

April 2017



Technical specification for BioGas Injection Compressor

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1. Introduction

NGF Nature Energy A/S intends to install a compressor for injection of upgraded biogas, into the natural gas grid on Fyn.

The compressor must cover the maximum capacity of 500 Nm³/hr, with an inlet pressure in the range 2.5 - 4.0 barg and an outlet pressure of max. 19,5 barg. In general designation of pressure in the different grids is in bar overpressure. Furthermore the compressor must be able regulate down the capacity/speed.

The compressor must be delivered as packaged unit.

1.1 Units

Metric units shall be used in documentation as well as installations.

1.2 Design data

According to GPTC all pressure retaining materials shall in general have a design factor of 0.5. In special cases for vibration bottles a lower design factor may occur.

Gas composition is according to C-12 "gasreglementet" – gas data are listed in the compressor data sheet.

1.3 Definitions

Supplier:	Vendor/Manufacturer of the packaged compressor unit
Purchaser:	NGF Nature Energy A/S
AT :	"Arbejdstilsynet" – The Danish Working Environment Authority
PED :	Pressure Equipment Directive, DIR 97/23/EC
P&ID: :	Process and Instrumentation Diagram
CE :	European Conformity
DBI :	Danish Institute of Fire and Security Technology
FAT :	Factory Acceptance Test (Shop Test)
SAT :	Site Acceptance Test
QHSE: :	Quality, Health, Safety, and Environment
SIK :	Danish Safety Technology Authority

2. Scope

The scope of this specification is to define the requirements for the supply of the mechanical and electrical equipment for the compressor unit as well as for the enclosure.

The detailed package unit design must be developed based on specific design data for each package ordered under this specification.

2.1 Scope of supply

Supplier's scope of supply for each complete unit is the design, manufacture, installation, testing and commissioning of the following equipment and materials:

1. A complete reciprocating compressor installation placed in one enclosure for outdoor installation, equipped with all equipment necessary for the compression process, the end product being a gas that meets the listed outlet pressure specifications. The pressure equipment shall fulfil demands as stated in PED and rotating equipment shall fulfil demands as stated in the EU Machinery Directive, including risk assessment for the compressors. The equipment scope is as follows, but is not limited to the listed equipment depending on the applied technology.
2. Inlet and outlet piping to the compressor including motorised isolation valves.
3. Cooling unit and lube oil unit, including pumps and heat exchangers.
4. All internal piping, including safety measures as required by AT and all other functional demands.
5. Control and Safety equipment, pressure safety valves connected to vent system, gas detectors in compressor room.
6. Verification of the plant equipment (pressure retaining parts) by Notified Body according to AT Notice 661, expenses shall be included in tender.
7. All instrumentation, electrical equipment, frequency converter as speed controller, all cabling and local control unit, necessary for the operation of the compressor.
8. Control philosophy and programming for compressors in parallel with adaption of control signals from the system for control of load etc. e.g. flow/pressure at biogas plant.
9. The control system shall have a web-interface accessible from the Internet for external monitoring of the gas compressor operation status incl. alarm. The web-interface shall be used by the operation centre to evaluate any malfunctions for the compressor.
10. Design of enclosure and cooler foundations, including load requirements for construction by Purchaser.
11. Planning, execution of FAT, SAT and Commissioning.
12. Training of operators, minimum 2 persons for 1 day at NGF NE premises in Denmark.
13. Any required special tools.
14. CE-marking of the entire system in accordance to applicable EC directives.
15. Documentation including material certificates, FAT, SAT, As-Built, declaration of conformity etc.
16. 2 years of warranty valid from the date of delivery.

2.1.1 Works by Others

Other contractors will provide the following services:

- Local authority approval covering building permit and environmental approval only.

- Construction of the foundations for compressor unit and for the enclosure based on Supplier design drawings.
- Tie-in piping from supply distribution piping and tie-in piping to discharge distribution piping, finished at agreed compressor pipe inlet/outlet flange.
- Main power supply, 3 x 400 VAC, from the electricity Supplier to compressor main switchboard.
- Signal transfer cable to the interfaced PLC unit.
- Supply and installation of cable pipes outside the enclosures.

3. Regulations, Norms & Standards

3.1 Regulations

Danish legislation, incl. all EU directives implemented applies, e.g.

- Pressure Equipment Directive (PED) 2014/68/EU.
- ATEX Directive 2014/34/EU.
- Machinery Directive 2006/42/EC.
- Low Voltage Directive 73/23/EEC c/w revision 93/68/EC.
- EMC Directive 89/336/EC c/w 92/31/EC.
- AT notice no. 190, design of pressure equipment.
- AT notice no 414, Safety requirements for natural gas systems.
- AT notice no. 661, Designation of Notified Bodies.
- AT Guideline F.0.1, natural gas installation – The Danish Working Environment Authority.
- Danish Building Regulation - 2008.
- Danish Environmental Protection Agency – external noise no.5/1984.
- Danish Safety Technology Authority – “Gasreglementet C-12” Natural gas regulations.
- Danish Power Regulation: Stærkstrømsbekendtgørelsen, afsnit 6 Elektriske installationer, 2001.
- Danish Law announcement 990 of December 8, 2003- “Stærkstrømsloven” – Consolidated Act electrical power installations and electrical equipment.
- Danish Guidance note VEJ nr. 14018 the 01 of November 1984 "Ekstern støj fra Virksomheder" - External noise from enterprises.
- Regulation 232, Automatic Fire alarm systems, DBI - Danish Institute of Fire and Security Technology, or equal European standard.
- Regulation 233, Automatic Fire alarm systems, DBI - Danish Institute of Fire and Security Technology, or equal European standard.

3.2 Norms & standards

Applicable norms and standards are:

- ANSI B 16.5, Pipe flanges and pipe fittings.
- API 5L, Specification for line pipe.
- API 546, Brushless Synchronous Machines - 500 kVA and Larger.
- API 614, Lubrication, shaft-sealing and oil- control systems and auxiliaries.
- API 618, Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services.
- API 661, Air-Cooled Heat Exchangers for General Refinery Services.
- API 671, Special purpose couplings for Petroleum, Chemical and Gas Industry Services.
- ASME (BPVC) VIII, Boilers and pressure vessels.
- BS CP 2012-1 - Foundations for reciprocating machines.
- DS 452 Code of practice for thermal insulation of technical service and supply systems in buildings
- EN 1012-3, Compressors and vacuum pumps – Safety requirements
- EN 13501, fire classification of construction and building elements
- EN 9606, Qualification test of welders.
- EN 837, Pressure gauges.
- EN 17637, Non-destructive examination of fusion welds.
- EN 17636-1, Radiographic testing of welded joints.
- EN 1990 (Eurocode 0), Basis of structural Design, including Danish Annex to the code DS/EN 1990 DK NA:
- EN 1991 (Eurocode 1), Actions on Structures, including Danish Annexes to the codes, DS/EN 1991-1-(1-7) DK NA:2007.
- EN 10204, Metallic products - Types of inspection.

