation shall not be stored on site.

1.05 PROJECT SITE AND DESIGN CONDITIONS

A. Design Conditions:

1. Number of compressors-Base bid One simplex package for a total of one compressor—note that the system shall be designed to accommodate the future installation of one additional compressor.

2. Inlet Gas Flowrate (total) 500 scfm per compressor at dryer outlet pressure (with station inlet pressure of 60 psig). Proposers are required to fully utilize the main driver horsepower at maximum station inlet pressure. Proposers are encouraged to provide higher flow solutions if these can be achieved at nominal additional cost.

3. Minimum Process Flow Pipe Size-Inlet Three-inches.

PART 2 - PRODUCTS

2.01 SYSTEM DESCRIPTION AND PERFORMANCE OF CNG COMPRESSOR

A. Simplex compressor skid shall be fully packaged and enclosed.

B. Equipment mounted on the skid including the compressor frame, the compressor crosshead, the compressor cylinders, the cooler, the motor, the piping, separators, filters and vessels and control panels shall be mounted as close to grade as practical and supported directly from the frame. Mounting of this equipment to the deck plate is not acceptable. Provision shall be made to allow for shimming of the compressor. If floor decking is used, access holes with minimum six-inch diameter sleeves to facilitate shimming and grouting shall be provided into each frame cavity.

C. The output of the compression equipment shall be rated at a minimum of the flowrate specified above for each compressor at the pressure downstream of the CNG dryer at typical station inlet and 4,500 psig discharge. The potential range of pressures on the incoming gas service line is provided in Section 18000. The compressors shall float continuously without adjustment through this range. (Note that these suction pressures are at the station inlet and not the actual compressor suction). If the compressors cannot float through the entire range, a regulator or

pressure controller must be provided on each compressor to limit the maximum pressure to prevent excessive rod load or power requirements. This regulator or pressure controller must allow free flow below its setting so that the compressors utilize the pressure available. The setting of this device shall be specified.

D. Compressors shall be rated for continuous and intermittent/transient operation.

E. Compressors to be multi-stage reciprocating compressors. On opposed machines, individual throws will be balanced to within 16 ounces of the opposing throw.

F. Interstage temperatures shall not exceed 325 deg F. A minimum four stages of compression are required.

G. Crankcases shall be lubricated by a pressurized lubrication system.

H. Cylinders are to be lubricated unless the Proposer can demonstrate a recent history of success with non-lubricated service. This will require the Proposer to provide with their bid, documented evidence of successful and reliable operation of at least 10 CNG compressors installed in the past 24 months in North America with consistent ring and packing life of at least 4000 hours. Evidence must address the methodology used to provide high ring life including ring materials, bore/piston clearance and hardening, piston speeds, maximum temperatures and other design data deemed necessary by the Consultant.

I. Oil carryover control: As a minimum, each compressor package shall include:

1. The final coalescing filters on lubricated machines shall be a pre-coalescer and a coalescer filter in series for each compressor. Each filter shall be sized to handle a minimum of four times the maximum compressor capacity at maximum suction conditions and a discharge pressure of 1,000 psig. (Minimum acceptable filter shall be a Parker J-6.) On non-lubricated compressors, a single coalescing filter with manual drain and sized to handle a minimum of four times the maximum compressor capacity at maximum suction conditions and a discharge pressure of 1,000 psig. (Minimum acceptable filter shall be a Parker J-6.)

2. The compressors shall use a PAG based synthetic oil for crankcase and lubricator that is rated for this service by the oil manufacturer. (Lubricated designs only)

3. Proposers are to specify with their bid, the percentage of oil added that will be recovered in the filtration system before the gas leaves the compressor skid.

4. Oil shall be fed to the lubricator pump from the crankcase sump (Lubricated compressors). On atmospheric pressure crankcase machines, the crankcase oil level will be continuously replenished from a 5 U.S. gallon “day tank” with sight glass. Each compressor that includes an external oil injection pump (not required on pressurized crankcase compressors) must be equipped with:

a. An explosion-proof or intrinsically safe low lube flow rate switch, and

b. An explosion-proof or intrinsically safe oil level switch.

J. Control, safety and isolation valves:

1. One manual two or three piece fire rated ball valve (API 607) shall be installed immediately outside of each package. Valves to be carbon steel body and stainless steel trim and a locking kit. Valves shall be ANSI 150 flanged body.

