Title
ESCAR HELIUM REFRIGERATOR COMPRESSOR SET

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1.0 Scope

This specification covers the supply of two (2) direct drive helical rotary screw compressors with oil injection. The units shall be refrigeration type machines package assembled on a steel base and factory tested.

2.0 Operating Conditions and Performance

2.1 The compressors will circulate dry helium gas, purity < 5 ppm closed circuit, at ambient suction temperatures as high as 70°F. Operating modes for two required conditions are described, although operations need to span 25% to 100% capacity with some reserve capacity. Slide valve controls are required for both machines.

<table>
<thead>
<tr>
<th>Low Stage Compressor</th>
<th>Refrigeration mode</th>
<th>Liquefaction mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet pressure</td>
<td>1.0 atm ± 0.1</td>
<td>1.0 atm ± 0.1</td>
</tr>
<tr>
<td>Discharge pressure</td>
<td>3.0 atm</td>
<td>3.3 atm</td>
</tr>
<tr>
<td>Design mass flow</td>
<td>100 gm/sec (1275 SCFM)*</td>
<td>60 gm/sec (765 SCFM)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High Stage Compressor</th>
<th>Refrigeration mode</th>
<th>Liquefaction mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet pressure</td>
<td>3.0 atm</td>
<td>3.3 atm</td>
</tr>
<tr>
<td>Discharge pressure</td>
<td>18.5 atm</td>
<td>21 atm</td>
</tr>
<tr>
<td>Design mass flow</td>
<td>220 gm/sec</td>
<td>200 gm/sec</td>
</tr>
<tr>
<td></td>
<td>(2800 SCFM/933 ACFM)</td>
<td>(2550 SCFM/772 ACFM)</td>
</tr>
</tbody>
</table>

*SCFM at 1 atm (14.7 psi) and 20°C.

2.2 Both machines shall be the same basic unit to simplify spare parts and maintenance. Minimum displacement shall be 1650 CFM at maximum speed of 3600 rpm, with rotor diameter of 255 mm, L/D ratio = 1.65 and internal compression ratio = 3.7.

2.3 The compressors shall be designed and constructed for continuous service.

2.4 The assembled compressors shall be leak tight at operating pressures with no detectable leaks on the most sensitive scale of a General Electric Halide Leak Detector. Ultimately a helium mass spectrometer will be used by LBL to leak hunt to less than 1 x 10^-6 std. cc/sec. The system shall also be capable of evacuation for charging and subatmospheric suction operation without air leakage.

2.5 Each machine shall have a three-stage oil separator with field replaceable final filter elements. Minimal oil carry-over in the process stream from the high stage compressor is desired, 100 ppm or less, not to exceed 200 ppm by weight.

3.0 Compressor Construction

3.1 All castings shall be high tensile strength, low porosity cast iron designed in accordance with ANSI B 9.1 and hydrostatically tested to
600 psi. All joints shall use O'-rings for positive sealing. Compressor stator shall be double wall for structural rigidity and low noise level.

3.2 Rotors shall be SAE 1035 carbon steel with non-symmetrical rotor profile, sealing strips on each rotor, and matching groove on the male only. Male rotor with four (4) lobes shall be directly connected to the motor. Female rotor shall have six (6) interlobe spaces.

3.3 Rotor radial loads shall be supported by steel backed babbitt sleeve bearings, flange mounted for service ease with chrome plated journals. Thrust bearings shall be angular contact ball bearings. All contact surfaces shall be force fed lubricated. Rotor end thrust shall be balanced with oversized rotor shaft ends.

3.4 Provision shall be made for complete evacuation of all gas passages including inter- and after-coolers and all internal cavities. This will be done with external vacuum pump supplied by LBL. All seals must be double acting holding pressure as well as vacuum.

3.5 The shaft seal shall be a rotating carbon face type located on the discharge end of the low side compressor, suction side of the high side compressor. Seal shall be located in a seal cavity flooded in oil. Oil shall be supplied to the face via a circular groove completely around the carbon face.

3.6 Each compressor shall have a capacity reduction slide valve for 100% to 10% modulation actuated with a hydraulic cylinder and a mechanically positioned pilot valve. The pilot valve shall be moved in response to an electric or pneumatic signal via a small electric motor and ball screw. The system shall provide a means of manually setting a fixed capacity and holding it. To minimize starting loads after shutdown, the slide valve shall be spring loaded for automatic return to unloaded capacity. The capacity control shall be a proportional type for automatic stable operation to minimize hunting. A slide valve visual position indicator is required.

4.0 Lubrication System

4.1 All bearings, shaft seals and the capacity control system shall be force lubricated with an integral oil pump driven off the female rotor. Oil pump circuit shall have dual 10 micron non-collapsible element oil filters, pressure regulating valve, pressure relief valve, and check valves.