- DS/EN 3183, Steel pipes for pipelines for combustible fluids.
- EN 10675-1, Non-destructive testing of welds.
- EN 12944-2, Paints and Varnishes. Corrosion protection of steel structures by protective paint systems. Part 2, Classification of environments.
- EN 13445, Unfired pressure Vessels.
- EN 14382, Gas safety shut-off devices for inlet pressure up to 100 bar.
- EN 13480, Metallic industrial piping.
- EN 15609, Specification and qualification of welding procedures for metallic materials.
- EN 23278, Non-destructive testing of welds - Magnetic particle testing of welds - Acceptance levels.
- EN 60034-1 to 18: Rotating Electrical Machines.
- IEC 60947-4, low voltage switchgear and controlgear
- EN 60079-0: Explosive Atmospheres - Part 0: Equipment - General Requirements
- EN 60079-14: Explosive Atmospheres - Part 14: Electrical Installations Design, Selection and Erection
- EN 60079-17, Explosive atmospheres – Part 17:Electrical installations inspection and maintenance
- EN 60204-1, Safety of machinery – Electrical equipment of machines – part 1 : General requirements.
- EN 60445, Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors.
- EN 60751, Industrial platinum resistance thermometers and platinum temperature sensors.
- EN 60947/1-7 Low Voltage Switchgear and Controlgear Components.
- EN 61439-1, DS/EN61439-2 and 61439-5: Low-Voltage Switchgear and Controlgear Assemblies.
- ISO 3183, Steel pipe for pipeline transportation systems.
- ISO 3511, Industrial process measurement control functions and instrumentation.
- ISO 1217, Displacement compressors - Acceptance tests.
- ISO 5208, Industrial valves - Pressure testing of metallic valves.
- ISO 10438, Petroleum, petrochemical and natural gas industries - Lubrication, shaft-sealing and control-oil systems and auxiliaries.
- ISO 10628, Diagrams for the chemical and petrochemical industry – Graphic symbols.
- ISO 13706, Petroleum, petrochemical and natural gas industries - Air-cooled heat exchangers.
- ISO 15547, Plate Heat Exchangers for General Refinery Services.
- ISO 17638, Non-destructive testing of welds - Magnetic particle testing.
- ISO 17640, Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels, and assessment.
- GPTC Z380.1 - Guide for Gas Transmission and Distribution Piping Systems
TEMA C, Manufacturers design standard – Air cooled heat exchangers.

Any deviation from current EN standards will only be accepted, if a written acceptance from Purchaser exists.

The equipment must comply with existing regulations at the time of approval.

In case applicable norms and standards are not strictly adhered, it shall be clearly stated in the tender documentation from the Supplier.

3.3 Authority approval

The compressor package unit must be CE marked in accordance with relevant European directives, as minimum:

- Pressure Equipment Directive (PED) 2014/68/EU.
- ATEX Directive 2014/34/EU.
- Machinery Directive 2006/42/EC.
- Low Voltage Directive 73/23/EEC c/w revision 93/68/EC.
- EMC Directive 89/336/EC c/w 92/31/EC.

The declaration of conformity with the pressure equipment directive for the compressor unit must be based on full quality assurance plus design examination.

The declaration of conformity must be in both English and Danish language.

4. General Technical Requirements

4.1 General

The design life of the compressor package shall be minimum 20 years.

4.1.1 Stationary compressor units

The enclosures for the gas compressor and utilities shall comply with the area classification given in section 4.3.3.

The gas compressor shall be installed in one enclosure. Utilities may be installed in a separate enclosures if found most appropriate. Furthermore an air – water cooler is expected to be installed on a separate foundation.

The compressor units will normally be installed close to existing M/R-stations, and Purchaser will provide the necessary power supply and connections to the gas control centre as well as the interface piping from the gas supply line to the compressor unit and from the compressor unit to the main gas pipeline.

The foundations and footprint for the enclosures shall be designed as part of this Contract.

4.2 Compressor equipment

4.2.1 General

The compressor package includes frame oil lubrication, capacity control, closed cooling water system incl. air cooled heat exchanger, pulsation dampener on suction side, pulsation dampener on discharge side, suction strainer, non-return valve, bypass, safety valves, instrumentation, control cabinet, gas piping, cooling water piping, instrument piping/tubing, main driver, frequency converters and compressor enclosure.

In the following sections, the main functional requirements for the equipment is described.

4.2.2 Skid boundary connections

The compressor including lubrication, cooling systems etc. shall be packaged skid mounted equipment, and the exact location of inlet and outlet connections on the compressor, dimension, schedule and material shall be shown on P&I diagrams and plant layout drawings. The Skid must be mounted on springs.

4.2.3 Compressor

The compressor shall be of proven construction for gas compression and built according to recognised standards such as API 618/EN 1012-3. The Compressor shall have speed control by a frequency converter and shall be constructed for potentially explosive atmosphere according to the ATEX directive.

Safety protection systems shall be present, including but not limited to:

- Pressure monitoring at compressor suction to protect the compressor and prevent gas inlet pressure falling below the “minimum suction pressure” specified by the Purchaser.
- Pressure protection at compressor discharge to protect from overpressure.
Protection of compressor suction side, preventing the downstream distribution net pressure to accidentally flow back into the upstream system.
- Over-speed protection.
- Protection against backflow of gas into the cooling lines

The overpressure protection must fulfill the Danish requirements, given in AT Guideline F.0.1. The protection shall consist of two independent safety devices. The capacity of a safety relief valve is 110% of

the outlet capacity of the compressor, and must be operational in case in counter pressure on the valve, caused by opening of a safety relief valve with a higher set point. Set point of the safety relief valves on suction line is 4,2barg and on discharge side 19,5 barg.

4.2.4 Oil lubrication and cooling unit

Complete oil lubrication system, including pump, cooler, filter, fittings, piping and instrumentation, accessories etc.

The oil cooling system shall be designed to comply with the parameters in ISO 10438-3 section 4.6 para. f).

4.2.5 Pulsation dampeners

Vessels, connecting pipes, flanges, instruments, etc. must be designed for internal pressure and temperature stresses, and if necessary designed for fatigue (life time of 20 years).

Vessels must be designed and fabricated in accordance with PED.

The compressor unit must be provided with pulsation dampeners. The pulsation suppression system must be designed in accordance with design approach 2, as according to API 618. As pulsation suppression device, volume bottles with choke tubes are preferred. The pulsation dampeners shall limit the pressure fluctuations to $\pm 1\%$ ripple at the average pressure on inlet as well as discharge.

Maximum allowable pressure drop through the pulsation suppression devices shall be less than 0,25 % of the average pressure at rated flow conditions.

Pulsation dampeners must be provided with a drain valve.

The pulsation dampeners must be furnished with liquid level switches for detection of condensates.

If the pulsation dampeners are fabricated of pipe and fittings, the maximum allowed design factor is 0,4 in accordance with GPTC.

4.2.6 Gas systems

Hazardous processes and operations for the compressor must be clearly described, and a safety plan describing the safety systems, gas detection.

4.2.7 Operating environment

The compressor installation locations can be of different nature. The compressor may be placed close to the sea, in a housing area or in an industrial area. Therefore the environment may contain moisture and chloride solutions that need to be taken into account when choosing finishing of materials.

Outdoor temperature will be:

- Lowest minimum -25 °C
- Highest maximum +35 °C

Mean of yearly max. temperature +10.9 °C

Mean of yearly min. temperature + 4.3 °C

Mean barometric pressure 1013 hPa

Mean relative humidity	84%
Frost proof depth below ground:	0.90 m
Gas Temperature inlet	0- 20°C
Gas Temperature outlet	< 45°C

4.3 Functional requirements

The following functional requirements shall apply.

The pressure in Purchasers 19 bar grid can vary in range of 7 to 19 barg, therefore the compressor shall be able to handle this.

4.3.1 Operational availability

Availability of the compressor unit is important. The Supplier must specify a guaranteed availability which must be minimum 98%. The compressor unit is not considered to be available, when it is stopped for planned maintenance.

4.3.2 Operation and Control System

The compressor shall be fully automatically controlled. The compressor shall be instrumented, so that the gas compressor can safely start and stop depending on the gas pressure at the inlet and the outlet side of the compressor.

Any not normal operation shall be handled by the control system, giving a controlled shutdown. Any unintended stop shall give an alarm which can be read by purchaser directly in the PLC via RJ45 cable to GCC. All relevant pressures and temperatures etc must present for the purchaser to read directly in the PLC.

The compressor units shall be controlled by a PLC. The PLC shall be able to communicate with a Siemens ET200S by a bus connection giving an easy data exchange to the GCC. The PLC shall be provided with a coloured graphic operator LCD-panel as interface to the gas compressor status, alarms and for adjusting parameters.