2. A wafer style suction check valve with a carbon steel body, stainless steel trim and an O-ring seal (bubble tight) shall be installed on the suction line to each compressor.

3. A spring return (NC) actuated two or three piece fire rated ball valve (API 607) with a carbon steel body and stainless steel trim shall be installed on the suction line upstream of each compressor inlet.

4. Each separator shall include its own check valve and a normally open (NO) actuated ball valve with its own pilot solenoid valve to control drainage of condensates from each stage separator or filter independently. Separators and filters shall be flushed hourly and also on shutdown of the compressor to the recovery tank(s).

5. The final compressor discharge shall be equipped with a check valve.

6. One high pressure manual ball valve shall be installed immediately outside of each package. Valves to be stainless steel body and stainless steel trim and a locking kit. Valves shall be compression connection or SAE thread.

7. Compressor suction, recovery system and each stage shall be equipped with an ASME "UV" stamped safety relief valve set and sealed at the design pressure. SRVs on air receivers or other air equipment shall be equipped with a manual activation lever. This is not permitted on other SRVs.

   a. For SRVs located between the compressor inlet and discharge, inlet and outlet ports of SRVs shall be equipped with integral ANSI flanges or compression fittings with tube adapters of appropriate pressure rating, which will ensure that the valves can be reinstalled repeatedly without damage or difficulty in returning the valve to the exact orientation, prior to removal.

   b. For the SRV located on the recovery system, a manual, locked open, isolation ball valve shall be provided upstream of the flanged inlet port to the SRV.

8. Manual, stainless steel service drain valve (rising plug or gauge valve type) shall be provided between sections of piping, and vessels to allow them to be safely blown down to the vent stack. Any sections of the compressor not bled

down by the service valve shall be clearly identified in the maintenance procedures.

K. Suction and Interstage Gas Filtration and Pulsation Control:

1. Suction filter complete with minimum 0.9 micron absolute filter cartridge. Suction filters and valves must be sized so that the pressure drop shall not exceed two psig at a flowrate of 1.5 times the maximum compressor capacity at maximum suction conditions. If the recovery line is tied into the suction line upstream of the filter, without a coalescing filter, a coalescing, high efficiency, sub-micron oil removal type filter, designed to remove aerosols, liquids and solids down to 0.9 microns absolute size and 0.0014 ppmw oil concentration is required. The filter drain port shall be equipped with a manual, lockable isolation valve and tied to the condensate collection tank through a separate drain line.

2. Each compression stage shall be equipped with a properly sized knockout, mesh pad, or vortex separator to remove oil and condensates. This separator shall be mounted after each cooler stage. Piping and coolers shall be oriented to be self draining to the separators, without inadvertently trapping condensate within sections of pipe or cooler.

3. Suction and/or discharge pulsation bottles/dampeners shall be provided as per compressor block manufacturer's recommendations.

L. Cooler Requirements:

1. Each stage shall be equipped with an ASME Section VIII, Division 1 Coded Cooler. (As an alternative a serpentine cooler will be accepted.) This cooler shall have sections for each stage of compression, and for the crankcase oil.

2. Approach Temperature: Coolers shall be designed and sized to reduce the cold side interstage gas temperature to 20°F above ambient temperature at maximum compressor cylinder discharge temperature and maximum ambient temperature.

3. Heat exchangers shall be oversized a minimum of 10 percent to compensate for fouling and damaged passes (which require plugs). Thus the cooler must be able to meet the specified approach temperature with 10 percent of the tubes plugged, on all stages.

4. The cooler shall be thoroughly cleaned and purged to ensure that contaminants and hydro testing water are removed.

5. The main cooler fan(s) shall be direct driven from a 480 VAC electric motor.

6. The noise generated by a single cooler fan and motor alone (i.e. without sound attenuation equipment) shall not exceed 85 dBA at three feet in open field conditions.