4.2 Injection oil delivered to the rotors for sealing and cooling shall be injected at a point after compression begins, although an auxiliary variable supply may be provided at suction. Injection oil circulation shall be by gas pressure differential.

4.3 All oil leaving the sump separator shall be cooled and strained with a 100 mesh strainer before entry to the stator or pump.

4.4 The oil cooler will be water cooled using a cleanable tube and shell exchanger to cool the oil to 105°F with water entering at 85°F. The
cooler shall be designed for 100 psi on the water side and 300 psi on the oil side. Oil temperature shall be controlled with a 2 or 3 way valve sized for the application.

4.5 The oil separator/sump shall have three stages of separation with easily replaced final elements, and shall remove oil to less than 200 ppm. The sump shall have three sight glasses for oil level indication and a 500 watt thermostatic controlled heater to maintain oil temperature during shutdown.

4.6 The oil charge will be purchased and handled separately. Oil selected will be mutually acceptable to LBL and vendor. LBL desires an inexpensive oil with high flash point, low vapor pressure and high density with optimal properties for final separation to less than 0.001 ppm. Synthetic lubricants as made by Tenneco, Monsanto or DuPont are thought to best answer the need.

5.0 Controls and Instruments

5.1 Each compressor shall include a NEMA-1 panel enclosing all control and safety switches. All controls will be functionally tested at the factory.

5.2 Operating controls shall include:
   a. Oil pressure buildup 10 second time delay.
   b. Motor anti-recycle timer and master control relay.
   c. Capacity control pressure switch, relay and timer for rate adjustment.
   d. Selector switch for automatic or manual start-stop.
   e. Start and emergency stop push buttons and safety switch reset button.
   f. Selector switch for manual or automatic operation of capacity control system.
   g. Increase-decrease switch for manual mode of electrically varying capacity.
   h. Separate control and oil heater circuit breakers.
   i. Hand crank for mechanical mode of manually varying capacity.

5.3 Safety controls shall include a motor starter overload relay and manual reset switches for:
   a. High discharge temperature.
   b. High oil temperature.
   c. Low oil pressure differential.
   d. High discharge pressure.
   e. Low suction pressure.
   f. Low oil sump temperature.

5.4 Panel mounted indicators shall include a running time meter and:
   a. Gauges 4.5" dia. for suction pressure, discharge pressure, oil pressure, oil temperature, and discharge temperature. Gauges shall be suitable for evacuation and provided with isolation valves. A three-way valve and/or circuit is required to check oil filter pressure drop.
b. Panel mounted lights shall indicate: Motor on, oil pressure failure, high discharge, low suction, recycle, load-unload capacity and motor load limit.

6.0 Motor and Starter

6.1 Compressor motors shall be squirrel cage induction motors of NEMA design sized to deliver flow rates defined in 2.1. Motor shall have normal starting torque for reduced voltage start; 460 volts, 3 phase, 60 Hertz, with full load speed = 3550 rpm, (2 pole motor). Nominal motor sizes are 175 hp and 750 hp. Motors shall be open drip-proof construction unless a hermetic system is offered. Motor service factor shall be 1.15 unless delivery and/or cost can be improved otherwise.

6.2 Motor starters will be provided by LBL.

7.0 Codes and Fabrication Specifications

7.1 All electrical equipment and wiring of the compressor system shall be constructed in complete accordance with the National Electric Code both as to materials and workmanship.

7.2 All pressure vessels shall be designed, constructed and tested in accordance with Section VIII of the latest ASME Code for Unfired Pressure Vessels. Each compressor shall have a minimum rated pressure of 300 psig on the discharge side and 150 psi on the suction side. Certified test reports are required.

7.3 All piping shall be designed to ASA B31.5A, 1968 of the Refinery Piping Code. All pipe and tubing shall be of seamless construction. All brazing must be "silver brazing" using techniques in accordance with recommendations of Handy & Harman, New York.

7.4 Properly sized and set relief valves shall be provided for the compressor discharge and any circuit which can be isolated and trapped.

7.5 All carbon steel surfaces of equipment shall be prepared and painted according to manufacturing standards.

7.6 All equipment must be designed and installed to conform with the relevant OSHA requirements.

8.0 Liaison and Information

8.1 Seller shall furnish a technical representative for compressor startup, and maintenance instructions at separately quoted costs. Three copies of operating, maintenance and erection instructions shall be supplied as well as spare parts manuals, suitable for ordering replacement parts.

8.2 Seller shall provide certified drawings for installation within three (3) weeks after receipt of purchase order.

8.3 Because of the developmental nature of this project, and the advance in the state-of-the-art, close liaison between Seller's engineering and fabrication groups and LBL engineering is required.

8.4 Bidders should furnish a complete description of their equipment and/or describe any deviations from the specification.
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