The control of the gas compressor shall be as follows:

The compressor shall have a ready signal from the system allowing the compressor to start at suction pressure above high pressure start level specified by the Purchaser.

The above set points and variables shall be parameters which an operator can adjust from a local panel.

4.3.3 Area Classification

Biogas is an explosive gas and so ATEX directive are valid for this project.

The biogas is lighter than air with a relative mass index of 0,6 and will therefore spread upwards in the atmosphere.

The compressor including switchboards and control panel is expected to be installed in one enclosure. Switchboards and control panels must be located in a separate gas tight electrical room.

4.3.4 Interfaces

The compressor has two process interface points, suction inlet line and the compressor outlet line.

The compressor package must be furnished with ANSI cl 150 flanges for the 19 bar grid.

4.3.5 Emission demands

The compressor shall be as gas tight and emission free as possible.

Furthermore venting to atmosphere is only acceptable in case of emergency operation. If required, a solution in which the gas is returned to the suction line shall be implemented.

4.3.6 Sound emission levels

Noise and environmental requirements of the compressor shall comply with the Danish guidance note guideline no 14018 of 01/11/1984 table I & II. The compressor unit including auxiliary equipment shall as a minimum comply with the noise limits for a type 3 area (area for both private household and industry areas).

The supplier may be asked to deliver a compressor, enclosure and cooler with maximum allowable joint average noise values as stated in the table below.

	All nights 22.00-07.00
Type 2 industry areas	60 dB(A)
Type 3 for both private household and industry areas	40 dB(A)
Type 6 summerhouse or recreational areas	35 dB(A)

The above stated levels shall be kept at area fence line, which is defined as 10 m from equipment acoustic center (compressor enclosures and air coolers ect., respectively).

The values are average values in dB (A) within the 30 minute period with the most noise. However, in case of "pure tone" (ren tone) the maximum allowable values shall be lowered with 5 dB (A). Also, in case of audible impulse noise the maximum allowable values shall be lowered with 5 dB (A).

Furthermore, noise impulse level shall not exceed 55 dB(A) measured as FAST (125 ms average). i.e. the blow down stack for emergency blow down must therefore be designed to comply with this demand.

5. Mechanical

5.1 General requirement

The compressor, including lubrication, cooling systems etc. shall be packaged skid mounted equipment. The Supplier shall include plot plans and general arrangement drawings in tender material.

5.1.1 Skid boundary connections

The exact location of inlet and outlet connections on the compressor, dimension, schedule and material shall be shown on P&I diagrams and plant layout drawings.

All interfaces and connections to the compressor shall be specified on P&I diagram and layout drawings.

Plot plans showing ATEX classification zones shall be prepared by the Supplier.

5.2 Compressor design requirements

The compressor stages must be oil free design, meaning lubrication oil is prevented from entering the compressed gas. This must be solved with a prolonged distance piece between cylinder and crankcase.

The compressor cylinders shall be of the liner type for easy exchange and must be capable for minimum 10 compressor starts pr. hour.

5.2.1 Valve unloaders

For start-up and capacity control of the compressor, valve unloaders to be used instead of a by-pass line for small gas volumes.

5.2.2 Packing Cases and Pressure Packing

The Supplier shall in his proposal select the type of packing, taking into account that the compressor may be stopped in the pressurized condition for periods of up to twelve (12) hours and that gas leakage shall be minimized as much as at all possible, both during operation and when the compressor is stopped in the pressurized conditions.

5.2.3 Compressor Frame Lubrication

Auxiliary oil pump driver:

The driver of the auxiliary oil pump shall have an electric motor.

Oil cooler type:

Water-cooled shell and tube type is preferred.

5.2.4 Cylinder and packing lubrication

Lubricators shall preferably be driven by the main electrical motor.

The lubrication system shall be furnished with divider blocks, monitoring each lubrication line. Pressure relief valve shall be used to protect against overpressure.

5.2.4.1 Lubricant and reservoir

Synthetic low lube oil is preferred as lubricant.

High and low level alarms shall be implemented as part of the unit control.

5.2.5 Couplings

The compressor and driver shall be designed for direct flexible coupling without reduction gear.

5.2.6 Piping and Appurtenances

The coolant system shall be a closed forced circulation system with a pressurized expansion tank, pumps, valves, thermostat controlled bypass, freezing and corrosion precautions, control and monitoring system (temperature and pressure).

Drain and Vent piping:

Drains for coolant containing equipment shall preferably end together in one outlet.

All gas vents from relief valves shall be piped to a vent header leading to above roof.

Vent line from the crankcase shall be connected to a gas recovery unit.

Hot surfaces of equipment exposed to personnel during normal operation shall be avoided. When guarding is not possible, there shall be adequate warning signs with graphical symbols.

5.2.7 Cooling

Air cooled heat exchangers with low speed low noise fans shall be delivered with certified noise data sheet.

The heat exchanger air fans shall be frequency controlled variable speed drive 50 - 100 %.

The air cooled heat exchanger shall be mounted on a foundation and will be located in unclassified area.

The cooling system shall be furnished with alarm, shutdown and control system.

It is in purchasers scope to furnish the fabricated piping between compressor and air cooled heat exchanger.

Pump and filter to the cooling water system must be placed indoor in same enclosure as the compressor. The pump must be certified for use in ATEX zone 2, and the motor for ATEX zone 1.

5.2.8 Pulsation and Vibration Control Requirements

The Supplier shall supply pulsation dampeners at the suction and discharge connections, including necessary supports. Dampener vessels shall be in accordance with the requirements in section 4.2.5.

Vibrations shall be kept at a minimum and must be monitored at all times during operation. In start and stop sequence it is allowed to ignore vibrations. If an area of resonance is defined the control philosophy must take this into account reducing the risk of brake down and decreased lifetime expectancy.

5.2.9 Filter

Inlet gas filter is within scope of supply. The filter shall be a single stage gas filter for separation of solids and liquids larger than allowed for safe compressor operation.

The filter cartridge shall be easy interchangeable installed downstream of the actuated inlet valve. The filter shall be provided with a drain valve. Manufacturer standard is acceptable.

The filter shall be designed in accordance with ASME VIII and vessel materials in accordance with DS/EN 13445-2.

The filter shall be pressure tested to 1,5 x design pressure and tightness tested afterwards.

5.3 Other Mechanical requirements

Flange connections

All flange connections for gas piping and equipment must be raised face type and in accordance with ASME B.16.5. Only stud bolts to be used for flange assemblies. Internal sockets are not allowed. Link seals can be used where gas pipes penetrates the enclosure.

5.4 Pressure and tightness testing

All gas containing components, vessels, filters, heat exchangers etc. must be pressure tested to min. 1,5 x design pressure and tightness tested afterwards.

6. Electrical

6.1 Introduction

The general electrical specifications given in the present section shall be fulfilled for all electrical equipment, components and installations provided for the Project.

6.2 Limits of Supply

The limits of supply for electrical installations shall be as described below unless otherwise specified in previous sections.

6.2.1 Included in the Works

Design, supply and installation of below equipment are included in the Works:

- All switchboards including motor starters, contactors for operation of pilot valves, switches and indicators for manual operation, etc.
- Termination of main power supply cables type AI.
- All unit mounted components, including motors, valve actuators, emergency switches, repair switches, instruments and transmitters, on/off switches for automatic control, junction boxes.
- All power distribution cabling between switchboards included in the Works.
- All unit cabling of power supply cables.
- All unit cabling of control cabling.
- All cable racking including cable penetrations through fire separations, concrete walls/ceilings, etc.
- Any special lighting mounted on or inside machines and equipment.

6.2.2 Supplied by Others

Other contractors will provide the following services:

- Main power supply AI cables 3x400 V from transformer to the switchboards included in the Works done by others.