7. Impellors shall be aluminum or plastic composite construction.

8. The cooler shall be equipped with an explosion proof or intrinsically safe vibration switch.

M. Piping and Pressure Retaining Components:

1. Minimum process flow tubing size on discharge side of compressor is 3/4-inch for a 500 scfm compressor.

2. Interstage coolers, piping, separators and appurtenances shall be designed for 350 deg F and a minimum of 20 percent or 50 psi (whichever is greater) above the interstage discharge pressure at maximum suction pressure and 4500 psig discharge pressure. All of these devices shall be stamped and certified for the actual maximum design pressure of the device rather than the calculated required pressure. (For example if a vessel is required to be rated for 600 psig but is actually capable of 680 psig using ASME design standards, the vessel shall be stamped for 680 psig.)

3. Final discharge cooler, piping, separators and appurtenances shall be designed for 350 deg Fahrenheit and a minimum of 5,000 psig.

4. Piping, instrumentation tubing, electrical conduit and devices shall be routed and installed to allow for full access for inspections and repairs of the cooling coils.

5. Coolers and downstream piping shall be designed, constructed and oriented such that all liquids (condensate and oil) will drain by gravity from the cooler inlet to the suction separator of the next stage.

N. Gas recovery system:

1. A "run down" sequence is not acceptable except on high suction pressure machines where permitted by the Consultant.

2. Gas vented during the unloading cycle shall be captured in an ASME Section VIII, Division 1 vessel(s) and cycled back to the compressor suction on the next start up. The recovery receiver shall be sized to contain all gas released from two shutdowns and no recirculation between shutdowns without relief valve activation under any circumstances. Where multiple tanks are used, gas is to be vented into one near the bottom, flow out of the first near the top and into the second at the bottom, then out of the second near the top to the next tank or to compressor suction. Contractor shall supply calculations to validate recovery tank size.

3. A manual, lockable, isolation ball valve shall be provided on the inlet of the first recovery tank and on the outlet of the final recovery tank.

4. A recycle pressure controller or regulator shall be provided downstream of the manual isolation valve on the outlet of the final recovery tank and its pressure

drop shall not exceed five psig at a flowrate of twice the maximum compressor capacity at maximum suction conditions. This pressure controller shall be controlled by the Unit PLC using a 4-20 mA output.

a. A NC actuated, carbon steel or stainless steel ball valve with stainless steel trim shall be mounted downstream of the recycle pressure controller at the connection to the suction line which shall be upstream of the suction pulsation dampener.

b. The line from the recovery tank to the suction shall be sized to allow continuous recycle flow of the compressor when the compressor is running unloaded.

O. Controls and Instrumentation:

1. Each compressor package shall be equipped with a Unit Control Panel (UCP) and instrumentation as indicated in Section 18550, Control Systems. The UCP shall be mounted to facilitate easy field connection and service.

2. Compressor suction, discharge at each stage, final discharge (downstream of discharge check valve), recovery system, pilot air and compressor crankcase oil system shall be equipped with remotely mounted, glycerin filled, 2-1/2 inch pressure gauges. Instrumentation tubing shall be included.

3. Compressor suction, discharge at each stage, final discharge (downstream of discharge check valve), recovery system, pilot air and compressor crankcase oil system shall be equipped with explosion proof or intrinsically safe pressure transducers. A manual, lockable, isolation valve shall be provided for the recovery system pressure transducer. The compressor crankcase oil system pressure transducer shall be mounted as close as possible to the compressor. All other pressure transducers shall be mounted remotely. Instrumentation tubing shall be included.

4. The discharge from each stage, ambient temperature, compressor oil, and the enclosure interior shall be equipped with Type J thermocouples or RTD equipped with a stainless steel armored sheath and cable. Thermocouple wires shall run continuous to their termination point on the UCP PLC thermocouple card.

5. The compressor shall be equipped with an explosion proof or intrinsically safe vibration switch.

P. Enclosure:

1. Each compressor shall be housed in an enclosure. The enclosure shall shield the compressor and auxiliary equipment from climatic conditions. The enclosure shall be provided with adequate ventilation to prevent heat or gas build up and reject heat generated by the compressor and after cooler.

2. The enclosure shall be designed to limit acoustic emissions from the package by the use of noise attenuating insulation, baffles, silencers, soundproof doors, panel gasketing and low noise fans. Maximum sound emission is to be 75 dBa at 15 feet from the shelter.