6.3 Regulations

6.3.1 General

The Supplier shall comply with the terms and intentions of the relevant Danish law and codes which apply to the design, manufacture, installation and operation of the system. These include, but are not limited to, the listed codes and standards.

6.4 General Conditions and Requirements

6.4.1 Power Supply

Electrical power supply will be:

- Voltage : 400/230 Volt, +6%/-10%
- Frequency : 50 Hz, ± 1 Hz
- Wiring : 3-phase, 5-wire system (TN-S-5, 3L+N+PE).

The Supplier shall in his contract clearly indicate whether the offered equipment and system cannot accept above conditions.

6.4.2 Control Voltages and Signals

In general the following control voltages shall be applied:

Where the ESD pushbuttons/control circuits are inside the compressor skid, 230 VAC coils are accepted. In other cases the following are required.

- Relay coil voltages: 24 VDC
(motor starters, pneumatic/hydraulic valve actuators, PLC binary output)
- On/off switches: 24 VDC
(PLC binary input)

- Analogue signals: 4-20 mA / 24 VDC
(PLC analogue input)

All DC-coils shall be provided with a by-pass diode for protection of switches in the circuit.

The requirement for 24 VDC coil voltage may be exempted upon written approval by Purchaser in the case of heavy duty contactors.

6.4.3 Transient Protection

The electrical main supply for the installations shall be provided with overvoltage protection class II in the main switchboard. Protection level max. 1.5 kV at 15 kA, profile 8/20µs (combined surge gap and varistor discharger).

In case above protection is found insufficient by the Supplier to provide and secure the specified performance this shall be clearly indicated in the offer.

6.4.4 Electro Magnetic Compatibility (EMC)

The electrical installation shall be designed for EMC – Environment 2 (unprotected industrial environment). The project includes high voltage installations and electronic frequency converters. Cable glands shall be EMC-type. Pig-tail connection of cable sheathing is not allowed. Special cable clamps shall be used.

Radio frequency interference

All electrical and electronic equipment involved in this supply, including interconnecting cables shall be protected in order to avoid interference with the radio based digital telephone system (DECT).

6.5 Workmanship

6.5.1 General

The Supplier shall be responsible for ensuring that all materials and processes employed in the works are comparable with each other and meet the current requirements of the relevant Danish standards, codes of practice and construction codes. Reference to a code or standard shall be deemed to include all other codes and standards referred to in the specified code or standard.

Materials proposed by the Supplier must not be a potential hazard to health and environment.

6.5.2 Design

Switchboards shall be located in a separate mechanically ventilated room. Provisions for access to switchboards shall be provided in a safe and practical manner.

Switchboards shall be designed in accordance to EN61439-1, but breakers in the switchboards shall be selected so that the breakers can be continuously loaded with the designed rating. This may include selection of next higher rated component. E.g. a "630A" breaker shall be able to load 630A continuously, this may require installation of a 800A breaker.

Further the rated diversity factor for the busbars in the switchboard shall be 1.0. No diversity derating will be accepted.

All speed control of motors shall be by the use of frequency converters.

In general all electrical installations shall be designed and carried out to allow for easy access for maintenance and repair purposes.

Main motor is to be provided with a safety/repair switch disconnecting all phases.

6.5.3 Cable Installations

Cable shall be routed in such a manner that it does not interfere with the removal of mechanical equipment for service and repair.

Horizontal cable racking for single or few cables shall be conduits or cable trays.

In general power cables and control cables shall be installed in separate cable racks.

All cables connected to components, which are moving during operation or maintenance activities, shall be provided with an extra length. The cable extra length shall at the component be coiled and fastened by plastic strips.

All cables shall at both ends be relieved at the termination so that the cables are fixed immediately at the entering of a component, junction box, switchboard or control panel.

Splicing of cables, by any means, will not be accepted.

6.6 Electrical Equipment

6.6.1 Switchboards

Below the phrase “switchboard” includes all electrical switchboards, cabinets, cubicles, panels and other enclosures used for electrical installations and control purposes.

General Mechanical Design

All electrical switchboards must be of a sheet metal, front entry, with a minimum of 1.5 mm wall thickness without sharp edges or corners. Doors and casing of sheet steel, folded and seam welded to form a rigid self-supporting structure. Brace and stiffen to accept the weight of internal components and control assemblies.

All floor-mounted switchboards shall be provided with a bottom frame of 100 mm height.

Switchboards shall be built-up using standard modules, and they shall be furnished with main circuit breakers or power interrupters for each individual system.

Units shall be fully enclosed and constructed for easy maintenance. Special emphasis shall be placed on easy replacement of components, easy access for adjustment, control and fault-finding. Extra space shall be allowed for connections, enclosures and adaptation to changes and expansion.

All switchboards and control panels shall have a uniform design and be manufactured to enclosure protection IP44.

The switchboards shall be provided with a high quality heat-treated paint. They must be properly prepared, primed and provided with two coats of enamel paint on all sides.

Switchboards weighing more than 50 kg, including installed components, shall be fitted with eyebolts.

All external cables shall enter the switchboards through cable glands. The switchboards shall be provided with bolted flanges for insertion of cable glands. The flanges shall be sized according to the number of incoming cables in the different cable sections.

All parts of requiring access for operation or maintenance shall be mounted at least 500 mm and no more than 1800 mm above floor/platform level.

Clearance in front of switchboards and control panels must not be less than 1 m.

General Electrical design

Supply cables rated higher than 63 A will be stranded aluminium conductors. Other cables will be stranded copper conductors.

The termination plinth for incoming main supply cables shall be designed for connection of parallel cables.

The incoming cables will at the supply end in the main switchboard (supplied by others) be provided with disconnectors and fuses. The Fuses will be sized according to information provided by the Supplier.

The short circuit level at the end of the main supply cables will be informed by Purchaser.

Circuits rated 63 A or lower shall be protected by MCBs.

Motor starter contactors shall be chosen in accordance with the operational classification AC-3 given in IEC 60947-4.

Motor starters shall be of the electronic type with integrated I/O and communication modules. The communication module is meant as open/close feedback signals.

Motors rated 12.5 kW or lower may have direct start, while motors above 12.5 kW shall have starting limitation to 2.2 times normal current and in addition be equipped with full protective devices (thermistor protection).

Special attention shall be given to motors with long starting duration and motors started in loaded situation.

Switchboards providing power supply shall be equipped with facilities for indication of actual and maximum current and voltage level preferable by a multifunction meter. Furthermore, it shall be provided with facilities for kWh and kW readings. Signals shall be available at a bus interface for the Purchaser monitoring system.

Requirements to internal separations, as per EN 61439-1:

- Circuits up to 63 A: Form 1, Components can be placed in an open cabinet.
- Circuits above 63 A: Form 3b, with horizontal and vertical covers. Each circuits to be provided with separate door.

The switchboards shall be of a fuse-less design. MCB's and similar shall be used for short circuit protection. NH fuses can be used for VFD and CF gG for power supply.

Each switchboard shall be provided with an internal 400V/16A CEE socket outlet.

For circuits up to 63 A external cables shall be terminated in terminal rows. Only one wire per terminal is accepted.

For circuits above 63 A external cables shall be terminated directly at the terminals on the component in the switchboard.

Equipment, which requires online adjustment and testing by non-electrically qualified personnel, shall be accessible and adjustable without interrupting the supply or overriding safety interlocks.

All wiring within switchboards shall be arranged in looms and/or perforated trunking.

Terminals shall be fully shrouded, recessed or otherwise protected against accidental contact.

Any live equipment, which cannot be isolated, shall be covered with a shield carrying appropriate warning labels.

All wiring looms and trunking shall allow minimum 20% future extension.

Only one wire from incoming cable must be terminated in each terminal.

Switchboards shall be provided with temperature controlled electrical heating elements and/or other means to effectively avoid moist inside the switchboard.