3. Minimum required construction of the compressor shelter includes:

    a. The enclosure is to be designed to be robust and provide a 20 year life without issues of corrosion or wear or leakage of rain. Doors are to be mounted with hinges designed for site adjustment and designed to support a door at least twice the weight of the doors used. Hinges are to be designed to be either self-lubricating or to have external provision for lubrication. Door sagging will not be accepted.

    b. Wall and roof constructed of primed and painted galvanized steel outside panels. If inside panels are used, they shall be perforated galvanized panels.

    c. Dampers are to be extruded aluminum with gasketed tips.

    d. Openings shall be gasketed and/or sealed, except those required for air flow which shall be equipped with silencers.

        1) Insulation in silencers shall be protected from external damage using polyester or nylon fabric between the insulation and the perforated steel panels or as approved by Owner.

4. Air openings shall be equipped with bird screens or other guards to prevent birds and other animals from entering the package.

5. Sufficient access shall be provided using doors and hatches to perform routine or major work on the compressor (e.g. SRV replacement, cooler tube inspection, cooler fin cleaning, oil changes, belt replacement, ring and valve replacement, control valve replacement, compressor frame and cylinder rebuilds), without removing or disassembling the enclosure. Door holdbacks shall be provided on each door.

    On horizontal air flow fans, a minimum clearance of 18 inches shall be provided between the cooler and silencers/baffles to allow for cooler fin cleaning. Service access for infrequent repairs required less than once per year shall be provided by either a door or a removable panel (e.g. installation of cooler plugs, removal of a cooler or section for repair).

6. Materials shall be non combustible or fire rated materials. This shall include insulation, interior and exterior panels, roof, floors and doors, and enclosure framing members.

7. A 480 VAC 3 phase electric exhaust fan shall be provided in the enclosure. Fan shall be activated if the temperature inside the enclosure exceeds 110

deg F and the compressor is not operating, and shall be sized to ensure that with 100 deg F ambient air, that the air temperature inside the shelter does not exceed 120 deg F. The fan shall also be activated by a manual purge switch on the unit control panel door and by the MCP in the event of a gas detection event. The cooler fan(s) may be used to provide this function.

8. Two Class I, Division 2, Group D explosion proof lighting fixtures shall be provided inside each enclosure.

9. Compressor crankcase shall be equipped with an explosionproof, electric immersion heater. This heater shall be the maximum wattage allowed by the compressor manufacturer.

10. Compressor enclosure shall be equipped with space heaters if required by climatic conditions to ensure that equipment starts and operates reliably at the lowest ambient conditions.

Q. Main and secondary motors:

1. The prime mover shall be an 1,800 rpm electric motor with continuous nameplate horsepower rating equal to or exceeding the maximum compressor and connected ancillary equipment horsepower requirement.

2. Compressors and main motors shall be direct coupled without gear reduction using a flex disc coupling, or approved equal. This coupling shall be designed for continuous cyclic loading. Provide a compressor mounted flywheel to reduce the amplitude of torsional variances.

3. Compressors of 300 horsepower or less may be belt driven.

R. Miscellaneous Requirements:

1. The compressor shall be equipped with a prelube pump. The prelube pump shall be rated for continuous 24 hour per day 7 day a week operation. Under ambient conditions of 30 degrees Fahrenheit (site setable) or above, the pump shall start and run only for a limited period of time to establish compressor crankcase lubrication prior to compressor startup. Under ambient conditions below 30 degrees Fahrenheit (site setable), the pump shall start automatically and run continuously to distribute heat from the immersion heater and to ensure compressor startup when required. Under ambient conditions below 30 degrees Fahrenheit (site setable), the pump shall shut off automatically 30 seconds after compressor start and shall remain off for 30 minutes (site setable) after compressor operation.

2. Guards including fan and belt guards shall be OSHA compliant and shall be of a spark proof construction.

2.02 MANUFACTURERS

A. Compressor Packages shall be designed and manufactured by:

1. ANGI Energy (packaging Ariel Compressors)
2. Atlas Copco (Greenfield Compression) (packaging Sulzer Compressors)
3. Cobey
4. IMW
5. JW Operating (packaging Ariel Compressors)
6. Approved equal, if requested a minimum of 14 days prior to bid closing.