Control panels

Flexible looms shall be used for connection between door mounted and interior mounted components, so that wires do not break or weaken with repeated door openings.

Control panels shall be provided with temperature controlled electrical heating elements and/or other means to effectively avoid moist inside the panels.

Outdoor cable conduits to be properly sealed for entrance of water and/or vermin etc.

6.6.2 Electrical Motors

Motors shall be in accordance with IEC Publication no.60034-1 to 18.

Motors shall be high efficiency types - at least IE2 level.(in accordance to European Commission ecodesign regulation No 640/2009 on electric motors). Type of motors shall be designed and selected in accordance with the mode of operation and the environment, in which they will to be used. Motor rating shall be minimum 110 % of the requirement of the compressor.

Motors operated by frequency converters shall be provided with thermo sensors embedded in the stator.

The motor shall be designed to perform at least 10 successive starts per hour at operating temperature.

6.6.3 Frequency Converters

Frequency converters shall be delivered as separate units. (Not as part of a motor).

Frequency converters shall have efficiency higher than 97% at 75% load.

The THiV extent on the power supply side shall comply with the Danish Regulations. The installation site may be in office areas, in industrial areas and in the open land. Therefore the highest THiV requirement shall be complied to.

The power factor at the power supply side of the frequency Converter shall be better than 0,99. The frequency converter cables shall be a type approved for frequency converter operation and shall be recommended by the frequency manufacturer. The outgoing motor cables shall be screened cables and be installed in accordance to the frequency converter manufacturers recommendation. The frequency converter shall CE-marked and be in compliance with the Low Voltage directive, The Machinery Directive and the EMC-directive.

6.6.4 Safety/Repair Switches

The switch shall have additional contacts for remote indication of switch position.

6.6.5 Emergency Stops

Design of emergency stop buttons must be in accordance with DS/EN 13850.

Push buttons for emergency stop shall be of the "mushroom" type with locking function. The push buttons shall be coloured red and shall be locked in the off-position when pressed. Push buttons shall have contacts for remote indication of switch positions.

All push buttons shall be located within easy reach of the operator.

Each emergency stop push button shall be marked with a red sign with the text "NØDSTOP" in 50 mm letters heights.

6.6.6 Cables

All cables shall be rated 750 VAC minimum.

Motor cables for frequency controlled motors shall be of fully symmetrical design and shall be provided with screen.

Cables shall be selected to suit the specific purposes. Special consideration shall be given to cables in areas submitted to vibrations, high temperature, sunlight (UV rays) and oil spillage.

Conductors in control and signal cables with more than 5 conductors shall be individually numbered.

6.6.7 Cable Racks and Supports

All cable racking and cable supports shall be in galvanized steel.

6.7 Earthing and Bonding

The Works shall include bonding of the complete assembled process equipment, cable racks, reinforcement in foundation and all other supplies included in the Contract.

The Supplier shall ensure that all extraneous conductive parts of the system are effectively bonded to earth. An extraneous conductive part is defined as being a part, which is liable to transmit a potential, including earth potential and not forming part of the electrical installation. Each component constitutes an extraneous conductive part.

Bonding shall be provided to ensure that the various exposed conductive parts and extraneous conductive parts as defined by the regulations shall carry substantially equal potentials.

Electronic and electrical equipment shall be protected against over-voltage.

All earthing, bonding and electrical protection shall comply with regulations as laid down in the Danish Power Regulation "Stærkstrømsbekendtgørelsen".

7. Instrumentation

7.1 General

All instrumentation shall be insensitive to shock or vibration effects normally encountered in gas and oil installations.

Instrumentation to be connected directly to pipes shall be insensitive to - and not affect - cathodic protection currents.

Electrical supply voltage for electrical instrumentation shall be 24V DC except for electrical supply to EEx i circuit instrumentation.

All housings shall have a minimum enclosure protection to IP 54 in accordance with IEC 60529.

Safety systems (Gas-, Fire-, ESD-, etc.) instruments shall be fail-safe.

7.2 Temperature instruments

7.2.1 Temperature Indicators

Thermometers shall be of industrial type in steel or high pressure nitrogen dial type suitable for thermowell mounting. Thermometers for outdoor use or vibration application shall be liquid filled.

Thermometers mounted directly to thermowells shall be fitted with an adjustable nipple for positioning.

Thermometers with remote indication shall be temperature compensated, and generally be insensitive to changes in the surrounding ambient temperature.

Thermometers shall have minimal response times.

Thermometer housings shall be waterproof and corrosion resistant, preferably of a stainless steel construction.

Thermometers shall be function tested by the manufacturer and issued with a test certificate.

Certificates for thermometers with an accuracy class requirement of 1.0 or better shall include a calibration curve with traceability maintained via the thermometer serial number.

7.2.2 Temperature Switches

Temperature switches for remote control or alarm purposes shall be no-touch inductive proximity sensors built integral with an indicating thermometer.

The switches shall be part of an Exi circuit where explosion protection is required.

Temperature switches shall be function tested by the manufacturer and issued with a test certificate.

7.2.3 Temperature Sensing Elements

Temperature sensing elements shall be Resistance Temperature Detectors (RTD's) of the type Pt 100 in accordance with EN60751 form B for insertion in thermowells.

The elements shall be part of an EEx i circuit where explosion protection is required.

The RTD shall be connected to a temperature transmitter by a 4-wire cable making lead resistance adjustment unnecessary. The supply will be a constant DC voltage giving a suitable measuring current.

All temperature sensing elements shall be function tested by the manufacturer and issued with a test certificate.

7.2.4 Electronic Temperature Transmitters

2-wire smart analogue/digital signal transmitter with an analogue output signal directly proportional to the temperature, and digital communication facilities for configuration and maintenance.

The smart transmitter shall be a microprocessor designed for:

- Attainment of high accuracy, including automatic recalibration of amplifiers, zero drift elimination, ambient temperature correction and self-diagnostic tests.

The smart transmitter shall at the same time give a continuous analogue output signal and allow digital communication on the output signal lines by connection of a portable terminal to the lines. The digital communication shall at least make ranging, calibration and diagnosis via the terminal possible.

The temperature transmitter shall transmit power to a Resistance Temperature Detector of the type Pt 100 in accordance with EN60751 form B and receive the input signal via a 4-wire cable.

Supply and signal circuit shall be part of an Exi circuit where explosion protection is required.

The temperature transmitter shall comply to following:

- Span - Adjustable between 20 and 100% of the range.
- Zero - Adjustable between -20 and +80% of the span.
- Input signal - Via Pt 100, maximum load current 10 mA.
- Output signal: 4-20 mA directly proportional to temperature.
- Output load ≤ 600 ohm.
- Accuracy $\leq \pm 0.25\%$ of calibrated span

Testing and certification:

All temperature transmitters shall be function tested by the manufacturer and issued with a test certificate

7.3 Pressure Instruments

7.3.1 Pressure and Differential Pressure Indicators

Pressure gauges shall comply with the requirements of EN 837.

Additional codes and standards:

- EN837-1+2+3 Pressure Gauges

Pressure gauges shall be capable of withstanding a permissible overload in excess of 10% of its range without effect to its accuracy, and 30% without bursting.

Differential pressure gauges shall be capable of withstanding the maximum operation pressure.

Pressure gauges shall be liquid filled and fitted with a safety blowout plug. Material of wetted parts shall be stainless steel.

Type test - All pressure gauges shall have a type test approval certificate issued by an approved independent inspection authority (TÜV, Lloyd's, DnV, etc.).

Pressure gauges with an accuracy class requirement of 0.6 or better shall also have calibration curves issued with the test certificates with traceability being maintained via the pressure gauge serial number.

7.3.2 Pressure and Differential Pressure Switches

Pressure and differential pressure switches for remote control or alarm purposes shall be:

- No-touch inductive proximity sensors built integral with pressure gauges, or Diaphragm-operated electronic switches

The switches shall be part of an Exi circuit where explosion protection is required.

They shall comply to following standard: EN60947-5-6: Low Voltage Switchgear and Controlgear: Part 5-6 Control Circuit Devices (Namur)

The setpoints shall be visible and adjustable over the entire scale range and - for the pressure gauge type - visible.

Differential travel shall not exceed 1% of the pressure gauge scale.

All pressure and differential pressure switches shall be function tested by the manufacturer and issued with a test certificate.

7.3.3 Electronic Pressure Transmitters

2-wire smart analogue/digital signal transmitter with an analogue output signal directly proportional to the pressure, and digital communication facilities for configuration and maintenance.

The smart transmitter shall be a microprocessor designed for:

- accuracy, including automatic recalibration of amplifiers, zero drift elimination, ambient temperature correction and self-diagnostic tests.

The smart transmitter shall at the same time give a continuous analogue output signal and allow digital communication on the output signal lines by connection of a portable terminal to the lines. The digital communication shall at least make ranging, calibration and diagnosis via the terminal possible.

The sensor shall be separated from the process by a diaphragm with the pressure transmission between the diaphragm and sensor provided by silicone oil.

The sensor may be of the semi-conductor, strain gauge or capacitor type.

The power supply to the pressure transmitter and the output signal shall be via a 2-wire cable.

Supply and signal circuit shall be part of an Exi circuit where explosion protection is required.

Span - Adjustable between 20 and 100% of the range.

Zero - Adjustable between 20 and +80% of the span.

Output signal: 4-20 mA directly proportional to the pressure.

Output load: ≤ 600 ohm.

Accuracy: $< \pm 0.5\%$ of the measured value

All pressure transmitters shall be function tested by the manufacturer and issued with a test certificate, inclusive of a calibration curve for the required span. Traceability between the certificate and the transmitter shall be maintained via the transmitter's serial number.

7.4 Gas Detectors

Detectors shall be designed, tested and approved as described in "DBI Forskrift 233 AGA Automatic gas detection system" to the extent required by the authorities and this specification.

Detectors shall be operable over the range 0-100% lower explosivity limit, LEL, with a sensitivity span of 0-30% LEL at an accuracy to within $\pm 2\%$ of the operable range. (LEL being approximately 5% volume in air for methane at 25°C and at atmospheric pressure).

Detector type Gas detectors shall be of the type based on the catalytic combustion principle, with two elements (one sensing and one as reference) suitable for detecting natural gas below the LEL.

All gas detectors shall be fitted with a collecting cone to allow sensing at a very low % LEL.

The gas detectors shall not be poisoned by gas concentrations over the LEL.

Terminals shall be for a 2-core -wire cable.

Gas detectors shall be tested and approved as described in "Forskrift 233 for AGA-anlæg" by a company accredited with certification and inspection by "Industri-og Handelsstyrelsen" (The National Agency of Industry and Trade).

7.5 Technical Documentation

All instruments exposed directly to process medium pressure shall have material certificate EN 10204-2.1 (certificate of compliance).

All instruments shall have manufacturer's test certificates conforming to EN 10204-2.3 or equivalent (inclusive of calibration details).

All electrical equipment suitable for use in potentially explosive atmospheres shall have EEx approval and conformity certificates. The certificate requirements for EEx i (intrinsically safe) equipment shall make connection to standard EEx i relays possible.

Manufacturer's test certificate to EN 10204-2.3 or equivalent together with EEx approval and conformity certificates all as stated above.

7.6 Reference Designation and Marking

7.6.1 Equipment Identification

All equipment and components shall be identified by an ID-number according to the P&IDs.

The extent of application of equipment identification shall correspond to the documentation provided, and shall allow for a unique and unambiguous identification of each piece of equipment and component.

7.6.2 Signs and Marking

General

All marking shall be clear and durable. Life expectancy of marking shall correspond to the life expectancy of the units labelled.

All text marking shall be in Danish and easily readable.

Marking shall generally be replaceable and made of metal or sturdy white plastic signs with at least 0.5 mm recess black characters.

Markings of field components shall be fixed with bolts and nuts.

Marking text shall be given on plans and drawings and approved by Purchaser prior to production whenever practicable.

7.6.3 Marking of electrical equipment

All equipment shall be marked with an ID-number corresponding to the agreed Reference Designation System.

The marking shall be carried out with signs, which are safely and securely fixed to the equipment.

The Supplier shall propose a marking system for the different installations (switchboards, switchboard components, cable terminals, cables, components, etc.).

Marking of Switchboards and Panels

On the front of each switchboard and panel the following information shall be indicated (on the door of the incoming section):

- The switchboard ID-number.
- ID-number of the main switchboard (main power supply)
- The voltage level within the panel section (for clear warning of risks).

All front mounted switches, controls and indicators shall be clearly marked with their function.

All components inside the panel shall clearly be labelled with ID-number corresponding to ID used at schematics. All labels shall be glued or fixed by screws at the fixed parts of the components or at the cabinet.

All wires shall be provided with permanently fixed numbered ferrules with numbers corresponding to numbers fixed to terminals. Terminal shall be provided with identification and coding as used on drawings, schematics and schedules.

Cable marking

All wiring inside switchboards and panels shall be colour coded as follows: DS/EN 60445

- | | |
|---------------------|--------------------|
| • Line (L): | Brown, Black, Grey |
| • Neutral (N): | Blue |
| • Protective earth: | Yellow/green |

Control voltage wiring:

- | | |
|------------------------------------|-------------|
| • 24 VAC control voltage (L): | Violet |
| • 24 VDC control voltage (+): | White |
| • 24 VDC control voltage (-): | Black |
| • 24 VDC control wire: | Grey |
| • 230 VAC Control Voltage Phase: | Brown |
| • 230 VAC Control Wire: | Red |
| • 230 VAC Control Voltage Neutral: | Darkblue |
| • 4-20mA intrinsic safe: | Light blue |
| • 4-20mA not intrinsic safe: | Orange |
| • External control voltage: | Transparent |

The individual cables shall be marked unambiguously, clearly and durably as follows, so that they can be identified immediately in connection to fault-finding, etc.:

- At terminal blocks, in switchboards, control panels, etc.
- At all junction boxes, wiring accessories, etc.
- At both sides of fire barriers
- On cables entering enclosures from below ground
- On cables leaving cable routing arrangements

The marking shall be carried out no more than 200 mm from terminal block, junction boxes, wiring accessories, etc. The marking shall identify the cables in accordance with the relating documentation. At cable terminations the cables shall in addition be marked with identification of the equipment connected at the opposite end of the cable.

The principle and the cable numbering system shall be approved by the Purchaser supervision team.

8. Enclosures

8.1 General

The enclosures may be either light weight concrete building or steel containers.

The roof shall be designed with an explosion relief opening. Alternatively the roof shall be designed as a light structure as defined by F.0.1.

Roofs shall be sloping with minimum 1:40 so rain is drained away from the building according to the 2010 Building Regulation".

Floors shall be designed in a non-sparking material with, anti-static resistance 1 mΩ.

The enclosures shall fulfil the requirements of the Danish building regulation and the Danish requirements defined in At Guideline F.0.1, natural gas installation – The Danish Working Environment Authority.

The enclosures shall be equipped with lighting, ventilation etc. Further the enclosures shall be delivered painted in RAL 7016.

8.2 Enclosure Works and foundations

8.3 Walls for compressor enclosure

The walls surrounding the compressor unit shall be classified REI 60 A2-s1,d0 according to EN 13501. The walls shall be able to resist an internal pressure of 5 kN/m². Doors in the wall (to the compressor room) shall be able to withstand the same pressure of 5 kN/m². Any double doors shall be furnished with locking pawl at top and bottom which can withstand a pressure of 5 kN/m². Locking pawl at top must be operational from maximum 1,7 m above room floor level.