2.03 MATERIALS

A. Guards over moving parts shall be non-sparking aluminum construction meeting all OSHA requirements.

PART 3 - EXECUTION

3.01 SHOP AND FIELD QUALITY CONTROL

A. Mechanical/Acoustical Vibration Analysis and Testing:

1. If the compressor package supplier has produced identical packages in past projects, operating under essentially the same conditions, and the packager can supply documented test data to prove that vibration and pulsation levels on the equipment are within the specified requirements, the analysis portion of this Section will not be required. Third party field tests are required during commissioning/testing to verify that the equipment meets the specified values.
2. A professional regularly engaged in vibration analysis shall supervise the vibration measurements and interpret the results.
3. Test the installed compressor and site piping and make modifications to meet the requirements of this specification.
4. The vibration measuring instruments shall be capable of narrowband frequency analysis from 1 Hz to 50X running speed. They shall be capable of summation averaging for a time period of 30 seconds minimum at all frequencies.
5. Provide instrumentation and make measurements to prove the mechanical integrity of the equipment.
6. Hard copy plots of the vibration amplitude versus frequency of each measurement point shall be supplied to Owner. The shaft speed shall be identified on these plots.
7. In addition to the requirements outlined herein, provide suction, interstage and discharge pulsation vessels, orifice plates and the like as specified by the

compressor manufacturer or as required to meet their recommended pulsation and vibration limits.

8. Piping:

   a. The entire range of operating conditions (loaded operation from minimum to maximum suction pressure and from 1,000 psig to 4,500 psig discharge pressure as well as unloaded operation) shall be modeled.

      1) As a percentage of average absolute line pressure, shall be limited to seven percent or 3R percent (R = stage pressure ratio), whichever is lower.

      2) Pulsation generated unbalanced forces shall be evaluated in all piping and shall be less than 100 lbs peak-peak X nominal pipe size to maximum of 1,000 lbs peak-peak for frequencies up to 30 Hz. At frequencies above 30 Hz the maximum level shall be decreased in a manner similar to the line side pulsation guideline specified in API 618 (i.e. the square root of 30/frequency).

      3) The mechanical vibration levels of the piping on the assembled and installed compressor package and the site piping shall not exceed the lesser of 10.0 mils peak to peak displacement, 1 inch/sec peak velocity or 2 G peak acceleration with the compressor running at normal operating speed.

9. Rotating Equipment:

   a. The equipment vibration amplitude at all frequencies shall not exceed the lesser of 5.0 mils peak to peak displacement, 0.2 in/second peak velocity on rotating equipment, 0.4 in/second peak velocity on reciprocating equipment or 1 G peak acceleration with the compressor running at normal operating speed.

   b. The vibration amplitude may be plotted in acceleration, velocity or displacement; however the limits outlined above shall be clearly identified at each frequency of interest.

B. Shop Testing:

1. Cycle valves under maximum operating pressure by actuating solenoids.

2. Function test to check operation of controls systems, system annunciation, safety alarms and shutdowns, coordinated with others.

3. Calibration of instrumentation.

4. Operations of subsystems including ESD and remote alarms.

5. Successful compressor operation at full and partial load on test loop for eight hours.

6. Performance tests to check motor voltage, current draw and power.

C. Field Testing During Commissioning:

1. Mechanical reliability of componentry.

2. Verification of controls logic and wiring.

3. Verification of safety and control device calibration and program logic.

4. Successful operation for 100 loaded compressor hours on each compressor within predicted performance parameters (pressures, temperatures, flow, noise, pulsation and vibration). If the package operates out of specified performance levels, or if nuisance shutdowns occur during this period, correct the underlying problem and the test period shall be restarted.

5. The above flow test will require isolating each compressor with no buffer or other compressor on line and flowing through a single calibrated dispenser to fill a bus. Flow in scfm will be calculated based on the weight of the gas dispensed. Ambient temperature, gas flow temperature and compressor inlet pressure are to be recorded. This data is to be compared to data provided with the proposal. Compressor flow shall be not less than 97 percent of predicted flow.

6. Provide a site test of vibration levels of piping, vessels and other major components (compressor, cooler, motor) for each compressor after startup. This site test will be evaluated to confirm compliance with specified vibration levels.

7. Performance tests to check motor voltages, current draws, and power distribution to other components. Verify all circuits are operational.

8. In-situ noise testing to confirm that CNG compressor package noise levels are within the levels permitted by this specification.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. No separate measurement or payment will be made for the work required by this section. The cost for this portion of the Work will be considered incidental to, and included in the Lump Sum price bid for the Project.

End of Section