8.4 Ventilation

The compressor enclosure shall be ventilated either forced or naturally in order to keep the room free of gas and the room temperature at a reasonable level (< +35°C).

The Switchboard enclosures shall be mechanical ventilated. Ventilation air shall be taken at least 1 m above the roof. The switchboard enclosure will be unclassified area.

8.5 Lighting System

The enclosures shall be provided with necessary lighting for normal service and inspection functions at least 200 lux shall be provided.

The lighting system light fittings and installation in the compressor enclosure shall be certified for zone 2.

In case of activation of emergency bottom the lighting system must still be in operation.

8.6 Heating

The enclosure shall not be heated. The switchboards and terminal boxes may be provided with anti condensation heating. This is the responsibility of the contractor to assure that the gas compressor can start at any condition within the specified environmental window.

8.7 Control room

The control room shall be prepared with power sockets next to the entrances.

- 1 pc. 230V/13A Danish model socket outlet Type K
- 1 pc. 400V/16A CEE (3P+N)

Power and internet sockets for temporary installation of laptop.

- 2 pc. 230V/13A Danish model socket outlet. Type K

9. Fabrication

9.1 General

The Supplier shall follow the fabrication procedures and material recommendations in accordance with API 618.

The Supplier shall collect and ensure that all relevant information related to the fabrication process.

9.2 Materials and material certificates

9.2.1 Piping

Piping material shall generally be carbon steel piping according to recognised standards, such as ISO EN 3183 PSL 2 or API 5L.

All main gas piping shall be flanged, screwed connections is not acceptable. Cooling water piping shall be flanged for dimensions $DN \geq 40$ mm.

For all pressure retaining materials the following requirements are applicable:

- Materials shall be normalised.
- Max. Carbon content is 0.25% and max. CE-value is 0.42%
- Material certificates level 3.1 according to EN 10204 for all materials having a specified minimum tensile strength < 450 N/mm²
- Material certificates level 3.2 according to EN 10204 for all materials having a specified minimum tensile strength ≥ 450 N/mm²
- As specified in ISO EN 3183 shall be Charpy V tested at -20 °C to minimum 27 J.

9.2.2 Tubing

Instrument tubing shall be stainless steel 316L. Tubing fittings shall be of the twin ferrule compression type.

The Purchaser uses compression fittings of make Parker EO in other installations. Tubing dimensions shall all be in metric.

9.2.3 Valves

All valves installed in gas systems shall be of fire proof design.

The actuated shut-off valves at compressor unit inlet and outlet shall be double block and bleed ball valves.

Safety block valves must be fitted so that testing of the valve is possible without dismantling of the valve. Pilot tubes must be furnished with one valve and two test couplings (stauff type) for connection of manometer and test gas (nitrogen).

Valve leakage rates:

Valves shall be tested in accordance with ISO 5208 and the acceptable rates shall be as follow:

- Ball valves - rate A
- Other valves - rate AA

Pressure safety valves shall be delivered with certificates in accordance with PED category IV. All valves must be delivered in accordance to F.0.1. Piping design for pressure safety valves must be prepared for testing without dismantling, the PSV must be isolated with a block valve and have two test connections

for a manometer and test gas, manoflanges may be used if feasible. All block valves required for testing must be locked in open position with a mechanical lock (customs seal).

9.3 Welding and welding inspection

The Supplier shall submit preliminary welding procedure specifications, WPS and approved WPQR according to DS/EN ISO 15609-1. All dimensions, all combinations of materials to be joined and all repair weldings shall be covered.

Welders shall be qualified in accordance with the requirements of DS/EN ISO 9606 + AC, bend test is mandatory.

Weld seams on gas pressure retaining piping shall be 100% inspected using radiographic inspection. Inspection requirements in accordance with DS/EN ISO 17636/A1. Acceptance criteria as per DS/EN ISO 10675.

Visual inspection, 100% of all weld seams, shall be performed according to DS/EN ISO 17637. Accept criteria level B.

Where radiographic inspection cannot be performed, ultrasonic inspection according to DS/EN ISO 17640 may be used.

Where ultrasonic inspection cannot be performed, magnetic particle inspection according to DS/EN ISO 17638 shall be used. Accept criteria as per DS/EN ISO 23278 level 2.

All welding inspection and non-destructive examination shall be performed by authorised personnel with accreditation.

9.4 Pressure testing

Before painting and surface treatment, all gas containing pipespools, must be pressure tested to min. 1,5 x design pressure and tightness tested afterwards.

9.5 Painting and surface treatment

Painting systems shall be minimum for corrosion class 4 (industrial areas) in accordance with DS/EN 12944-2.

10. Inspection and Testing

10.1 General

Factory and Site acceptance tests shall be included in the supply. Test procedures and protocols shall be provided by supplier and submitted for Purchasers approval no later than 4 weeks prior to tests.

Prior to acceptance of the compressor, the Supplier must demonstrate and document that the equipment meets the performance requirements as specified.

Prior to delivery, the compressor shall be tested at the Suppliers shop as far as possible and punch items shall be cleared and accepted by the Purchaser before delivery on site.

- Functional and performance test of the complete gas compressor unit incl. utility consumption and a noise test as per API standard and any requirements specified in this document.
- Actual compressor performance.

The Supplier shall prepare test protocols and Purchaser shall be invited to the tests with a minimum of one week notice. The testing protocol shall be submitted to the Purchaser for approval not less than 4 weeks before the test date.

Quality plan:

Supplier shall perform the standard quality control plan and if necessary supplemented with following.

Test	Controlled by Supplier	Witnessed by third party	Observed by Purchaser	Witnessed by Purchaser
Material certificates for pressurized components	Yes (2.2)			
Hydrostatic test	Yes (3.1)			
Leakage test	Yes (3.1)			
Functional tested	Yes (3.1)			

All tests shall be reported and included in the documentation package of the unit.

All expenses to control by Supplier and third party inspection are paid by the Supplier.

"Observed" means that Purchaser can participate in the tests.

"Witnessed" means that Purchaser or representative inspector shall participate in tests and tests cannot be started without presents of Purchaser or representative.

10.2 Factory acceptance test (FAT)

The FAT shall be carried out in accordance with the requirements in API 618 and performance test in accordance with ISO 1217.

Hydrostatic and leakage test:

The manufacture shall perform hydrostatic and leakage test of the compressor cylinders. Cylinders shall be leakage tested with helium. Both tests shall be witnessed by Notified Body.

Test of unit control and electrical system:

In connection with the mechanical running test the electric motor driver shall be tested according to EN 60034-5.

The following test and check procedures shall as a minimum, but not limited to, consist of:

- Check of performance of components and unit control system
- Check of quality of component materials and surface treatment
- Check of cable and wiring systems
- Check of function of components
- Test of electrical insulation
- Total function test of unit control system with simulated input signals

If the manufacturers standard test program has additional requirements, these additional tests shall be carried out as well.

Compressor performance test:

The performance measurements with the acceptance criteria's in the following table 10.2, shall be carried out at:

- Minimum volume flow rate
- Three volume flow rates between min. and max. flow (25%, 50%, 75%)
- Maximum volume flow rate
- No load power

Nitrogen is to be used as test media.

Measured variable	Maximum permissible deviations	Maximum permissible fluctuation from average during any set of readings
Inlet pressure	$\pm 5 \%$	$\pm 1 \%$
Discharge pressure	$\pm 2 \%$	$\pm 1 \%$
Pressure ratio	$\pm 5 \%$	-
Isentropic exponent	$\pm 3 \%$	-
Gas constant x compressibility, $R \times Z$	$\pm 5 \%$	-
Shaft speed, N	$\pm 4 \%$	$\pm 1 \%$
Difference between inlet temperature of external coolant and the gas inlet temperature	$\pm 10 \text{ }^{\circ}\text{K}$ for coolant air $\pm 5 \text{ }^{\circ}\text{K}$ for coolant liquid	$\pm 2 \text{ }^{\circ}\text{K}$ $\pm 2 \text{ }^{\circ}\text{K}$
External coolant flow	$\pm 10 \%$	$\pm 10 \%$

Table 13.2 Maximum deviations from specified values and fluctuations from average readings

In general the performance test shall be carried out and all measured values of the different parameters shall be treated in accordance with BS ISO 1217.

The Supplier shall in the tender material specify overall efficiency at the five stated flow rates above.

Mechanical running test:

The complete compressor unit and auxiliary equipment shall pass 4 hours mechanical non-stop running test. The running test shall be observed by the Purchaser and cannot start before Purchaser is present. The manufacture shall no later than 10 working days before test date confirm the date to Purchaser.

10.3 Inspection

After the running and performance test, the compressor shall be inspected by random inspection, e.g. disassembly of at least one main bearing, one cross head and one cylinder. All inspections of parts shall be performed with boroscope by the Supplier proving excellent condition of internal surfaces.

If irregularities are found the compressor has to be further disassembled and inspected, and damaged parts shall be replaced.

In case of exchange of parts as a result of inspection, after assembly, the 4 hour mechanical running test shall be repeated and new parts installed shall be inspected and found in order.

10.4 Preparation for shipment

All materials shall be properly packed and protected as required for the chosen method of transport and shall be suitable for a storage period of approx. 1 year.

Packing shall be strong enough to withstand rough and frequent handling.

Openings in equipment shall be suitably covered to prevent damage and/or foreign matter from entering.

All equipment shall be completely drained of water, thoroughly dried and cleaned prior to packing and shipment to prevent freezing and corrosion.

Threaded or bevelled pipe ends shall be covered with plastic caps to prevent foreign matter from entering. Finished and coated surfaces shall be protected from abrasion.

10.5 Commissioning

All test and findings shall be reported.

Leakage test:

The main contractor shall perform a complete leakage test on compressor package, auxiliary systems and all connected piping at the compressor area. At the same time the Supplier shall test the pulsation dampener system and the compressor cylinders for any leakage.

Test of unit control and electrical system:

The following test and check procedures shall as minimum be carried out:

- Check of cable and wiring systems
- Check of function of components
- Total function test of unit control system with input signals from existing control system.

10.6 Site Acceptance Testing (SAT)

All SAT tests shall be witnessed by the Purchaser and documented in a SAT-report.

Purchaser shall document the Noise emission from the compressor unit including auxiliary system(s). Measurements shall be for start-up, continuous operation and shut down. Supplier shall demonstrate that the equipment meets the performance requirements as specified.

The SAT-report shall be forwarded for comments as specified in API 618 sec. 8.3.1.

Mechanical 72 hours running test:

The mechanical 72 hours test of continuous operation with gas of a pressure within the stated operating pressure range shall be performed by the Supplier or under his direction and responsibility, but in close co-operation with the Purchaser.

During start-up the compatibility between the unit parts supplied by the Supplier and the equipment provided by others shall be checked.

During the test no faults of the unit parts shall occur. Perfect operation of the unit devices and controls shall be verified. In case of interruption, due to a fault in the unit or auxiliary equipment, the test shall start again from the beginning as soon as the fault has been eliminated.

The mechanical running test shall as a minimum include 3 (three) starts and 3 (three) shutdowns with no fault in the sequence.

Noise emission from the compressor unit including auxiliary system(s) shall be measured for start-up, continuous operation and shut down.

In case of repetition of testing for leakage, mechanical running and / or performance test caused by Suppliers failure, the arising costs shall be carried by the Supplier accordingly.

In case gas pressures are lower than indicated for guarantee points, the Supplier shall perform the verification performance data by calculation.

Final acceptance will be given when the Purchaser receives a written certification stating that the Supplier had complied with all existing laws and regulations and delivered documents and certificates as required.

11. Documentation

11.1 General

After signing of the contract, and within agreed time schedule, the Supplier shall substantiate that all relevant equipment including access to all equipment and enclosure are in accordance with EU machinery directive 2006/42/EC and CE marked in accordance with directive 93/68/EEC.

The Supplier shall submit all necessary documents to Purchaser for design approval of the compressor package by the Danish Working Environment Authority. Purchaser will have all contact with the Danish Authorities.

11.2 Documentation

Documentation shall be submitted as follows:

With the Tender documents

To be supplied with Suppliers quotation:

1. System description
2. Description of Control and Safety systems and equipment, safety plan, description of safety procedures when servicing the compressor
3. Estimated availability
4. Preliminary P&ID's for compressor skid and auxiliary systems
5. Typical general arrangement drawings for the largest and smallest skid/system, including overall dimensions and weight
6. Noise Emission (expected and guaranteed sound pressure level) with detailed description of noise reduction of the enclosure, coolers and blow down stack
7. Quality system description
8. Utility requirements
9. Interface specification for SCADA

10. Signal list/Instrument list
11. Performance test plan according to ISO 1217 and guaranteed efficiency verification
12. A list of any non-conformities to this specification
13. Capacity and efficiency curves for the compressors types

Engineering documentation

To be supplied in accordance with the agreed time schedule:

1. Detailed drawings and calculation of enclosures incl. explosion relief opening in roof
2. System description incl. sizes of equipment and materials and painting specifications
3. P&ID, PFD's and mass balance diagrams
4. Plot plan
5. Area classification
6. Detailed arrangement drawings of the unit complete with auxiliaries, and of all other major system components
7. Instrument schedule and list of alarms and trip points
8. Instrument connections to the control system
9. Software documentation
10. Cause and effect diagram and list including all interface ESD/EDP signals
11. Interface list incl. loads on pipe tie-ins, and utility consumption
12. Specification of electricity supply capacity required.
13. Input for foundation design drawings and specification
14. Acoustic simulation and piping restraint analysis
15. Performance curves, including torque/speed curves for compressor and motor

Authority approval documentation

Material required for the authority approval shall be supplied by the Supplier to Purchaser.

Construction documents

Revised and detailed versions of the documents listed above incl. operation and maintenance instructions, mass balance diagrams, test protocols and equipment and piping drawings etc. specifying all interfaces incl. tie-in loads. Data sheets on equipment and major valves shall be included together with a detailed spare parts list.

Documentation stored by Supplier

The Supplier shall deliver following data to Purchaser and store copy of the data for at least 10 years:

- Necessary or specified certification of materials, such as mill reports
- Test data and results to verify that the requirements of this specification have been met
- Fully identified records of heat treatment, whether performed in the normal course of manufacture or as part of a repair procedure and other examinations such as magnetic particle, liquid penetrant, radiography and ultrasonic
- Results of quality control tests and inspections
- Details of all repairs

11.3 Tag Numbering

Any item of a system and equipment (e.g. valve, instrument, line) shall be given a tag number for identification.

Tag numbering shall be in accordance with recognised standards as ISO 10628 and ISO 3511/1 and 2.

11.4 Numbering System and Formats

Suppliers standard numbering system are accepted. All documents shall be furnished with a unique number or name.

Document numbering system shall be enclosed with the Suppliers proposal.

Documentation on papers shall be supplied in the original size.

Other documentation on data files has to be agreed upon. Information can include

- format, i.e. definition and contents.
- medium (e.g. DVD or CD-ROM)
- standard (e.g. ASCII, IGES)Time Schedule

12. **Delivery**

12.1 **Delivery on site**

The Compressor unit must arrive on site Hønselavevej, 5771 Stenstrup, Denmark no later than November, the 1st 2017.

12.2 **Commissioning**

Commissioning must be completed no later than November the 13th 2017.

12.3 **Hand over**

Hand over of the complete compressor installation must take place on November the 30th 2017.